DISSERTATION

DROUGHT AND SAMBURU PASTORALISM: A COLLABORATIVE EFFORT TO EXAMINE THE CAUSES, ADAPTATION PROCESS, AND GRAZING INNOVATIONS IN NORTHERN KENYA

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ABSTRACT

DROUGHT AND SAMBURU PASTORALISM: A COLLABORATIVE EFFORT TO EXAMINE THE CAUSES, ADAPTATION PROCESS, AND GRAZING INNOVATIONS IN NORTHERN KENYA

The central focus of my doctoral research is to understand the changing relationship between pastoralism and drought, from a pastoralist perspective. Drought is a problem that varies in meaning and significance depending on the social and environmental activities it disrupts. The communities that experience these periods that lack rainfall also define it for themselves. The social-ecological systems centered around the livelihood of livestock husbandry and herding make up pastoralism. Pastoral cultures, especially those in semi-arid and arid lands, have developed strategies over centuries or millennia to respond to regularly occurring periods that lack rainfall. Pastoral systems have recently undergone rapid societal and environmental changes, including increased rangeland fragmentation and sedentarization. Many of these changes threaten pastoralists' ability to respond to drought's causes and impacts. Concurrently, climate change is likely to increase the frequency and severity of meteorological droughts (low precipitation anomalies) in dryland areas. I conducted a case study of Samburu pastoralism in northern Kenya to explore the relationship and evolution of drought and pastoralism. My work investigated pastoralists' understanding of drought, their experiences, and droughts causes, (Chapter 2) the drought adaptation process they have used (Chapter 3), and the 2017 drought effects on sheep and goat husbandry in community conservancies (Chapter 4).

I first answer, in Chapter 2, from the Samburu pastoral community's perspective, 'what is the drought problem and what causes it?' It is necessary to make sure scientists and the community discuss the same problem in regard to drought, before understanding how people cope with, adapt to, or recover from a drought. Additionally, any actions pastoralists take will be in response to the problem and the causes they perceive. In 2017, my research team and I conducted 16 community focus group discussions with Samburu pastoralists in eight villages in the lowlands of southeastern Samburu County, Kenya. I selected communities that collectively represent the lowland Samburu pastoral culture and ecological system, with heavily overlapping community livestock resource use. I limited participants to adult women and men who could share their drought experiences from the 1970s to 2017.

I found that the Samburu have two main words that refer to dry periods that commonly match scientific drought terminology: *ngolong* and *riai*. *Riai* is a severe drought, usually distinguished by its effects: livestock death and the suffering of people. Pastoralists considered severe droughts as crises, but these events did not match with all low-precipitation anomalies. Nine severe droughts occurred between 1970 and 2017, on average once every five years. I found no evidence to conclude that drought impacts on Samburu pastoralists' well-being got worse over this period. The central determinant of whether pastoralists perceived a severe drought to occur was livestock forage sufficiency (based on availability, access, and demand). Lack of rainfall did cause loss of forage production, but pastoralists perceived mobility, violent conflict, and livestock factors to influence forage access and demand. Therefore, social and environmental processes caused this type of drought events. My team and I also found that the 1984 drought caused and began a trend of significant unwanted environmental changes. Samburu described environmental changes like the loss of soil, large mammalian herbivore species,

herbaceous plants, and an increase in small trees that were less palatable for livestock grazers. These environmental changes meant less cattle forage production, lower cattle productivity, and a shift in pastoralists' diets from livestock and foraged foods to imported foods.

In chapter 3, I present research about Samburu pastoralism's drought adaptation process. How do Samburu pastoralists cope with, adapt to, and recover from droughts, and what adaptive capacity did they use? I answer this question while exploring the Samburu experience of severe droughts from the 1970s through 2018. I use the same community focus group discussions in Chapter 2 and additional follow-up community discussions to understand these issues.

I found that following the most severe drought in 1984, Samburu pastoralists began sending their children to school in increased numbers. Parents sent their children to school so they would get jobs and start businesses to support the family's livestock husbandry. After the 1984 drought the Samburu people also began to herd sheep and goats in much larger numbers to support the part of the family that settled to access schools. During the 2017 drought, families reduced drought impacts in part because their children they earlier sent to school, now, had employment and sent remittances to purchase food and helped transport livestock or organize access to drought forage. Drought impacts on cattle were still high in recent droughts, but pastoralists developed new coping strategies that led to less overall suffering. I found that after 1984 the Samburu people relied upon women's increased labor and husbandry of sheep and goats to support sedentarization. The community's diversification of livelihoods and livestock husbandry also led to a faster and easier livestock recovery following the 2017 drought compared to past droughts.

Understanding the Samburu drought adaptation process builds knowledge of how adaptation strategies support and interact with one another. This contributes to drought

adaptation theory by helping identify key linkages between drought adaptations. This information based on local knowledge can help non-local actors working in community-based and top-down rangeland management improve their efforts to support the drought adaptation process.

In chapter 4, I narrow my drought focus to understand the 2017 drought impacts on sheep and goat husbandry in community conservancies. Increased sheep and goat husbandry and establishment of community conservancies are both adaptations to rangeland fragmentation and sedentarization that also influence drought responses and impacts. Sheep and goats reduce mobility needs and support settled families. Community conservancies, a form of community-based rangeland management, create livestock drought forage reserves by establishing conservation areas. This may reduce the need to move livestock during droughts and community conservancies secure communal land tenure, which can reduce rangeland fragmentation. I examine how the 2017 drought affected vegetation production and sheep and goat herds' production, mobility, and vegetation cover that the herds accessed. I also assess whether sheep and goat herds benefited from access to conservancy drought forage reserves. This chapter provides descriptive information about sheep and goat herding practices and movements and analyzes which measured variables predict sheep and goat drought resistance at the household-herd level.

I found that the 2017 drought caused severe losses in vegetation production. Household movements and herd and herder characteristics rarely predicted observed differences in sheep and goat production throughout the 2017 drought. The exceptions were that larger herds were more productive during one drought monitoring period, and herds that accessed greener vegetation were more productive during a pre-rain plant green-up period. Households near

conservancy drought forage reserves accessed them and these areas had higher shrub cover during one drought monitoring period. This information can help community-based rangeland management efforts in Kenya incorporate sheep and goat husbandry, which is typically considered problematic for rangeland management.

I explain how the relationship between drought and pastoralism has changed and make recommendations for NGOs and non-local policy makers working with pastoral communities in rangeland and drought management. Despite many drivers towards greater drought vulnerability, pastoralists are adapting and, in their view, are less drought vulnerable now compared to the past. However, these adaptations might be creating or ignoring negative environmental consequences that limit cattle production and mobility. More research is needed to investigate more recent adaptations, like sheep and goat husbandry, to see if there are ways to improve their benefits and reduce negative impacts. NGOs, scientists, and policy makers must better incorporate local knowledge from a pastoral perspective to help with the drought adaptation process.

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CHAPTER 1

INTRODUCTION

This dissertation presents my study of drought in the context of Samburu pastoralism. My research focuses on how this pastoralist culture perceives and experiences drought. Droughts are an integral disturbance within this social-ecological system that is culturally centered around livestock husbandry and herding. Like many dryland pastoral groups, the Samburu people living in central-northern Kenya have developed a way of life intertwined with drought. Its ever-looming presence is often anticipated, suffered, learned from, and overcome, while it shapes the flora, fauna, and opportunities of the Samburu semi-arid rangelands. Samburu pastoralists thus have critical perspectives on how they have wrestled with droughts. I used a collaborative, ethnographic scientific approach to understand droughts, previous and ongoing solutions, and potential innovations in this pastoral system. I hope the knowledge generated and presented in this dissertation will be useful to Samburu pastoralists, community-based rangeland management, and the scientific community to help address drought challenges.

This Introduction provides background information about the research and its organization. First, I give an overview about drought and Samburu pastoralism. The overview describes pastoralism as a social-ecological system where drought is common. Scientific theory and terminology are defined, and concepts and language described. Second, I take a step back to appreciate the road that brought me to this work and let the reader know some of the ways the science and Samburu people's story are filtered through my interests (or my positionality). I use this information to help explain my intentions and methods used in this collaborative and

ethnographic effort to discover and document knowledge with the Samburu people in a scientific journey. Finally, I give an overview of the three research chapters and a final reflection.

1.1. Pastoralism and Drought

Pastoralism, pastoralists, and pastoral systems

I use the term pastoralism to refer to cultures, comprised of a system of beliefs and behaviors, that are centered around the livelihood of livestock husbandry and herding (Dyson-Hudson and Dyson-Hudson, 1980). Pastoralists are the people who embody those cultures (Bollig and Schnegg, 2013; Fratkin, 2001; Reid et al., 2014). Others define pastoralists as herding people who maintain domestic animals such as cattle, camels, sheep, goats, llama, equids, or reindeer (Reid et al., 2014). This definition can be useful to understand livestock production as the center of pastoral livelihoods. However, it might suggest to a reader that only the herders within a society are pastoralists, or that if someone who once was involved in livestock husbandry switches to another livelihood, they are no longer a pastoralist. 'Pastoralist' definitions are open for discussion, but pastoralists tend to consider all members of their culture as part of their group; pastoralism as a culture is held by people beyond their means of production (Bollig and Schnegg, 2013). The degree to which a society considers itself centered around the livelihood of herded livestock or what counts as *herding* varies. Bollig and Schnegg (2013) classify pastoral groups using a gradient of diversification and specialization in livestock husbandry (e.g., maintaining one livestock species versus multiple species) and in other livelihoods (i.e., pure pastoralism versus pastoralism combined with income from other livelihoods like crop farming). They do this based on the proportion of two investment indicators

(labor and capital) that pastoralists put into pastoralism and a third indicator, worldview (pastoralists' view of themselves compared to others). Ranchers typically use a highly specialized form of pastoralism to raise grazing livestock for commercial purposes, often in fixed land parcels that individuals own or control (Fratkin, 2001; Sundaresan and Riginos, 2010). Agropastoralists practice a highly diversified form of pastoralism that includes growing crops and herding livestock from largely fixed locations (Reid et al., 2014). In this dissertation, I distinguish ranchers and agropastoralists as separate from the customarily more mobile and subsistent pastoral societies that reside in most rangelands (Reid et al., 2014). Some examples of these pastoral cultures in East Africa are the Samburu, Maasai, Borana, Gabra, Turkana, Pokot, Karimojong, Rendille, Somali, and Afar. These people make up a small percentage of the East African population but reside in large proportions of East African land (Fratkin, 2001; Reid et al., 2014).

In addition, a pastoral system refers to the social-ecological system in which a pastoral group, their livestock, and environment exist and interact, and these systems are dynamic and continuously changing (Galvin, 2009; Reid et al., 2014). A social-ecological system represents an interconnected society, natural resources, ecosystem services, and ecosystem dynamics; it is a type of system that emphasizes the inclusion of humans and their livelihood practices that are dependent on diverse ecosystem functions (Chapin et al., 2009). Pastoral systems include the customary institutions comprised of governing bodies, rules, and other cultural practices that dictate livestock husbandry and herding in grazing lands–and the management of rangeland biodiversity (note, I use the term 'biodiversity' to mean both species richness and abundance and as a general reference to life's flora and fauna) and ecosystem functions that support or interact with livestock and pastoralists (Glowacki, 2020; Reid et al., 2014; Renom et al., 2020). Pastoral

systems (sometimes, interchangeably referred to as rangeland systems) are complex and dynamic as pastoralists' actions or environmental changes cause subsequent social or environmental outcomes, to which humans and biodiversity react and adapt (Bollig, 2016; Bollig and Schnegg, 2013; Galvin, 2009; Thornton et al., 2019). A social-ecological system can be defined at many scales and this definition can be adjusted to best represent the interactions of interest but, in this dissertation, I distinguish this social-ecological system by the Samburu ethnic group.

Rangelands

Rangelands have many qualities that determine pastoral lifestyles and prohibit or limit other agricultural livelihoods (Briske et al., 2020; Dyson-Hudson and Dyson-Hudson, 1980; Liao et al., 2020; Reid et al., 2014). Pastoralists herd their livestock on rangelands across much of the world (Dyson-Hudson and Dyson-Hudson, 1980). Rangelands are natural environments dominated by open land cover of grasses, forbs, or shrubs, but that may contain trees. Rangelands often support grazing livestock and wildlife (Fuhlendorf et al., 2017). These non-forested environments, such as grasslands, savannas, shrublands, and deserts cover roughly 40% of the world's land surface, depending on the definition used (Fuhlendorf et al., 2017; Reid et al., 2014; Wei, 2021). Most rangelands are drylands in the semi-arid and arid regions of the world, where soil moisture limits vegetation growth, but subhumid rangelands exist, such as those in parts of South America (Galvin et al., 2008; Fuhlendorf et al., 2017). Rangelands that receive high and frequent levels of precipitation are wet rangelands dynamically maintained from tree encroachment through interactive disturbances. In some areas, fire and large browsing mammals suppress tree growth and thus provide opportunities for grasses to dominate. These disturbances create and maintain savannas or similar habitats; whereas, livestock or wildlife grazing can

encourage woody growth when fire intensity is reduced shifting areas into open woodland or bush. Browsing herbivores can have opposite effects (Augustine et al., 2011; Van Langevelde et al., 2003). Drylands have relatively small areas suitable for sustainable crop production, such as riverine areas or wetlands) because seasonal rainfall is often too inconsistent in any single location to reliably grow crops (Behnke, 2008). Livestock production is often far more profitable in these drylands than crop production (Behnke and Kerven, 2013). This is particularly true in parts of East Africa where bimodal rainfall (two wet seasons) distributes precipitation too spread over the course of a year to grow many cereals to maturity. The same average rainfall, however, would be sufficient for cereal crops as a unimodal system because it is concentrated in one shorter season (Ellis and Galvin, 1994). For this reason, pastoralists, with lifestyles dependent on grazing animals that move and can track vegetation growth and biomass and that rely on diverse plant communities, reside in many drylands, and benefit greatly from mobility (Dyson-Hudson and Dyson-Hudson, 1980; Liao et al., 2020).

Pastoralist and livestock mobility in drylands is a key feature of pastoralism to maximize production in heterogenous landscapes and, if mobile, livestock are unlikely to overgraze large areas and cause degradation in biodiversity (Briske et al., 2020; Liao et al., 2020; Reid et al., 2014). Rangeland functional heterogeneity is the spatial or temporal variability of key resources in rangelands at a scale that affects specific ecological processes (Fuhlendorf et al., 2017). Here, I mostly use it to describe forage variability at scales that matter to livestock grazing (but perhaps not migratory birds or snakes). It is an important feature because different types of vegetation may serve different purposes. For example, dry coarse grasses may sustain livestock populations through droughts, and different types of green, new growth provides needed nutrients for different life stages such as pregnancy, lactation, and growth. Additionally, other forage sources

like shrubs and seasonal tree pods provide essential dry season forage in many rangelands. In drylands, the periods of limited forage biomass or quality largely determine herbivore populations (Fuhlendorf et al., 2017; Hempson et al., 2015). Some semi-arid and arid regions have high rainfall variability and frequent droughts that result in highly variable forage production and unstable herbivore populations. These areas are considered nonequilibrium systems (Ellis and Swift, 1988), because they are dynamic and ecological processes do not form fixed production or herbivore carrying capacity levels. In these drylands, climate and weather patterns primarily dictate vegetation growth and its variation (Vetter, 2005). For livestock without accessible drought forage reserves this means lack of rainfall will kill livestock and their frequency or severity will largely determine livestock numbers (Briske et al., 2020; Moritz et al., 2018). Under mobile livestock scenarios, these rangelands rarely have high enough livestock or wildlife populations to severely overgraze and degrade landscapes (Ellis and Swift, 1988; Moritz et al., 2018). Livestock do, however, cause vegetation changes and may cause environmental degradation, typically at smaller than landscape scales (Illius and O'Connor, 1999). Degradation usually refers to the long-term (often three decades or longer) loss of biodiversity that may require rehabilitation efforts to overcome and may inhibit livelihoods (Reed et al., 2015). For example, significant livestock impacts on vegetation have been observed in (1) wet season grazing areas when plants are growing and reproducing, in (2) small patches of grazing intolerant species found in a matrix of grazing tolerant plants, or (3) when grazing is too recurrent around specific points, such as water resources, towns, roads or corrals (Illius and O'Connor, 1999; Liao et al., 2017).

Rangeland resource heterogeneity, disturbance regimes, and human management at the country or regional level contributes to diverse pastoral cultures (Fuhlendorf et al., 2017; Little,

1996; Reid, 2012). In Kenya and much of East Africa, landscapes are highly diverse (e.g., great topographic and edaphic diversity), and, along with natural and human controlled fires and large mammalian grazers, have created some of the most biodiverse and heterogenous rangelands in the world (Bhola et al., 2012; Little, 1996; Reid, 2012). As a result, this area supports some of the most diverse pastoral cultures with great variation in pastoral herding practices and drought management (Fratkin, 2001; Reid, 2012; Reid et al., 2014). The diversity and adaptability of specialized and diversified pastoral livestock practices that efficiently converts plant energy from sources that are not edible to humans into into highly nutritous food sources in the form of livestock products. Pastoralism's efficiency and adaptablility to disturbances has allowed pastoralists to maintain it in East Africa through major droughts, climate change, and social upheavals for 4800 years or more, while contributing to rangeland heterogeneity (Bollig et al., 2013; Marshall et al., 2018).

Drought, a community-defined problem

Drought is a disturbance that presents itself in many forms. Meteorologists typically standardize or designate droughts based on measures of low precipitation and high evapotranspiration anomalies (Kallis, 2008). Meteorological droughts account for local or regional seasonal precipitation averages and identify precipitation anomalies. Climate change has made and continues to make these dry events more likely to occur (Cattani et al., 2018; Conway et al., 2019; Ouma et al., 2018). Scientists often categorize droughts into three additional broad types based on the area of impact most socially felt: hydrologic, agricultural, and socio-economic (Wilhite et al., 2007; Wilhite and Glantz, 1985). People may experience two droughts with the same exposure (as measured meteorologically) in very different ways, even within a single

society because of differences in culture or livelihood. Most useful for our discussion is the definition that droughts are abnormal periods that lack rainfall to a degree that hinders livelihood activities (Kallis, 2008; Wilhite and Glantz, 1985). In most societies, droughts arrive through lack of precipitation but are felt and defined through their impacts. We use the community's perspective to define in detail these disturbances and their causes (Bennett et al., 2016; Galvin et al., 2020). This allows for drought's many forms to be more meaningfully considered as complex natural hazards that impact people's livelihoods and environments (Bennett et al., 2016; Smit and Wandel, 2006).

Droughts of dryland pastoralism ('of' because they are held within a cultural perspective) are unique compared to droughts perceived by many other cultural groups because dryland pastoralists have developed their livelihood to withstand dry seasons and droughts (Anderson and Bollig, 2016). Although pastoralists choose livestock husbandry and diversified livelihood practices to match drought conditions and use mobility and other coping strategies to avoid drought impacts, droughts have caused severe suffering among pastoral people (Anderson and Bollig, 2016; Bollig et al., 2013; Galvin, 2009; Huho et al., 2011; Huho and Mugalavai, 2010; Turner and Schlecht, 2019). Pastoralists make tremendous efforts to recover and adapt their livelihood following major drought events (Anderson and Bollig, 2016; Bollig, 2016; Bollig and Schnegg, 2013; Galvin, 2009). Historical and modern droughts have created major pastoral crises that devastate lives (Anderson and Bollig, 2016; Bollig et al., 2013). Pastoral systems are resilient because they are dynamic and ever changing but also because they are well suited to dryland environments; historically there have been few alternative dryland livelihoods (Fratkin, 2001; Reid, 2012). Pastoralism is less physically risky than hunting large mammals in these rangelands and food, in the form of milk, is more readily accessible than hunted food (Prins,

2000; Reid, 2012). When droughts are less severe or coping strategies are largely successful, the pastoral lifestyle can be bountiful and has historically supported advanced societies and militaries (e.g., 13th–14th century Khan dynasty). Today, droughts are complicated pastoral problems that still create human suffering and thus are a focus of science as well as humanitarian efforts (Bennett et al., 2016; Galvin et al., 2020; Kallis, 2008).

Pastoral customary institutions and property regimes

Grazing lands can be owned or used in several distinct ways that may determine use and management; these combinations of tenure and management are called property regimes (Moritz et al., 2019). Grazing lands are owned either by individuals (private), groups (private), a community, or the state. Private grazing lands (private property regimes) are typical of ranching systems, where an individual or a group of individuals own and make land-use decisions. In some cases, large numbers of individual property owners can collectively open their land for member use (Reeson et al., 2008). This sometimes blurs the lines of communal management systems (Bedelian and Ogutu, 2017). It is less typical that a community owns land in a strictly legal sense (this does exist), but communal tenure and land-use management from the customary perspective is how many grazing lands are organized (Moritz et al., 2019; Ostrom, 1990). Often, communal management (communal property regimes) takes place on state owned lands, where the national government claims ownership, but the community has land-use rights. Alternatively, state owned lands may be left as open-access systems (open property regimes) that are not managed in a strict sense and sometimes have multiple ethnic groups or mobile-communities grazing the area. In both open and communal property regimes, individuals or families may own or control specific natural resources, such as water points. These pastoral systems thus have

mosaic property regimes that use resource restrictions for different groups at different scales, and these variant property regimes impact grazing practices (Robinson, 2019). State property regimes occur where the state both owns the land and administers grazing regulations and may manage grazing lands for diverse ecosystem services, e.g., in the United States and Botswana (Moritz et al., 2019).

Most pastoral customary institutions are organized around two of these land-use categories, selected to sustainably meet their social and environmental context: open-access and communal (Moritz et al., 2019). Open-access grazing lands have rules that allow pastoralists from one or multiple ethnic or sub-ethnic groups to have unrestricted movements within the grazing land. These customary institutions typically do not need rules that restrict non-livestock land-use practices but have rules or norms that maintain the free movement of people and livestock. These customary institutions have low costs and largely exist where the threat of rangeland fragmentation is historically low (Moritz et al., 2019). Communal property is established when non-pastoral people threaten grazing land resources. Communal land tenure restricts access to grazing lands from outsiders and uses flexible but more fixed boundaries. These customary institutions are more likely to have governing bodies that restrict herd movements within the grazing land, at least seasonally, to help protect rangelands from overgrazing and ensure equitable resource use (Moritz et al., 2019). Nomadic and semi-nomadic people, who move between dynamically available resources (Dyson-Hudson and Dyson-Hudson, 1980), often establish open-access grazing lands. While other semi-nomadic groups and transhumant cultures, who generally have preplanned seasonal movements, in comparatively smaller and more forage stable environments establish communal property regimes. When droughts occur movements often necessarily become unrestricted, unless enclosures are used to

establish drought forage reserves (Angassa and Oba, 2008; Napier and Desta, 2011; Turner and Schlecht, 2019).

Pastoralism has been frequently misunderstood as necessarily leading to overgrazing and environmental degradation because of a 'tragedy of the commons'. This scenario occurs when livestock forage (or other resources openly accessible in grazing lands) are grazed above livestock carrying capacity *and* are ungoverned. In these situations, it is possible that an individual's benefits from adding livestock, and thus consuming resources beyond what is sustainable, are greater than the individual's costs because negative resource impacts are distributed across all resource users (Hardin, 1968; Ostrom, 1990). Under these conditions, individuals may face incentives to tragically overexploit, subtractable natural resources reduces overall wealth for the entire user group. Historically, the tragedy of the commons is unlikely to occur in grazing lands because its two premises rarely occur, at least simultaneously for long. (1) In drylands, livestock are not maintained at carrying capacity. In these areas, droughts frequently limit livestock numbers, and their populations are normally below carrying capacity. During droughts livestock have limited impacts on dormant plants before livestock begin to die (Ellis and Swift, 1988; Moritz et al., 2018; Vetter, 2005). (2) In wet rangelands, livestock numbers may normally be maintained closer to carrying capacity, but there almost always exist community governance of resource access. Historically, in rangelands that are at risk of overgrazing, customary institutions exist that use management or cultural norms to reduce risks of overgrazing or reduce individual benefits from amassing livestock (Moritz et al., 2019; Ouma et al., 2012; Spencer, 1965). One of the most important pastoral practices that helps avoid a potential 'tragedy of the commons' situation is herd mobility. While droughts keep livestock numbers dynamic, mobility can avoid negative livestock impacts, match localized plant

production with grazing, build plant heterogeneity in rangelands, or establish drought forage reserves (Augustine et al., 2011; Berhanu and Beyene, 2015; Liao et al., 2020; Moritz et al., 2014; Reid and Ellis, 1995). The fact that the tragedy of the commons are historically rare situations, does not mean cases of rangeland degradation do not occur. Livestock influence plant populations in rangelands or have the potential to cause undesired impacts at smaller than landscape scales for dynamic reasons (Riginos et al., 2012). Mobility and the customary institutions that help maintain healthy rangelands are under threat from rangeland fragmentation, and thus some scientists have put forth that the real threat is a 'tragedy of enclosure' (Moritz et al., 2018; Reid et al., 2014). What these customary institutions historically may not be prepared to handle at current scales is violent conflict, non-local governance, population growth, extractive industries, infrastructure development, and climate change, which hamper mobility or increase the need for mobility (Fratkin, 2014, 2001).

Rangeland fragmentation and loss

Worldwide, in East Africa, and in northern Kenya, pastoralists face pressure from violent conflicts, non-local or undemocratic governance, internal and external population growth, extractive industries, infrastructure development, and climate change that have undermined or overtaxed the capabilities of their customary institutions and has led to rangeland fragmentation and loss, and subsequent reduced mobility (Anderson and Bollig, 2016; Fratkin, 2001; Galvin, 2009; Moritz et al., 2019; Reid et al., 2014). Rangeland fragmentation is defined as physical or social barriers that divide the landscape with consequential reduced mobility (Hobbs et al., 2008). It is a major threat to pastoralists, livestock, and wildlife because access to key resources can be reduced in a heterogenous landscape and drought vulnerability can increase (Boone and

Hobbs, 2004; Hobbs et al., 2008; Ogutu et al., 2016; Reid et al., 2014; Western et al., 2009). For example, fences are increasingly used across rangelands where pastoralists and non-pastoralists are privatizing grazing lands, this limits livestock movements (Boone and Hobbs, 2004; Lesorogol and Boone, 2016). Extractive industries, like mining, and infrastructure development can convert rangelands to permanent non-pastoral or agricultural uses (Weng et al., 2013). Ethnic regionalization occurs when governments demarcate regional boundaries based upon ethnic identities that do not necessarily represent historical flexible natural resource use and movement patterns. This action can put harder boundaries, such as gazetted land rights, on historically mobile groups. Also tactics to create a homogenous voter base in administrative areas creates real or perceived threats of violence that deter cross-boundary mobility (Fratkin, 2014; Greiner, 2013; McPeak and Little, 2018). In all its forms (e.g., fences, land loss, social divisions), rangeland fragmentation more than any other factor is the mechanism that has decreased large mammalian populations (Ogutu et al., 2016; Western et al., 2009a), and reduced livestock production with increased livestock drought vulnerability (Boone et al., 2005; Hobbs et al., 2008; Reid et al., 2014). When people's ability or desire is inhibited to follow their customary institutions, pastoralists are less likely to organize community scale adaptations to the drivers that cause rangeland fragmentation or its impacts. For example, communities may lose the ability to regulate grazing practices that help ensure healthy rangelands in more fragmented landscapes if government policies reduce customary institutional control over grazing lands (Fratkin, 2001; Mortiz et al., 2019).

Violent conflicts have erupted at greater scales over the last few hundred years and continue to this day in East Africa in ways that force pastoralists to move and settle in grazing lands mismatched to customary environmental use (Fratkin, 2001; Greiner, 2013; McPeak and

Little, 2018). Pastoralist groups have moved and created new home ranges over decades and centuries in different rangeland regions of East Africa (Reid, 2012). Through either violence or negotiation pastoralist groups have been able to track environments to match their cultural livestock practices or, alternatively, have adapted their livelihoods to match environmental changes in fixed locations (Bollig et al., 2013). However, the role violence plays in recent history appears much more significant in disrupting pastoral lives and mobility. In recent centuries, European colonialism and its violence forced some pastoral groups to settle, even while it mitigated violence for some groups. In recent decades, violence has become even more problematic. Particularly during droughts, livestock must be moved to remaining forage often in contested border lands. Pastoralists have increasingly armed themselves in response to violent conflicts and the severity of violence has increased (Krätli and Swift, 1999; McCabe, 2007; McPeak and Little, 2018; Turner, 2004). In Kenya, during election years, violence can erupt as politicians try to scare ethnic minorities away from voting in certain administrative areas or to secure ethnic voter support (Greiner, 2013). Violence is thus a major contributor to rangeland fragmentation through social barriers, but with its own direct impacts on human well-being, for example pastoralists' nutritional health (Fratkin, 2001; Pike et al., 2016).

Undemocratic governance and external policy that was made without local, pastoral engagement (for example, from some conservation efforts and colonization) have redefined pastoral borders and converted grazing lands (Cockerill and Hagerman, 2020; Fratkin, 2001; Gebeye, 2016). This includes policies that promote farming or make livestock mobility so difficult that pastoralists convert their grazing lands to less productive or unsustainable crop lands or migrate to urban areas (Cochrane and Legault, 2020; McPeak and Little, 2019; Reid et al., 2004). In some areas this land conversion and reduction in grazing land is the major threat to

livestock production. Relatively small parcels of dry season or drought grazing areas, for example along riverine areas, have critical roles as buffer resources to protect livestock populations from complete collapse during droughts (Fuhlendorf et al., 2017; Hobbs et al., 2008). For example, in the Afar region of Ethiopia, many riverine grazing areas have been converted to sugarcane and cotton production that is far less productive overall but provides income to elites that maintain the system (Behnke and Kerven, 2013). In the past, but still a challenge today, rangeland conservation efforts have actively displaced pastoralists to protect wildlife or secure trophy hunting grounds (Cockerill and Hagerman, 2020; Packer et al., 2011). These efforts while perhaps well intentioned, often ignore the ecosystem contributions pastoralists make, through fire and livestock grazing disturbances, to heterogeneity and biodiversity (Augustine et al., 2011; Fratkin, 2001; Fynn et al., 2016; Riginos et al., 2012; Vuorio et al., 2014). They also often ignore pastoralists rights to their grazing lands. Undemocratic processes continue to marginalize pastoralists politically and physically to smaller and less productive rangeland areas (Cockerill and Hagerman, 2020; Fratkin, 2001).

In pastoral areas, internal and external population growth has decreased livestock and resource availability on a per capita basis for pastoralists. For example, in Kenya, livestock biomass has largely remained unchanged in recent decades, but cattle production has decreased, smallstock production has increased, and the human population has rapidly increased (Ogutu et al., 2016). In Kenya the human population has increased from 10.9 million in 1969, to 37.7 million in 2009, and to 46.6 million in 2019 (Kenya National Bureau of Statistics, 2019). In pastoral areas, human population growth with fixed or decreasing cattle production has led to greater poverty (Catley et al., 2016; Holechek et al., 2017). This per capita decrease in cattle production means pastoralists have had to become more dependent on some undesired, imported

foods that are less nutritious (Holtzman, 2007; Spencer, 1965; Sperling, 1987). External population growth (along with ethnic regionalization) has enclosed some pastoral groups within their traditional wet season grazing areas and limited access to historic drought forage areas. When pastoralists are surrounded, they are pressured to form new governing bodies and rules to negotiate with non-pastoralists (Fratkin, 2001; McPeak and Little, 2019; Moritz et al., 2019). Customary institutions face new challenges to protect and regulate these resources in equitable ways, particularly when fragmentation has reduced mobility or encouraged families to settle (Fratkin, 2001; Holechek et al., 2017; Lamprey and Reid, 2004).

Climate change adds complexity because warming, drying, and increased carbon dioxide levels are changing vegetation growth and other environmental factors in drylands around the world (Wei, 2021). It is possible the spread of woody plants in Kenya is due to increasing CO_2 levels in the atmosphere which promotes faster tree growth that is more likely to escape fire suppression (Bond and Midgley, 2000; Reid, 2012). Woody plants also have increased likely because of decreasing elephant and browser populations and less frequent or intense fire regimes (Georgiadis et al., 2007; Prins, 2000). Climate change effects include increasing rainfall variability, decreasing rainfall during the short rains of March through May, increasing temperatures, and increasing evapotranspiration rates (Bobadoye et al., 2016; Cattani et al., 2018; Ouma et al., 2018; Pricope et al., 2013). In some of the dryland areas of East Africa, including northern Kenya, climate change and changes in land-use practices have resulted in an increased risk of drought and decreased vegetation growth (Pricope et al., 2013). This makes it harder for pastoralists and their undermined customary institutions to adapt and respond to the complex drivers of rangeland fragmentation while navigating more rapid biodiversity changes and losses (Holechek et al., 2017; Liao et al., 2020; Thornton et al., 2019).

Rangeland fragmentation, particularly during drought events, has led to lower livestock production, pastoral sedentarization, and the loss of biodiversity across much of East Africa (Galvin, 2009; Ogutu et al., 2016). The diverse drivers of rangeland fragmentation (described above) have also forced or contributed to pastoralists' decisions to settle (Fratkin, 2014, 2001; Galvin, 2009). With settlement pastoralists send their children to school and diversify incomes to adapt to drought and increase income (Little et al., 2009; Turner and Schlecht, 2019). Settling and market access generally has not necessarily improved pastoralists diets and in some cases has caused poorer nutritional status (Fratkin et al., 2004, 1999; Galvin et al., 2015). However, it is possible that these foods provide a more consistent source of calories than livestock production during droughts. Livestock in settled communities are less productive and at greater risk from drought (Boone, 2007; Boone et al., 2005). They are also more likely to negatively impact vegetation through recurrent, overgrazing (particularly if supplemental feeding is used that maintains livestock in a fixed location), unless mobility is maintained through concerted efforts (Briske et al., 2020; Liao et al., 2020, 2017). Rangeland fragmentation, less mobile livestock, and changes to vegetation growth likely have contributed to the decline of wildlife. In Kenyan rangelands large mammalian populations have decreased on average by 68% from 1977 to 2016 (Ogutu et al., 2016). This decline has occurred inside and outside of formally protected areas, which indicates rangeland fragmentation even affects protected areas and improved conservation efforts must involve pastoral communal lands (Western et al., 2015, 2009b). Rangeland fragmentation and vegetation shifts are likely also responsible for the decline of cattle populations. The Kenyan cattle population (the livestock species that requires greatest mobility) has declined 25%, but livestock biomass has only decreased 4% because of the rapid rise in

sheep and goat numbers that are more easily herded around permanent settlements (Ogutu et al., 2016).

Efforts to revitalize or replace customary institutions in Kenya

Pastoral communities in large swaths of northern Kenya have recently created new community-based natural resource management and development institutions called *community conservancies* to help them address and adapt to the complex challenges they face. In Kenya, a conservancy is land owned and managed privately or in a group (including as a community) for wildlife conservation and other land-uses to better livelihoods (KWCA, 2016). Like other community-based natural resource management efforts, community conservancies use a collaborative approach between the community and outside institutions, including government, conservation, and development agencies, to expand technical and financial resources for community needs (Berkes, 2009; Dressler et al., 2010; Shackleton et al., 2010). Community conservancies in Kenya work to improve livelihoods and conserve wildlife through a variety of social and ecological interventions (WCMA, 2013). Communities have established conservancies for a variety of reasons but often they are established to counteract rangeland fragmentation forces including land privatization, fencing, and ethnic violence (Reid et al., 2016). A portion of conservancy efforts are directed to manage rangeland resources that support livestock and wildlife because they consider these resources and management the foundation of pastoralism and potential well-being. To address these challenges and rehabilitate the rangeland, some community conservancies have created rangeland management programs that formalize and create new rules for how pastoralists access and use livestock forage (Bedelian and Ogutu, 2017; Pas, 2018; Tyrrell et al., 2017). While community conservancies can revitalize customary

institutions (NRT, 2019), diverse goals in collaborative groups can cause conflict or end up replacing customary governing bodies (Bedelian and Ogutu, 2017; Cockerill and Hagerman, 2020; Pas, 2018). Additionally, programs can be implemented with limited community input or approval leading to confusion in rangeland management and inequitable outcomes (Bedelian and Ogutu, 2017; Glew et al., 2010). Scientific studies more commonly document social than ecological outcomes in community-based conservation programs (Galvin et al., 2018), in part because environmental successes require time to develop and may be harder to measure. More research is needed to understand pastoral customary institutions and community conservancy processes and outcomes (Renom et al., 2020). Best (or good) practices of conservancies in rangeland management remain largely an open question in dryland pastoral systems.

Adaptation conceptual framing of research

For my doctoral research, I have chosen to examine Samburu pastoralism and drought through the lens of adaptation theory. This is because my central interest is to understand the changing relationship between drought and pastoralism among the Samburu people of northern Kenya. Adaptations are the changes or actions people make to cope with or adjust to changing conditions. Adaptation theory often places adaptations in the context of adaptive capacity or vulnerability (Smit and Wandel, 2006). This context is useful in this study because droughts are an unwanted change that cause human suffering. The degree of suffering depends in part on the vulnerability of pastoralism and the relevant social and environmental variables that dictate how well it provides as a livelihood. The vulnerability of different pastoral variables, for example sheep and goat production, depends on its exposure to drought's effects and its sensitivity to change. Drought sensitivity is the degree that a variable is impacted by drought. Sensitivity and

adaptive capacity are highly interconnected concepts, because adaptive capacity will largely determine sensitivity over time (Adger, 2006). Adaptive capacity is the ability to access and use human, physical, and natural resources to make adaptations as needed. Greater adaptive capacity reduces vulnerability, but it is also determined by one's social-ecological situation (Cinner et al., 2018). I analyze how Samburu pastoralists make adaptations to gain a better understanding of their adaptive capacity to droughts.

I examine adaptations in relation to drought events to better understand the drought adaptation process. I use three categories to look at adaptations based on when they were made in relation to drought events: anticipatory, coping, and recovery. I use the term 'strategy' with each 'action' or 'change' because I want to indicate an adaptation may not have the intended outcome. Anticipatory (adaptation) strategies are used in an attempt to mitigate future droughts but are sometimes made to take advantage of new conditions. They are used between drought events when there is the perception that a drought will come in the future. In dryland pastoral systems droughts are almost guaranteed to arrive again within a decade and thus drought anticipatory strategies are commonly implemented. Pastoralists make anticipatory strategies when past coping strategies were insufficient, or the next drought is predicted to be more severe (Opiyo et al., 2015; Thornton and Manasfi, 2010). Anticipatory adaptations, like income diversification, can also be made to improve the drought recovery process (Nelson et al., 2007). Coping strategies are used during a drought event to resist drought impacts. They are temporary actions that determine the systems sensitivity to drought. In the scientific literature coping strategies sometimes are called reactive adaptations and often rely upon knowledge of previous hazard experiences (Thornton and Manasfi, 2010). For example, pastoral mobility during a drought is a coping strategy category and good mobility will often save livestock (Opiyo et al.,

2015; Turner and Schlecht, 2019). Recovery strategies are made in the changing, improved, conditions that arrive when a drought ends. After droughts, pastoralists face decisions of whether to use remaining resources to recover their herds to previous levels. Just because livestock die during a drought does not mean livestock husbandry was not the best livelihood strategy at the time or might not be best suited for the post-drought period. Pastoralists' ability to actively recover livestock through breeding efforts, social networks, or markets can determine future well-being. For pastoralists full or partial recovery of livestock holdings are integral to their central livelihood and cultural identity (Lesnoff et al., 2012; McCabe, 2007; Nkedianye et al., 2011; Reid, 2012). Adaptation theory rarely considers the recovery process to drought but as we will show in Chapter 3 it was a topic of great importance to Samburu pastoralists.

1.2. Reflexivity Statement

Pros and cons of a reflexivity statement

A reflection on my beliefs, societal position, and role in my research is valuable to help me and others understand strengths and biases that may have influenced the study's questions, results, conclusions, and discussion. In my opinion, the social and ecological sciences are an important approach to understand and document cultures and environments in ways that develop intercultural connections. Nevertheless, the choices social and ecological researchers make about how they engage their study community and subjects will determine–to a degree–what is measured and observed. We live in a social world where beliefs affect how scientists conduct their research in the social and ecological sciences. For example, my research included a participatory, collaborative approach with the Samburu people and others from many different cultural backgrounds and life experiences. My encounters with Samburu people shaped what I

measured, observed, and concluded; however, there was assuredly unintentional influence that should be considered. For example, my beliefs, including my preferences and knowledge, guided me to my research questions the variables I measured. My thoughts about my role in society, Samburu culture, and their perceptions of me changed my interactions with study participants and this changed my observations. Many others impacted my research including the scientific community and Kenyan research assistants, who served as cultural ambassadors, with their own sets of research biases, but I am unable to reflect on all these factors. This reflexivity statement (also called a positionality statement) guided how I interpreted my research results. It may also help others consider my results in a larger context and perhaps reinterpret aspects of my work as they take into consideration with the strengths and biases of other researchers' works. In this section, I reflect on these potential influential factors and in the next section I reflect on the collaborative process that was intended to overcome some of these issues.

In many ways this reflection is limited because it was not done during the process of conducting my research. This reflection relies on my self-awareness and tries to capture some of my beliefs and thoughts that are dynamic. I did not document many of the influential factors described below while my research was ongoing. As a result, this is a difficult and largely insufficient post-hoc analysis.

In future studies, I will strive to better document my beliefs about research participants and cultures prior to making research actions–and take them as personal research hypotheses that I dynamically update. I will also record important interactions that influence the research throughout the study. Part of this process should in most cases include discussion and analysis about how the study population views me and others on the research team. I think carefully documenting my beliefs and the study in stages would be more reliable than a reflexivity post-

hoc analysis. I appreciate that there will always be underlying social factors that I am unaware exist and thus a reflexivity statement will have value. More valuable, in my opinion, will be to the careful documentation of researcher decisions and actions combined with a collaborative process to better account and avoid research biases.

I worry that a reflexivity statement may only reinforce stereotypes about how two different cultures, sexes, or races necessarily interact. In truth, there is a great diversity of individuals within the cultural groups I collaborated with and great variation in the interactions that took place. I try to avoid playing into stereotypes about anyone's societal position if they were not likely a factor in my interactions, however, I still use inexact societal labels for both myself and others. I acknowledge it is impossible to really know what was or was not a factor. Despite these limitations and risks, and to be more open and honest about my work, I put forward this reflection on my work.

Factors that may have unintentionally influenced my research process

I have a bias towards science and information that explains causation, and this may have led me to discount some participants' knowledge. My philosophy is science in its most basic form is rational reason and the process is to understand facts including mechanisms–why something occurred the way it did. This does not mean I am always reasonable or properly identify reasonable ideas, but that I strive towards this ideal and search for it in others. In my opinion, scientific capacity is not limited to (or by) professional, academic scientists. Humans have a unique ability to process counterfactual events in their minds through hypotheticals to determine why something occurs with varying degrees of accuracy. This helps form evidence that we can then use to make logical and reasonable arguments. Improved methods of scientific

observations and analysis (like those in academia) can help determine cause-and-response with greater certainty in complex systems. The complexity of the scientific process needed depends on the research question and has been developed in many cultures. For these reasons, I view science as a common (but not necessarily ubiquitous or consistent) quality in the human psyche across cultures. There is great ecological knowledge within many individuals, especially those with generations of environmental experiences to draw upon, which should not be ignored. I consider traditional, Indigenous, and local knowledge as scientific in many cases. While I tried to remain open and avoid selection bias in data collection from how pastoralists described their social-ecological system, I perhaps missed or ignored information that to me did not seem reasonable, explain causation, or appeared tangential to the research topic. This behavior and selection bias towards scientific explanations also could have dictated my follow up questions and how my conversations proceeded during initial interviews and community group discussions. I realize that this may have led me to miss opportunities to learn and led me to misrepresent the beliefs of those I spoke with.

I often consider myself, and others (including many East Africans) often view me, as an American, male, white, highly schooled with knowledge in academic science, and financially wealthy. Each of these factors influenced my collaborative research approach in ways I identify here. My overall goal going to Kenya was to work with a pastoral community to scientifically study rangeland management issues. My hope was to do this with their participation to increase the chances my research would be useful to them and the scientific community. I also wanted to learn from this research process in a way that satisfied my Ph.D. requirements. My efforts to collaborate with the Samburu pastoral community were limited to the community members I interacted with and the ideas they shared with me. Being an American citizen and majority

racially white (Spanish and British descent) made me a clear outsider to most Kenyans. While I prefer to hold the view that I am a global citizen and like the idea that all people should have a voice in conservation and ecological issues around the world, I recognize this view is not currently practiced and is perhaps impossible to implement justly. Some Kenyans saw me as an outsider who should not be involved in local conservation and development decisions; I spoke with some of them. Others welcomed me out of kindness, openness, or with favorable views of international support in development and rangeland management, and for my assumed ability to provide finances or knowledgeable solutions. I gravitated to those that were more welcoming. I connected myself to a non-government organization, the Northern Rangelands Trust (NRT), which the United States Agency for International Development in part funds, and the community conservancies (community-based rangeland management organizations) affiliated with NRT. I mention this because many of the interactions that guided the formation of my research questions was with people that thought development agencies had an important role to play in pastoral people's progress to greater well-being. Additionally, pastoralists that knew, or suspected, I was connected with these outside institutions perhaps altered what they expressed to me about these organizations and their programs. This does not mean they only expressed positive views about them (I spoke with people that took issue with community conservancy efforts), but perhaps they changed responses in ways they would have otherwise discussed with people from their own culture. It may have also decreased the chances that I spoke with individuals in conflict or with views antagonistic to the work of foreigners, development agencies, or community conservancies. My position as a somewhat wealthy American and a graduate student at Colorado State University might have encouraged those that were more inclined to ideas of American or scientific solutions to seek me out for collaborative research efforts. I also recognize this opinion

may have discouraged community members from sharing their own knowledge with me if they view it as less valuable. I am male and identify in my cultural view and Samburu cultural views as a man. In Samburu and most Kenyan cultures there are relatively large limitations in how men and women commonly interact compared to my own cultural practices where I try to not let gender views dictate many of my behaviors. I cross some of these barriers being a non-Kenyan, but this division limited what women I spoke with and likely limited the responses to the question of how I might help and collaborate. Samburu culture is male dominated in community decision-making, and as a male, I may have had more access to people in pastoral power than a female researcher would have. For these reasons, my societal position changed how I was able to collaborate with the Samburu community and other Kenyans. I reflect in my research chapters how specific issues appeared to limit the study results and extrapolation of conclusions.

I have experience being marginalized and discriminated in American and global cultures for my personal attributes and think this has led me to be more compassionate and considerate towards many other marginalized groups. I do not think it is necessary to have been discriminated upon in order to have compassion for others in relatable situations. However, I do think in my case it helped me gain a deeper understanding of the harm those with power (including myself in some situations) can intentionally and unintentionally cause. I take this as a strength of my research so far as I was able to see discrimination in the context of Kenyan society. This is part of what led me to work with pastoral people, who I consider largely marginalized from non-pastoral cultures, with little control over land-use planning by national or international governments, and who do not easily fit into or benefit from standard capitalist economic approaches to development. Samburu pastoralists have their own forms of discrimination. The limited role, representation, and mistreatment of women stands out as an

issue, and women actively voiced these injustices to me. Younger males are also marginalized in decision-making power. Elder men largely have final say over community and household decisions. My experiences led me to make extra efforts, intentionally and unintentionally, to engage and include women's ideas in my work and to make sure I was not prioritizing the issues of men. I think this helped me improve my research questions in ways that were more likely to identify areas of greatest improvement and, in this case, move away from elder-cattle centric pastoral research (largely focused on by the majority of researchers and development efforts). This led me to include sheep and goat husbandry as a research focus because they more directly support women and children and ensured women collaborated in my research. I failed in some ways to fully collaborate with younger males but some young adults, including male and female research assistants, influenced the study design and my understanding of Samburu culture. Of course, this is not the first-time research with women pastoralists has been done, but I hope this helps continue to balance some aspects of academic research interests in pastoralism and supports others (namely scientific women that have different societal positions, strengths and biases) to do research with women pastoralists or different marginalized pastoral groups.

I appreciate I view the world through the lens of my own mind and societal position, which has led me to scientific collaboration and the desire to build the capacity of science and academic participation in others. Perhaps this reflection has limited value, but it does remind me that my contribution and viewpoint should be considered in the context of other scientific work. It is my impression that the researchers who attempt to understand rangelands and pastoralists have so far been skewed to a homogenous group of American and European non-pastoralist researchers. They have made important scientific contributions, but their findings would likely be improved in the context of further research by diverse scientists that have different strengths

and biases. I am happy to be fortunate enough to be able to help build understanding between cultures and want to support others to do the same. I try to recognize my limited knowledge and abilities and try to make up for it through collaboration with others.

1.3. A Collaborative Research Effort

I decided to study community-based rangeland management in northern Kenya because this system provided the opportunity to work on my interests in several areas: societal well-being, livestock-environmental interactions, and community-based conservation efforts. How societies might improve their lives (i.e., develop) and simultaneously improve their environments fascinates me. The reason I pursued this Ph.D. is because I sought to improve my skills and knowledge so I can contribute to development and conservation actions. I define conservation as the preservation and promotion of life and its well-being. Therefore, development and conservation contain, in some senses, the same goal but are set at odds with one another when the well-being of humans is in conflict with other life. This occurs frequently, but changes in perspective about well-being and learning about social-ecological systems can better harmonize progress in conservation and development. In Kenya, there are unique government, NGO, and community efforts being made that appear to be at the forefront of discovery about how to decrease human suffering and promote the biodiversity of life. In Kenya's pastoral-rangeland systems there are opportunities to learn from local communities seeking to adapt their livelihoods to gain wealth and alleviate certain kinds of suffering while continuing to conserve wildlife. My interest was to understand how pastoralists can be supported to make their desired adaptations for greater social and environmental well-being. Northern Kenya specifically provided an opportunity to learn about these issues with pastoralists working on community-

based rangeland management efforts, and I had the social connections, experience, and resources necessary to conduct work in this area.

I attempted to use both collaborative and ethnographic methods to design my research and to improve the study's value to stakeholders (those with interest and influence, or that are influenced) of community-based rangeland management in Kenya. My advisors and others encouraged me to use a collaborative research approach that would have stakeholders of community-based rangeland management in Kenya actively involved in many aspects of the research process (Shirk et al., 2012). One piece of advice that resonated for me from my advisor, Robin Reid, was that my research was an opportunity to help give voice to the marginalized and that this could change the conversation of those in power. It was with this ethic–my work should serve foremost the studied community–that guided my decisions about the research approach. I chose a collaborative approach because I was limited in access and time with pastoralists in northern Kenya but wanted stakeholders to participate in the study goals, design, data collection, interpretation, and discussion. A collaborative approach allowed me to maintain control over my research, as opposed to a co-created or collegial approach (Shirk et al., 2012), but likely at a cost of some missed knowledge and less value to the community. Based on *science with society* guidelines, I was able to include aspects of each of the seven steps: (1) exploration, (2) partnership formation, (3) multiple knowledge systems, (4) co-design, (5) co-produce, (6) communicate and act, and (7) co-develop future opportunities (Steger et al., 2021). I have so far been strongest in steps one through five, but weakest in steps six and seven. My research into sheep and goat herding practices during a drought (Chapter 4) was started first chronologically and only contained steps one, two, and four. With more time in the field, I was able to better collaborate on the research presented in Chapters 2 and 3. At the same time, I used an

ethnographic approach that grounds the problems in a cultural context, in this case drought and drought adaptations. When done well, this provides information about why and how people within a culture respond to drought and reduces the assumptions used in explanation of findings from my personal or the scientific community's understanding (Fiske et al., 2014). Furthermore, an ethnographic approach may integrate traditional or local ecological knowledge with academic knowledge to provide more options for better collaborative environmental management efforts, like those being made in northern Kenya (Raymond et al., 2010). I describe the actions I took, outcomes, and reflect on the process of this collaborative-ethnographic approach in the dissertation's final chapter.

1.4. Dissertation Overview

This dissertation covers the research I conducted with my research team about drought and Samburu pastoralism in three research chapters (chapters 2, 3, and 4) and has a conclusions chapter (chapter 5). In chapter 2, I mostly use qualitative research methods based on community focus group discussions with Samburu pastoralists in northern Kenya to identify and describe the problem of drought. Samburu pastoralists practicing community-based rangeland management identified these dry events as the periods when they most suffered and that had created important societal and environmental changes. The purpose of this research was to understand how droughts cause Samburu pastoralists to suffer and how they understand this major challenge that they regularly adapt to. I describe, using Samburu local and traditional knowledge and experiences, how drought is defined and categorized, what severe drought events have occurred since the 1970s (with comparison to remotely sensed drought measures), what causes drought in Samburu pastoralism, and how droughts change the environment and, thus, the likelihood of

future droughts. The findings in chapter 2 show how these events are environmentally and socio-economically driven and are culturally understood. As far as I know, chapter 2 contains the most in-depth scientific examination of drought from any pastoral cultural perspective and shows the importance of understanding climate events and climate change from the ground-up.

In chapter 3, I present research about the drought adaptation process in Samburu pastoralism. This chapter uses qualitative data from the same community focus group discussions in chapter 2 and additional follow-up community discussions to learn how Samburu pastoralists have adapted to the severe drought events in their lives. This chapter describes the anticipatory, coping, and recovery strategies to drought, changes in drought impacts, and what facilitated these adaptations. An understanding of this drought adaptation process leads to understanding of how adaptation strategies rely upon and interact with one another and thus shifts our understanding of adaptive capacity and how the scientific community and community-based rangeland management efforts might support future pastoral drought adaptations.

In chapter 4, I examine sheep and goat husbandry, including how it is supported by another drought and environmental adaptation strategy, community conservancies. I use quantitative and qualitative mixed methods to explore how sheep and goat production and herding practices were impacted and altered over the course of the 2017 drought in three Samburu communities. This included GPS tracking of sheep and goat herds and recording herd and herder characteristics. I compared how these variables relate to the vegetation-greenness level that the herds accessed and sheep and goat body condition scores and market values in three drought monitoring periods and one post-drought recovery period. I wanted to understand how different herding factors might contribute to herd movements, herd access to vegetation, and drought resistance and post-drought recovery. This included whether herds had access to drought

forage reserves organized by community conservancy. This work provides descriptive information about sheep and goat herding practices and movements, but also explores which variables predict sheep and goat drought resistance in households. Future studies can use this information to identify how community-based rangeland management efforts in Kenya can begin to incorporate sheep and goat husbandry for improved livelihoods.

Finally, in chapter 5, I summarize my main messages from the previous research chapters, describe the implications for NGO practice and policy in northern Kenya and related community-based rangeland management efforts, and reflect on my collaborative research process and how it could be improved. My description of implications centers around why it is essential to collaboratively build an ethnographic understanding of drought and to manage for these periods in community-based rangeland management. My reflection on my research process includes insights from conversations with my Samburu friend and co-researcher. The purpose of this research evaluation is to understand how I might improve my future collaborative research efforts to better serve development and conservation.

Researcher roles and use of pronouns

Seventeen individuals had significant roles as researchers with major contributions to the scientific ideas or data collection and analysis presented in the research chapters of this dissertation. These studies required the collaborative participation of scientists and research assistants to improve the research and make findings possible. Since I do not want to underplay their contributions, I refer to any given chapter's research team with the pronoun 'we' and describe the actions 'we' took in that chapter. Where appropriate I distinguish between different researcher roles in the chapters. In the 'Introduction' and 'Conclusions and Recommendations'

chapters of this dissertation, I use the pronoun 'I' because I (Tomas Pickering) contributed the ideas with critiques from my advisors. The following is a list of all researchers and their major roles or contributions to each chapter's study, not including the work I did.

– *Chapter 2: A Samburu pastoral perspective on drought crises and their causes*

- Annemiek Pas – Contributed to research ideas, questions, and study methods.
- Kasmira Cockerill – Contributed research ideas, questions, study methods, and focus group data collection.
- Daniel Lenkaina – Facilitated focus group discussions and annotated qualitative data.
- Apin Yasin – Contributed to research ideas, field assistant, and annotated qualitative data.
- Headman Lenaiyasa – Field assistant and annotated qualitative data.
- Abigail Stokes – Completed NDVI anomaly analysis.
- Patrick Keys – Advised NDVI anomaly comparison strategy.
- Brett Bruyere – Contributed to initial research ideas and advised field methods.
- Kathleen Galvin – Advised all aspects of this study.
- Robin Reid – Advised all aspects of this study.

– *Chapter 3: The drought adaptation process of Samburu Pastoralism*

- Annemiek Pas – Contributed to research ideas, questions, study methods, and initial data analysis.
- Kasmira Cockerill – Contributed research ideas, questions, study methods, focus group data collection, and initial data analysis.
- Sarah Walker – Contributed to framework for discussion and interpretation of results.
- Daniel Lenkaina – Facilitated focus group discussions and annotated qualitative data.
- Apin Yasin – Contributed to research ideas, field assistant, and annotated qualitative data.
- Headman Lenaiyasa – Field assistant and annotated qualitative data.
- Kaitlyn Ammerlaan – Assisted with qualitative data analysis collected in 2019.
- Brett Bruyere – Contributed to initial research ideas and advised field methods.
- Kathleen Galvin – Advised all aspects of this study.
- Robin Reid – Advised all aspects of this study.

– *Chapter 4: Effects from drought and conservancy forage reserves on sheep and goats*

- Sarah Carroll – Led NDVI remote sensing data collection and analysis and GIS analysis of shoat movement data.
- Apin Yasin – Managed team of field research assistants and contributed to research ideas.
- Felix Kiprono – Contributed to research ideas and assisted with field data collection.
- Kelly Jones – Advised initial study design and analysis.
- Jeffrey Worden – Advised initial study design and analysis.
- Randall Boone – Advised remote sensing and herd movement data analysis and advised initial study design.
- Kathleen Galvin – Advised all aspects of this study.
- Robin Reid – Advised all aspects of this study.
- A team of field research assistants collected all field data – Francis Lekanta, Isaya Lemerketo, Evans Saidimu Lenaiyasa, Alan Lepirei, Sammy Lekumoisa, Cain Lemaramba, Adiela Nalusu, Benedict Lekoomet, Silvia Lengila, Joshua Letoole, Christine Lekalkuli, and Dominic Lenarum.

CHAPTER 2

"RIAI IS WHEN PEOPLE AND LIVESTOCK START TO DIE": A SAMBURU PASTORAL PERSPECTIVE ON DROUGHT CRISES AND THEIR CAUSES

2.1. Introduction

Drought is a socially constructed problem based on lack of rainfall. Cultures have their own definitions of drought and perspectives of its causes, which depends on their livelihood and local concerns (Bennett et al., 2016; Wandel et al., 2016; Wilhite and Glantz, 1985). Pastoralist livelihoods depend on herding grazing livestock so they observe and respond to drought's effects on livestock (Herren, 1991).

In general, human adaptations to environmental changes depend on how societies perceive the problem they adapt to (Smit and Wandel, 2006; Thornton and Manasfi, 2010). Adaptations are adjustment responses to changing conditions and can be made prior (anticipatory), during (coping or reactive), or after (recovery) a drought event (Thornton and Manasfi, 2010). These actions are dependent upon adaptive capacity, that is the ability to use resources to make desired responses. Higher adaptive capacity reduces drought vulnerability (Engle, 2011). For these reasons, it is necessary to understand pastoral cultural perspectives on drought and its causes prior to studying their drought adaptations to connect drought stressors and response behaviors. In this chapter, we (this chapter's research team and I) examine pastoralist perspectives on drought as a basis to understand their adaptation process.

Many scientific studies have described pastoral drought adaptation processes even though very few have comprehensively documented pastoral perspectives on drought (Herren, 1991; Ifejika Speranza et al., 2010; Wandel et al., 2016). Pastoral drought adaptation studies, like those

that focus on the key coping strategy of livestock mobility, usually do not describe how pastoralists classify dry or drought periods (Butt et al., 2009; Opiyo et al., 2015; Turner and Schlecht, 2019). Do pastoralists designate all periods that lack rainfall as a drought, or do they use lack livestock forage, or water scarcity as part of their drought definitions? If, for example, they define drought as periods that lack livestock forage, then what other factors might contribute to a drought? These types of questions are usually ignored or assumed when discussing pastoral drought adaptations. A comprehensive understanding of pastoral perspectives on drought should include (1) local cultural definitions of drought, (2) perceived important effects, (3) determine perceived causes of drought, and (4) identify perceived drought events (Herren, 1991; Ifejika Speranza et al., 2010; Miller et al., 2014; Ouma et al., 2012).

Research documenting local pastoralist knowledge of drought and interacting environmental changes informs external and community-based rangeland management (CBRM) institutional drought policy, adaptation efforts, and assessment (Conway et al., 2019; Galvin et al., 2020; Wilhite et al., 2014). An emic or ethnographic research approach to understand drought, and climate change, helps add granularity to external climate policy (Conway et al., 2019; Crate 2011). This helps avoid universal policy and frameworks that are usually less effective at creating locally desired change (Rayner, 2010). Furthermore, the process of integrating local and scientific knowledge to understand natural hazards, like drought, can create new opportunities for community-based solutions, the co-production of knowledge, and improved environmental management (Berkes, 2009; Raymond et al., 2010; Reid et al., 2021; Smit and Wandel, 2006; Thornton et al., 2019). Drought is the climatic hazard that causes the greatest impact on human welfare around the world, but impacts are felt over extended periods (Kallis, 2008). In pastoral systems solutions that bring together diverse drought experiences can

be formulated in CBRM institutions that bridge local and external knowledge sources (Berkes, 2009; Kallis, 2008; Wandel et al., 2016; Wilhite et al., 2007). We address this knowledge gap here, with our case study about how Samburu pastoralists in northern Kenya understand and perceive drought in their rangelands.

Our scientific ability to provide robust information to inform drought efforts across multiple social-ecological systems is hindered because drought is a culturally dynamic and place-based construct. Societies and scientists in different fields use various and changing threshold measures to designate when a drought occurs (Wandel et al., 2016; Wilhite and Glantz, 1985). Kallis (2008) provides a standard conceptual definition of drought, "drought is [...] a temporary lack of water, which is, necessarily but not exclusively, caused by abnormal climate and which is damaging to an activity, group, or the environment". The observer identifies droughts based on their interest in an activity, group, or environment. Wilhite and Glantz (1985) used the degree of water deficiency and the activity impacted to categorize standard scientific drought definitions into four major groups: meteorological, agricultural, hydrological, and socio-economic. Meteorological droughts are defined by the intensity and length of the dry period. Agricultural drought incorporates the effects of the drought on specific plants or crop growth. For pastoralists this could include livestock forage. Hydrological drought focuses on changes to surface or subsurface water properties. Socio-economic drought typically has qualities of the three previous categories but also use thresholds based on the specific livelihood activities disrupted to designate droughts (Wandel et al., 2016; Wilhite and Glantz, 1985). Socio-economic drought definitions also incorporate a natural hazards perspective of drought, which views drought as a normal process that creates problems when it interacts with human systems (Wilhite et al., 2007). Different cultures apply different operational drought definitions for different purposes, and this

can make it difficult to compare and learn from drought experiences between study systems or livelihoods (Mishra and Singh, 2010; Slette et al., 2019).

If cultural drought perceptions are ignored in science or governance, then understanding from external groups will likely determine when a drought occurs or not, and thus when and what drought relief responses are made (Bryant, 1992; Wilhite et al., 2014). Some of the most impactful actions to resist immediate drought impacts are made from external national or international support systems. However, these efforts often miss opportunities to improve effectiveness using local input of issues (Wilhite et al., 2014). Communities need to be able to participate in the discussion about when drought events happen and what causes them if they are to most effectively coordinate coping strategies or get help with their adaptation process (Bennett et al., 2016; Wilhite et al., 2014). This recognition provides communities voice and power (Berkes, 2009; Bryant, 1992). The social sciences can play an important role in bridging cultural gaps in understanding to better support the adaptation process to natural hazards like drought, especially when applied to community-based rangeland management programs (Bryan, 2004; Fiske et al., 2014; Reid et al., 2021).

Pastoralists have developed in-depth drought actions through their customary institutions that have historically helped maintain or build their adaptive capacity resist drought impacts (Glowacki, 2020; Moritz et al., 2019; Renom et al., 2020). Many pastoral cultures, particularly those in semi-arid and arid lands, have a long history filled with frequent drought experiences (Moritz, 2008; Reid et al., 2014). Yet, they have dynamically maintained pastoralism through adaptation and coping strategies and have shown themselves to be highly adaptable to drought (Bollig and Schnegg, 2013; Reid, 2012). Pastoral societies have formed customary institutions, which are governing bodies, rules, and norms. These institutions promote drought adaptive

capacity (Butt et al., 2009; Moritz et al., 2019; Opiyo et al., 2015). These customary institutions often encourage flexibility, agency, learning, and social organization to respond to drought, key features of adaptive capacity (Bollig, 2016; Cinner et al., 2018; Galvin, 2009; Reid et al., 2014). For example, in northern Kenya, pastoral customary institutions have helped people endure droughts and environmental change for millennia through dynamic responses (Anderson and Bollig, 2016; Bollig, 2016; Bollig and Schnegg, 2013). Studies across pastoral ethnic groups in this region have documented drought adaptations like the shift from cattle production to camels, sheep and goats, income diversification, increased formal education, or methods of maintaining livestock mobility (Little et al., 2009; McCabe, 2007; Opiyo et al., 2015; Sperling, 1987; Volpato and King, 2019; Watson et al., 2016). Our study aims to understand the reasons for some of these adaptations in one pastoralist group in northern Kenya.

There is also an immediate need to better understand recent and potential future drought impacts on Kenyan pastoralists because some drought drivers are increasing, and some customary institutions have been undermined. Climate change has increased the need for mobility, while land-use changes and sedentarization have reduced mobility in Kenya and neighboring regions (Ayal et al., 2018; Fratkin, 2001; Huho and Mugalavai, 2010). In Kenya, measures based on annual rainfall and national emergency designations show some evidence of an increase in drought frequency and severity (Huho and Mugalavai, 2010; Orindi et al., 2007). Northern Kenya has experienced an increase in maximum and minimum average daily temperatures of 0.74 degrees C and 0.60 degrees C, respectively, with a possible, but as of yet non-significant, decreasing rainfall trend from 1961 to 2013 (Ouma et al., 2018). Opiyo et al. (2015) also presented limited evidence of increased drought frequency and severity from measures of livestock loss and annual rainfall in Turkana County, Kenya. Drier rangelands and

more frequent droughts require greater livestock mobility (Moritz et al., 2013; Said et al., 2016). However, pastoralists in Kenya have become more settled, rangelands are more fragmented, and external government policies have undermined customary institutions (Fratkin, 2014, 2001; Reid et al., 2014). These changes limit livestock mobility and potentially other drought coping strategies. At the same time novel drought adaptations have also taken place in recent decades, and there remains an open question of whether and how pastoral drought drivers and vulnerability have increased or decreased in the eyes of pastoralists (Bennett et al., 2016; Galvin et al., 2020). To better understand changes in drought vulnerability it is useful to compare meteorological or agricultural (forage) droughts to locally perceived droughts. Rank ordering the perceived severity of drought events also can be used to examine if a drought vulnerability trend exists.

Kenya's drylands have also undergone significant environmental changes that may be caused by drought or change drought's impacts. Environmental factors shape livestock management, herding, and potential livestock productivity, and thus how droughts are experienced (Briske et al., 2020; Fernandez-Gimenez and Le Febre, 2006; Moritz et al., 2018). In northern Kenya, studies using remotely sensed measures have documented shifting vegetation patterns, decreased vegetation productivity, and extreme wildlife losses since the late 1970s (Ogutu et al., 2016; Pricope et al., 2013). Over the same period, Ogutu et al. (2016) found cattle (*Bos indicus*) have decreased in population by 25% and sheep (*Ovis aries*) and goat (*Capra aegagrus hircus*) populations have increased by 76%, with smaller increases in camel (*Camelus dromedarius*) and donkey (*Equus africanus asinus*) populations (Ogutu et al., 2016). Some regional studies have also used pastoral local knowledge to describe landscape level vegetation declines that reduced cattle production (Angassa and Oba, 2008; Galvin et al., 2020; Roba and

Oba, 2009). Trends of high levels of soil erosion and an increase in unwanted woody plant species has been documented in the Samburu County lowlands of northern Kenya (Kimiti et al., 2017). These studies show the need to understand environmental changes from a community perspective to better understand the context in which drought happens and to be able to compare drought occurrences and adaptations over time.

Study objective and research questions

The purpose of this chapter is to describe a pastoralist society's knowledge of drought and the changing environmental conditions as a result of droughts. Our objective is to answer five sets of research questions based on Samburu people's local knowledge that will develop baseline information about droughts from a local setting we will use later (in Chapter 3) to understand the drought adaptation process. These five questions are: (1) What drought definitions and categorization processes do Samburu pastoralists use to recognize and discuss droughts? (2) What severe drought events have Samburu pastoralists experienced in their lifetimes and how do they rank order these droughts based on severity of impacts? (3) How do Samburu pastoralists identify droughts compare with remotely sensed normalized difference vegetation index (NDVI) anomalies in Samburu County? (4) What causes drought from the Samburu pastoralist perspective? (5) What environmental changes has drought caused and do these changes alter how Samburu pastoralists experience drought? Together these questions help us understand Samburu pastoral droughts from their cultural perspective and thus the problem that they adapt to.

2.2. Study System and Research Methods

Study communities

We (my team and I) focused this study on eight villages (Sereolipi, Ntilal, Lerata, Laresoro, Naisunyai, Ngutuk Engiron, Nalepoboo, and Lekiji) in the lowlands of southeastern Samburu County, Kenya (Figure 1.1). We selected two villages from each of the four community conservancies, Sera, Westgate, Kalama, and Meibae, that make up the greater lowland area. We selected these communities to represent a large area of the southeastern Samburu lowlands that have similar social-ecological characteristics and political history. People in these villages negotiate and overlap in natural resource use for livestock across different seasons and during drought events (Pas, 2018). The closest of these communities is approximately 8 kilometers from another and the farthest community is approximately 62 kilometers away. With the exception of the larger Sereolipi community, my team and I estimated these communities were made up of around 30 - 80 households each, with at least some individuals from most families living there permanently. The study area's four community conservancies cover a combined land area of 526,807 hectares and represent an estimated population of 32,692 people (Kenya National Bureau of Statistics, 2019; NRT, 2019). Samburu is the majority culture in all of these communities but relatively small numbers of people from other ethnic groups have moved or married into the area (Pickering, pers. obs.).

Figure 2.1. Approximate location of eight pastoral communities where focus groups discussions took place. The map shows much of the lowlands of southeastern Samburu County, Kenya. Image produced using Google Maps (https://www.google.com/maps).

Samburu pastoralism: geography and environment

Samburu County, located in central-northern Kenya, administers an area of 21,000 km^2 and a population of 224,000 people (Kenya National Bureau of Statistics, 2009). The Samburu people form a pastoral ethnic group that make up the majority of people within Samburu County. However, there are significant populations of other pastoral groups like the Turkana, Pokot, Rendille, and Borana that live mostly in towns in Samburu County or herd their livestock into the area during droughts (Samburu County Government, 2019). Samburu pastoralists historically focus on the husbandry of cattle, but today have increased their production of sheep, goats, and camels (Ogutu et al., 2016). The Samburu people in the southeast portion of the county,

generally organize the county into two large regions, the wetter, cooler highlands (*ldonyo*) in the north and west and the drier, hotter lowlands (*lpurkel*) in the east and south (Pas, 2018).

My team and I focused our study to the southeastern portion of the lowland region. This area is generally 800 - 900 meters in elevation where settlements reside but also contains large hills. The forested Mathews Mountain Range, with peaks around 2500 meters, intersect and are potentially accessible to many people and livestock in our study communities (Pas, 2018). Rainfall in this semi-arid to arid environment is highly variable in spatial distribution and time, but averages around 350 mm +/- 170 mm per year, with most falling during the long rains from March to May and less during the short rains from October to December (Pas, 2018; Wittemyer, 2001). Droughts are predicted to become more frequent due to meteorological drivers, like an observed temperature increase and decrease in rainfall (Ouma et al., 2018; Pricope et al., 2013). The Ewaso Nyiro river is the only permanent natural water source that forms much of the Samburu County southeast border, but people also access water for themselves and livestock through shallow wells (hand dug and boreholes) and earthen dams during dry seasons. Livestock rely on these waterpoints less during the rainy season and these waterpoints may dry up during a drought (Pickering, pers. obs.).

The lowland region is a semi-arid to arid environment with a mix of shrub, savannah, and bush habitats. *Vachellia elatior* and *Vachellia tortilis* (previously *Acacia spp.*) are the most common large trees in riparian and lowland areas, while smaller tree species like *Commiphora spp*. or *Vachellia reficiens* make up much of the bush habitat (Kimiti et al., 2017). There are a large diversity of grasses and other herbaceous plants that grow in the area and support cattle and sheep grazing (Odadi et al. 2017). A few studies describe a habitat shift away from *Vachellia tortilis* savannah to more shrubland and bush habitats over recent decades and this matches with

community-identified rangeland management challenges (Glew et al., 2010; Kimiti et al., 2017). These new, bushier habitats better support wildlife and livestock browsers, like goats and camels, compared to grazers, like cattle and sheep (Augustine and McNaughton, 1998; Watson et al., 2016). The greater region still supports diverse and endemic wildlife species adapted to the drier environment, like the Somali ostrich (*Struthio molybdophanes*), oryx (*Oryx beisa*), gerenuk (*Litocranius walleri*), Grevy's zebra (*Equus grevyi*), lesser kudu (*Tragelaphus imberbis*), and reticulated giraffe (*Giraffa camelopardalis reticulata*). The black rhino (*Diceros bicornis*) has been reintroduced to the eastern portion of Samburu County. Our study community's grazing areas also support wildlife populations interconnected with Samburu National Reserve, Shaba National Reserve, and Buffalo Springs National Reserve to the south and the Mathews Forest Reserve to the north (Berger-Wolf et al., 2016; Ipara et al., 2017; Wittemyer, 2001). Extreme wildlife declines have been observed since 1977 in Samburu County (Ogutu et al., 2016). Neither the habitat-vegetation shifts, nor the wildlife declines have been scientifically described from the Samburu people's perspectives in relation to past or potential droughts.

Livestock movements, pastoralist sedentarization, and herding

Livestock movements within Samburu County, including across the highlands and lowlands, to access forage in different seasons or times of drought are possible but must be socially negotiated (Pas, 2018). Land privatization and fencing restricts some livestock movements in the highlands (Lesorogol and Boone, 2016). The lowlands have a long history of grazing regulations but remain largely non-privatized common pool resources. This helps maintain livestock mobility and counters limited resource availability during droughts and seasonal changes (Boone et al., 2005; Pas, 2018; Western et al., 2009a). Since the early 2000s,

community conservancies have formed and become involved in grazing regulation. According to the Kenya Wildlife Conservancies Association (2016), conservancies are "land designated by a community or private land owner, groups of owners or corporate body for purposes of wildlife conservation and other compatible land uses" (KWCA, 2016). Community conservancies, those owned and managed by a community, are a type of community-based natural resource management or community-based rangeland management (CBRM) institution (Bedelian and Ogutu, 2017; Berkes, 2009; NRT, 2019). These CBRM programs appear to have made it harder for some herders and easier for others to negotiate livestock movements or participate in making grazing regulations across our study area (Glew et al., 2010; Pas, 2018). These community conservancies have mixed levels of support and authority from the communities but potentially have a large influence on drought planning at the community scale (Cockerill, 2018; Pas Schrijver, 2019; Pickering pers. obs.). The environmental impacts of rangeland management in community conservancies have not been well studied, but there are some indications of positive environmental outcomes from community conservancy actions (Glew et al., 2010; Kimiti et al., 2017).

Samburu households have become more settled over the last century, and this has led to many subsequent changes in their livelihood. British colonialists encouraged more firm borders between the Samburu and other ethnic groups from the around the 1920s to 1963. Over time, missionaries, international development organizations, and Kenyan social services have all coerced or incentivized pastoralists to settle and form permanent communities (Fratkin, 2001; Spencer, 1965). Sedentarization has also coincided with livelihood diversification. For example, diversification within pastoralism like sheep, goat, and camel production or non-pastoral activities like small businesses have all increased among pastoralists of northern Kenya (Little et

al., 2014; Opiyo et al., 2015). These livelihood changes can form a positive feedback that supports sedentarization and may entrench poverty if alternative livelihoods are not structured to support pastoralism (Little et al., 2008).

Samburu pastoralism is undergoing changes to its herding practices. Within Samburu culture, a bachelor-warrior age-group of young men called *lmurran* (variations on spelling, singular *lmurrani*) are largely responsible for herding cattle. These cattle herders take and defend their livestock on their journeys to distant forage, across county, ethnic, and privatized land borders during droughts (Pas, 2018). Inter-county or ethnic movements (along with mutual ethnic livestock raiding and political motivations) often lead to violent conflict that has gotten worse in recent decades (Greiner, 2013). This violence also indirectly creates negative impacts on people's nutritional well-being in Samburu communities (Pike et al., 2016). Some *lmurran* have attended school and no longer herd livestock or take on this pastoral role part time. Education changes the pastoralists' aspirations and land-use goals of both young men and women and often sets them apart from their peer herders (Bruyere et al., 2018; Lesorogol, 2008a; Lesorogol et al., 2011; Schewel and Fransen, 2018). Elder men (elders) and women, in this polygamous society, often remain in permanent settlements taking care of sheep, goats, and camels, to allow their children to attend school (Pas, 2018). Violence and changing societal roles might factor into how the Samburu people experience the impacts and causes of drought.

Methodology

My team and I chose to collect data from community-level focus group discussions to answer our main research questions. This method is effective at gathering information, helps bridge scientific and local knowledge, and has relatively low costs and time commitments

(Nyumba et al., 2018). We studied drought perceptions across communities with similar pastoral livelihood strategies that also overlap in their natural resource use because we wanted to limit confounding variables and build up baseline drought knowledge from largely shared experiences. Communities were selected to represent Samburu pastoralism in the southeastern lowlands of Samburu County. This makes it easier to contextualize drought aspects the Samburu people in this area consider important. It also represented their knowledge across much of the landscape area that these communities regularly use rangeland natural resources. We wanted focus group discussions to provide an effective way for people to collectively think through their shared experiences of drought and changes to pastoralism, including their environment. The process of hearing and discussing each other's responses to questions was meant to further illicit memories and connect responses to build a richer understanding of events and their relationship to one another (Caretta and Vacchelli, 2015). We separated focus group discussions by gender because we wanted a more comprehensive view of drought at the community scale and to compare aspects of drought experiences between genders. Gendered discussions also helped ensure women felt comfortable speaking their ideas in a society that is highly patriarchal and separated into gender roles (Glew et al., 2010; Spencer, 1965). Women often requested to have separate discussions in preliminary community conversations with the researchers. We did not have focus group discussions with young male herders, *lmurran*, because they were too young to describe drought experiences over our period of interest–since the 1970s. Other researchers in Samburu have used similar methods to successfully gather community perspectives on aspects like the impacts of community conservancies, livelihood diversification, and Samburu grazing history (Glew et al., 2010; Lesorogol, 2008a; Pas, 2018).

Research Methods

We conducted 16 focus group discussions, two in each of the eight study communities, one in each community with men and women, between September 19th and October 12th, 2017 during an ongoing drought in the region (Colorado State University IRB 042-18H, March 2017). We selected the number of focus groups (16) to balance representation between communities as we confirmed key points of information and to give ample time to reach theoretical saturation about our research questions (Onwuegbuzie et al., 2009). Each of the 16 focus groups were made up of 6 to 7 pastoralists who were above 45 years in age and had been familiar with their current community area over a period of 30 years or more. The age restriction was set to increase the chances that the participants would be able to describe and understand perceived causes of droughts and environmental change from their lived experiences. In practice my team estimated that most participants tended to be in their 50s or 60s with some older. We used community leaders and key informants to suggest participants based on our criteria and they further tried to invite individuals with high levels of knowledge about pastoralism and who were likely to express their thoughts well and actively participate in a discussion.

In each community we conducted two group discussions, one with men and one with women, in a single day. Each discussion lasted approximately 3 hours. All discussions were conducted in the Samburu language (Maa dialect). In each focus group discussion, we followed an initial structured portion to define, identify, and rank drought events in people's lifetimes (Appendix 1.1). The discussions then varied but overlapped heavily in a second less-structured portion, allowing us to learn about what caused these droughts and what drought related environmental changes occurred. Research facilitators did their best to fill in gaps in their understanding from one discussion group to the next. Field researchers took on different roles as

facilitators, notetakers, and translators during the focus group discussions. Samburu researchers took notes in English of participant responses that were also translated in real-time to English for foreign researchers. Notetakers tried to capture relevant respondent comments verbatim but summarized points made as well when needed. Within two days following a focus group discussion all field researchers met together to combine notes, discuss responses to gain a shared understanding, and add annotations to the notes for context. The three Samburu researchers provided contextual explanations and annotations to many of the notes that supported analysis. While describing environmental changes, Samburu respondents named specific plants using Samburu-Maa terms, which meant they did not always match scientific classifications at the species or higher levels. In some cases, they did and could be scientifically identified. In other cases, plants were identified through community descriptions to general plant types (e.g., grasses, small plants, large shrubs, vines, and trees).

I thematically analyzed focus group discussion notes with annotations using NVivo 12 software (1.2). Initially with the help of two other researchers, we created and agreed upon themes and codes that represented responses to research questions through an iterative process (Braun and Clarke, 2006). Once codes were established, I thematically coded all qualitative data; therefore, no inter-coder reliability check was necessary. I selected and placed into a code text that represented a single relevenat idea or that connected themes together. In practice this usually was a few sentences long, but sometimes to avoid breaking up relevant points was longer (Braun and Clarke, 2006). The goal was to help the researchers systematically and categorically represent the information shared with us. We also used gender and drought event variables to categorize the qualitative data.

I used these codes to analyze and compare responses from different focus groups and then wrote the results to represent the perceptions of the people in the 16 focus group discussions across the 8 communities. Our results present a diversity of viewpoints that do not necessarily represent any individual's or community's perspective but represent the combined understanding of the history of drought and pastoralism of all focus groups. This combination of methods and the way the results are presented is meant to strengthen research findings by providing a full picture of community responses, but, perhaps as a tradeoff, runs the risk of masking researcher bias of perceived importance of responses from discussion groups. We do our best to represent the information provided to us by the community focus group discussions in a way that we think balances their emphasis on points with our research objective. We have aggregated responses from discussion questions relevant to each research question to collectively represent the perceptions of all discussion groups.

To gain a better understanding of the diverse drivers and experiences of drought, we compared pastoralist perceptions of drought events with remotely sensed vegetation-greenness anomalies. The methods we describe were chosen iteratively to identify a number of vegetation droughts similar to the number of Samburu community-identified droughts during the same time period. For example, an analysis of soil moisture anomalies identified too many of these kinds of droughts to practically compare to Samburu experiences (Figure A1, Appendix 1.3). The data for remotely sensed drought analysis comes from National Oceanic and Atmospheric Agency's Normalized Difference Vegetation Index (NDVI) using Global Inventory Monitoring and Modeling System based on Advanced Very High Resolution Radiometer Sensors (3rd Generation) images. Our dataset ranges from July 1981 to December 2013 and is composed of 780 images, each of which contains 15-day average NDVI values with a spatial resolution of 5

arc minutes per pixel. We spatially cropped the image-collection so that all analysis would be calculated only within the Samburu County region. We chose Samburu County as the spatial unit because generally livestock forage within this area is accessible to Samburu herders and thus livestock are less likely to die when forage is available in this area, (based on Samburu definition of severe drought events described in results). A new image collection was created that contained one image for each Kenyan season across all years by taking the average of all images falling within each respective seasonal date range as defined below.

Short Dry = January – April; Long Rain = April and May; Long Dry = June – November; Short Rain = November and December

We then compared these seasonal images to the long-term average from 1981-2013 to find each season's NDVI anomaly. For example, the image for the average Short Dry season across all years was subtracted from the image for the Short Dry season of 1981, 1982, …, 2013 each, with the resultant images being the NDVI anomalies. We condensed these anomalies and exported as single values by taking the average across all pixels within Samburu County and then were used to construct a time series plot with date (by season) on the x-axis and NDVI Anomaly on the y-axis. If an anomaly fell below the 5% significance level (according to a lower-tailed t-test), it was flagged as being a severe drought using the color code of red. Otherwise, it was marked as green for normal. We considered seasonal anomalies that were within a year period from one another a cluster, and part of a single vegetation drought event, because this appeared to better match with how Samburu pastoralists discussed drought events. This was a subjective researcher decision but matches our goal to use this comparison as reflection and discussion point, not to

prove whether Samburu pastoralist perceptions were accurate or not accurate with vegetation droughts.

2.3. Results

Samburu drought definitions and categorization process

In our interviews, Samburu informants commonly used four Samburu words associated with periods that lack rainfall: *lamei*, *ngolong*, *riai*, and *mutai* (Table 2.1). Respondents applied and used these terms to categorize event-time periods based on their judgement of the severity of negative effects on the well-being of livestock and people from insufficient rain. While the perceived impacts from a dry period can vary among individuals, Samburu typically discuss and collectively determine at a village or larger scale the severity and categorization of these dry events. Table 2.1 describes these words in order of least to most severe drought effects on well-being.

Table 2.1. Descriptions of drought related terms from 16 focus group discussions in eight pastoral communities in the lowlands of Samburu County, Kenya.

Samburu-Maa Term	Standardized Description	Example of descriptions given
Lamei	A dry season. A time period that lacks rainfall but with little negative impact on the well-being of livestock or people. There is a shorter dry season from January to April, *lamei dorop*, and the longer dry season from June until November, *lamei odo*.	"...when the *lamei* comes they can sell and still eat meat and the livestock will be in good health but when it's *riai* the livestock get sick and there is no food at all." - Lerata woman
Ngolong	A time period with insufficient rainfall that leads to a lack of	"Like during when we expect rain and it doesn't rain at all and we see clouds, but it is

	forage for livestock. This is a drought with lesser impacts. Ngolong is often based on cattle forage (mostly herbaceous plants) and means cattle during this time suffer and produce little to no milk.	not raining, that shows there is *ngolong*." - Lerata woman "*Ngolong* is the one which you see that there is not enough grass or leaves but does not kill the livestock." - Laresoro woman "*Ngolong* happens if one rainy season is skipped but if two rainy seasons are skipped then it is likely *riai*." - Ngutuk Engiron man
Riai	A time period with severe lack of rain affecting a large enough area that leads to the death of livestock and hunger, sickness, or death of people.	"When *ngolong* lasts a long time, that is when it is *riai*, which is when it kills the livestock." - Naisunyai man "*Riai* is when there is not *sagaram* [*Vachellia tortilis* pods] and there is nothing anymore for the livestock to feed on and even *sieu* gets finished from trees [the dried leaves that fall down from trees and shrubs]." - Sereolipi woman
Mutai	A disaster or catastrophic event with wide scale death of people. The last time this most likely occurred was in the late 1800s with smallpox and/or rinderpest epidemic. It can be associated with *riai* and drought periods but does not have to be.	"*Mutai* is when people get sick and most of them die, an example is the outbreak of *Nkeaya Mara* [likely smallpox disease]" - Nalepoboo man "*Mutai* is when people and animals are dying from an outbreak of diseases or war. It is when a huge number of people die." - Lekiji man

Lamei refers to an expected dry season. This is a time period lacking rain that causes the senescence of plants, but with little effect on the overall health of livestock. It often means that cattle will have to be moved from the household's immediate home area (preferred rainy season location or permanent settlement). Typically, herders, not the entire family, move cattle to a familiar range that creates minimal social conflict. Herders usually do not need to move sheep

and goats from the household's home area. I present more specific Samburu cultural descriptions of wet and dry seasons in Appendix 1.3.

Ngolong refers to a time period with insufficient rainfall that has led to a lack of livestock forage and hungry livestock and people. Typically, *ngolong* occurs when a single rainy season fails. During *ngolong* cattle produce little or no milk that families can consume, instead families rely on sheep, goat, and camel milk, meat, or alternative livelihoods for support. The discussion groups explained that *ngolong* were important events that made up a first, less severe, but notable set of impacts on their lives. *Ngolong* was also used as a general term for difficult periods with insufficient rainfall (a general term for droughts) that can also encapsulate a second, more severe, level of impacts on livestock and human well-being, *riai*.

Riai (plural *riaa*) is a time period with severe lack of rain affecting a large enough area that it causes the death of livestock, particularly cattle, and hunger, sickness, or death of people. Informants commonly used this threshold of cattle, or livestock, dying but it was unclear exactly how many or how widespread this needed to be for a community to define an event as *riai*. Respondents described how at times of cattle death people would undoubtedly suffer from hunger, disease, or even death as well, but they described livestock, particularly cattle, effects first in relation to *riai*. Interviewees generally named five thematic measures that determined the overall severity of a *riai* event: (1) cattle effects, (2) violent conflict effects, (3) death, sickness, or hunger of people effects, (4) sheep and goat effects, and (5) water resource effects. *Riai* are very significant periods of suffering in people's lives. Often when people introduced themselves in the focus group discussions (knowing the general context of what we would discuss) they referenced *riai* events as decisive points that impacted their lives often causing them to move from one area of Samburu County to another. These communities recognized *riai* as important

drought events that commonly impacted and shaped pastoralism, and they suggested we discuss these events to best learn about the connection between droughts and Samburu pastoralism.

Mutai means catastrophe or disaster. These events are very rare and can have many causes. *Mutai* is not necessarily connected to lack of rainfall. *Mutai* refers to a period when many livestock and many people die. We include this term here because the discussion groups brought it up to explain that impacts could get worse than those associated with *riai*. Some participants preferred to not even mention the word because they thought it would bring bad luck.

The discussion groups also emphasized the relationship between these terms and the common connection to lack of rainfall. We were told how many *lamei*, dry seasons, could make a *riai*, severe drought. The men from Nalepoboo community described the threshold between *ngolong*, *riai*, and *mutai* by saying,

> *'Ngolong* is when we are hungry, and when it is *ngolong* people and livestock are all hungry, but *riai* is when people and livestock start to die and the soil gets completely dry and there is no water, that is *ngolong* [general use for droughts]. When it is not raining and all wildlife, trees, livestock are dying because of water it is called *riai*. *Ngolong* comes first then *riai* and *riai* when it is extreme becomes *mutai*.' (Nalepoboo men)

Severe drought (riai) events - history and severity

The community discussion groups consistently identified the same nine *riai* events, or major droughts, from the 1970s until 2017 (Table 2.2, Chapter 2). The nine *riai* events have multiple names across communities, which we matched through common descriptions of relevant events during the *riai*, and the approximate year respondents remembered it to have occurred (Table A2, Appendix 1.3). The process of creating *riai* timelines with the groups showed us that some *riai* events were well known and regularly discussed among community members, while others were not. It was a process for groups to agree as to whether certain, less

impactful *riai* should be included on the list of *riai*, as opposed to categorized as a less severe drought, *ngolong*. All discussion groups named between 5 and 9 *riai* events from the 1970s until 2017 (mean = 7.31, standard deviation = 1.2). The first *riai* identified was in 1975 - 1976 and these events have occurred on average every 5 years since then, with a standard deviation (sd) of 3 years. There did not appear to be an increase in frequency of droughts from the 1970s to 2017.

Table 2.2. Summary of severe drought (*riai*) events and their perceived severity rank order (lowest rank = most severe) in eight communities in Samburu County, Kenya.

Riai Common Name	**Number of the 16 groups to identify it**	**Average severity rank order**	**Standard deviation of severity rank order**	**Severity-area index (scale of riai)**	**Rank order of riai by severity-area index**	**Year of riai**
Riai Elakira Elolkudongoe	11	5.82	1.99	0.53	**8th**	1975, 1976
Riai Ekulu	12	5.33	2.39	0.44	**7th**	1980, 1981
Riai Enaisicho	5	6.60	2.07	1.32	**9th**	1982
Riai 84	16	1.69	1.30	0.11	**1st**	1984
Riai Empurrwa	14	5.21	1.42	0.37	**5th**	1992, 1993
Riai Elparna	14	4.93	1.69	0.35	**4th**	1995, 1996
Riai Eldonyokeri	12	4.50	1.31	0.38	**6th**	2005
Riai Elpingwai	15	3.00	1.20	0.20	**2nd**	2009
Riai Loidikdike	14	2.93	2.20	0.21	**3rd**	2015 – 2017

Each discussion group rank ordered the *riai* events they identified from the most severe (number 1) in terms of impact to the least severe (ranged from 5 to 9). We calculated the average severity rank order for each of the nine *riai* events (Table 2.2). *Riai* events not identified by a discussion group were likely perceived as less severe droughts, *ngolong*, and very likely would have received a lower rank if we had requested a severity rank be assigned. To account for this and better compare the severity of *riai* events across discussion groups, we also calculated a *severity-area index* by dividing the *average severity rank order* by the number of groups that identified it as *riai*. Lower index values represent more widespread or severe droughts; if all 16 groups ranked a *riai* first, most severe, this value would be 0.06.

Some droughts were considered more severe than others. These communities consistently thought that the 1984 drought was the most severe drought event in their lifetimes. The second and third most severe drought events were in 2009 and then 2017, respectively. The three least severe droughts (1976, 1981, 1982) were the oldest listed by the discussion groups, but these were immediately followed by the worst, most severe drought in memory (1984). While the discussion groups ranked the drought of 2017 (ongoing at the time of discussion groups) third most severe, its rank order varied highly across groups; six groups identified it as the most severe ever, while two groups considered it *ngolong* not *riai* (not ranked). Based on Table 2.2, it appears there is no clear trend in droughts getting more or less severe with time from the perspective of Samburu pastoralits, but there seems to be a divide between pre- and post-1984 droughts becoming more severe.

We found subtle differences in perceptions of severe droughts between men and women. Male discussion groups and female discussion groups both identified the same nine events as *riai* (Table A3, Appendix 1.3). There was some minor variation in the severity rank order assigned

between gendered groups. The biggest differences between the ranking of men and women occurred in two droughts. Women ranked the 2005 drought as the fourth most severe and men ranked it as seventh. Women ranked the 1993 drought as seventh most severe and men ranked it as fourth. These differences indicate that generally the household perceives negative effects from lack of rainfall similarly but some droughts might have features that cause one gender to perceive its impacts as more or less severe. This was only determined after focus group discussions took place. We were not able to directly investigate the reasons for these gender-differentiated impacts during specific major droughts.

Severe droughts compared to remotely sensed vegetation droughts

Using NDVI anomaly clusters as a proxy, we identified vegetation droughts that matched in time with all the severe droughts, *riai*, that Samburu communities experienced, but vegetation droughts occured more frequently than *riai* events (Figure 2.2). Nine vegetation droughts were detected in this time period compared to six *riai* events. The three most recent vegetation droughts measured were the top three most severe NDVI anomalies, in terms of deviation from expected, but not duration of drought conditions (Table 2.3). None of the 16 community discussion groups classified the first (2011), fifth (2001), and sixth (1991) ranked most severe NDVI anomalies as major droughts, *riai*. Community drought rank order based on the *severity-area index* does not appear to match or follow a relationship with the rank order based on larger NDVI anomalies.

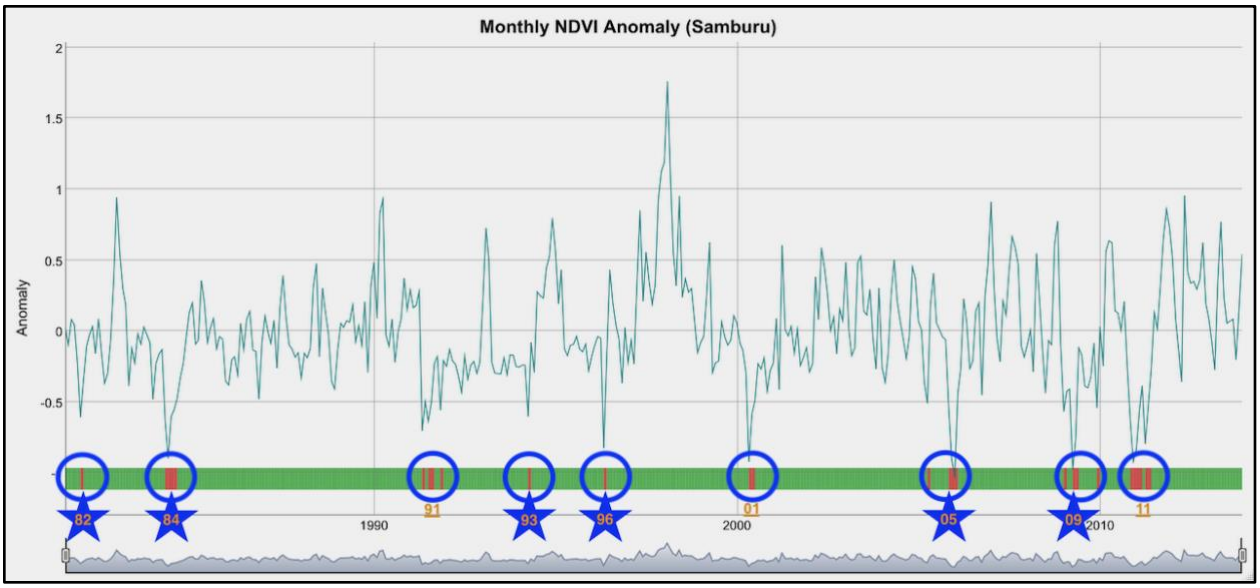

Figure 2.2. NDVI anomalies aggregated for Samburu County from July 1981 to December 2013 based on NASA/NOAA's GIMMS NDVI from AVHRR Sensors (3rd Generation). Red vertical bars indicate significant seasonal anomalies, that either individually or in clusters indicate a vegetation drought, which are circled in blue. Blue stars identify *riai* events described by the 16 focus groups. All *riai* events match with an NDVI anomaly event.

Table 2.3. Comparison between NDVI anomaly severity rank order and community rank order of severity-area index.

Riai year(s) or Remotely sensed NDVI anomaly year	**NDVI anomaly based severity rank order**	**Rank order of riai by severity-area index**
1975, 1976	Prior to analysis period	8th
1980, 1981	Prior to analysis period	7th
1982	8th	9th
1984	4th	1st
1991	6th	Not classified as *riai*
1992, 1993	9th	5th

1995, 1996	7th	4th
2001	5th	Not classified as *riai*
2005	2nd	6th
2009	3rd	2nd
2011	1st	Not classified as *riai*
2015 to 2017	Post analysis period	3rd

Perceived causes of severe droughts

The people in these community discussion groups described to us a complex causal model for droughts (Figure 2.3). Respondents identified 'lack of rainfall' as the main direct cause of *riai* events, but also perceived 'God's will' as the main controlling variable over rainfall. When asked why God did not bring rain, people explained that they either did not know (it was God's unknowable will) or, at least for the 2017 and 2009 droughts, that it was because God was angry or upset with them. God was mostly angered because of internal conflict, more so than external (violent) conflict. Interviewees explained that in recent times there was greater 'hatred between people' and 'fighting between the elders and *lmurran*'. The Naisunyai men described this by saying,

> 'We as elders keep asking ourselves why the rain has stopped for so long. It is God who is seeing us as not respecting and helping other people so God is punishing us. Hatred is also the cause of this. People hate each other, this hatred was not there before, and God is punishing us.' (Naisunyai men)

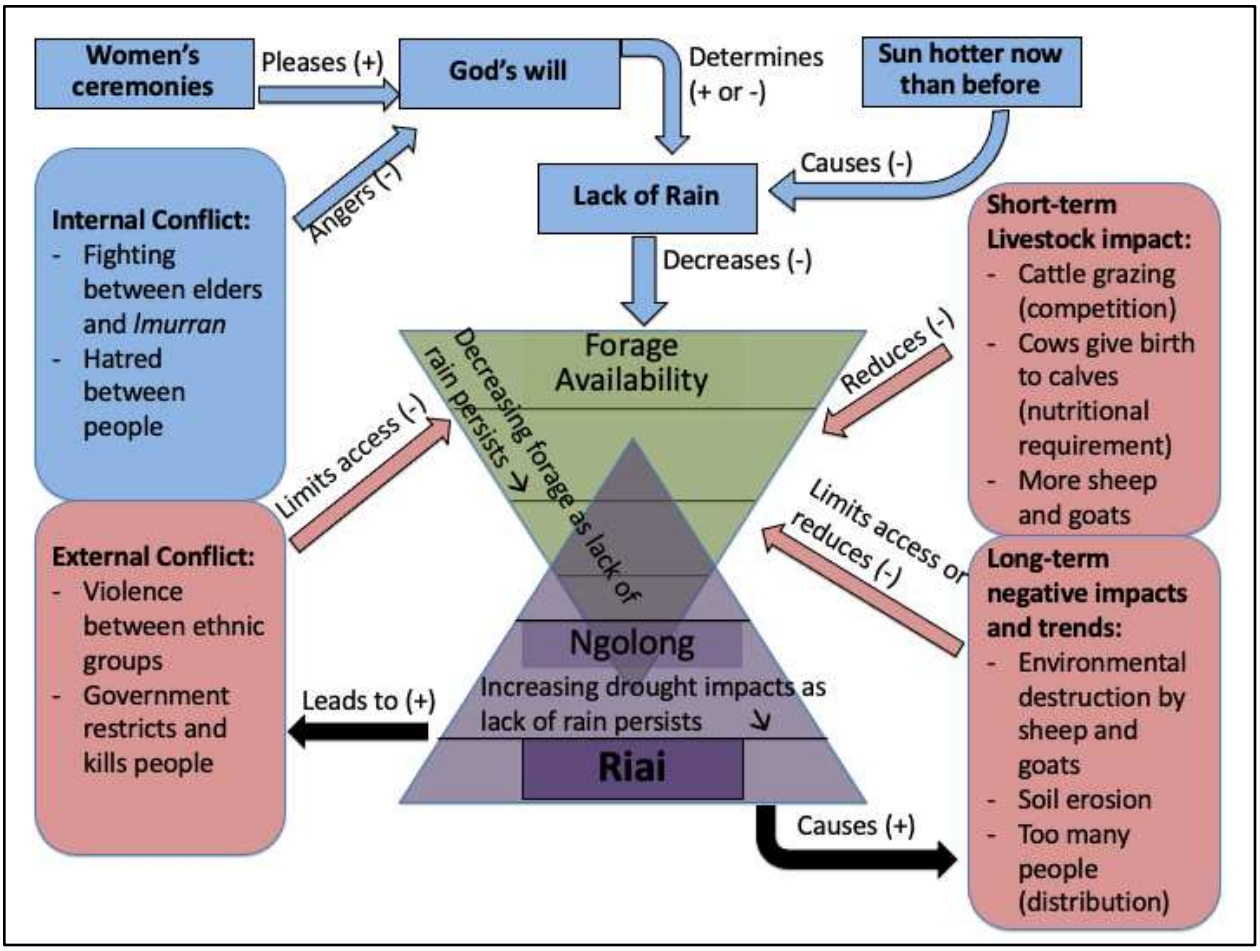

Figure 2.3. Causal model of *riai* relationships. Processes in blue were related to 'lack of rain'. Processes in red further reduced or limited access to forage availability. The green triangle represents decreasing forage availability moving down the figure, leading to more severe impacts and the stages of drought in the purple triangle.

Another factor that caused lack of rainfall was a change in the intensity of the sun. Discussion groups described how the sun has become hotter and burns more nowadays compared to the past ('Sun hotter now than before') and that this causes a decrease in rainfall. The hotter sun was also said to kill plants and limit their ability to grow, but this was discussed less in relation to causes of *riai* and more in relation to long-term environmental changes. The change in the sun was the closest indication of experiences of climate change that people spoke about, but

it was only described as the sun being hotter and actually burning more and not explicitly about changes in temperature or rainfall patterns.

'External conflict', made up of 'violence between ethnic groups', namely the Somali, Borana, and Turkana, and violence with the national government army, Kenya Defense Force, ('government restricts and kills people') was perceived to limit access to forage in a major way. Discussion groups understood this violence to increase the chances of *riai* or its severity during periods that lacked rainfall. Interviewees remembered violent conflict occurring during all nine *riai* events, but the trend was that violent conflicts have gotten much worse over time. The 2009 and 2017 droughts were considered the two most violent conflicts during a *riai* event and possibly the most violent during people's lifetimes (at least since the 1970s). Respondents explained this is why these two droughts were ranked 2nd and 3rd most severe (Table 2.2). A woman from Lekiji explained while describing the 2009 drought, "If it was not for the government, we would still have so many cows and not so many could have died" (Lekiji woman). While a woman from Lerata stated in relation to the 2017 drought, "Also in this drought the government is not helping, since they are killing people who break the rules and graze like in Laikipia [County]" (Lerata woman). Discussion groups also told us that *riai* events prior to the 1984 drought were less violent and without as many guns. They said the Samburu began to arm themselves with guns more heavily starting around the time of the 1993 drought, while groups like the Somali had guns before them. Violent external conflict was more often described as a consequence of *riai* or *ngolong* rather than a cause.

Focus group participants also described how livestock can exacerbate the effects of lower rainfall, and even become a cause of *riai* somewhat independent of rainfall. We were told about many variables we categorized as 'short-term livestock impacts' and 'long-term negative impacts

and trends' that reduced or limited access to available forage during dry periods. The participants explained how competition between cattle and competition with sheep and goats could cause the death of cattle, that would thus distinguish a drought as *riai*. They also explained that in some cases *riai* came about because cows would give birth to too many calves–likely referencing higher nutritional requirements for lactating cows that could not be satisfied. Respondents also told us how long-term environmental changes were also increasing the chances of *riai*. This included less available forage from the impact of sheep and goats, soil erosion, and limited ability to move to some pasture areas compared to the past because there were too many people and communities distributed throughout the landscape. Respondents explained the problem with 'too many people' was not necessarily the number of people but more often how spread out people settled across the rangelands, limiting drought forage reserves.

Respondents described two options that could lessen the anger or please God: 'women's ceremonies' and a decrease in social conflict. Women have the ability to conduct ceremonies that request rain from God and try to please God with gifts. We are unsure of the last time these ceremonies were conducted. Respondents did not report conducting these kinds of ceremonies during the 2017 drought. Women have not done these ceremonies recently in part because women did not have time because of their increased labor responsibilities compared to the past. The elders from Lerata community explained this by saying,

> 'It is the women who are the ones that can sing at the mountain [Sabache mountain] and slaughter a sheep at the mountain and pour all the fat on the mountain and sing for God and ask God to give them rain. It is the elders who will slaughter the sheep but give the fat to the women who will take it in their calabash with water mixed with milk to pour around the mountain. God is angry because so many people have been killed [in the recent violence] and he is not sending rain. Women do not have time anymore to do the ceremonies [to please God].' (Lerata man)

The participants explained that the main way social conflict could be improved was to fix the fighting between elders and *lmurran* herders. The elders did not expect this to happen with the current generation but hoped their relationship with *lmurran* would get better when the next age-set is initiated into this role and the current age-set become junior elders. The discussion groups also thought well-being in general would improve with the initiation of the next generation. This is both because they see it as a new opportunity to start fresh and because some elders believe there are generational and yearly cycles connected to *riai* and well-being. They described each age-set of bachelor-warriors, *lmurran*, followed a cyclical pattern of good (named *siria*), moderate (named *lmaina*), and bad (named *lnyankik*) times (Appendix 1.3). The current disagreement between elders and the *lmurran* and the need for a change in age-sets was emphasized by a man from Lerata community,

> 'Before, young *lmurran* were respecting the elders but now they are not respecting us at all since Riai Empurrwa [1993]. *Lkishami* and *Lmooli* [two most recent *lmurran* age-sets] are the ones who started to not follow the elders' rules. They cut their ears off because we asked them to give us their ears, they didn't want to listen. It will not be until the next generation becomes *lmurran* when the rains will get better.' (Lerata elder)

Environmental trends caused by and affecting severe droughts

Our participants reported how some long-term environmental changes have both been an effect of lack of rainfall and also a subsequent cause of greater impacts during dry periods making *riai* events more likely (Figure 2.4). Respondents understood these cofactors to form the setting in which droughts took place and influence how people adapt to drought events. Generally, the discussion groups named six different types of environmental changes connected with drought: (1) 'loss of desired grasses and small plants', (2) 'increase in undesired trees and other plants', (3) 'loss of soil', (4) 'loss of wild fruits', (5) 'lower potential cattle productivity', and (6) 'loss of wildlife'. Participants consistently viewed the 1984 drought as a turning point for

these environmental changes in their communities. To them, the 1984 drought initiated a long-term trend, further exacerbated by future *riai* and *ngolong* (droughts) and other societal changes.

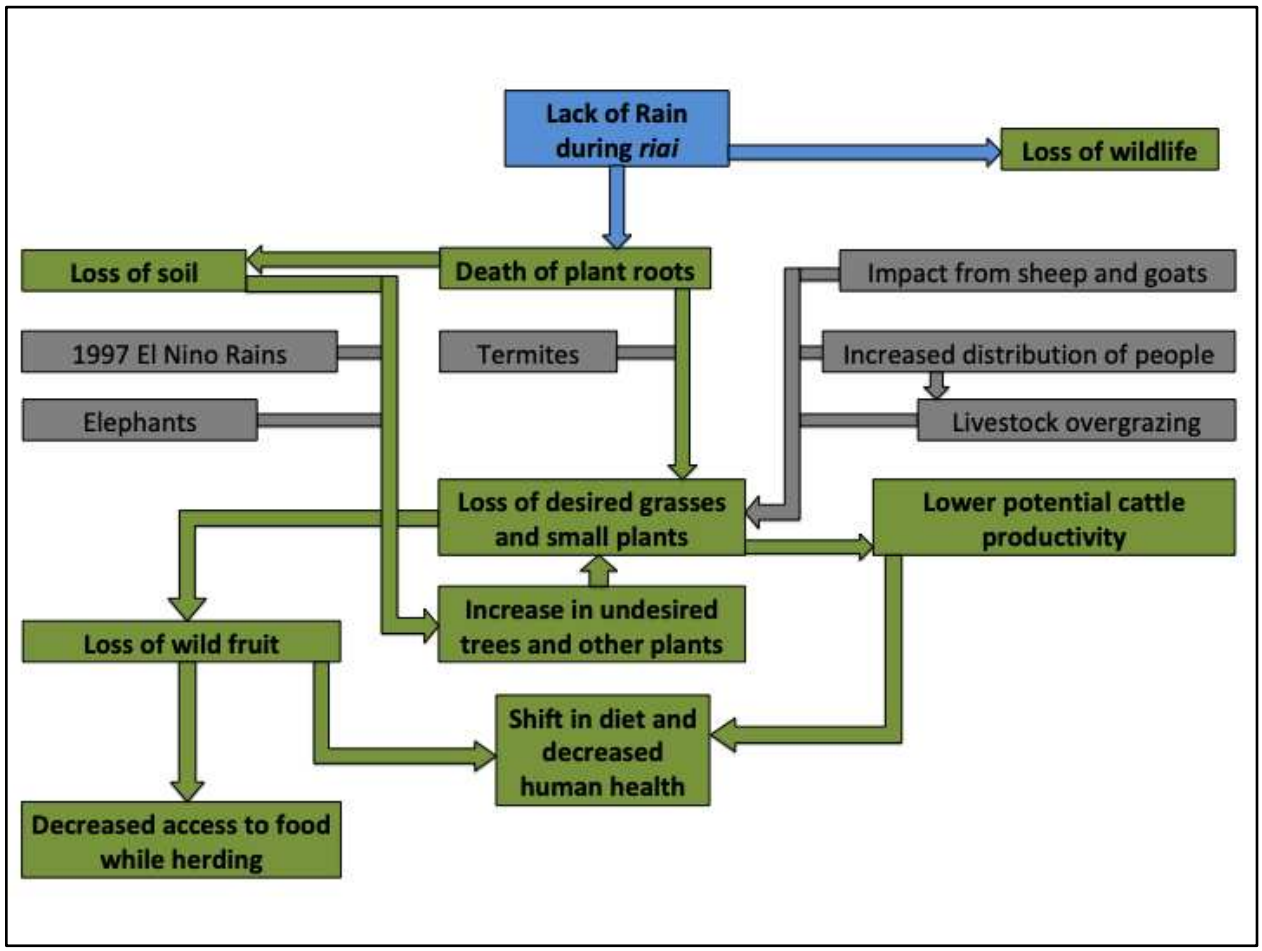

Figure 2.4. Causal diagram of long-term environmental and pastoral changes due to drought and other causes (initiated by the 1984 drought). Respondents described concepts in blue and green in greater depth and were more heavily emphasized than those in gray. Concepts in gray are also independent from drought, not ultimately linked to lack of rainfall.

The discussion groups frequently described the loss of desired plants as a consequence of both drought and livestock grazing impacts, in part caused by the loss of pasture areas. Respondents named many grasses and other small plants that were considered valuable as cattle forage that were lost or reduced in abundance since the 1984 drought. This included grasses like *laraa* (*Eragrostis superba*), loroturoto (*Tetrapogon roxburghiana*), *lounoro* (*Cenchrus ciliaris*)

lanana (unknown sp., possibly *Chloris virgata*), *lkawa* (unknown sp.), and *loyieti* (unknown sp.). In their place, other species of grass that were valued less as forage like *rumoto* (*Eragrostis racemosa*) and *ntalakwani* (*Pennisetum stramineum* and/or *Stipagrostis sp.*) have become more common, at least as a proportion of grass. We were told some other small herbaceous plants and shrubs that were valued for livestock like *lmarag* (*Blepharis edulis*, small herbaceous), *likitagesi* (*Indigofera spinosa*, small shrub), and *lturkan* (*Sericocomopsis pallida*, small shrub) have also decreased in abundance. Respondents also said less palatable plants for cattle were increasing in abundance like *sukurtuti* (or *sukurdumi*, possibly *Kedrostis gijef*, a woody vine good for camels and goats) and *oldupai* (*Sansevieria frequens* and *Sansevieria robusta*, herbaceous plant with poor nutrition for livestock). The discussion groups explained these desired grasses and small plants in the past were more abundant in community settlement and riparian areas. Now these plants are mostly limited to the hills and small mountains within the lowlands, or they have disappeared altogether. Participants told us that the rivers were now filled with more sand and wetlands and riparian areas were smaller. Descriptions of these changes were often similar to these comments made during the Ngutuk Engiron women's discussion group,

> 'Before Riai 84 [1984] this school was full of trees and grass [the school where the group discussion took place]. Even in the river there were so many tall grasses and when Riai 84 [1984] came it destroyed all the vegetation and water sometimes disappears from the river for so long. *Lmarag*, *lorian*, *lopeeria*, *lkawa*, *nkapurugi*, *mpachach*, *nkoliai* are some of the plants that reduced with the 84 *ngolong*. *Samanderi*, *Mporo eyeyioo*, and *lchurai* [unwanted plants] have all increased. *Lchurai* [*Vachellia reficiens*] has really increased and it has affected the buffer zone [conservation and drought forage area for the Westgate conservancy] and it does not allow any grass to grow. We are cutting *lchurai* so much.' (Ngutuk Engiron woman)

Discussion group participants remembered the loss of desired plants to have started during the 1984 drought, but they explained losses were still happening during the 2017 drought. More desired plant species were still being reduced in abundance and dying from the lack of rainfall.

Respondents suspected that when the rains next returned less grass would be able to grow compared to the past.

Starting shortly after the 1984 drought, the people we spoke with began to observe an increase in undesired trees like *laichimis* (cluster of species within Burseraceae family), *samanderi* (*Commiphora sp*.), and especially *lchurai* (*Vachellia reficiens*). They said that these small trees can limit the growth of more desired herbaceous plants underneath them and have limited value as browse for goats and sheep. We were told these trees also grow in thick thorny stands and make it difficult to herd livestock through them. The discussion groups considered *Commiphora sp*. as more useful for goats and sheep compared to *Vachellia reficiens* because the fallen dried leaves (*sieu*) of *Commiphora* are eaten by both species during dry periods and the fresh leaves are commonly eaten by goats.

Respondents viewed lack of rainfall as a cause of the loss of desired plants, but, in some cases, they also considered it to be caused by a combination of livestock overgrazing, sheep and goat hoof impacts, soil loss, and increased human population numbers and distribution (Fig 2.4). They described the combination of increased livestock numbers and households living in areas where it was once only bush (*soro*) as the reason for the loss of desired plants. Some groups were unsure of why *Commiphora sp*. and *Vachellia reficiens* were spreading while others attributed it to their ability to hold the soil, elephants spreading their branches, and the heavy (*El Nino*) rains after the 1996 drought that had an associated increase in termites that killed desired plants.

Some groups described the loss of soil and the change in soil color from white or brown to now mostly red. This change was first noticed during the 1984 drought but also was perceived to have gotten worse during the 2009 drought. Respondents attributed soil loss and the formation of gullies throughout the area to the loss of trees and increased bare ground. The discussion

groups stated that lack of rain and termites could cause the roots of plants to die, which was linked to soil erosion. The elders from Lekiji described how this change in soil was affecting their livestock and increasing undesired plants,

> 'Anything that grows now it is not that strong and can't grow and last long and before when the cows graze, they become stronger and now when they feed on the plants, they are not that strong because the soil was so nutritious and nowadays they are not nutritious. *Oldupai* [*Sansevieria frequens* and *Sansevieria robusta*, herbaceous plant with poor nutrition for livestock] and *ltepes* [*Vachellia tortilis*, tree with nutritious pods for livestock] they really like this red soil and *mathenge* [*Prosopis juliflora*, non-native] is also doing well in this soil.' (Lekiji elders)

Participants also noticed a loss of wild fruits and edible plants and a related shift in diet. They commonly described how when they were young, they ate many different types of wild fruits and some other edible plants, but these plants were no longer as abundant and were rarely eaten now. They said prior to the 1984 drought families, but particularly herders and children, could rely on these fruits and plants during *riai* events for food. This helped make herding at these times easier. The discussion groups explained that they previously did not need to carry or have food from the shops taken to them while herding, as is currently done during a drought. They described this loss across a wide diversity of plants, like *njasani* (a vine with sweet tubers), *ngopito*, *lpupo*, *naisugom*, *monok* (gum-sap from tree), *lpaas* (a dish made from wild fruits and blood), *lpusan*, *luka*, *lkinoi* (*Lannea edulis*), *sagaram* (pods from *Vachellia tortilis*), *lkalkaloi* (*Grewia lilacina*), *naadonker*, and *salapani* (*Cordia sp*.). After the 1984 drought, they said they began relying more heavily on food from shops. Some people said they liked the options and diversity of new foods but also groups described that fewer people got sick eating the diet of the past, including wild fruits, milk, blood, and meat, compared to now.

The discussion groups stated one of the consequences of the changing environment was a general trend of lower cattle productivity. Participants said in the past there were more cattle kept

per household and cattle and sheep were perceived to be individually healthier, fatter. Again, starting with the 1984 drought and connected to the loss of forage, they described a general decrease in livestock productivity and people's reliance on milk, blood, and meat. Many people in our discussion groups referred to the past with nostalgia, describing the past as times of plenty and intertwined these statements with descriptions of the loss of plants and wildlife. They used the loss of these foods from livestock as a reason to explain why people were less healthy today compared to the past. The Lekiji elders said that the last time there was a time of plenty, *lari*, was a long time ago before the *lkishami-lmurran* (current bachelor-warrior age-set) were circumcised, prior to the 2005 drought.

These community focus groups also described the loss of wildlife as an impact during *riai* and a general environmental change. They thought lack of rainfall during *riai* directly caused the loss of mostly large mammal populations from the area. Respondents said while *riai* prior to the 1984 drought killed wildlife, this *riai* was when there was a major loss of different wildlife species that did not return or were reduced permanently to very low numbers. They said it was during the 1984 drought when black rhino (*Diceros bicornis*), buffalo (*Syncerus caffer*), eland (*Taurotragus oryx*), and waterbuck (*Kobus ellipsiprymnus*) were lost from the area and populations of Grevy's zebra (*Equus grevyi*), warthog (*Phacochoerus africanus*), gazelle (*Nanger granti* and/or *Eudorcus thomsonii*), giraffe (*Giraffa camelopardalis reticulata*), oryx (*Oryx beisa*), ostrich (*Struthio molybdophanes*), and elephant (*Loxodonta africana*) populations were permanently reduced. There were only two statements made of people killing wildlife, hunting zebra and selling elephants (likely ivory trade), as a drought coping strategy during a *riai* and there were no statements made identifying hunting as the reason for the decrease in wildlife populations.

2.4. Discussion

Samburu drought definitions and categorization process

The Samburu communities in our study have drought definitions and a categorization process that allow them to discuss and compare dry periods based on impacts to the well-being of people and livestock. They use two words that fit a standard socio-economic classification of drought, *ngolong*, a less severe drought, and *riai*, a major or severe drought (Wilhite and Glantz, 1985). To help distinguish these terms from broader socio-economic or other drought definitions we refer to these as *pastoral droughts*. Samburu pastoralists use an additional term, *lamei*, to identify expected dry seasons showing these communities distinguish pastoral droughts as abnormal (caused when expected rainfall does not arrive) or fairly unpredictable events the same way standard drought definitions do (Kallis, 2008). Samburu people use scale dependent thresholds to help categorize dry periods into these three terms: *lamei*–dry period expected with minimal impact; *ngolong*–unexpected, hungry-suffering people and livestock; *riai*–unexpected, livestock death. The perceived severity of impacts within any category varies based on flexible factors connected to the well-being of people and livestock.

Samburu understanding of drought as a crisis is very similar to how the Mukogodo-Maasai from central-northern Kenya understand drought, but different from those of agropastoralists in Makueni, Kenya. Two studies (Herren, 1991 and Ifejika Speranza et al., 2010) represent the only other comprehensive examinations of African pastoralist perspectives that we have identified and can directly compare our work to. Samburu pastoralists think of drought as a crisis, determined by impacts, not the absence of rainfall. This is the same way the Mukogodo-

Maasai term, *olamei*, is used in neighboring Laikipia County, Kenya (Herren, 1991). For both the Samburu and Maasai, pastoral droughts are about periods of suffering, and wanting, and the exact causes change between dry periods. It appears possible that these types of crises occur even when normal rainfall patterns occur, for example, through livestock diseases. The Samburu appear to have one more drought term, *riai*, than the Mukogodo-Maasai, that distinguishes a severe drought from a less severe drought, *ngolong*. This might be because they are in a drier environment where periods of low-level suffering are more common. *Pastoral drought* appears to be a different concept of drought than agropastoralists in the former district of Makueni use; these agropastoralists define drought as lack of rainfall or when multiple rainy seasons were missed (Ifejika Speranza et al., 2010). This definition centers on a cause whether or not impacts occur. Besides these two studies, we have not been able to identify any other published studies that specifically describe pastoralists' definitions of drought in Africa. Drought definitions are not necessarily easy to document because groups may not have a standard definition for terminology themselves. These perspectives help set the stage for an understanding of drought experiences. More pastoral ethnographic studies are needed to know how drought definitions vary among pastoral groups.

Pastoral droughts are useful to identify periods of suffering, and external or CBRM institutions should pay attention to them. Knowing when pastoral droughts are happening (from the pastoral perspective) can help development and government organizations determine when and how to assist (Wilhite et al., 2014). Pastoral droughts, not necessarily precipitation anomalies, are when pastoralists need help. Pastoralists are more likely to predict these events with their complex causes, than just tracking meteorological or vegetation (e.g., NDVI) datasets (Bennett et al., 2016; Conway et al., 2019; Wandel et al., 2016). It therefore may be valuable to

examine methods to establish pastoralist early warning systems that help mitigate or respond to the diverse causes of droughts. Organizations could establish pastoral drought monitoring using social networks of pastoralists across pastoralist areas to report by phone estimates of how sufficient livestock forage remains. This measure would ideally capture how long livestock forage is likely to feed livestock before long-distance movements are needed that could cause violent conflict.

Severe drought (riai) events - history and severity

Our severe drought event timeline did not indicate that droughts are getting more frequent or impactful. Because the community discussion groups have common drought definitions and recognized *riai* as a severe drought, we were able to create an event timeline identifying nine severe droughts from 1970 to 2017. Contrary to our hypothesis and observations of other scientists (Opiyo et al., 2015), participants did not describe a clear trend over the last five decades of major droughts increasing in frequency or severity. We were surprised that the communities reported the 1984 drought had the most severe impacts on people and livestock well-being, but this may have been because of the duration of the 1984 drought or possibly how closely it was preceeded by other drought events. We expected, like others, that hotter temperatures and decreasing rainfall trends along with social factors like sedentarization to have resulted in greater suffering during droughts in more recent times (Boone et al. 2005; Ouma et al. 2018; Pricope et al. 2013). We hypothesize that adaptation processes among the Samburu people may be lessening the impacts of drought. Even though there did not appear to be a clear trend of increasing severe droughts, the 2009 and 2017 *riai* events were the second and third most severe droughts, respectively. This was in part because they were considered the most violent periods in

people's lifetimes. Perhaps more time is needed to determine whether a trend of worsening droughts will appear.

Women and men identified similar major droughts and severity patterns, but there were some indications that certain *riai* events could have differential impacts on gender roles. There were minor differences between how women and men ranked the severity of drought events, but both groups collectively identified the same events as *riai*. We expected there to be more differences because in Samburu society men and women have fairly set roles related to livestock husbandry (e.g., cattle, that are more sensitive to drought impacts, tend to be herded exclusively by men, while women often herd and care for sheep and goats). Other studies have suggested gendered drought impacts might be an important outcome to measure in pastoral groups (Bryant, 1992; Miller et al., 2014; Walker et al., 2021a), however, our results indicate, men and women likely discuss droughts as a household and community and share opinions of what makes a crisis. This does not mean they do not experience and respond to droughts in different ways just that they identify severe droughts similarly.

Severe droughts compared to remotely sensed vegetation droughts

We compared the people-livestock droughts the Samburu communities experience to remotely sensed vegetation droughts to better understand the drought drivers and identify future adaptation research questions. Event timelines based only on perceived pastoral droughts (that are determined by suffering) cannot be used to assess the influence of meteorological drivers or climate change. It is necessary to compare pastoral droughts to meteorological or vegetation drivers, like NDVI anomalies, to get a better understanding of the drought exposure that create a socio-economic drought. For example, in our case, the NDVI anomalies we identified coincided

with all *riai* events. However, there were vegetation droughts in 1991, 2001, and 2011 that did not cause *riai*. These were not the anomalies with NDVI levels closest to expected seasonal averages. We do not know if these events were classified as less severe droughts, *ngolong*, or not. The 2011 vegetation drought was the largest NDVI anomaly in our analysis window (1981 to 2013), while the 1984 drought was 4th most severe in terms of vegetation but 1st most severe in terms of impact on people and livestock well-being. This indicates that while meteorological drivers of drought may be getting worse (Ouma et al., 2018; Pricope et al., 2013), more complex drivers of pastoral droughts are at play (see below). However, we did not compare duration of NDVI anomalies, just the level from expected value. We do not know if the duration of low NDVI values may better represent livestock forage shortages. This confirms that droughts have multiple drivers but highlights the limited value of only evaluating or predicting pastoral experiences based on meteorological or vegetation indicators. Climate change must be understood from the ground up (Bennett et al., 2016; Galvin et al., 2020). As far as we know, no other studies have compared pastoral perceptions of multiple droughts to meteorological or NDVI based droughts to understand changes in impacts and exposure over time.

What helped Samburu communities avoid pastoral drought in 1991, 2001, and 2011 or made Samburu communities susceptible to the big drought in 1984? Two of our Samburu researchers suspect that livestock death was avoided in 2011 because the cattle population was still low following the 2009 drought because of government violence. In 2011, herders were able to keep the smaller population of cattle within Samburu County and avoided violent conflict with other ethnic groups that may have otherwise led to a *riai* event. In 2001 violent conflict was also avoided, perhaps because it was a different generation of *lmurran*, bachelor-warriors, herding the cattle who were less prone to violence. We do not know why Samburu pastoralists were

susceptible to drought in 1984. Perhaps this was an extended drought (it appeared to have the longest duration of significanlty low NDVI in Figure 2.2) and it was preceded closely by two other severe droughts in 1981 and 1982. We also suspect, based on the neighboring Mukugodo-Maasai experience, that it was because a long history of colonialism and development actions had limited livestock mobility in a society that was highly dependent on cattle, not yet diversified (Herren, 1991). This ability to identify vegetation or meteorological droughts through remote sensing can be compared to community experiences to better research drought adaptations and vulnerabilities. We suggest this method of comparison could be helpful in other pastoral studies to better assess drought adaptation and vulnerability processes (Smit and Wandel, 2006; Thornton and Manasfi, 2010).

Perceived causes of severe droughts

Understanding what causes pastoral droughts, *riai*, may assist communities and outside institutions to help avoid it (Fig 2.3). The Samburu communities know that social and environmental factors contribute to whether or not livestock die, or the degree people suffer during a drought. Addressing factors such as ethnic violence, short-term and long-term livestock impacts, and permanent settlement distributions might help improve availability or access of livestock to forage during droughts. It is also possible community-based rangeland management and drought planning programs will have greater overall success and community participation if they support community perceptions of what will apease or propitiate God, for example reduce internal social conflict or promote women's ceremonies. This is especially true given the major role that women have in adapting to drought, as we will see in Chapter 3. These actions will be

seen by many to please God and may encourage people's agency to resist the impacts of droughts and avoid *riai* events.

This Samburu knowledge of what causes drought also shows that they are more focused on a concept of *forage sufficiency* (a term we coin here) than lack of rainfall; perhaps scientists should likewise understand rangeland dynamics more directly based on this concept. The Samburu perceived causes of drought are centered around whether forage is available and accessible and meets the demand of the current livestock population (Figure 2.3). How this forage sufficiency varies in these three factors seems to determine whether a pastoral drought, and suffering, will occur. Lack of rainfall only determines one aspect of this, forage availability, but all three are important. In other studies, the forage sufficiency concept better predicts the relationship between rangeland and pastoralism (cultural) practices (Liao et al., 2020; Moritz et al., 2018) than forage availability alone. We speculate that methods measuring forage availability, accessibility, and demand will better allow rangeland scientists to serve pastoral needs. This information will relate to pastoral perceptions of drought and thus may provide a better understanding of why pastoralists react or adapt behaviors to droughts. Science that coordinates with societal concerns likely has a greater chance of assisting community-based rangeland management (CBRM) transformations to counter climate, social, and environmental pressures (Reid et al., 2021).

Environmental trends caused by and affecting severe droughts

The Samburu story of the loss of desired plants and wildlife support and provide nuance to help frame the changing environmental conditions in which droughts continue to happen. Ogutu et al. (2016) and Pricope et al. (2013) report the loss of wildlife and vegetation

production, respectively, across much of central-northern Kenya. Compared to the relatively steady declines these studies were able to measure, our community discussion groups provide evidence that many of these environmental changes occurred somewhat abruptly during the 1984 drought. It appears that Ogutu et al. (2016) did not document the rapid wildlife decline following the 1984 drought, perhaps because of limits in their analysis or perhaps Samburu perceptions are not accurate. The 1984 abrupt changes in wildlife, vegetation, and soil that the Samburu pastoralists described, seem difficult to recover from. The Samburu respondents considered the environment degraded for cattle, less productive with rehabilitation efforts needed for recovery (described more in Chapter 3). This matches with a 25% decline in remotely sensed cattle numbers in Samburu County since the late 1970s (Ogutu et al., 2016).

While the Samburu do not perceive that the wildlife control plant communities, their perception of the simultaneous wildlife and vegetation changes may help explain an ecological relationship. The loss of many large mammal browsing species from the area in the 1984 drought could have contributed to the increase in woody vegetation because it would have decreased herbivory on woody species (Augustine and McNaughton, 1998). This change along with increased sheep grazing pressure on grasses and increases in carbon dioxide that are advantegous for woody plants may describe a perfect storm of events that have caused these rangelands to be less suitable for cattle (Bond and Midgley, 2000; Løvschal et al., 2019). Sheep and goats likely play a role in vegetation impacts, which the Samburu acknowledge, but wildlife loss should also be investigated because management to improve wildlife populations might help prevent future droughts. For example, the reestablishment of large mammal browsers, like elephants and black rhino, may help naturally control bush encroachment and may create opportunities for grasses to regrow (Georgiadis et al., 2007; Pachzelt et al., 2015; Van Langevelde et al., 2003). Camel

populations have also increased in Samburu County and their browsing may aid in the effort to control bush encroachment (Ogutu et al., 2016; Sperling, 1987). Added browsing pressure may help avoid some of the heavy labor requirements to remove species like *Vachellia reficiens* (Kimiti et al., 2017). This may be important for discussion and co-learning with pastoralists about how wildlife might help reduce labor to sustain rangelands.

Summary

Together these findings an understanding of what droughts Samburu pastoralists face and how they define them. This information is essential for understanding the drought adaptation process that we investigate in Chapter 3 (Smit and Wandel, 2006; Thornton et al., 2019; Thornton and Manasfi, 2010). It not only outlines what is drought in the Samburu culture, but when these severe events have occurred, what were the perceived causes, and how the environment (that pastoralists adapt to) has changed. This study provides an example of the value of doing an ethnographic investigation of pastoral droughts. It was only through this detailed methodology that we gained a sufficient understanding of what the problem of drought means to Samburu pastoralists. We suggest other studies in different pastoral areas take this general approach so a better understanding of drought and climate change can be developed for the region (Conway et al., 2019; Galvin et al., 2020).

CHAPTER 3

THE DROUGHT ADAPTATION PROCESS OF SAMBURU PASTORALISM AND HOW WOMEN FACILITATE CHANGE

3.1. Introduction

The importance of pastoral drought adaptation processes

Humans need pathways to continuously adapt to the environmental changes caused by droughts in their effort to improve social-ecological well-being (Adger et al., 2005; Fazey et al., 2016; Janssen and Ostrom, 2006; Thornton et al., 2019). Environments are not static, and therefore neither are livelihoods dependent on their natural resources (Ifejika Speranza et al., 2014). Natural hazards, like droughts or floods, cause short-term impacts, and their repetition shape long-term environmental trends (Seidl et al., 2016). Droughts require livelihood adjustments interwoven with climate change, environmental management, and poverty reduction (Thomalla et al., 2006). Societies sometimes fail to cope with natural hazards or adapt to associated ecological changes leading to catastrophes. People can even contribute to their own demise through maladaptations, which are adaptations with significant unintended consequences (Magnan et al., 2016). Changes in land-use practices and climate have increased the rate at which droughts and biodiversity shifts occur, and thus the rate people need to adjust their lives (IPCC 2014; IPBES 2019). How will people keep up?

Pastoralists define droughts as crises when lack of rainfall contributes to short-term vegetation loss that causes livestock suffering or death, which leads to human suffering (Herren, 1991; Chapter 2). Pastoral people's central livelihood is the husbandry of grazing livestock such

as cattle, camels, goats, and sheep (Bollig and Schnegg, 2013). Droughts are abnormal periods that lack rainfall but are culturally constructed events. This means that communities or societies define and imbue meaning on droughts based on their livelihood or environmental concerns (Kallis, 2008; Wilhite and Glantz, 1985). Pastoralists in Kenya, and perhaps more broadly, define drought mostly by whether livestock forage is sufficient to maintain their livestock herds (Herren, 1991; Ifejika Speranza et al., 2010; Chapter 2). Particularly in semi-arid to arid landscapes or drylands, lack of rainfall frequently creates shortages of livestock forage that cause livestock to die. For subsistence pastoralists who rely on livestock milk, meat, and blood for food, this has major repercussions on their family's well-being (Herren, 1991; Moritz et al., 2018; Opiyo et al., 2015). Pastoralists mark these occasions of livestock death and human suffering as severe pastoral droughts using culturally specific terminology (Herren, 1991; Chapter 2). These pastoral droughts may differ from vegetation droughts, which occur when lack of rainfall induces a significant and unexpected loss of vegetation production. In a pastoral drought, other causes, such as violence, may also limit access to drought forage reserves (Chapter 2). However, when vegetation droughts occur, pastoralists may avoid severe pastoral droughts through coping strategies.

Meteorological droughts (low precipitation anomalies) can cause long-term vegetation shifts at landscape scales that alter the likelihood that vegetation droughts and pastoral droughts will occur. Meteorological droughts and other disturbance regimes, such as fire and herbivory, can cause changes in plant abundance or biodiversity (Hempson et al., 2015; van de Koppel et al., 2002; Wandel et al., 2016). Vegetation shifts will change forage availability for specific livestock species (Samuels et al., 2016). For example, a decrease in grass productivity and an increase in woody plants lowers cattle forage, and cattle-centric pastoralists sometimes perceive

these vegetation shifts to be a type of environmental degradation (Bollig and Schulte, 1999; Chapter 2). However, this same change may be advantageous to goats and camels that mostly browse shrubs and trees (Augustine and McNaughton, 1998; Watson et al., 2016). Vegetation shifts change the relationship between when meteorological droughts, vegetation droughts, and pastoral droughts occur (Huho and Mugalavai, 2010; Little, 1996; Opiyo et al., 2015; Chapter 2). Therefore, pastoralist adaptations to vegetation shifts will also determine their drought vulnerability.

Pastoralists may now be more vulnerable to severe pastoral droughts because of threats to livestock mobility (Reid et al., 2014; Turner and Schlecht, 2019). Pastoralists move their herds to obtain forage as livestock consume it or plant production shifts in location because of randomly patchy rainfall (Liao et al., 2020; Turner and Schlecht, 2019). Pastoralists perceive early or less severe drought stages when livestock forage becomes locally insufficient and livestock go hungry (Herren, 1991; Nkedianye et al., 2011; Opiyo et al., 2015). At these times, pastoralists move their herds greater distances, or in planned directions, to drought forage reserves to limit adverse livestock effects (Berhanu and Beyene, 2015; Butt et al., 2009; McCabe, 2007). Changes in land-use and rangeland management over recent centuries have fragmented rangelands with physical and social barriers (Galvin et al., 2008). These barriers reduce the ability of herders to access drought forage reserves (Fratkin, 2001; Reid et al., 2014).

Additionally, pastoralists face more frequent periods that lack forage and require high mobility because of climate and environmental changes. Climate change has so far had a small observable effect in northern Kenya, causing an expansion in the duration and increase the frequency of low-precipitation anomalies that reduce vegetation production (Ouma et al., 2018; Pricope et al., 2013). Some rangelands are also experiencing carbon dioxide-, climate-, land-use-,

and livestock-induced shifts or losses in plant communities that reduce forage production for culturally preferred livestock, such as the reduction of grass for cattle (Bond and Midgley, 2000; Liao et al., 2017; Oba and Kaitira, 2006; Oba and Kotile, 2001; Watson et al., 2016). However, it is an open question whether these threats are resulting in more significant impacts on pastoralists. Their well-being during droughts also depends on how well pastoralists' adapt to drought. The purpose of this study is to examine the drought adaptation process of one pastoralist society, the Samburu people in the lowlands of northern Kenya, over the last five decades to pastoral drought events. We want to know if and how they have dealt with severe droughts and changing stressors.

A framework for understanding the drought adaptation process

To study drought adaptation processes, scientists commonly analyze adaptation strategies, including their effects on vulnerability and how people enact adaptations (Adger, 2006; Nelson et al., 2007; Smit and Wandel, 2006). The adaptation process is a dynamic and continuous selection and refinement of adaptation strategies (Thornton et al., 2019). Many drought adaptation studies are post hoc analyses because it is challenging to test drought's complex interventions and outcomes in real-world scenarios (Bennett et al., 2016; Opiyo et al., 2015). It is crucial for researchers to first describe the adaptation problem from the perspective of those adapting (Thornton and Manasfi, 2010). Our case follows the Samburu pastoral perspective about the drought problem, which we have described in Chapter 2. Here in Chapter 3, we use an adaptation theory framework to explore and discuss the pastoral drought adaptation process (Figure 3.1). We have selected these adaptation concepts and framework because it is well suited to evaluate how the adaptation process links different adaptation strategies with outcomes and

important adaptive capacity factors in the context of a complex natural hazard, like drought (Bennett et al., 2016; Smit and Wandel, 2006; Thornton et al., 2019).

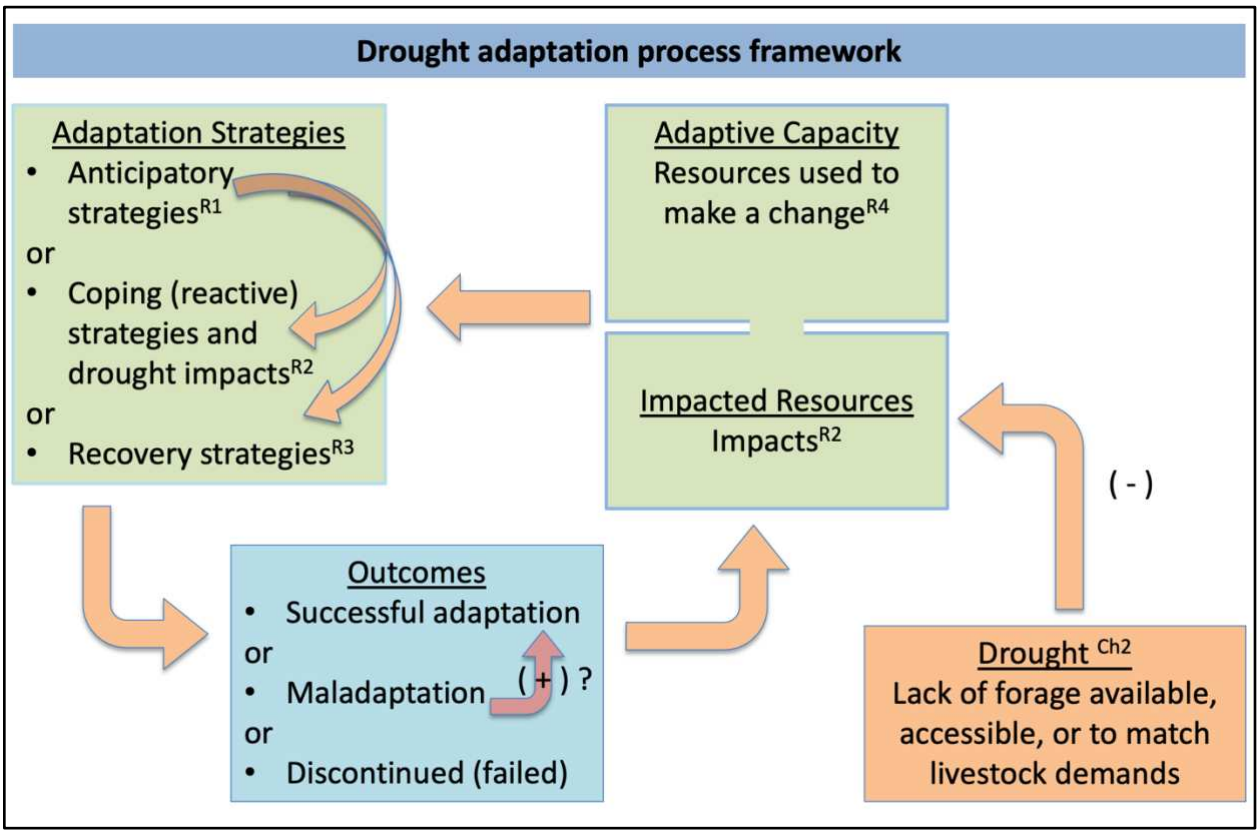

Figure 3.1. Important adaptation concepts in relation to drought. Superscripts identify our research questions (R1-4) and chapter 2 (Ch2) research topic. The blue boxes contain concepts used in our discussion that are not direct findings. The orange box describes pastoralist perceptions of central issue causing impacts and suffering.

People make three broad types of drought adaptation strategies that vary relative to drought occurrence: anticipatory, coping, and recovery. The Intergovernmental Panel on Climate Change defines adaptations as "the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC 2007). Droughts carry a real or perceived threat to harm people and the environment (Kallis, 2008). Particularly in drier environments, pastoral societies have developed

with droughts and expect regular drought events to continue to occur (Anderson and Bollig, 2016; Bollig et al., 2013; Miller et al., 2014; Opiyo et al., 2015). Between droughts or before the next drought, people implement anticipatory strategies that seek to mitigate impacts or take advantage of changed conditions during or after a drought. Anticipatory strategies are planned (Thornton and Manasfi, 2010), for example the decision and actions to sell livestock and invest in a business. During a drought, people use coping strategies to resist drought impacts. Coping strategies are reactive and dynamic to drought stressors (Adger et al., 2003; Smit and Wandel, 2006). For example, pastoralists move livestock or rely on alternative incomes and food sources to cope with the lack of livestock forage during droughts (Butt et al., 2009; Catley et al., 2016). In some senses, coping strategies are a type of drought impact on human behavior and can be difficult to disentangle from dynamic drought effects (Thornton and Manasfi, 2010). For example, pastoralists move livestock to drought forage, a coping strategy, but this might be considered an impact when it forces them into locations, or perhaps violent situations, they would prefer not to be. Following a drought, when vegetation production and livestock conditions improve, people use recovery strategies to regain previous livelihood activities or adjust to the new environmental conditions. Like anticipatory strategies these actions are planned but distinct because their goal is to reestablish the livelihood that was drought impacted. For example, the decision to use financial savings or a loan to purchase cattle that were killed during a drought. For pastoralists, recovery of livestock holdings is integral to the resilience of their central livelihood and cultural identity (Lesnoff et al., 2012; McCabe, 2007; Nkedianye et al., 2011; Reid, 2012). Some anticipatory strategies improve coping strategies or recovery strategies, but they can also directly reduce livelihood sensitivity through diversification (Adger, 2006; Nelson et al., 2007).

Scientists classify adaptation strategies based on their outcomes as either a successful adaptation, a maladaptation, or a discontinued adaptation. People intend adaptation strategies to have good, positive outcomes. Those that do are called successful adaptations (Adger et al., 2005). For example, some pastoralists have succesfully adapted to drought by ensuring that open and flexible livestock mobility is possible (Moritz et al., 2019). However, positive effects do not always result from adaptation strategies. Maladaptations are those adaptation strategies that increase overall vulnerability. For example, some pastoralists have privatized and fenced grazing areas to guarantee they are not converted to other land-use purposes, but this may increase drought vulnerability from lost livestock mobility (Boone, 2007). While these adaptations may have some benefit, they cause additional significant undesired changes that threaten the social-ecological system to drought (Magnan et al., 2016). Maladaptations can be considered separate from a failed or discontinued adaptation strategy that created no benefits or is too costly to continue implementing. For example, in Samburu district during the 1950s, the British colonial government created top-down grazing regulations and limits to livestock numbers to avoid landscape degradation (as they perceived it) and drought vulnerability; the Samburu resisted these actions and the colonial government abandoned these grazing schemes in 1961 (Pas, 2018). Adaptation strategy effectiveness is not always easy for scientists or practitioners to judge and sometimes depends on the scale of analysis, such as individual, household, community, or social-ecological system scales (Adger et al., 2005). For example, establishing a private drought forage reserve may benefit a family or clan, but increase drought vulnerability for other pastoralists in the landscape (Angassa and Oba, 2008).

People make adaptations within the limits of their adaptive capacity, and understanding these limits can help increase future adaptive capacity. Adaptive capacity is the ability of people

to use resources to make desired adaptations to change (Smit and Wandel, 2006). People invest their resources (e.g., knowledge, physical, natural) through pathways to produce adaptation strategies for greater well-being (Brown and Westaway, 2011; Thornton et al., 2019). Scientists that use different adaptation theories and frameworks (e.g., vulnerability theory or resilience theory) universally consider greater adaptive capacity as a benefit to adaptation strategies (Engle, 2011; Siders, 2019). This makes adaptive capacity a practical variable for scientific evaluation. Resources (or assets), flexibility (opportunities for changes), social organization, agency (power and freedom), and learning are all facets that contribute to an actor's adaptive capacity (Cinner et al., 2018). Droughts restrict natural resources but do not necessarily limit other aspects of adaptive capacity. How pastoralists have used resources to create adaptations to past droughts sheds light on their adaptive capacity and what limits their ability to more successfully adapt to future droughts.

Scientists can learn about a community's adaptation process to natural hazards, like drought, by describing and understanding local knowledge about their natural hazard experiences, and this information can be used to support collaborative adaptations (Armitage, 2005). A community's cultural perspective and local knowledge of a social-ecological system determine how they perceive, cope with, and adapt to droughts (Glowacki, 2020; Renom et al., 2020; Thornton and Manasfi, 2010). Local community input is therefore a great source of information to describe adaptation processes and scientific efforts to learn how to better reduce drought vulnerability (Armitage, 2005; Crate, 2011; Fiske et al., 2014; Thornton et al., 2019; Wandel et al., 2016). Community-based and top-down climate risk management efforts involve non-local agents that may not be deeply familiar with local cultural perspectives or past experiences (Armitage, 2005; Cinner et al., 2018). Studies of local drought adaptation processes

build understanding for non-local actors making climate models, actions, and policies (Conway et al., 2019; Crate, 2011; Galvin et al., 2020).

Our research objective and questions

Our objective is to present a pastoral culture's perspective on their drought adaptation process, including the adaptive capacity that they used. In this study, we answer the following six research questions to understand how Samburu pastoralists in northern Kenya have used and changed their drought adaptation process. (1) What drought anticipatory strategies have Samburu pastoralists used? (2) How have Samburu pastoralists changed drought coping strategies and the types and severity of drought impacts? (3) How have these adaptation strategies changed the drought livestock recovery processes? (4) What aspects of adaptive capacity have pastoralists used to facilitate these adaptation strategies and how has their adaptive capacity been changed in the process? We will discuss these findings to suggest how scientists can understand local knowledge about pastoral adaptation processes to support future community-based rangeland management efforts. We intend our results to support learning among non-pastoralists that collaborate with or plan policies that affect pastoralists. We will also discuss the implications of our findings for adaptive environmental management to natural hazards like drought.

3.2. Study System and Research Methods

Study System

The study's social-ecological system, Samburu pastoralism in the lowlands of southeastern Samburu County Kenya, has undergone centuries of crises followed by adaptations, with more recent rapid globalization and environmental changes including numerous concurrent droughts (Anderson and Bollig, 2016; Lesorogol, 2008b; Pas, 2018; Chapter 2; Pricope et al., 2013). In this broad respect, it is not too different from many pastoral societies undergoing rapid change in Kenya, East Africa, and other parts of the world (Reid et al., 2014). When we began collecting data in 2017, there was an ongoing drought that presented an opportunity to discuss droughts with communities and get a better understanding of their impacts and people's adaptations. Our goal was to learn about the drought adaptation process from a society that we knew had a rich and long history of herding and managing livestock in the face of drought (Anderson and Bollig, 2016). It is a society that has drought lessons for the global pastoral community that may help them prepare and support their own community-based and indigenous adaptation processes.

The study focuses on the drought adaptation process that community members experienced and remembered from the 1970s through 2018. We provide a brief context of the social-ecological system below. Our description of this Samburu pastoral system and its history, particularly prior to the 1970s, is based on a literature review, not our interviews, and thus does not necessarily match with how our study community perceives this system or its history.

The Communities

We chose eight villages (Sereolipi, Ntilal, Lerata, Laresoro, Naisunyai, Ngutuk Engiron, Nalepoboo, and Lekiji) in which to conduct our focus group discussions (Figure 3.2). These villages were selected to represent a large area of the southeastern Samburu lowlands that forms a shared social-ecological system, with a shared history, and uses community conservancies to govern (Pas, 2018). According to the Kenya Wildlife Conservancies Association (2016), conservancies are "land designated by a community or private land owner, groups of owners or corporate body for purposes of wildlife conservation and other compatible land uses" (KWCA, 2016). The only lands held outside of a community conservancy in the Samburu lowlands are County managed wildlife protected areas and small areas of privatized land around a few large towns. We included two villages from each of the four community conservancies, Sera, Westgate, Kalama, and Meibae, that make up this greater lowland area. There is a fifth community conservancy, Namunyak, in the Samburu lowlands, but the Mathews Mountain Range intersects this conservancy and possibly creates different drought forage options, so we have left it out of this study. These community conservancies have rangeland management programs that help manage natural resources, mainly livestock and wildlife forage and water, within their boundaries. They also negotiate natural resource use for livestock across conservancy, ethnic, or county level boundaries. We selected two villages from each conservancy: one close to its conservancy headquarters (and conservation management areas) and another more distant. This was done to get a more representative sample in case conservancies had more impacts in villages closer to their headquarters. Conservancy rangeland management programs have had both negative and positive social and environmental outcomes

(Glew et al., 2010; Kimiti et al., 2017; Odadi et al., 2017, 2018; Pas, 2018; NRT, 2019), but their role in pastoralists' drought adaptation process has not been evaluated across such a wide area before. The villages are between 8 to 62 km apart from one another. The communities have around 30 - 80 households each, with at least some individuals from most families living there permanently. The exception is the larger Sereolipi community. Samburu is the major ethnic group in all of these villages but small numbers of people from other ethnic groups have moved or married into the area (Pickering and Yasin, pers. obs.).

Figure 3.2. Approximate location of 8 pastoral communities where focus groups discussions took place. The map shows much of the lowlands of southeastern Samburu County, Kenya. Image produced using Google Maps (https://www.google.com/maps).

Samburu population and environmental changes

The study communities are interconnected with the larger Samburu society that resides mainly in Samburu County. The population in this county has grown quickly in recent decades.

From 2009 to 2019 it increased 39%, from 224,000 to 310,327 people, the majority of which are Samburu pastoralists (Kenya National Bureau of Statistics, 2019). Other ethnic groups, especially other pastoralist groups from the surrounding counties such as the Turkana, Pokot, Rendille, and Borana, reside in some of the larger towns within Samburu County. These other pastoralists also cross into Samburu County with their livestock when grazing is limited in their home areas. Generally, Samburu County can be divided up into the wetter, cooler highlands to the north and west and the drier, hotter lowlands in the east and south (Pas, 2018). The study area's four community conservancies cover a combined land area of 526,807 hectares and represent an estimated 2019 population of 32,692 people (Kenya National Bureau of Statistics, 2019; NRT, 2019).

The study is focused on the southeastern portion of the relatively drier Samburu lowland region that experiences frequent severe droughts. This area is generally 800 - 1100 meters in elevation where people reside (Pickering, pers. obs.), but also contains large hills. The forested Mathews Mountain Range, with peaks around 2500 meters, intersect and are potentially accessible to people and livestock from the study communities (Pas, 2018). Rainfall in this semi-arid to arid environment is highly variable in space and time but averages around 350 mm +/- 170 mm per year, with most falling during the long rains from March to May and less during the short rains from October to December (Pas, 2018; Wittemyer, 2001). Droughts are predicted to become more frequent as temperatures increase and rainfall decreases with climate change (Ouma et al., 2018; Pricope et al., 2013). The Ewaso Nyiro river is the only permanent water source and it forms much of the Samburu County southeast border, but people also access water for themselves and livestock through shallow wells (hand dug and boreholes) and earthen dams

during regular dry seasons. Livestock rely on these waterpoints less during the rainy season and these waterpoints may dry up during a drought (Pickering pers. obs.).

The lowland region is a semi-arid to arid environment with a mix of shrub, savannah, and bush habitats. *Vachellia* (formally *Acacia*) *elatior* and *Vachellia tortilis* are the most common larger tree species in riparian and lowland areas, while smaller tree species like *Commiphora spp*. or *Acacia reficiens* make up much of the bush habitat (Kimiti et al., 2017). There are a large diversity of grasses and other herbaceous plants that grow in the area and support cattle and sheep grazing (Odadi et al., 2017). In recent decades, *Vachellia tortilis* savannah has shifted to shrubland and bush habitats and this has become a community-identified rangeland management challenge (Glew et al., 2010; Kimiti et al., 2017). These new, more bushy habitats better support wildlife and livestock browsers like kudu (*Tragelaphus* spp.), camels and goats, and give less support to grazers like zebra (*Equus* spp.), cattle or sheep (Augustine and McNaughton, 1998; Kimiti et al., 2017; Watson et al., 2016). The greater region still supports diverse and endemic wildlife species adapted to the drier environment, like the Somali ostrich (*Struthio molybdophanes*), oryx (*Oryx beisa*), gerenuk (*Litocranius walleri*), Grevy's zebra (*Equus grevyi*), lesser kudu (*Tragelaphus imberbis*), reticulated giraffe (*Giraffa camelopardalis reticulata*). The black rhino (*Diceros bicornis*) has been reintroduced to the eastern portion of Samburu County. Our study community grazing areas also support wildlife populations interconnected with Samburu National Reserve, Shaba National Reserve, and Buffalo Springs National Reserve to the south and the Mathews Forest Reserve to the north; some of these wildlife species sometimes come into conflict with community members (Berger-Wolf et al., 2016; Ipara et al., 2017; Wittemyer, 2001). However, extreme wildlife declines have been observed since 1977 in Samburu County (Ogutu et al., 2016). Chapter 2 describes some of these

environmental trends from the Samburu community perspective and how they relate to severe droughts and other drivers. Pastoralists described the 1984 drought as a pivotal point when environmental changes began that decimated wildlife, vegetation and forage, soils, and cattle productivity (Chapter 2).

Samburu pastoralism in transition

Samburu pastoralism prior to the 1970s focused on cattle (*Bos indicus*) husbandry, and understanding this history helps us comprehend how the droughts changed pastoralism. The Samburu people were a cattle-specialized pastoral culture (for an unknown period prior to the 1970s and very much identify this way today even though sheep (*Ovis aries*), goats (*Capra aegagrus hircus*), and camels (*Camelus dromedarius*) have greatly increased in number (Ogutu et al., 2016; Spencer 1965). They have experienced severe droughts, human epidemics (smallpox), and cattle epidemics (rinderpest), especially in the late 1800s. The Samburu were able to recover from these events, sometimes with the help of the neighboring Rendille people who herd camels. Decision-making and authority were historically kept at the household and family levels with older men (senior elders) able to wield influence and direct many aspects of cattle grazing and husbandry (Spencer 1965). Within Samburu culture there exists a bachelor-warrior age-group of young men called *lmurran* (variations on spelling, singular *lmurrani*) who are largely responsible for herding cattle. These cattle herders cross county, ethnic, and privatized land ownership borders with their livestock in response to droughts (Pas, 2018). These kinds of movements, along with livestock raiding between pastoral ethnic groups that are sometimes catalyzed by political motivations, often lead to violent conflict that has gotten worse in recent decades (Greiner, 2013; McPeak and Little, 2018). This violence also indirectly,

negatively affects people's well-being in Samburu communities, such as their nutritional health (Pike et al., 2016). Some *lmurran* have attended school and no longer herd livestock or herd livestock part-time. Education changes the pastoral views and land-use goals of both young men and women and often sets them apart from their peers (Bruyere et al., 2018; Lesorogol et al., 2011; Lesorogol, 2008a). Elder men (elders) and women, in this polygamous society, often remain in permanent settlements taking care of sheep, goats, and, to a lesser extent, camels, as their children attend school (Pas, 2018). Violence and changing societal roles might factor into how the Samburu people experience the impacts and causes of drought.

Samburu households have become more settled and have diversified their incomes in response to external institutional policies and coercion, or social service incentives, or both. British colonialists established more firm borders between the Samburu and other ethnic groups, and their forced grazing schemes beginning in the 1930s limited pastoralist movements (Pas, 2018). Missionaries, international development organizations, and Kenyan social services incentivized settling down and the formation of permanent communities (Fratkin et al., 1999; Lesorogol, 2008b; Pas, 2018; Spencer 1965). Sedentarization drives pastoralists to diversify their livelihood because settling limits livestock movements that maximize livestock production. These livelihood changes can form a positive feedback loop to sedentarization by increasing physical and social barriers that further limit livestock mobility and production. This may entrench poverty if settlement and land-use policy is not structured to support pastoralism in these semi-arid regions (Little et al., 2008). Lenaiyasa et al. (2020) found that Samburu families in our study area over the last 25 years generally used three divergent strategies: (1) maintained focus on livestock husbandry, (2) diversified into other livelihoods but maintained some livestock, or (3) diversified income, with few livestock. Income diversification in this region

happens in response to natural hazards like drought and also by changes in pastoral preferences (Lenaiyasa et al., 2020; Schewel and Fransen, 2018).

The southeastern Samburu County lowland area is largely under communal land tenure and shared common pool resource management, organized and gazetted as group ranches and community conservancies. There has been some privatization of land around the larger towns in the lowlands area, mainly Archer's Post, the largest settlement, but there is much less privatization of land in the communities where this study took place (Glew et al., 2010; Pas, 2018; Pickering and Yasin, pers. obs.). Much greater levels of land privatization have taken place in the Samburu highlands. This creates ownership boundaries, and physical barriers like fences, which lowland herders have to navigate during droughts when they often take cattle to these areas (Lesorogol and Boone, 2016). This kind of privatization might have benefits for those securing land parcels but causes other pastoralists to have to adapt to the restricted landscape (Galvin, 2008).

In Chapter 2, we presented how the Samburu communities in our study identified nine severe droughts (called *riai* in Samburu-Maa language; effects included cattle death) from 1975 to 2017 occurring approximately every 5 years (Chapter 2). The 1984 drought was rank ordered the most severe in terms of impacts on human and livestock well-being, followed by the droughts of 2009, 2017, 1993, 1996, 2005, 1980, 1975, and 1982 (Table 2.3; Chapter 2). Pastoralists perceived that these severe droughts occurred when cattle forage was insufficient for survival. They perceived that forage availability depended on the rains but that the rains depended on God's will and factors that pleased (for example, women's ceremonies) or displeased (for example, Samburu internal social conflict) God. Samburu respondents also stated that factors

that limited access to livestock forage caused droughts, such as ethnic violence (Figure 2.3; Chapter 2).

Methodology

We collected data from village-level focus group discussions, separated by men and women, to answer our main research questions and used follow-up focus group discussions that combined participants from different communities to verify and co-interpret some results. Our goal was to represent Samburu perspectives from the southeastern Samburu County lowland social-ecological system. To do this, we studied the drought adaptation process across villages with similar pastoral livelihood strategies that also overlap in their grazing and natural resource use. In this way, we limited confounding variables and accrued drought knowledge from largely shared experiences. We selected eight villages to represent pastoral livelihoods in the Samburu County eastern lowlands. We present their knowledge of the adaptation process at the larger community (inter-village) scale that common pool resource management decisions are often made (across conservancies). Focus group discussions are considered to be effective at gathering information, help bridge scientific and local knowledge, and have relatively low costs and time commitments (Nyumba et al., 2018). We assumed focus group discussions would provide an effective way for people to collectively think through their shared experiences of drought and changes to pastoralism, including their environment. The process of hearing and discussing each other's responses to questions is meant to further illicit memories and connect responses to build an understanding of events and their relationship to one another (Caretta and Vacchelli, 2015).

We separated focus group discussions into local-gendered groups (i.e., men or senior elders and women) because we wanted to compare some differences between men and women so

that we could build a more comprehensive view of drought at the community scale. We also separated participants by gender into focus groups because we wanted to ensure women felt comfortable speaking their ideas. We did this at the suggestion of several Samburu women in the research communities that we spoke with prior to formal focus group discussions. We did not have focus group discussions with young bachelor male herders, *lmurran*, or young women since we sought individuals with the age and memory to describe shifting drought and environmental trends from shared, lived experiences since the 1970s. Other researchers in Samburu have used similar methods to successfully gather community perspectives on impacts of community conservancies, livelihood diversification, and Samburu grazing history (e.g., Glew et al., 2010; Lesorogol, 2008a; Pas, 2018). To ensure we represented these community perspectives well and limited bias we included follow-up community focus group discussions to confirm general findings and co-interpret aspects of the results. This process was meant to improve the quality of results and help build social learning around the drought adaptation process for researchers and participants (Reid et al., 2016; Ross and Berkes, 2014).

Research Methods

To answer the main research questions, we conducted 16 focus group discussions, two in each of the eight study villages, one in each village with older men and another with older women, between September 19th and October 12th, 2017, during an ongoing drought in the region (Colorado State University IRB 042-18H, March 2017). In each focus group discussion, we first asked participants to define, identify, and rank drought events in people's lifetimes (Appendix 1.1, data used in Chapter 2). The discussions then varied but overlapped heavily in the second portion of questions that asked participants to describe the history of impacts

(including social-ecological trends), coping strategies, and adaptation strategies following specific drought events, information we use in this chapter. Nine severe droughts from 1975 to 2017 were the subject of the second part of the focus groups and are presented here. The design of the focus group discussion and main research questions were organized by all field researchers and was revised through advice from supporting advisors. The field researchers who guided the focus group discussion process tried to fill in gaps of understanding from one group to the next while making sure main points were confirmed between groups to build a representative body of information for all communities.

Each of the 16 focus groups (for both men and women) were made up of 6 to 7 pastoralists who were above 45 years in age and were familiar with their current community area over a period of 30 years or more. The age restriction was set to increase the chances that the participants would be able to describe perceived causes of social-environmental change from their lived experiences. In practice we estimate that most participants tended to be in their 50s or 60s with some older. We used a snowball technique by asking community leaders and key informants to suggest participants based on our criteria and they further tried to invite individuals with high levels of knowledge about pastoralism and who were likely to express their thoughts well and actively participate in a discussion. This process produced successful discussions, but we are uncertain of how well each group truly represented their community or the Samburu lowland region.

In each community we conducted two group discussions, one with men and one with women, in a single day. Each discussion lasted 2.5 - 3 hours. All discussions were conducted in the Samburu language (Maa dialect). Field researchers took on roles as facilitators (led by a Samburu individual), notetakers, and translators during the focus group discussions. Notes were

rapidly handwritten in English by Samburu researchers and responses were translated into English for non-Samburu researchers. Notetakers tried to capture relevant respondent comments verbatim but summarized points made as well when needed. Within a day or two following a focus group discussion all field researchers met together to combine notes, discuss responses to gain a shared understanding, and add annotations to the notes for context. The three Samburu researchers provided contextual explanations to many of the notes that supported analysis. This process was meant to help remove bias and misunderstandings of the non-Samburu researchers. Respondents named specific plants using Samburu-Maa terms, which means they may not match exactly with scientific classification at the species or higher levels. In some cases, they do, and we scientifically identified them, but we could always at least identify plants through community descriptions to general plant types (e.g., grasses, small plants, large shrubs, vines, and trees) and their value for livestock (NRT, 2018).

I thematically analyzed focus group discussion notes with annotations using NVivo 12 software (1.2). Initially with the help of two other researchers, we created and agreed upon themes and codes that represented responses to research questions through an iterative process (Braun and Clarke, 2006). Once codes were established, I thematically coded all qualitative data; therefore, no inter-coder reliability check was necessary. I selected and placed into a code text that represented a single relevenat idea or that connected themes together. In practice this usually was a few sentences long, but sometimes to avoid breaking up relevant points was longer (Braun and Clarke, 2006). The goal was to help the researchers systematically and categorically represent the information shared with us. We also used gender and drought event variables to categorize the qualitative data.

I used these codes to analyze and compare responses from different focus groups and then wrote the results to represent the perceptions of the people in the 16 focus group discussions across the 8 communities. Our results present a diversity of viewpoints that do not necessarily represent any individual's or community's perspective but represent the combined understanding of the history of drought and pastoralism of all focus groups. This combination of methods and the way the results are presented is meant to strengthen research findings by providing a full picture of community responses, but, perhaps as a tradeoff, runs the risk of masking researcher bias of perceived importance of responses from discussion groups. We do our best to represent the information provided to us by the community focus group discussions in a way that we think balances their emphasis on points with our research objective. We have aggregated responses from discussion questions relevant to each research question to collectively represent the perceptions of all discussion groups.

In January 2019 we conducted two follow-up, inter-community focus group discussions to help correct and validate our findings, to co-interpret and discuss results that the field researchers thought may have long-term pastoral implications, and to learn more about the 2018 drought recovery process. Individuals in these focus groups met the same age and pastoralist criteria for inclusion described above. Some individuals had participated in the first focus group discussions in 2017 and others had not. The first meeting in 2019 brought together eight men and seven women from the Sereolipi, Lerata, Ntilal, and Laresoro communities. The second meeting later that month brought together seven men and six women from the Ngutuk Engiron, Nalepoboo, Naisunyai, and Lekiji communities. This mixing of community members and genders occurred to share and discuss the initial findings. We also discussed whether droughts and differential adaptations between households were having an impact on livestock wealth and

inequality. This was a key potential long-term impact that we speculated was occurring based on the initial focus group discussions. We also discussed the drought recovery process in 2018 and how it occurred differently from past drought recoveries because of the recent changes in the adaptation process to drought. These discussions were organized in the same way as the initial focus group discussions and notes were analyzed again using NVivo 12 software to help analyze responses related to drought recovery and livestock wealth inequality.

3.3. Results

Anticipatory adaptation strategies

We identified six major thematic anticipatory adaptation strategies from discussion group descriptions following each severe drought (*riai*) event. Generally, respondents understood anticipatory strategies as the things they learned and changed after a drought and the changed environmental conditions. These adaptation strategies supported one another within and across households or communities. In our coding, we found that our informants adopted most strategies after the 1984 drought, a pivotal point (explained below in 'coping strategies and changing drought impacts'), and then they continuously adjusted them in ways that altered coping strategies and the recovery process for the next five severe droughts through 2018. Following are six broad anticipatory strategies:

- **Increased schooling** – Includes descriptions about how more children are going to school and the relationship of schooling to drought and livestock herding.
- **Shift to sheep and goats** – Descriptions of people shifting from cattle husbandry to increased reliance on sheep and goat husbandry.

- **Shift to camels** – Descriptions of people shifting from cattle or sheep and goat husbandry to increased reliance on camel husbandry.
- **Anticipatory income diversification** – Descriptions of increased reliance on alternative incomes, including money sent from family members with jobs or businesses. This includes descriptions of people's use or planned use of banks and changes to livestock markets. Mostly these were descriptions of adaptation strategies to drought but also community members described general trends due to changes in social preferences or non-drought related causes.
- **New technologies and innovations** – Descriptions of the use of new tools and innovations, especially transportation and technology, to make actions or decisions about livestock mobility especially during times of drought.
- **Conservancies and rangeland management** – Descriptions of conservancy or community planned rangeland management and restoration activities to address drought or unwanted environmental changes.

– *Increased schooling*

Following the 1984 drought many households in our study communities began sending, or wanting to send, some or all of their children to school as a long-term investment. The 1984 drought on average was the drought with the most severe impacts on social-ecological well-being, particularly cattle death, that community members had experienced in their lifetimes and it created a pivotal point when many lessons were learned, and pastoral practices were changed (drought impacts are described more below). There was a clear motivation in the past and even during the 2017 drought for these parents to send their children to school in the hopes that they

would then assist them in the future. For example, this was expressed by the Ntilal women's group in the statement, "If you pay for their school fees by selling the livestock, after they finish school and get a job they will come back and buy their families more shoats [*ndare*]" (Ntilal woman). Many families thought it was best to invest heavily in their children's education even at a major cost to their pastoral livelihood. The Serolipi women said, "When you have children in school, and you don't have any money to pay school fees it's better you sell the cows even if it is only one which is remaining. It is better you sell and pay school fees because drought might come and kill all the ones you have" (Serolipi woman). The two droughts, 1984 and 2009, with the heaviest loss of cattle were the times when labor needs were reduced that led to more *lmurran* (bachelor-warrior-herders) going back to school.

Sending children to school was not necessarily an easy decision for some families and included risks and trade-offs. Some adults worried that if their children could not find work after schooling then their children would also not be well trained in herding. Respondents thought this might result in their children becoming criminals or bad members of society in other ways. This worry still existed and was thought to have occurred within some families at the time of our focus group discussions during the ongoing 2017 drought. The women from Naisunyai described the schooling transition and risk to children following the 1984 drought by stating,

> 'The kids started to go to school and when all the cows died they [parents, women] all think that it is only education which is the option to their kids and people started to open banks and also selling more livestock and put money in the bank, and before they were thinking if any child go to school they will get knowledge and become "mkora" [someone who is not trusted or might steal, does not like to work] and they won't come back [after moving away for school]. Even before [the 1984 drought] people did not want jobs because they think they have enough wealth in terms of livestock.' (Naisunyai woman).

Increased formal education came at the acknowledged trade-off of fewer herders and less available labor. Accessing schools also caused families to move into certain communities and to settle into more permanent places where a portion of the family typically remains year-round. Those families that did not send all or sent none of their children to school could move more easily and their children were around to help with herding.

– *Shift to sheep and goats*

Also following the 1984 drought and its immediate impacts many households in all of these communities began a transition to a greater reliance and management of sheep and goats (term generally used was *ndare*, similar to small-stock or shoats representing both species). Discussion group participants explained to us that prior to the 1984 drought, when many of them were children, households had few to no sheep and goats. An elder from Ngutuk Engiron described that around the time he was born, "At that time we had only cows, not even one shoat [*ndare*]. Some of us had not even seen shoats before" (Ngutuk Engiron man). The women from Nalepoboo community described the sheep and goat herd sizes around the time of the 1981 drought, stating, "People had few shoats [*ndare*] at this time. A person with many shoats only had 20" (Nalepoboo woman). These comments are representative of what all the groups described along with descriptions of a sharp rise in the sheep and goat populations following the 1984 drought that has continued to grow to the present. Respondents perceived the increase of sheep and goat husbandry to have occurred in part because there were relatively few shoat deaths during severe drought events but high cattle deaths and limited recovery. Others explained that the Catholic mission in their area gave them sheep and goats after the 1984 drought to help with recovery. Some also described how they would also sell sheep and goats at good, productive

times to buy cattle, but this was not the general trend. While some households began or increased sheep and goat husbandry after the 1984 drought, others described how they did not make the transition until the 1993 drought and large herds became more common following the 1996 drought. While some of this transition was somewhat passive, much of it was made very intentionally for additional benefits from this livestock diversification (as below).

The discussion groups recognized drought and other supportive benefits of sheep and goats compared to cattle. These were (1) less mortality than cattle during drought, (2) greater ability to be kept close to settled households with women and children, in part to support increased formal education, (3) ability to be sold more easily at markets, (4) faster reproduction rates, and (5) the availability of fat from sheep to help cure sick people. Sheep and goats were seen as less likely to die from lack of water or lack of forage during drought periods. The groups also explained that there was less of a need to move sheep and goats away from a settled family, which allowed them to benefit from the milk, meat, and sale of these livestock while cattle were moved farther away. Milk production from sheep and goats is a major benefit and one group mentioned that it takes about 20 goats to equal the same as one cow or camel in terms of milk production, while special shoat breeds were thought to produce more. People also appreciated that sheep and goats, but particularly goats, could normally get a good price at livestock markets and there was enough demand for them to be sold easily. The money from these sales helped pay for children's school fees or to purchase other foods. To be clear, the transition to sheep and goats was remembered as a wanted, anticipatory drought adaptation strategy and some households made an active reduction in cattle to increase the sheep and goat population. One elder from the Lerata community explained their decision following the 1984 drought, "We also started selling cows to buy more shoats [*ndare*]. Shoats are my bank account and educate my

children" (Lerata man). Respondents said sheep and goats also reproduce more quickly than cattle and provide more rapid benefits. Finally, sheep are useful because their fat was very healthy to consume and could help the recovery of sick people. Many Samburu still love cattle more than sheep and goats because of their cultural significance including cattle's ceremonial roles, but most people are happy keeping all livestock. We were told sheep and goats have started replacing cattle in some cultural roles like dowry payments, though cattle are preferred. People commonly mentioned the negative unintended consequence of keeping sheep and goats is their impact and destruction of the environment.

– *Shift to camels*

Focus group discussion participants explained to us that they now rely on more camel production across the Samburu lowland study region than in the past, but it is not an easy transition to make. Even more so than sheep and goats, very few households in southeastern Samburu County took care of camels prior to the 1984 drought. Afterwards, some households made an effort to acquire camels when possible. This desire for camels as a drought anticipatory strategy continues today. Households at times sell cattle, sheep, or goats to make the purchase of camels, which are more expensive. More people would have purchased camels if not for their high price and limited supply. Some participants remembered that camels were first purchased from the Somali ethnic group, while others remembered that it was people of mixed Samburu and Rendille heritage (*Lmasagara*) who explained to the Samburu that it was important to keep camels in their communities.

Informants recognized several main advantages of keeping camels over cattle or sheep and goats based around camels higher drought resistance, meaning they are very unlikely to die

during a drought event. There is no need to take them to temporary corrals away from settlements during drought events, because there is plenty of food for them from leaves on trees near settlements. Camels do not affect the grass or hurt the environment, and they produce more milk compared to other livestock during dry periods. Respondents understood camels that could be kept around the main household near a settlement to support elders, women, and children throughout dry periods with milk. The women of Nalepoboo described these advantages in relation to the current 2017 drought by saying,

> 'We see people with camels are happier during this drought [2017] because they take tea with milk. Now people who have young children and camels are able to give their children milk, but for us we cannot because we do not have camels. Camels will get so much food in this area, especially along the river and camels feed on acacia so there is plenty of food for them.' (Nalepoboo woman).

This statement also shows the continued preference to keep more camels. Unlike sheep and goats, camels respondents did not perceive that camels hurt the environment. The desired camels because they produce more milk than cows on an individual basis and could sometimes be milked as often as four times a day. Camels are rarely sold but some people expressed that they would sell camels to purchase cattle if the grass returned. There were no disadvantages or unintended consequences of keeping camels expressed by the groups, but people did express the need or benefit of keeping cattle, sheep, and goats for purposes that camels did not serve, like easier sale at market or value for ceremonial purposes.

– *Anticipatory income diversification*

These Samburu communities viewed income diversification outside of livestock production as an important step they had made to better deal with droughts. People sought both jobs and businesses when possible and made the long-term investment of sending some of their

children to school in the hopes that they would be better positioned to get employment or start businesses. Prior to the 1984 drought respondents stated that few businesses existed. One group mentioned selling ostrich-egg necklaces during the 1981 drought to help cope with the impacts, but all groups mentioned the 1984 drought as a period when livelihoods changed. Shortly after the 1984 drought some were able to get jobs with 'the Germans' doing restoration and tree planting activities for payments in food and small amounts of money at a time when many were severely livestock poor. Others described how they started selling livestock as a business and sold cattle in order to have funds to start a non-pastoral business. During the 1984 drought some individuals began leaving the Samburu area for Nairobi to look for work as a coping strategy that furthered encouraged this anticipatory behavior. For example, some of the local businesses that were started following the 1984 drought sold local brews (*maratina* and *mauwa*, alcoholic drinks), sold beadwork to tourists, sold *sagaram* (*Vachellia tortilis* pods) as livestock feed, and sold firewood and charcoal (this last activity they mentioned they do not like to do but are forced sometimes out of poverty). As described previously, the sale of sheep and goats became a much more common business activity at this same time. People commonly described the money gained from these income generating activities going to pay for children's school fees, to purchase food, especially during droughts, and to purchase livestock, sometimes as a drought recovery action.

– *New technologies and innovations*

In part with the help of their schooled children, the people in our discussion groups described how they adapted and used new methods to move and make decisions about moving livestock, especially during the 2017 drought compared to past droughts. We were told how the 2017 drought was the first time many Samburu pastoralists hired trucks to transport livestock to

the Laikipia-Samburu County highlands to access better pasture. Mostly trucks were used to transport cattle, but some people also used them to move sheep, and fewer people used trucks to move goats. The 2017 drought was the first time that sheep and goats needed to be taken to the highlands to avoid drought impacts. Many livestock were walked to the highlands in 2017 as in the past. The women from Ngutuk Engiron described the benefit of using trucks, stating,

> 'There were no other ways and we really wanted to go and find the grass while it has not been finished so transporting them [cattle] will be easier because of time [...] Our kids who are in school are the ones who gave us that idea so they compete also like a race on who to reach fast and find a better grazing place [...] and also the trucks does not take so much time compared to just walking that might take so much [of their] time.' (Ngutuk Engiron woman)

Some families also currently use motorbikes to transport young sheep while the adults were herded. In 2017, elder men and women would often stay in the settled communities with their children who attended school and typically took care of all or some of the household's sheep and goats. They would communicate with their family members, typically *lmurran* and younger women, in the highlands using cellphones, a newer technological practice. Family members between the highlands and lowlands in 2017 also sometimes used motorbikes to supply each other with livestock or purchased foods. The Serolipi elders, the community farthest from the highlands that we spoke with, also described selling some sheep or goats in order to purchase livestock forage, hay, that was transported in for their remaining sheep and goats during the 2017 drought. Samburu pastoralists used cellphones to arrange the transport of hay or identify and communicate good areas to graze livestock.

– *Conservancies and rangeland management*

Another anticipatory adaptation strategy that pastoralists (with others) created, but one that has occurred not at the household but at the community scale, is community-based rangeland

management and the formation of community conservancies. The people in our group discussions remember and were told by their parents and elders about a long history of grazing management that began prior to the severe drought events we discussed. They mentioned the grazing schemes put in place towards the end of British colonization and certain traditional practices started long ago. We have insufficient information to understand and present a full history of grazing management and a full picture of the influence of drought events on grazing management decisions. The more recent changes to community grazing management seemed to vary more between the study communities than other anticipatory strategies described to us. Generally, before and after the 1984 drought elders in many of these communities had in place wet season and dry season grazing restrictions for cattle to help reserve dry season or drought forage. Some households would graze around their village area during the wet season and reserve dry season forage in the hills or other areas farther from their communities. It is unclear from our recordings when and how often these types of restrictions were made and how much these activities changed due to the 1984 drought or other drought events, but there was some indication that more grazing restrictions began taking place after the 1984 drought at the village scale. It was only more recently around the 2009 drought that some of the villages in community conservancies implemented some grazing restrictions. During the 2017 drought respondents expressed the need for more seasonal grazing rules that elders enforced to help with future droughts.

Some people in different discussion groups highlighted some of the benefits they gained from the formation of community conservancies between the early to mid-naughts (2000s) and the present (2017). Some groups appreciated the education bursaries that the community conservancies provide to help send their children to school, the help they provide in security and

maintaining peace (that helps them access certain grazing areas), help with transportation and livestock veterinary care, and the help with grazing management and enforcement of rules. In particular, the discussion groups from Naisunyai and Ngutuk Engiron villages in Westgate conservancy expressed more benefits to their lives from their conservancy and their coordinated grazing management efforts than in communities in other conservancies. These communities also thought the grazing restrictions they made following the 1984 drought, during the group ranch period, helped improve forage production and even attracted other pastoralists to come graze there. Some groups said conservancy grazing rules were not new but that the ways they were enforced were new. Elders were less likely to enforce grazing rules through cursing families, as in the past, and more likely to use a livestock fine. Some also mentioned that community conservancies expanded the amount of grazing land restricted for dry seasons or droughts. Other respondents and communities described how conservancies made it harder to plan grazing management because they had to coordinate with too many other elders from different communities. They would have preferred to focus on their own village area. Some respondents also thought the community conservancy wildlife conservation areas (a smaller protected area within the conservancy) were increasing human-wildlife conflict during the 2017 drought, but they did not explain why.

Communities have also taken additional rangeland management steps in anticipation of future droughts. In response to recent severe droughts (in one community it was the 1996 drought, for others earlier) these communities have become more likely to restrict the cutting of certain trees including *Vachellia tortilis* (Samburu: *ltepes*) because they provide forage pods (Samburu: *sagaram*) during dry seasons and droughts. Some of our discussion groups also generally described an increase in restrictions around the shaking of these trees to make seed

pods fall down to feed livestock in the dry season. They would set times when shaking trees for Vachellia seed pods was allowed to help make their access more equitable among community members. If this were not done, strong youth shook trees sooner and took pods before older people could access them or some individuals might break branches if they shook trees too hard. In coordination with some of the conservancies, villages are also making an effort to cut unwanted tree species like *Vachellia reficiens* (*lchurai*) and restore and seed areas for better grass production.

Coping strategies and changing drought impacts

We coded and identified seven different coping strategies and impacts of drought on well-being based on responses from these focus group discussions. Participants said that these coping strategies generally became easier to implement over time because they implemented new anticipatory strategies (described above), or they received more external support, or both. Respondents described their coping strategies and suffering in connection to specific drought events or as a difference between drought events. These groups often recommended that we should discuss and contrast the impacts and coping strategies of the 1984 drought and the ongoing 2017 drought. For this reason, most of the information we gathered comes from descriptions of these two severe droughts, but we also got briefer descriptions about the impacts and coping strategies from all nine severe droughts since 1975, with more emphasis on the 6 droughts from 1984 to 2017. We use our coded, seven impact and coping strategy areas to broadly organize and compare severe drought events in these results and link response categories to show their interconnectedness.

- **Death, sickness, or hunger of people** – Impacts and coping strategies related to the death, sickness, or hunger of people, including drought relief, and some about violent conflict or general comments about long-term negative trends in diet or livestock productivity.
- **Reactive income diversification and mental stress** – Drought directly caused people to leave Samburu to look for alternative livelihoods and possibly give up connections to their Samburu families. This also included descriptions of the mental or emotional stress that drought causes people. This includes stress during a drought or even long-term worry.
- **Livestock-people mobility** – How drought has directly caused livestock and people to move. This can include broader descriptions of changes in livestock mobility over time.
- **Violent conflict** – Descriptions of violence (most often but not limited to ethnic violence and violence with the Kenya Defense Forces Army) that increase risk to safety and decrease the ability to safely move livestock.
- **Cattle effects** – Impacts caused by drought on cattle health and well-being. This includes short-term declines in forage specifically for cattle. It includes cattle diseases influenced or caused by a drought event.
- **Sheep and goat effects** – Impacts caused by drought on sheep and goat health and well-being. This includes short-term declines in forage specifically for sheep or goats. It also can include comments about sheep and goat diseases influenced or caused by a drought.
- **Water and disease effects** – How drought has impacted water resources. It also includes disease risk from water resources.

Respondents thought the 2017 drought was easier to deal with compared to previous droughts largely because of their educated children now provided income support during droughts through employment and businesses. Generally, families started investing more in their children's education after the 1984 drought. During the 2017 drought there was a continued drive to send children to school. Most described that they had more work and business opportunities now compared to the past and how this helped with the current severe drought. There was more income from activities like selling sand from the rivers to construction companies, selling beadwork to tourists and the community conservancies, buying small goods from shops in towns to sell in villages, and from increased sales of livestock especially sheep and goats. The elders from Naisunyai stated, "There is more work now for people to do and get paid... We could have rated this drought [2017] number 1 [in the *riai*, severity rank activity, they ranked it number 7 out of the 7 severe droughts they named, see Chapter 2 results] if there were no shops with food or other incomes that we could rely upon or if there was no rain in Maralal [highlands of Samburu]" (Naisunyai man). They also described how their children who had gone to school were now educating them. They were teaching them how to use banks, encouraging them to sell livestock before a severe drought, put the funds in banks or invest in business, move closer to the roads to get help more easily when they were sick or to be supplied with food, and to use phones. At the same time, these adults worried that their children might steal the money from the banks and complained that they had to beg their children for help during dry periods and sometimes it did not come.

– *Death, sickness, or hunger of people*

Drought impacts on overall human well-being got more severe from 1975 to 1984 before slowly improving through 2018. Respondents defined severe drought events largely by impacts that caused livestock death, and respondents linked these livestock impacts to causing people to be hungry, sick, or, sometimes, die. During the 1976, 1981, and 1982 droughts, the groups described hunger but not the death or sickness of people. These severe droughts were not considered as severe compared to others in impact (see Table 2.2, Chapter 2). They described how externally produced food options, like maize flour or sorghum (cereals), were very limited during these droughts, and that they relied more heavily on wild fruits and game meat as an alternative food source. Cereals were limited and harder to access in high quantities then, compared to store bought foods during the 2017 drought. This was described in the Nalepoboo women's focus group discussion,

> 'There was Riai Elakira [the 1976 drought] when we were eating meat and we were sharing in all the villages. Also, our mothers were going to the bush to get wild fruits and there were no spoons and that is when we were just feeding on the meat, but the livestock were so skinny. That is when we were eating the zebra, there was no food and even now it is now *riai* [severe drought] and there is more food.' (Nalepoboo woman)

They emphasized meat consumption because milk production had run out during the drought. During the 1981 drought people said they ate *sagaram*, seed pods from the tree, *Vachellia tortilis*, which is now also regularly used as an important source of livestock forage, particularly for sheep and goats, during the long dry season (*lamei odo*) in August. During the 1981 drought they also described how the children who looked after the sheep and goats ate a specific type of wild fruit (*lpusan*) that is now less common. Many people died, primarily from lack of food during the 1984 drought. The Naisunyai women explained the starvation during the 1984 drought like this, "[...] going and buying food people were struggling and the number of people who were

getting to buy food were equal to those who did not buy anything and got [sick]. Then even some were dying when on the way to go buy food" (Naisunyai woman). People also died from diseases at this time, but lack of food was perceived as the major issue. This is the most severe drought where more people died from hunger compared to all other droughts. Respondents described people dying from diseases including cholera during the 1993 and 1996 droughts but not from lack of food. By contrast, during the 2005 drought, there was hunger, but people did not die. All deaths associated with the 2009 drought were associated with violence and fighting with the Kenyan army.

The group participants said development agencies and government provided drought relief in all but perhaps two severe drought events, 1982 and 2005. The purpose of drought relief, in the form of food relief, supplemental forage, or veterinary care, relieved suffering from hunger and prevented death of people or livestock. In addition, political disputes in election years often disrupted drought support from the Kenyan government. In 2017 the government supported herders with food in some distant areas where pastoralists grazed their cattle, but they discontinued this practice as political disputes occurred around the election and voting. Generally, respondents said food was more accessible during severe droughts following the 1984 drought, initially through drought relief but then through direct purchase. A Sereolipi elder explained how important access to food through shops had become during the 2017 drought, "this current *riai* [2017 drought] if there was no food from the shops we could have died" (Sereolipi man). The women from Ngutuk Engiron also expressed this sentiment, "At least now we are able to eat good food compared to Riai 84 [1984]" (Ngutuk Engiron woman). However, during the 2017 drought access to food from shops was not ubiquitously accessible and many did suffer from lack of food. During this drought, government drought relief provided less food

because of election politics. Some of the respondents described high levels of suffering including elders fainting and children going hungry from lack of food in 2017, but we heard of no direct deaths from starvation.

– *Reactive income diversification and mental stress*

People also described the mental stress caused by lost livestock wealth and the need to find immediate financial income during severe droughts. While mental stress likely underlies many of these impacts, respondents did not commonly state it on its own. When respondents described stress as a drought impact, it almost always referred to the ongoing 2017 drought. For this reason, it is difficult to compare mental stress between severe droughts. Some of the extreme consequences of this stress were told to us by the Lerata women's group, "So many people have lost their cows and commit suicide because of this severe drought [2017]" (Lerata woman). The same group also expressed more general worry, "Yes we worry. If this drought continues [2017] it will kill all our livestock and they are like our bank and our kids will drop out of school. If the government does not support the people with food, people will die" (Lerata woman). Related to this kind of mental stress is the need to seek work outside the Samburu region. This was said to have started with the 1984 drought. Groups described how people, particularly *lmurran*-herders, left the Samburu region for cities like Mombasa or Nairobi. Some described this as running away because of their loss of cattle, while others said they went to look for jobs. Some of these people lost touch with their Samburu families while others returned. Respondents might have emphasized this for the 1984 drought because it was the first time many people left and it was harder to stay in touch then, but it was also mentioned that people left during the 2017 drought to

look for work in Nairobi. Income and livelihood diversification was a long-term trend, as explained earlier, and less as a coping strategy.

– *Livestock-people mobility*

By far the most common impact of severe droughts were coping strategies related to livestock-people mobility. The search for cattle forage at these times always took at least some herders and their cattle outside present-day Samburu County, except possibly the 1982 drought. People take cattle to different locations in different directions from one another during a drought. Over the time period analyzed, respondents said families also began to more frequently split, so some could remain closer to their home settlement area during a severe drought, keeping sheep and goats with them. During a few droughts there was a single common location that cattle herders grazed animals across the majority of households and communities. It was not until the 1996 drought that the two communities, Lekiji and Nalepoboo, in Meibae conservancy, reported having to move sheep and goats to temporary corrals (called *lale* or *laleta*) away from the home settlement area to access forage. Other communities reported first having to make this kind of a move with sheep and goats during the 2005 drought. Prior to this drought, sheep and goats could be kept year-round next to permanent settlement areas. The 2017 drought was the first time that many households from most, if not all, of these communities took many of their sheep and goat herds to the highlands in Samburu and Laikipia Counties, locations previously only accessed by cattle during droughts. Women and children are often responsible for the herding of sheep and goats and they often provided labor to move sheep and goats to temporary corrals. This movement of small stock changed household labor roles and reduced the amount of small stock milk that was accessible to settled family members that do not herd. Participants also said the

Samburu people have not seen their mobility during times of drought decrease over time and at least some of them said it increased. A woman participant from Ntilal explained, “This severe drought [2017] is the one which has really finished this place. Even the [1984 drought] did not make people move so much because there was more vegetation”. A man participant from Sereolipi also described it similarly, “This drought [2017] and the [1984 drought] are the ones which are extremely bad. This severe drought [2017] is the severe drought that we Samburu have grazed everywhere” (Sereolipi man). During the 2017 drought in some of the communities, like Naisunyai, older women or first wives would remain in the community with some of the goats and sheep so their children could still go to school, while younger women or second wives would move with the sheep and goats to temporary corrals. These adjustments to maintain or increase mobility were possible in part because herders had access to new technologies and innovations such as mobile phones, as described earlier.

– *Violent conflict*

Participants described how violent conflict could restrict access to forage and even cause the death of livestock, but more often they described that livestock, particularly cattle, took their herders to locations that created violent conflict. Movements with cattle for forage to locations outside present-day Samburu County or border areas where other pastoralist ethnic groups also moved always led to violence in each of the nine severe droughts we discussed. The discussion groups described armed fighting and livestock raiding by and on the Somali, Borana, Turkana, and the Kenya Defense Forces (fighting with the army). The fighting has gotten more violent in recent severe droughts, in part because the current (*Lkishami*) and last (*Lmooli*) *lmurran* age-sets have more heavily armed themselves with guns and other ethnic groups are also more heavily

armed. In the 2009 drought some Samburu *lmurran* were said to have stolen livestock from people in Meru County and the government retaliated, impacting all the communities we spoke with. The Naisunyai men recounted these events to us,

> 'In 2009 that is when the government stole the cows from the Samburu people and other cows were forced to go to Baragoi [to the north in Samburu County] to escape but they died there because of the drought. The government came and stole the cows from people because the Samburu stole about 50 cows from Meru, but they came and took all the cows that the Samburu had. During this time of Kibaki [former Kenyan President] more than 5000 cows were taken by the government.' (Naisunyai man)

The Samburu also remember fighting with the Borana and Turkana during the 2009 drought. Many cattle were also taken by the Borana. These violent events are what most respondents remember about the 2009 severe drought; they ranked this drought as the second most severe drought, based on the severity-area index score (Table 2.2, Chapter 2). During the 2017 drought there was fighting again with the Kenya Defense Forces and Pokot in Laikipia County, the Turkana around the Archer's Post community (Isiolo County border), and the Borana around the Kom area (which is close to where Marsabit, Samburu and Isiolo counties all meet). Some people thought that the politics around the elections of 2017 contributed to the violence. The women from Sereolipi also stated that the conservancy scouts were helping keep peace and preventing violence in 2017 drought. They recognized that this anticipatory adaptation strategy had drought benefits even if violence was more severe at this time.

– *Cattle effects*

Cattle died during all nine *riai*, and this is what largely defines a severe drought (*riai*). Cattle were said to have died from lack of forage, diseases, and violence. They did not die directly from lack of water. Generally, the Samburu described themselves as having many cattle and being cattle focused with few other livestock species during the 1976, 1981, and 1982

droughts. The severity of the 1984 drought that killed many cattle was a transition point that led more people to herd sheep, goats, and camels. This transition to small stock was described by the Lekiji men, "During the *Lkimaniki* age-set [when they were *lmurran*], that is, when the cows were many and then 1982 drought made the number decrease and then 1984 drought continued to cause a decrease, and also this is when the soil went down" (Lekiji man). Many people described families as being left with only a very few or no cattle after 1984. During the 1993, 1996, and 2005 droughts, fewer cattle died. Some of these died from diseases, eating grass(es) with a toxic mold or fungus, and from eating poisonous plants around Mt. Kenya. In the 2009 drought, the death of cattle was largely directly and indirectly blamed on the violence with the government and other ethnic groups. During the 2017 drought, people reported few cattle deaths, but said that cattle had been away from home areas for years, an unusually long period.

– *Sheep and goat effects*

Sheep and goats only died in small numbers up until the 2005 drought. Referring to the 2005 drought, the Ngutuk Engiron women said, "so many sheep died at this time" (Ngutuk Engiron woman). It is during this same severe drought that more communities started having to move sheep and goats to temporary corrals to reach forage outside, but near, their home settlement area. Only a single Lekiji man reported large numbers of sheep and goats dying during the 2009 drought. In the 2017 drought sheep and goats died or were not healthy, causing their market price to be low. They had to be moved for the first time up the hills, in the Samburu lowlands, or to the highlands in Samburu and Laikipia Counties to find forage. Respondents repeatedly lamented the low market price for sheep and goats because it made this drought harder to cope with compared to others. The Lerata men described how the sun was hotter and

the wind had been particularly strong during the 2017 drought, which blew away much of the dried fallen leaves from shrubs and trees that sheep and goats would have relied upon otherwise. Sheep and goats also died due to diseases during some earlier severe droughts, but diseases were said to be more common during the 2017 drought. All this indicates that this anticipatory strategy, turned coping strategy, was becoming less reliable as a support to families during droughts.

– *Water and disease effects*

People in the discussion groups also described effects of severe droughts on water availability. The shortage of water was not very common. During the 1984 and 2017 droughts, the only permanently flowing river in the area, the *Ewaso Ngiro* (or *Nyiro*), dried up. The limited number of water points during severe droughts increased the chances of disease spreading to livestock and people. In the 2017 drought, donkeys were also said to be dying (this also was reported for the 1984 drought), which made it difficult for people to carry water from the remaining water points and caused people to move closer to them, restricting their access to livestock forage far from water points. Diseases were sometimes carried from distant drought forage areas, including the highlands, back to the Samburu lowlands during drought events. The community conservancies helped with livestock diseases through veterinary care, but respondents did not mention anticipatory drought strategies in relation to water access or availability.

Note, reminder on methods: *In the recovery strategies section we present information collected from the January 2019 inter-community and inter-gender, focus group discussions.*

Prior to these meetings we analyzed the results of the first 16 focus group discussions. Prior to these second round of focus group discussions, my team and I would have concluded that households were able to implement drought anticipatory and coping strategies to different degrees depending on household adaptive capacity. We further hypothesized that inequality in adaptive capacity likely led to post-drought inequality in livestock wealth. We speculated that this inequality would compound as droughts continued leading to an increasing livestock wealth inequality trend. We took these ideas to the 2019 discussion groups as part of our co-interpretation of results process and this is what largely led them to discuss and explain the drought recovery process and their categories of pastoral wealth, which we detail below.

Drought recovery process

According to the inter-community focus groups in January 2019, the drought livestock recovery process following the 2017 drought was faster and easier compared with past droughts because of the adaptation strategies the Samburu pastoralists previously put in place. The drought livestock recovery process is known as *awolo* in Samburu-Maa; it is a difficult word to succinctly translate into English. In the past *awolo* would mostly have included, for those most impacted by a drought, the acts of going to family and friends to request and receive livestock. These acts relied heavily on a livestock sharing system across social networks. The livestock recovery process in the past could also include livestock dowry gifts to the daughter's family. *Awolo* was also dependent on and said to include factors that increased livestock reproduction, like finding good pastures for remaining livestock, i.e., mobility factors.

The discussants named three main reasons why *awolo* was faster and easier in 2018 compared to previous drought recoveries: (1) new income sources from their educated children

and women, (2) sheep and goat production, and (3) women's more active roles in pastoralism. In 2018 the livestock recovery process also included using money from their children, who had been sent to school and now had work, to purchase more livestock. Additional income from businesses that women ran or from the reproduction and sales of sheep and goats cared for by women was being used in the 2018 *awolo*. Women took a more active role in going for *awolo*, that is, assisting their husbands in the process of visiting family members and friends to request livestock. We were told, "Even in the past, women were not going for *awolo*, it was only the men who were going to look for cows and shoats but nowadays even the women are doing so. It is better now because both of us are looking for food and taking care of the livestock together" (Ngutuk Engiron participant). All of this contributed to the sense these communities had more options to improve the livestock recovery process. We were told, "*Awolo* in the past was very slow compared to now. But now it is fast because there are more options…" (Lerata participant).

Participants described how the livestock sharing system also helped prevent greater livestock wealth inequality due to inequality in household drought adaptive capacity or luck. We were told that *awolo* depended on the state that you were in after the drought, that is, how many livestock you were left with. Drought was seen as an equalizing force between those with many and few livestock. A Lerata group participant stated, "[Severe drought] will sometimes make us equal because those who have more will lose and be the same like others, we meet in the same *Ndikirr* [*Ndikirr* is a stage]" (Lerata participant). However, some people escaped drought impacts through hard, proactive decisions and work. For example, households having good, focused herders that moved to the highlands early reduced livestock suffering. Luck also determined who avoided drought related livestock death. One woman moved most of her cows to the highlands and kept some at home. Ironically, it was the ones that she kept at home and fed hay that

survived the drought. Participants also described how rain was highly variable across the landscapes and this explained why some people were more impacted by droughts. A respondent emphasized high variability in local rainfall, saying, “The rain can rain on this side of the tree and cannot rain on the other side of the tree” (Lerata participant).

Even though the focus group participants in 2017 expressed their worry about deteriorating respect between Samburu people, the 2019 focus groups still felt that Samburu pastoralists helped one another in the livestock drought recovery process. This livestock sharing system was based on complex social interactions, including in part past kindnesses and respect. A person that gave livestock out when they were doing well was more likely to receive livestock when they were in trouble. A Lerata group participant stated, “And those who have given more cows during *awolo* they will still go around after the drought and get more donations from other people because he or she has already donated to other people before”. Participants in these focus groups expressed a strong sense that people help one another after a drought out of kindness and to build relationships.

The Samburu used livestock wealth categories to judge livestock wealth trends and household inclusion in groups to assess *awolo* relationships or responsibilities towards others. The participants described how these Samburu communities generally divided household livestock wealth into five categories: super-rich, rich, doing-ok, poor, and those-with-nothing. They had several names for some of these categories and these concepts were closely interlinked with the number of children someone had. The super-rich (*Loichoio nda koon*) are those with so many livestock they could not avoid giving to others; they would never be able to consume or use all their livestock resources. Respondents defined these households as having many children, 700 cows, 1000 shoats, and 400 camels (approximations). The rich (*Lparakuni*) were people that

needed nothing, they were able to completely satisfy themselves and had about 200 cows, 300 shoats, and 30 camels. The people in the middle, doing-ok (*Loikash*) were managing but could improve and had about 10 - 20 cows, 50 - 60 shoats, and maybe 1 camel. Below that category was the poor (*Ldorop*) who struggled with perhaps 2 - 3 cows and 10 shoats. And finally, there were those with nothing (*Ltolut*) that had no children, no livestock, and drank any money away; these people only lived in the larger towns.

Respondents did not think that livestock wealth inequality was getting worse, but that pastoralists in all wealth groups were becoming poorer. They thought the number of Samburu pastoralists in all upper wealth categories decreased because of droughts and the changing environment. However, they thought livestock poverty (the number of people in the two lower wealth categories) was increasing. Participants predicted in the future that cows in particular would continue to decrease in numbers. They said their children would go to school, seek other work, and give up livestock and cattle husbandry. However, they also thought that some Samburu would always remain with cows and find new solutions to drought, societal, and environmental changes; for example, like hiring herders to maintain livestock wealth and keep their culture.

Adaptive capacity

Families and communities in the study area were able to implement anticipatory and coping strategies, described above, because they increased the roles and labor of women in pastoralism. These discussion groups described how some adaptation strategies (like increased sheep and goat husbandry) supported other adaptation strategies (like increased schooling) and coping strategies (like changing diets). Respondents also recognized that women were the

primary source of the adaptive capacity needed to take advantage of these adaptation strategies. For example, women took on more and new work in society so they could send their children to school, shift to greater sheep and goat production, and to help with small businesses. Two men's discussion groups and all women's discussion groups commented on these changing roles of women in pastoral society.

Following the 1984 drought, women began herding and managing sheep and goats, which, in turn, allowed their families to settle to access schools for their children. This initial change has led to more diverse ways in which women support their family's anticipatory drought strategies. Prior to settling, children were often largely responsible for the few sheep and goats a family might own. Since children began going to school in greater numbers following the 1984 drought, women often became responsible for the care and herding of sheep and goats. Children do still help or sometimes have full responsibility for herding sheep and goats, but it is the increased labor from women that largely freed their children to go to school. Also, in more recent droughts, herders took sheep and goats to temporary corrals. In the 2017 drought, for the first time, herders took them far away to the highlands. It was women who often helped accomplish these novel large-scale movements with sheep and goats. In one community, women first herded sheep and goats to temporary corrals during the 1996 drought but in other communities this happened during later droughts. Women's changing role in livestock management also led to other greater responsibilities and greater voice in decision-making of the household. Women now sell sheep and goats and have better access to money and how it is used. They also help make grazing decisions about where to take their sheep and goats with their husbands and family. In most discussion groups, women said that the elders still made the majority of

community grazing rules at meetings without them and, later, their husbands would tell them about the rules. The women in Naisunyai community expressed these changes by saying,

> 'Yes, we are now selling the shoats and before we were not. Then [in the past] we were not supposed to hold the money, it was only the husband. Now both can hold the money and if there is any problem and they want to sell the shoats they can. And also, nowadays we can make decisions on how or where to graze the shoats also if we want to go to lale [temporary corral] we can as well go and stay there without husbands. It is now when that came [about] and this drought [2017] has changed everything that we can do, and the drought has become more frequent and has changed our way of life.' (Naisunyai woman)

In one community, Ngutuk Engiron, women attended grazing management meetings at the conservancy scale and felt like they had more respect given to them, because they would meaningfully contribute. The Ngutuk Engiron women said,

> 'Even the women are involved since the conservancy started and the women are happy to participate in these grazing rules. Even now there is not any meeting that women don't go, though there are not many women. We all go to meetings; sometimes we say something that is more important than what men say so there is more respect, and more people listen to us.' (Ngutuk Engiron woman)

Women now also use the money they have gained from businesses to help purchase medicine for sheep, goats, and cattle.

– *Adaptations with unintended consequences for future adaptive capacity*

Participants said that some anticipatory strategies led to less social cohesion and environmental degradation, which threatened their ability to cope with the ongoing 2017 drought. Respondents described how violence, busy-ness (lack of time), and schooling was reducing respect and good will between Samburu people. There was much greater internal social conflict and lack of cohesion between Samburu in different and diverging social roles (e.g., elders, women, and youth). This decline in cultural cohesion included the loss of certain cultural practices and ceremonies that some people found important, like women's ceremonies to

propitiate god. Respondents attributed some of this social unrest to the spread of guns to the last two *lmurran* age-sets and how this armed empowerment meant they no longer listened to the elders. Respondents also thought social unrest occurred because people were so busy now with businesses and other activities. These discussion groups also pointed out that the education of their children contributed to the lack of respect between the generations because the educated children thought they knew more than their parents and would ignore them. Some of their children would call them obsolete or outdated, which contributed to a breakdown of social relations and a lack of trust within families. One group mentioned that they sometimes had to beg their children for help during severe droughts and sometimes their children would not help. Women also complained that the elders drank too much and were lazy. Women thought they had taken on most of the extra work (created by their adaptation strategies) and the elders did not help enough. The women from Laresoro community stated,

> 'Also, the elders are not working or helping the women since they have underrated the women. They just want to eat, and they don't care where the food is coming from, but they don't question where they get food especially, they focus on the last wife and give her so much attention [these women were mostly first wives, older wives; the elders spend more time, have sex with, and give gifts and food to the younger wives]. Sometimes the elders herd the shoats but not often.' (Laresoro woman)

Respondents said the excess drinking occurred more around the larger towns like Archer's Post and was less a problem in the rural communities. The people said that their overall culture was retained but that there had been many changes to their diets, cultural practices (for example, less singing and dancing together), social relationships, and respect. This caused them stress.

Respondents also perceived that the increase in sheep and goat production also significantly negatively impacted the environment. Most of these comments came from men but also some women participants. They stated that sheep and goats affected areas in ways that were not good for cattle and competed with cattle. Thus, cattle had to be kept farther away from

settled communities now. Some people thought that both species of small stock contributed equally to the problem. However, some elders identified sheep as the main culprit, describing them as 'nail clippers' removing and uprooting small grasses, while goats fed on the leaves, which did not cause a problem for cattle. They also thought that the sharp hooves of small stock caused much destruction, damaging plants and contributing to soil erosion on the livestock pathways. An elder from Lekiji described why he knew it was the sheep and goats causing environmental issues, "When I was a *lmurran* during *Lkuroro* age-set there was a place called Lkarjaj near a place called Siambu where so many people had so many shoats; when you compare their ground cover to Marti, Marti had so much more grass and trees" (Lekiji man). Some thought that they now needed to control sheep and goat movements, which they did not need to do before, to help prevent environmental damage. However, they also said the additional management and movement of sheep and goats, including the idea of splitting sheep and goats into different herds, would be difficult because they lacked the labor since their children were in school.

3.4. Discussion

We identified Samburu perceptions of their major anticipatory, coping, and recovery strategies in response to nine severe droughts from 1975 to 2017. Samburu communities began implementing most of these adaptation strategies following the 1984 drought that caused great human and livestock suffering. These adaptations are responses to drought events and other drivers of change, such as a degrading cattle environment, lost mobility, and shifts in socio-cultural preferences associated with schooling. Many other pastoralist groups have struggled

with droughts and similar social and environmental drivers of change (Galvin, 2009; Liao et al., 2020; McPeak and Little, 2019; Reid et al., 2014). There are many similar adaptation strategies that Samburu and other pastoralist groups use in semi-arid to arid regions, including schooling, a shift to sheep, goat, or camel husbandry, income diversification, and the use of new technologies to aid mobility (Catley et al., 2016; Little et al., 2009; Ogutu et al., 2016; Watson et al., 2016). The Samburu experience exemplifies many East African pastoral groups' experiences with a changing social-ecological system in recent times. Perhaps the main difference compared to some other pastoral regions in Africa is that many Kenyan pastoralists have established community conservancies that may help prevent rangeland privatization and fragmentation (Bedelian and Ogutu, 2017; Cockerill and Hagerman, 2020).

Anticipatory adaptation strategies

Our results show Samburu pastoralists use interdependent anticipatory strategies to prepare for future droughts and changing environmental conditions. Anticipatory strategies are those actions that are planned and help improve future coping strategies and recovery strategies (Thornton and Manasfi, 2010). Samburu pastoralists began to send their children to school after the 1984 drought in preparation for future droughts. Adults consciously invested in their pastoral future with hopes their schooled children would eventually support them during droughts through schooling dependent new strategies, like technology use and income from businesses. Schooling was only possible for households that made additional adaptations to support the education of children and a more settled lifestyle, like shifting to sheep and goat or camel husbandry. Eventually, their children's schooling began to pay off, and income from diverse new sources helped support many households cope during more recent droughts, such as 2017, and in

the post-drought livestock recovery process. Other studies have documented most of these drought anticipatory strategies from Kenyan pastoralist groups (Little et al., 2009; Opiyo et al., 2015, Walker et al., 2021; Watson et al., 2016), but they do not describe the logic of interconnected adaptations from the pastoralist perspective. We describe the six major categories of anticipatory strategies in Table 3.1 and the perceived beneficial outcomes to reduce drought impacts and to support other adaptations, summarizing how adaptations are interconnected.

The existence of interdependent anticipatory strategies changes how researchers evaluate an adaptation's outcomes as 'successful' or 'maladaptive'. Scientists often deem single adaptations as either a successful adaptation (with beneficial effects), a maladaptation (with significant unintended consequences), or a discontinued adaptation (Adger et al., 2003; Bennett et al., 2016; Magnan et al., 2016). However, an evaluation of a single adaptation strategy may misrepresent its role in the adaptation process because, as we found, drought adaptation strategies are highly interdependent. Therefore, it may be valuable to assess how an adaptation strategy, like sheep and goat husbandry, despite its perceived unintended consequences, might support other adaptations with essential drought mitigation outcomes, like schooling. Below, we consider two different drought adaptations with significant unintended consequences and describe how understanding them in relation to other adaptation strategies changes our conclusion about them as maladaptations.

Sheep and goat husbandry is an anticipatory drought strategy with adverse environmental outcomes but that supports key drought adaptation strategies, and therefore it is not a maladaptive behavior. Samburu perceive that sheep and goat husbandry has essential positive

Table 3.1. Adaptations by type of strategy, adaptive capacity, beneficial outcomes, and negative outcomes.

Recent drought adaptations	**Type**	**Adaptive capacity used**	**Beneficial outcomes**	**Negative outcomes or limitations to implementation**
Schooling	Anticipatory	Women's labor	Improves income diversification; faster livestock recovery	Internal social conflict with elders; a change in social preferences away from livestock husbandry
Sheep and goats	Anticipatory	Women's labor and sale of cattle	Easier access to markets; more milk and meat for settled families.	Greater grazing pressure in settlement areas with negative vegetation impacts.
Camels	Anticipatory	Labor, financial, and social networks to learn (initially interethnic support)	More milk available for settled families; less competition with cattle.	None discussed, but not easy to implement quickly because of high costs to diverse resources and requires social network.
Income diversification	Anticipatory	Labor and knowledge from schooling; sale of livestock	Improves income; faster livestock recovery; less suffering during droughts.	None discussed, but required women's labor, schooling, and shift to sheep and goats to help diversify well.
Use of technologies	Anticipatory	Knowledge from schooling and social networks	Phones and trucks have made mobility easier during droughts for those able to afford it.	None discussed, but might be a difficult strategy for those with fewer livestock (costly). Supported by external inventions.
Conservancies	Anticipatory	Diverse knowledge and social networks with external financial support	Solves intercommunity drought issues. Helps diversify income and may help ration livestock forage.	Conflicts with some customary institutions and limits mobility for certain pastoralists.

Drought relief	Coping	External resources	Reduces human hunger and death and provides forage for livestock.	None discussed, but politics dictates implementation, making drought relief unreliable.
Food diversification	Coping	Financial resources	Reduces hunger in community and provides foods to herders.	Some discussion of how new non-livestock foods are more likely to make people sick. Often requires income diversification.
Reactive (unplanned, forced) diversification	Coping	Knowledge, sometimes schooling	Helps herders find income when livestock begin to suffer.	Undesired splitting of family members and forced livelihood choices.
Herding sheep and goats longer distances	Coping	Women's labor; additional herding labor	The use of temporary settlements for sheep and goats during droughts helps keep them alive.	Requires greater herding labor and is more difficult for those with smaller herds. Splits families.
Diverse recovery strategies	Recovery	Financial resources, knowledge, or social networks between livestock-wealth groups	Faster livestock recovery process, from use of traditional social networks with new finances and knowledge of markets	None discussed, but dependent on past adaptations including sheep and goat husbandry and women's labor. Possibly increases grazing pressure on the drought recovering landscape.

services but also unwanted environmental impacts. For example, sheep and goats support settled families accessing schools. However, Samburu pastoralists also noticed that they caused harmful soil erosion, and sheep overgrazed small or young grasses (also described in Chapter 2). Because of this, rather than label sheep and goat husbandry as maladaptive, it is likely worth either searching for ways to mitigate their negative impacts or, if discouraged, ensuring the benefits to the adaptations they support are replaced. There might exist opportunities for collaborative rangeland research with Samburu pastoralists to identify sheep and goat grazing practices that reduce negative environmental impacts, including unwanted vegetation shifts (Augustine et al., 2011; Augustine and McNaughton, 1998; Lalampaa et al., 2016; Weber and Horst, 2011). Rangeland scientists know sustainable grazing principles, but they know less about how to incorporate sustainable sheep and goat grazing practices in ways that continue to support settled pastoral households (Løvschal et al., 2019). Conservationists in northern Kenya sometimes suggest discouraging or penalizing sheep and goat husbandry in communal grazing lands to improve rangeland health. However, this may be an oversimplified solution. If conservancies, or others, put this plan into action, they should recommend a substitute for the benefits that sheep and goats provide to women and children. We imagine these small stock benefits are not easily replaceable and may require direct conservation payments to accomplish (e.g., Bedelian and Ogutu, 2017).

In contrast to sheep and goat husbandry, we view violent conflict as a maladaptive strategy in Samburu pastoralism that has short-term benefits for a small group, major unintended consequences, and does not support other key adaptation strategies. Samburu men and women did not perceive violent conflict as a coping strategy but acknowledged it occurred during the search for drought cattle forage. Although herders use violence to access grazing pastures during

droughts, we found, similar to others, that violence with other ethnic groups and the Kenya Defense Force (army) contributes significantly to drought crises (Pike et al., 2016). Samburu did not perceive violence as a strategy essential to other pastoral activities or adaptation strategies. Therefore, we consider violent conflict as a maladaptation that creates overall greater risk of suffering during droughts. Tackling this issue requires community-scale actions because of its ties to political and cultural issues (Greiner, 2013). Research into drought resource use and land rights that cross ethnic boundaries has also helped identify possible ways to reduce violence (Catley et al., 2016; McPeak and Little, 2018; Robinson et al., 2017). In our study, even Samburu households recognized that their efforts to defensively arm themselves with more guns led to more violence and internal social conflict. This leads us to conclude that efforts to reduce violent conflict will likely enhance the drought adaptation process.

Coping strategies and changing drought impacts

The Samburu drought adaptation process has improved coping strategies and reduced drought vulnerability since the 1984 drought (summarized in Table 3.1). Most anticipatory strategies led to changes to or novel coping strategies (for example, camel husbandry also provides milk during droughts). Drought coping strategies (reactive behavioral adjustments) are not easy to disentangle from drought impacts, but we learned about which droughts created greater overall suffering (Chapter 2). On the one hand, Samburu pastoralists have observed a continued increase in specific social, livestock, and environmental drought impacts, e.g., ethnic violence and loss of cattle forage and production (Ogutu et al., 2016; Pricope et al., 2013). However, because of the adaptations they used following the 1984 drought, Samburu pastoralists perceived a decreasing trend of overall human suffering (e.g., hunger and deaths) across the

subsequent five droughts. This finding shows that factors that increase drought exposure, such as climate change, sedentarization, and landscape fragmentation, do not necessarily increase drought vulnerability if people have a successful drought adaptation process (Adger, 2006; Adger et al., 2005; Smit and Wandel, 2006).

Our reduced drought vulnerability findings are surprising given that meteorological drivers of drought have increased and rangeland health has declined throughout the region; however, this adaptation process may be unsustainable if it is responsible for driving continued forage production declines. Researchers have found that meteorological droughts have gotten worse in northern Kenya and pastoral droughts more frequent among the more remote Turkana of northern Kenya (Opiyo et al., 2015; Ouma et al., 2018). Vegetation productivity in northern Kenya has generally decreased, and unwanted plants, like *Vachellia reficiens*, have spread across these rangelands (Kimiti et al., 2017; Pricope et al., 2013). We found some indications that vegetation droughts, based on NDVI, have gotten more severe (Chapter 2). Since the 1960s worldwide, droughts have increased in frequency and are affecting more people (IFRC, 2020). Despite all of this, Samburu pastoralists perceived human suffering generally decreased because of the adaptations they made. This combination of findings points to the significant potential of adaptations that diversify livelihoods, including markets and income diversification, to reduce drought vulnerability. However, there may exist a trade-off. It also appears that those Samburu adaptations have allowed the Samburu to avoid (and somewhat ignore) the negative impacts of declining rangeland health so far. Pastoralists have begun to address rangeland health and fragmentation with community conservancies. These community conservancies are working to create beneficial rangeland outcomes but are uncertain to be socially or environmentally successful and sustainable (Bedelian and Ogutu, 2017; Løvschal et al., 2019; Pas 2018). If they

fail and rangelands continue to decline, is a continued decline in pastoral production worth reduced drought vulnerability?

Community conservancies, that function as community-based rangeland management organizations with legal standing, have the potential to overcome rangeland management challenges through collaborative actions at large-scales (Agrawal, 2001; Berkes, 2009; Galvin et al., 2018). So far, conservancies have had mixed effects. Community conservancies attempt rangeland management at larger scales than individual pastoral households are capable of and with greater collaboration than customary institutions have historically managed. External policies continue to undermine customary institutions and create the need to change pastoral policies or create new community-based solutions (Fratkin, 2001; Reid et al., 2014). Community conservancies perhaps were not possible in the past. They benefit from, if not require, formally educated pastoralists to help integrate knowledge across cultures and science (Bruyere et al., 2018; Schewel and Fransen, 2018; NRT, 2019). Samburu pastoralists, so far, perceived limited drought coping benefits from community conservancy efforts. Our findings match with the mixed outcomes that other researchers have found from these community conservancies, including challenges with undemocratic decision-making that also undermine customary institutions (Cockerill, 2018) and benefits to vegetation production but also decreased mobility for some herders (Glew et al., 2010; Pas, 2018). However, conservancies show some signs of improving inter-ethnic rangeland management and have increased resource access to pastoralists from international institutional relation building (Robinson et al., 2017; Robinson and Berkes, 2011).

Community conservancies also may be in a unique position to rehabilitate rangelands and improve the availability of livestock forage during droughts (Kimiti et al., 2017; Odadi et al.,

2018). Traditional grazing practices often provided vegetation rest and recovery periods, but social and environmental changes have disrupted these practices in many grazing areas (Fratkin 2001, Moritz et al., 2019; Renom et al., 2020). In Samburu County, the establishment of conservancies and their conservation zones, which also act as drought forage reserves, have reduced livestock mobility in some cases (Pas, 2018). However, conservancies have some positive rangeland rehabilitation effects, like improving forage production in settlement areas or increasing grasses and reducing unwanted woody species in targeted rehabilitation areas (Glew et al., 2010; Kimiti et al., 2017; Odadi et al., 2018). Similarly, in regions of Ethiopia, when communities establish drought forage enclosures, they often improve rangeland herbaceous vegetation growth and soil conditions (Abdulatife Ibrahim, 2016; Angassa et al., 2012; Haftay et al., 2013; Hailu, 2017). As collaborative institutions, community conservancies have an opportunity to combine knowledge from the rangeland sciences and local pastoralists and their customary institutions to find new sustainable grazing solutions (Berkes, 2009; Liao et al., 2020). Many challenges exist with conservancies, but at least in our work, Samburu pastoralists did not perceive other adaptations with the potential to better rehabilitate rangelands.

Drought recovery process

We learned that anticipatory strategies had improved the livestock recovery process, making it easier and faster. Livestock recovery is an adjustment behavior to the improving environmental conditions following a drought; it is an active process (Smit and Wandel, 2006). Samburu pastoralists perceived the shift to sheep and goat husbandry with market access and income diversification, two areas that women now often manage, critical in helping make the livestock recovery process faster. They also perceived their social system of livestock exchange

between households with different wealth status (*awolo*) as functioning well. Most social-ecological adaptation theory ignores the post-disturbance recovery process but focuses on the flexibility and resistance aspects of resilient systems (Nelson et al., 2007; Smit and Wandel, 2006; Thornton et al., 2019). However, we learned pastoralists view that drought recovery relies on adaptations, and adaptations rely on recovery. We propose that adaptation pathways theory should include recovery processes to represent better pastoralist adaptation strategies, as shown in Figure 3.1 above (Thornton et al., 2019).

As pastoralists use different adaptation pathways or recovery processes, they can keep up with the dynamic fluctuations in biodiversity and maximize livestock production over the long term (Anderson and Bollig, 2016; Bollig and Schnegg, 2013; Ouma et al., 2012). For example, Samburu pastoralists said they would shift back and forth between more drought tolerant sheep and goats and cattle when cattle forage recovered in periods with higher rainfall. It is possible that livestock shifts also help allow certain vegetation types to rest and recover in areas where there has been overgrazing (Angassa et al., 2012; Liao et al., 2017). Active recovery provides opportunities to match livestock species with changes in plant communities and may help maximize production (Augustine and McNaughton, 1998; Ouma et al., 2012).

Adaptive capacity

Successful anticipatory strategies have depended mainly on women's labor and knowledge since the 1984 drought (Table 3.1). Following the severe impacts of the 1984 drought, Samburu communities began to invest in children's education as a means to future income diversification. These communities used women's knowledge and labor to mitigate potential livestock losses and diversify livestock species husbandry, i.e., shift to sheep and goat

or camel husbandry. When pastoralists invested in caring for more sheep, goats, and camels, they also expanded the types of forage they exploited. This shift in natural resource use helped many pastoralists settle. We learned some women are frustrated with the extra labor burden from drought adaptations. Some women appreciate the increased financial power they gained and grazing decision-making power in their households, though this benefit is not ubiquitously acquired. They would prefer if men (elders) helped more with these adaptation activities. Samburu women find freedom and the agency to decide what is best for them necessary for a good life (Walker et al., 2021a). Social responsibilities from adaptations can overtax women or not come with societal decision-making power. This lack of agency may threaten women's well-being (Holechek et al., 2017; Lesorogol, 2008a).

Our respondents recognized that many of their drought adaptation strategies caused unintended negative consequences (Table 3.1). For example, pastoralists knew sheep and goat husbandry caused further negative impacts on cattle forage. They also understood schooling youth led to a change in culture and social conflict across Samburu generations or groups differently educated. Other studies show how schooling can shift employment preferences and change pastoralist's prospects (Bruyere et al., 2018; Lenaiyasa et al., 2020; Schewel and Fransen, 2018). In Samburu and East African pastoral communities, peers of the same gender may limit interactions and form new sub-cultures among those similarly schooled or unschooled (Lesorogol et al., 2011; Lesorogol, 2008a). Pastoralists need opportunities to address these kinds of novel challenges that adaptation strategies often create. Adaptation to environmental change is encouraged and heavily researched, but we suggest more studies should investigate how pastoralists manage adaptation's unintended consequences. It is less likely that customary

practices address these novel issues. Below is one example of a potential unintended consequence that researchers could help pastoralists explore and identify collaborative solutions.

Since the post-drought livestock recovery process is faster and easier for Samburu pastoralists now compared to the past, we speculate this may change the relationship of livestock and vegetation dynamics in climate-driven (or non-equilibrium) systems. If Samburu communities were otherwise still dependent on livestock reproduction rates and smaller livestock markets for recovery, their livestock numbers would fluctuate with drought, following non-equilibrium system dynamics and have less impact on vegetation production (Ellis and Swift, 1988; Moritz et al., 2018; Vetter, 2005). Non-equilibrium theory posits that these systems are resilient to livestock grazing because regular droughts cause extended periods with low livestock numbers while pastoralists restock their herds (Ellis and Swift 1988). We predict that new adaptation strategies allow faster livestock recovery following droughts and thus shortens vegetation recovery periods during critical vegetation recovery stages and further drives unintended environmental loss (Fynn, 2012; Liao et al., 2020; Weber and Horst, 2011). With an increase in adaptive capacity for recovery from additional diverse income sources, livestock populations may be more stable and track rangeland carrying capacity better, more like an equilibrium system dynamic. This breakdown of non-equilibrium dynamics could result in shorter vegetation recovery periods and increase the relative impact of livestock on biodiversity richness and abundance (Briske et al., 2020). We do not know what Samburu pastoralists know about this topic, but it is an area again for more potential scientific and community learning (Oba, 2009; Renom et al., 2020).

CHAPTER 4

EFFECTS FROM DROUGHT AND CONSERVANCY FORAGE RESERVES ON SHEEP AND GOATS IN SAMBURU PASTORALISM

4.1. Introduction

Rangeland fragmentation, the division of formerly open land, and loss, the conversion of land to other uses, are two of the biggest challenges to mobile pastoralism worldwide (Galvin et al., 2008; Reid et al., 2014). Fragmentation and loss makes long-distance pastoral herd movements difficult and sometimes impossible (Hobbs et al., 2008). Livestock survival and production depend on movement to access temporally heterogenous forage, particularly during droughts when local forage is scarce (Boone, 2007; Goldman and Riosmena, 2013). Initially, colonial rule, national government policies, or civil wars forced many pastoral societies into restricted regional boundaries. Pastoral families adjusted to this coarse scale fragmentation and loss by settling parts or all of their household in permanent villages, a process of sedentarization. Pastoralists did this in part to access educational opportunities and diversify income (Fratkin, 2001). This transition to a less mobile pastoral lifestyle and villagization causes changes in land use and tenure that often creates finer-scale rangeland fragmentation, such as fencing private land parcels (Galvin, 2009).

In northern Kenya, and elsewhere, pastoralists with livelihoods centered around cattle husbandry use a variety of strategies to adapt to this fragmentation and loss of grazing land during droughts (Galvin, 2009; Opiyo et al., 2015). Two major adaptations stand out. First, families shift their herd composition to include sheep and goats that rarely need to move out of

village areas to find drought forage (Ogutu et al., 2016; Chapter 3). Second, they establish community conservancies with drought forage reserves that can be used by livestock and wildlife alike in times of need (Bedelian and Ogutu, 2017; Cockerill and Hagerman, 2020). Community conservancies are a form of community-based conservation and natural resource management in Kenya that also legally secure pastoralist communal property (Cockerill and Hagerman, 2020). Both adaptations are an attempt to maintain pastoral well-being and solve different aspects of the problem of landscape fragmentation during droughts (Chapter 3). However, information is lacking about the trade-offs and interaction of pastoral use of these very different adaptations to better resist drought impacts (Løvschal et al., 2019).

There are major gaps in our understanding of these two adaptations and how they are implemented and impacted during droughts. The success of these drought adaptations depends in large part upon (1) how well sheep and goat production avoids or resists drought impacts in a settled landscape and (2) how drought forage reserves in community conservancies benefit livestock during droughts. We have identified no previous studies that directly detail drought effects on sheep and goat production or management in African pastoral societies. A few studies have documented the narrower aspect of changes in small ruminant diet selection during droughts (e.g., Schroeder et al., 2019). Related studies focus on drought effects on cattle production or management (Butt et al., 2009; Nkedianye et al., 2011; Opiyo et al., 2105; Turner and Schlecht, 2019). Furthermore, there are very few studies of how drought forage reserves in conservancies are used or benefit livestock. Bedelian and Ogutu (2017) describe how pastoralists in the community conservancies of southern Kenya perceive both livestock production costs to establishing restricted grazing areas within conservancies and benefits to accessing these drought refuges when droughts occur. This study also documents when households access conservancies

for grazing during droughts and non-drought periods (Bedelian and Ogutu, 2017). Similarly, we documented in Chapter 3 the perceived value of sheep and goat husbandry and community conservancies as drought adaptations. This is similar to research on communal grazing enclosures among the Borana pastoralists of southern Ethiopia (Angassa and Oba, 2008). However, we do not know specific drought effects or detailed sheep and goat herding practices in Kenya or in relation to drought forage reserves. We lack information on how sheep and goats are being managed and how they are being affected by droughts. To address some of these gaps in our knowledge, we examined sheep and goat herding and production in relation to community conservancy rangeland management during the 2017 drought in northern Kenya.

Adaptations to landscape fragmentation and drought in northern Kenya

Actions that block livestock access to key natural resources during dry periods have grown in northern Kenya's pastoral systems (Pas, 2018). Most of these rangelands now have greater numbers of people who are more settled and homogeneously distributed than in the past (Kenya National Bureau of Statistics, 2019; Pricope et al., 2013). Samburu pastoralists say this limits their dry season grazing options and contributes to livestock mortality during droughts (Chapter 2). Particularly, in the Kenyan highlands, which receive higher precipitation, pastoralists convert rangelands to crop production and privatize grazing access (Lesorogol and Boone, 2016; Pricope et al., 2013). These activities restrict essential drought grazing areas for many pastoralists living in the highland and lowland rangeland areas (Lesorogol and Boone, 2016; Pas, 2018). In most rangelands, the proximate causes of fragmentation are physical barriers, such as fences, or social barriers between families, communities, or ethnic groups (Pas, 2018; Reid et al., 2014). For comparison, the drier rangelands of northern Kenya remain less

fragmented and more open than many of the wetter rangelands of southern Kenya, and this positive correlation of increased fragmentation with increased rainfall is generally true of rangelands (Pas, 2018; Reid et al., 2004).

Pastoralist societies in northern Kenya's drylands have a long history of adapting to droughts that cause livestock suffering. Droughts are abnormal periods that lack rainfall and cause a disruption in livelihood activities (Kallis, 2008; Wilhite and Glantz, 1985). In pastoral systems, meteorological droughts are low precipitation anomalies that may cause acute forage restrictions, which are often correlated with what we call 'vegetation droughts' (measured by low NDVI; Treydte et al., 2017; Wilhite and Glantz, 1985). This lack of forage increases livestock mobility requirements and may cause severe suffering of livestock and people, what we call a 'pastoral drought' (Butt et al., 2009; Nkedianye et al., 2011; Opiyo et al., 2015). In northern Kenya, pastoral droughts occur on average every 5 years (Opiyo et al., 2015; Chapter 2). Pastoralists in this area have a long history of continuously adapting their livestock management and livelihood strategies to these frequent droughts and changes in their environments. For example, many pastoralist societies develop customary institutions to help negotiate access to drought grazing lands outside their home territories or regulate internal seasonal grazing (Moritz et al., 2019). However, drought and new drivers of fragmentation and loss have led pastoralists to develop new adaptation strategies (e.g., increased sheep and goat husbandry or increased income diversification) (Reid et al., 2014; Chapter 3).

Pastoralists use a plethora of ways to adapt to their shrinking access to the natural resources as their rangelands fragment. Pastoralist households make adaptations with many social and environmental factors in mind to meet the needs of their households within their adaptive capabilities (Bennett et al., 2016; Galvin, 2009; Nelson et al., 2007). Different

adaptations take place in different locations at different times and with various degrees of implementation across households and communities making this process difficult to succinctly summarize (Adger et al., 2003). For example, pastoralists now use mobile phones and vehicles to help scout and negotiate access to distant grazing areas for their livestock (Asaka and Smucker, 2016; Butt, 2015). They often combine this adaptation with the use of trucks to transport livestock to avoid a difficult walking journey through a fragmented and fenced landscape (Goldman and Riosmena, 2013; Chapter 3). It is also now common in some pastoral systems for settled pastoralists to split the household into two: one located near town so that children can access schools and one in distant (or remote) pastures where herders make sure livestock can access sufficient forage (Liao et al., 2020; Pas, 2018). Development, especially new water access points in dry season grazing areas, encourages pastoralists to settle and graze these areas year-round, thus reducing important resting periods for the vegetation (Lamprey and Reid, 2004; Western et al., 2009a). Lack of dry season grazing areas has led some villages to practice seasonal planned grazing around their settled location to reserve drought forage or provide hay and fodder during dry periods (Turner and Schlecht, 2019; Chapter 3). Households, notably with remittances or business income, support herders with purchased of foods, which allows them more flexibility to move (McKune et al., 2015; Chapter 3). Camels are both more mobile than other livestock species and consume browsed vegetation that does not compete with the grass consumption by sheep and cattle (Volpato and King, 2019; Watson et al., 2016). Pastoralists are testing all of these methods and others to suit their needs in pastoral systems that are fragmented.

Pastoralists shift to sheep and goat husbandry

There is evidence that many cattle-specialized, and some camel-specialized pastoralists have increasingly used sheep and goat production to meet their needs in the sedentarization process (Galvin, 2009; Mendelsohn and Seo, 2007; Ogutu et al., 2016) or in response to major droughts (Opiyo et al., 2015; Watson et al., 2016; Chapter 3). Pastoralist societies have historically moved back and forth between the diversification and specialization in herd composition to adapt to vegetation changes, social preferences, or avoid species specific issues like diseases (Anderson and Bollig, 2016; Bollig and Schnegg, 2013). It is likely sheep and goats (also referred to as shoats, small ruminants, or small stock, because they are often herded together) have also helped transition some people to sedentarized or agropastoralist livelihoods. But now, with climate change, a shift to shoats can help with a transition away from crop agriculture to pastoralism in marginally productive lands (Little, 1996; Mendelsohn and Seo, 2007; Rufino et al., 2013). What is new, is how sheep and goat husbandry is used to specifically support sedentarization combined with development in cattle-centered societies (Bedelian and Ogutu, 2017; Løvschal et al., 2019; Ogutu et al., 2016). Generally, pastoralists began holding more and more sheep and goats in rangelands around the world over the last few decades, because sheep and goats can produce more milk and meat under less mobile conditions in semi-arid regions compared to other livestock (Degen, 2007; Hassen and Tesfaye, 2014). Skapetas and Bampidis (2016) report, from 2000 to 2013, a 34% increase in goat numbers worldwide with a 49% increase in Africa. In the Sahelian region there is a shift from cattle to more drought tolerant sheep and goats in increasingly sedentary communities, but the specific population changes are not well known (Turner 2011; Turner and Hiernaux 2008; Zampaligre et al. 2014). The best empirical monitoring of this adaptation and changes in sheep and goat numbers comes from

studies in Kenya. From 1977 to 2016 there was a 76% increase in sheep and goat numbers with a 168% increase in Samburu County (Ogutu et al. 2016). Bedelian and Ogutu (2017) found a 235% increase in small stock from 1977 to 2014 in the Mara ecosystem of southwest Kenya, with an acceleration since 1995. Opiyo et al. (2015) and Watson et al. (2016) have both documented greater sheep and goat husbandry as an adaptation strategy to droughts among the Turkana and Rendille ethnic groups in northern Kenya. What has not been documented in detail is sheep and goat management and herding practices in these sedentarized, formerly (or historically) cattle-specialized pastoralist societies (Løvschal et al., 2019; Turner and Schlecht, 2019).

Both pastoralists and rangeland ecologists worry and speculate that more shoats will have negative impacts on the environment, making it harder for cattle pastoralism and wildlife conservation to be successful (Lovschal et al. 2019; Chapter 2). There is a great deal of research and local knowledge that describes how cattle husbandry can have beneficial or limited negative impacts on many different East African wildlife populations (Augustine et al. 2011; Butt and Turner 2012; Prins, 2000; Reid, 2012). These potential ecological benefits have rarely been reported for sheep and goat husbandry. One study in southern Kenya found small stock did not necessarily limit the presence of other wild mesoherbivores at moderate densities (Bhola et al. 2012). In central Kenya, under specific grazing management practices, sheep and goats can have few negative effects on wildlife (Lalampaa et al. 2016). Wildlife do currently exist in some places with sheep and goat grazing and it is theoretically beneficial to some wildlife species under some conditions (Bedelian and Ogutu 2017; Fynn et al. 2016; Weber and Horst 2011). However, in central Kenya, Keesing et al. (2018) found that several species of large mammals avoided the presence of herded sheep and goats and their grazing areas. However, sheep and

goats could be a proxy measure of degraded land and human settlement and thus the wildlife may be avoiding people not shoats. There is not enough evidence to understand the potential unintended consequences from the large increases in sheep and goat husbandry across much of East Africa. Across Kenya, large increases in sheep and goat numbers are correlated with large declines in wildlife populations (Ogutu et al. 2016). However, the large reductions in sheep and goat numbers that some conservation researchers and practitioners advocate for, would have negative impacts on pastoralists' ability to cope with drought (Chapter 3). These reductions may be unnecessary if wildlife impacts depend upon how sheep and goats are herded in conservation landscapes.

Community conservancies and grazing management

Community-based rangeland management (CBRM) and conservation (CBC) efforts also can serve as an adaptation to landscape fragmentation and land loss (Bedelian and Ogutu 2017; Brooks et al. 2013; Galvin et al. 2018). Community conservancies likely slow the process of landscape fragmentation by preventing land privatization and the spread of physical barriers like fences (Cockerill and Hagerman, 2020). Community conservancies are legally state-registered entities that help support communal land management for the benefit of improving livelihoods and conserving wildlife (Cockerill and Hagerman, 2020; KWCA, 2016). Kenya is at the forefront of a notable social and environmental experiment in community governance and conservation of rangelands and wildlife through the widespread establishment of community conservancies (Reid et al. 2016). Conservancies are growing rapidly in number and coverage across the rangelands of Kenya (Cockerill and Hagerman, 2020; KWCA 2016). Conservancies have diverse goals and implementation strategies. Managers of community conservancies across Kenya reported their main goals were to conserve habitat, create jobs and income, improve

rangelands, help access land, and improve security (Reid et al., 2016). In northern Kenya, conservancies also work to reduce violent conflict between ethnic groups, especially in drought forage areas. This helps remove a major social barrier to pastoral access to rangeland natural resources (Greiner, 2013; Glew et al., 2010; Pike et al. 2016). However, it is likely conservancies create negative spillover effects, like excluding non-member or external pastoral communities from using conservancy resources, while creating benefits for members (Bedelian and Ogutu, 2017; Pas, 2018). Community conservancies are sometimes perceived as controversial, with limited support both internally and externally. In one instance, conservancy establishment contributed to violence between ethnic groups in northern Kenya (Greiner, 2012). If successful, the conservancy experiment could have significant implications globally for rangeland management and as a means to prevent fragmentation.

Another major conservancy activity is their creation of drought forage reserves, which restricts settlement distribution and may reduce the need for livestock mobility during drought (Bedelian and Ogutu, 2017; Glew et al., 2010). In Kenya's rangelands, conservancies have begun to regulate livestock grazing with the goal to improve rangeland conditions. Many of these communities, typically with support from outside institutions, choose to defer grazing in areas to benefit wildlife, when possible, but with the clear understanding that these areas function as drought reserves for livestock and wildlife forage when necessary (Lovschal et al. 2019). These reserves do not allow permanent settlements, and this provides greater opportunity for rehabilitation efforts to remove unwanted woody species and restore grasses for increased forage production (Kimiti et al., 2017; Odadi et al., 2017). Rehabilitation practices may help reserve more drought forage for livestock and thus reduce mobility requirements for nieghboring villages. These areas also have the potential to provide habitat for more human sensitive wildlife

species, and this provides tourism opportunities and income (Glew et al., 2010; NRT, 2019). However, these restrictions likely exclude or reduce access of pastoralists from outside the conservancy (Pas, 2018), and may increase grazing pressure in community areas with unknown consequences.

Community conservancies have largely been set up with cattle husbandry in mind and there is a need to incorporate sheep and goat husbandry. We do not yet know how sheep and goat management can best be integrated in conservancy management to achieve community goals (Lovschal et al. 2019). Sheep and goats have the potential to cause wildlife population declines (Ogutu et al., 2016), and pastoralists blame them for increased soil erosion and the loss of some grasses (Chapter 2). However, they are also essential support for current livelihoods because they improve food security for settled households during droughts (Degen 2007; Opiyo et al. 2015; Chapter 3). We do not know how pastoralists' shift to more sheep and goats will affect rangelands especially during critical drought periods, because little information exists about travel or grazing mobility of sheep and goats (Lovschal et al. 2019; Turner and Schlect 2019). We also do not know if and how sheep and goats benefit from drought forage reserves in conservancies. Drought periods provide a unique time to examine sheep and goat husbandry and learn how it can be refined to improve integration with community conservancies to reach desired community outcomes.

Our objective and research questions

We collaborated with pastoralists with the objective to better understand how they can manage sheep and goats to better cope with drought events in community conservancies. Here we use a case study approach in the lowlands of Samburu County, Kenya, to examine sheep and

goat herd production and management in three permanent villages within two community conservancies. We answered the following two research questions: (1) How did the 2017 drought impact pastoral families' sheep and goat herds' production, mobility, and access to vegetation in the Samburu lowlands? (2) Did sheep and goat herds benefit from access to drought forage reserves in community conservancies during the 2017 drought?

Our work helps inform how pastoralists husband their sheep and goats and how their practices might be integrated better with community-based grazing and conservation planning in a drought context. Samburu pastoralists in northern Kenya face complex challenges of how to balance recent increases in sheep and goat production with cattle and camel husbandry, other income generating activities, and environmental goals. While the specifics of our study may be unique to this area of Kenya, there are greater lessons to ponder about how to best support or manage trade-offs in community conservation efforts and household livestock management that apply to many other pastoral systems.

4.2. Study System and Research Methods

Study System

Our research took place in Samburu County, northern Kenya, in the eastern Samburu lowlands in three villages (Laresoro, Naisunyai, and Ngutuk Engiron) in two community conservancies: Westgate and Kalama. Seasons, droughts, borders, waterpoints, and hillsides all factor into pastoralist herding decisions in these communities. These lowlands are a semi-arid to arid environment that receive an average rainfall of 350 mm (+/- 170 mm), during two rainy seasons from November to December and from March until May (Pas, 2018; Wittemyer, 2001).

Small mountains or hills throughout the lowlands receive more rainfall and have no permanent settlements, making them useful dry season grazing areas. Major droughts that kill cattle and sometimes other livestock species occur on average every 5 years, +/- 3 years (Chapter 2). Temperature has increased and there is some evidence that meteorological droughts are more frequent and severe in the region (Ouma et al., 2018). This corresponds with a decline in regional vegetation production and some indication of more frequent and severe vegetation droughts, based on remotely sensed vegetation greenness (Pricope et al., 2013; Chapter 2). The study villages in Westgate and Kalama conservancies range approximately from 900 - 1200 meters in elevation but have steep hills accessible for livestock grazing that go up to 1700 meters, whereas the Samburu highlands farther to the west begin to plateau around 1700 meters (Pickering pers. obs.). The Ewaso Nyiro River borders Westgate conservancy to the west and south and Kalama conservancy to the south. Samburu National Reserve makes up a portion of the southern border of both conservancies. Other Samburu conservancies, Meibae, Sera, or Namunyak, surround the study conservancies to the west, north, and east (Figure 4.1).

The study area's population has grown, and land policies have changed in recent decades. In 2009 Samburu County had a population of 224,000 people, the majority of which were Samburu pastoralists (Kenyan Bureau of Statistics, 2009). As of 2019, the population had increased to 310,327 (Kenyan Bureau of Statistics, 2019). Other ethnic groups, especially other pastoralist groups from the surrounding counties such as the Turkana, Pokot, Rendille, and Borana, reside in the more urban communities, but also cross into Samburu County with their livestock when grazing is limited in their home areas. Generally, Samburu County can be divided up into the wetter, cooler highlands to the north and west and the drier, hotter lowlands in the east and south (Pas 2018). Our work focuses on the southeastern lowlands in areas with

Figure 4.1. Map of the study area in the Samburu lowlands of Kenya with three communities and two conservancies identified.

communal land tenure. Communal land rights were first established through group ranches and now are also organized as community conservancies. There has been some privatization of land around the larger towns in the lowlands area, mainly Archer's Post (the largest town), but not in the communities where this study took place. Much greater levels of land privatization have taken place in the Samburu highlands, which create ownership boundaries that lowland herders must navigate through during droughts when they take cattle to these areas (Lesorogol and Boone 2016; Pas, 2018). This kind of privatization might have benefits for those securing land parcels but causes other pastoralists to have to adapt to the restricted landscape (Pas, 2018).

In 2017, at the time of our study, there were five well-established community conservancies (and others in development) covering the vast majority of the southeastern

Samburu lowlands. These were Kalama, Meibae, Namunyak, Sera, and Westgate conservancies. Most of these community conservancies were set up in the early 2000s. In 2004, Northern Rangelands Trust, a non-governmental organization, began supporting conservancies in the region with finances, technical skills, and supportive administration (NRT, 2019). These community institutions work to manage their rangelands for improved. Most relevant to our work are their efforts to implement conservation zones that also function as drought forage reserves, and how they advise communities on grazing practices. Conservancies claim program administration in all villages within them, but not necessarily all people in these areas support the conservancy activities and some were unaware of their conservancy's goals and functions (Cockerill, 2018; Glew et al., 2010; Pickering pers. obs.). Some pastoralists support and benefit from conservancy grazing and conservation plans, while others find it makes movements, especially across conservancies, more difficult (Pas 2018; Glew et al., 2010).

Our research took place in two community conservancies, Westgate (36,294 hectares; 2019 population estimate 4,494) and Kalama (49,588 hectares; 2019 population estimate 9,958) (NRT, 2019). Both have well-established conservation zones, made up of a buffer zone and a smaller more highly restricted wildlife core zone. Conservancies regulate these two areas to limit livestock access to times when livestock forage is severely limited in settlement areas. They thus function as drought forage reserves for livestock and wildlife alike. We refer to these areas as drought forage reserves for simplicity and to distinguish their relative role in our study. Conservancies have implemented bunched cattle grazing, grass reseeding, and the removal of unwanted *Vachellia reficiens* (small tree) to rehabilitate some areas within the drought forage reserves (Kimiti et al., 2017; Odadi et al., 2017).

Scientific studies and pastoralist observations have noted important shifts in vegetation and habitat in this semi-arid environment since approximately the 1980s. The Samburu lowlands are made up of a mix of shrub, savanna, and bush habitats. Samburu communities generally describe the loss of perennial grasses and an increase in shrub and bush habitats following the regional 1984 drought (Chapter 2). Small tree species, *Vachellia reficiens* and *Commiphora spp*., have spread into many grazing areas, limiting grass for cattle and sheep (Kimiti et al. 2017; Chapter 2). This vegetation shift has coincided with an observed loss of vegetation production across northern Kenya (Pricope et al. 2013). Simultaneously, extreme wildlife declines in biodiversity and abundance have occurred since the 1984 drought (Ogutu et al. 2016; Chapter 2). Samburu pastoralists have noticed the loss of wild fruits (Chapter 2). This restricts their access to foods while herding when milk production is low, such as in times of drought (Chapter 2). People in these Samburu community conservancies have also perceived large-scale changes in soil color from darker brown to white or red soils and observed high levels of soil erosion and gully formations in recent decades (Chapter 2). Vågen and Winowiecki (2014), also have documented widespread soil loss from these conservancy areas. Prior to the 1984 drought this environment was not likely in a fixed state with no vegetation shifts, but Samburu pastoralists think this landscape now supports fewer cattle and requires greater cattle movements than previously, and these changes exacerbate violent conflicts with neighboring groups (Ellis and Swift, 1988; Chapters 2 & 3; Vetter, 2005).

Pastoralists from eight villages in four of the conservancies in southeastern Samburu County say that droughts have played a large role shaping their pastoral system and adaptations (Chapters 2 & 3). After the 1984 drought, five other severe droughts that killed livestock occurred in this area; these happened in approximately 1993, 1996, 2005, 2009, and 2017

(Chapter 2). First, following the 1984 drought, Samburu people started sending their children to school in greater numbers with the goal that one day these children would help support their families with remittances (Chapter 3). Pastoral families supported this investment by expanding their sheep and goat herds, because shoat herds could be kept year-round in permanent settlements close to schools. Samburu pastoral households appreciate sheep and goats for their ability to feed on forage that would not be suitable for cattle, such as goats browsing on shrubs and small trees and sheep grazing small grasses. Sheep and goats also can be sold more easily than cattle in local markets, particularly goats, and this income helps pay school costs (Chapter 3). Second, women increased their labor roles and input to help with the increased labor demands of sheep and goat husbandry. This adaptation process was described to us in our focus group discussions (Chapters 2 & 3), but we do not understand sheep and goat herding practices and how drought impacts them. These same communities recognize sheep and goats create unintended negative environmental impacts. They described how sheep and goat hooves create soil erosion pathways that form into gullies and how sheep eat down even the smallest of grasses (Chapter 2).

The age and gender of sheep and goat herders might determine how these livestock are moved or their ability to access more productive locations, but this has not been examined in other systems (Turner and Schlecht, 2019). Within Samburu culture, there exists a bachelor, warrior age-group of young men called *lmurran* (variations on spelling and formality, singular *lmurrani*) who are largely responsible for herding cattle (Spencer, 1965). These cattle herders take their livestock to sometimes distant forage, across county, ethnic, and privatized land ownership borders during droughts (Pas, 2018). These kinds of movements along with mutual ethnic livestock raiding and political motivations often lead to violent conflict that has gotten

worse in recent decades (Greiner, 2013; Chapter 2). This violence also indirectly creates negative livelihood and nutritional impacts on people's well-being in Samburu communities making it an important community issue (Pike et al., 2016). Some *lmurran* have attended school and no longer herd livestock or take on this role to a mixed extent. Education changes *lmurran* pastoral views and land use goals of both young men and women and often sets them apart from their non-schooled peers (Walker et al., 2021b). For example, many schooled youths no longer rank acquiring large livestock herds in their top goals and education forms stronger social bonds with those who have similar experiences (Bruyere et al., 2018; Lesorogol et al., 2011; Lesorogol, 2008b). Elder men (elders) and women, in this polygamous society, often remain in permanent settlements taking care of sheep, goats, and to a lesser extent camels and donkeys, as their children attend school (Pas, 2018; Chapter 3). These shifts change who herds and how families decide livestock grazing movements (Chapter 3).

Research methods

We selected three villages, Naisunyai (Westgate conservancy), Ngutuk Engiron (Westgate conservancy), and Laresoro (Kalama conservancy), to conduct this study. Ngutuk Engiron and Laresoro have access to their respective conservancy's drought forage reserve; Naisunyai does not. Each is a permanent settlement area with access to their own primary school, drinking water (i.e., shallow wells, earthen dam ponds, or river), and a small number of shops. All households in these villages, to our knowledge, own goats or sheep and most own cattle, donkeys, or camels as well. In a direct line, Laresoro is approximately 32 kilometers to the east or southeast from either Ngutuk Engiron or Naisunyai communities, respectively (Figure 4.1). Naisunyai is approximately 18 kilometers to the north of Ngutuk Engiron. Therefore, shoat herds

from these different villages do not overlap in their daily grazing movements, since these herds usually graze within about 5 km of their homesteads. However, Ngutuk Engiron and Laresoro communities neighbor other communities that have overlapping grazing areas with these villages, including portions of their drought forage reserves in conservancies; Naisunyai is more isolated. All three villages also have a grazing committee and elders that at least occasionally plan seasonal livestock movements in their area. Grazing plans usually focus more on cattle movements but sometimes apply to sheep and goat movements. These three villages also appeared to be representative of other pastoralist villages in these two community conservancies in size and pastoral practices. In this way we expect these villages to have sheep and goat production and management practices that are representative of many permanent villages in the conservancies of southeastern Samburu County.

We measured seven types of variables to examine pastoral families' sheep and goat herds' production, mobility, and access to vegetation and compare measured variables between households by monitoring period or by village. For each household that participated in our study, we measured their (1) shoat herd size and species composition (a measure of production), (2) goat body condition, sheep body condition, goat market value, and sheep market value (measures of production), (3) landscape vegetation greenness (measures of vegetation availability for all three villages and greater area), (4) shoat herd daily orbital distance traveled (measures of mobility), (5) shoat herd daily integrated NDVI (Normalized Difference Vegetation Index) accessed (measure of vegetation accessed), (6) vegetation cover in shoat herd preferred grazing locations (measure of vegetation availability), and (7) main herder age and gender (measure of management type) (Colorado State University IRB 042-18H, March 2017).

In order to capture the progression of the 2017 drought impacts on sheep and goat production and herding practices at our three village locations, we monitored production and practices during four different time periods between April and December 2017. During our focus group discussions presented in Chapter 2, respondents (throughout the Samburu eastern lowlands in September and October 2017) identified the ongoing drought as having begun in 2015 (or earlier). In our January 2019 follow-up community focus group discussions, we confirmed the drought transitioned into a recovery period when rains began in mid-October and lasted through December 2017 (Chapter 3). To examine the 2017 drought's impact on sheep and goat measures of production, we conducted four monitoring periods, each 10-days in length: from April 28th to May 7th, July 28th to August 6th, September 30th to October 9th, and December 5th to 14th. We refer to each of these periods as May, August, October, and December. We spaced the monitoring periods approximately two months apart to capture the progression of the drought, April to October, and a recovery period in December, following rain in mid-October (after the October sample), November, and December. For each research variable measured, we examined differences (significance level set at $\alpha = 0.05$ for all statistical tests) over the course of the monitoring periods to identify drought effects. The community defined this period as a drought, and our work examines outcomes during that drought but not cause and effect relationships.

To answer whether shoat herds benefited from access to community conservancy drought forage reserves during the 2017 drought, we compared our measured variables (except landscape vegetation greenness) among three villages with and without access to conservancy drought forage reserves. We selected three similar-sized villages to compare sheep and goat production in communities that differ in their access to drought forage reserves in community conservancies. Laresoro and Ngutuk Engiron each have access to two different drought forage reserves

(comprised of a buffer zone and wildlife core conservation zone) and Naisunyai does not. Laresoro and Ngutuk Engiron households range from 0.6 km to 5.4 km in distance to their respective drought forage reserve boundary. Naisunyai households, also in Westgate conservancy, do not have access to a drought forage reserve, which is approximately 20 km to the south of the nearest household. To use the Westgate drought forage reserve, herders in Naisunyai would have to move their shoat herds and create a new temporary corral and settlement; they did not do this in 2017. We identified 40 households that kept shoats in Naisunyai, 62 households in Ngutuk Engiron, and 65 households in Laresoro.

We randomly selected households during each monitoring period from a list of all households in each village for participation. In April we created household lists for each village following a census. All households we identified owned a shoat herd. Our census took place prior to when some households moved sheep and goats out of their permanent settlement area, as was done later in the drought. We explained our study and asked if the household would be open to participation in our study based on random selection. One household out of 62 in Ngutuk Engiron did not want to participate in our study, while all others agreed. During each monitoring period we randomly selected eleven households in each village for participation. For our August and October samples, we selected new households to participate if any households already in our sample had moved their entire shoat herd outside of the village since April. Given the small size of these villages, households were occasionally randomly selected multiple times across the four monitoring periods. In the end 131 households participated across all monitoring periods with 103 unique households.

– *Shoat herd size and species composition*

To assess shoat herd size and species composition, field research assistants counted the number of sheep and goat in each household shoat herd during each monitoring period. Two research assistants stayed in each of the three villages during every monitoring period. They directly counted sheep and goats in the herd for each participating household.

– *Sheep and goat body condition and market value*

The field researchers and I monitored sheep and goat body condition and market value (four measures) on the last day of the monitoring period or the day after to assess drought and conservancy drought forage reserve effects on shoat production. An elder Samburu pastoralist (research assistant) that was highly experienced in shoat husbandry, assessed body condition and market value of the sheep and goats in the herds that were monitored from all villages. A separate field research assistant semi-randomly selected 5 – 10 sheep and 5 – 10 goats in each herd for the elder to assess. This research assistant selected the sheep and goats without directly looking at the animal he was selecting. He would point in the direction of the animal in the herd without looking there first. He would move around the herd (if it was a large herd) so that he could point to different sections of the herd. He might have to repoint if the animal he selected was not the species needed for assessment. We piloted this method of selection in Archer's Post to make sure we felt comfortable that selection bias was limited as best as possible, but we did not test whether this method differed from true random selection in our herd production measures. Following animal selection, the elder research assistant evaluated and recorded a body condition score using a 0.0 to 5.0 scale with 0.5 increments, where 5.0 represented an ideally healthy and fat animal while lower numbers represented less healthy, less fat individuals; 0.0

represented animals severely emaciated and at the point of death. We did not use a published body condition score, instead we adapted this system use a scoring scale that matches how Samburu people evaluate the health of their sheep and goats. The elder researcher also estimated the market value of the animal in the hypothetical situation where the animal was sold in the Archer's Post livestock market during a regular, non-drought, season. We averaged these values across the individual animals to create an estimated average livestock body condition score and market value for the sheep and goats, separated by species and herd.

– *Landscape vegetation greenness (NDVI assessment)*

S. Carroll and I analyzed an NDVI (Normalized Difference Vegetation Index) time-series of 16-Day MODIS NDVI composite images for the years 2004 - 2017 to assess relative landscape vegetation greenness during the 2017 drought and our four monitoring periods. To compare vegetation accessed between herds daily movements during each monitoring period, we enhanced the NDVI spatial scale by sharpening the coarser MODIS NDVI data with finer resolution Landsat 8 NDVI images for the year we monitored herds (2017) (30m resolution, 16-day interval, Climate Engine, Desert Research Institute, 2016).

We clipped a total of 322 MODIS NDVI composite images to excise the study area in Samburu County of northern Kenya and downloaded the clipped images from Google Earth Engine. This study area included all of Kalama conservancy and Westgate conservancy plus a 2 km border area. This area was selected to represent the area that herds from all three study villages could access relatively easily. For 2017, we matched NDVI image dates as closely as possible to herd monitoring periods (Table 4.1). We cloud-masked Landsat 8 NDVI images and extracted and downloaded the median composite images from Climate Engine. For the July -

August study period, we used Landsat data composited over a greater number of days because many images were unusable due to extensive cloud cover in the study area during our herd monitoring days; we thus represent the best-pixel median composite of the images captured from July 5th - August 6, 2017.

Table 4.1. Four herd monitoring periods compared to 16-day MODIS NDVI composite imagery dates for 2017 sampling periods and best-pixel Landsat 8 median composite dates for Kalama and Westgate conservancy area in Samburu County.

Herd monitoring period dates in 2017	**MODIS 16-day composite dates in 2017**	**Landsat 8 median composite dates in 2017**
4/28 - 5/7	4/16 - 5/1	4/16 - 5/ 7
7/27 - 8/4	7/ 21 - 8/5	7/ 5 - 8/6
9/30 - 10/9	9/23 - 10/ 7	9/2 - 10/9
12/5 - 12/14	11/ 26 - 12/10	11/26 - 12/14

Time series of remotely sensed vegetation indices provide consistent and effective measurements to characterize trends in land cover as well as vegetation conditions and phenology across space and time (De Beurs and Henebry, 2004; Sakamoto et al., 2005; Lunetta et al., 2006). Scientists widely use the NDVI (Normalized Difference Vegetation Index) in ecological studies. NDVI represents the per pixel quantity of near-infrared (NIR) radiation minus visible red radiation divided by the sum of NIR and visible red radiation (Tucker, 1979; Reed et al., 1994; Pettorelli et al., 2005). Thus, NDVI values are theoretically proportional to absorption of photosynthetically active radiation: healthy, green vegetation reflects more NIR light trending the NDVI value toward positive one, and leaf-off, or ‘unhealthy’ vegetation reflects more visible light trending the NDVI value to zero.

We analyzed NDVI from MODIS Aqua/Terra Vegetation Indices because it has proven reliable to smooth time series data and remove negatively biased NDVI noise (Didan et al.,

2015). MODIS Vegetation Indices are generated from daily bidirectional surface reflectance bands that are atmospherically corrected and composited to remove lowest quality pixels (Didan et al., 2015). Despite post processing, the NDVI data often contain noise that can impact phenological analyses of the data due to variation in solar zenith angle, aerosols, cloud conditions, and other sources of variation. Thus, reliable analyses of time series satellite NDVI data benefit from additional analysis to "smooth" the time series data using statistical methods such as filtering and function fitting to remove negatively biased noise in the NDVI values. We utilized TIMESAT, a platform for pixel-based analysis of satellite derived time series data to process the MODIS 16-day composite images (Jönsson and Eklundh, 2004).

We used the TIMESAT GUI to spatially subset the data and examine the impacts of fitting parameters and smoothing method on fits to the raw NDVI values across the study area, which allowed us to integrate measures of greenness for each of the monitoring periods. For example, we examined the impact of the fitting method on NDVI values in high elevation wet areas compared to low elevation arid areas of the study area. Following this exploration process, we selected and applied an Asymmetric Gauissian function to smooth raw NDVI values. We selected this approach because the Asymmetric Gaussian method is generally robust and effective at noise reduction compared to other methods and it produced reasonable fits that retained the integrity of the NDVI trends for our study area and monitoring periods (Cai et al., 2017). The output is a time series of 322 images of smoothed NDVI values. From the fitted model functions within TIMESAT, a number of phenological parameters such as the beginning and end of the growing season can be extracted from the data. We used this process to calculate NDVI for the total of each monitoring period.

We hypothesized that herds and herders may be selecting available grazing at a finer spatial scale, at a level of detail that is not represented in the MODIS data. MODIS data provides high temporal resolution (i.e., incorporates daily measurements) but it has a relatively coarse spatial resolution (250m). Thus, to understand the relationship between herd movements and NDVI at a finer spatial scale, we sharpened the MODIS NDVI data with Landsat 8 NDVI images. We selected Landsat images that most closely matched the MODIS composite dates. Landsat measurements by themselves, which are made every 16 days, lack the temporal resolution to reliably interpret intra-annual seasonal phenological change based on NDVI values. Additionally, sensor differences and other differences, preclude meaningful direct comparisons between Landsat NDVI and MODIS NDVI data.

Instead, we used the Landsat data to add texture to the MODIS data, which spatially 'sharpens' the MODIS data while retaining the absolute NDVI values of the smoothed MODIS data. To accomplish this, we used iterative zonal statistics in ArcMap 10.6 to apply a correction factor to the 30m Landsat pixel NDVI values to create fused Landsat-MODIS NDVI images. For each fused image, the average NDVI value of Landsat data in zones (8x8 30m pixels) that spatially match a single MODIS pixel of 250m, is approximately equal (a difference of less than .0001 NDVI index value) to that of the MODIS fitted NDVI value at that pixel. Thus, the total, absolute value of the available NDVI landscape did not change when we incorporated Landsat data to produce NDVI landscapes at a 30m resolution. This method allowed for the reliable comparison of NDVI landscapes at both the 250m and 30m resolutions.

– *Shoat herd daily orbital distance traveled and daily integrated NDVI accessed*

We tracked the location of each sheep and goat herd in any given monitoring period for 10 days using small *i-gotU* loggers *GT 600* model (46 × 41.5 × 14 mm; 47 g) to assess shoat herd mobility. We put these devices in small plastic containers and handed them over to the livestock owner to tie, with nylon string, to a sheep or goat in the herd of their choosing, the day before the monitoring period began. We put one GPS unit with each household sheep and goat herd. GPS trackers logged the location of the herd every ten minutes throughout the 10-day monitoring period. Data were downloaded using @trip software, Mobile Action Technology, and then further analyzed through ArcGIS software, Esri. We kept only the location data for the period of 6:00 am to 7:00 pm for each day. This time limitation best captured daily herding orbits of our households. We mapped all herd movements and removed outlier locations through visual inspection of Google Maps plotted points, based on an assessment if the movement was possible to cover in the logged time between points or most likely was a GPS location error. We also did not use data from individual monitoring days that recorded less than 20 GPS points; 70 locations were about the average recorded when the GPS unit was functioning well.

To assess shoat herd daily distance traveled and the NDVI levels at shoat herd grazing locations, we projected all GPS collar data and NDVI images into Universal Transverse Mercator (UTM) 37N with a datum of WGS 84. We extracted fitted MODIS NDVI values (250 m) and Landsat sharpened and fitted MODIS NDVI values (30m) for the herd GPS location fixes using ArcMap 10.6. Because of positional error in the raw GPS collar data distance moved estimates, we recalculated the consecutive distances between projected GPS fix locations for each collar using the PointDistance function from the *Raster* Package in the R programming environment (R Core Development Team; Hijmans, 2019). We used this 'distance moved'

estimate to create a daily distance traveled estimate for the herd that we then averaged over the 10-day monitoring period. We acquired NDVI values for each herd point location and then made an area under the curve calculation, using R software, to calculate the integrated daily NDVI-accessed over an entire grazing day. The first point of each day was adjusted to start at 6:00 am and the last point was adjusted to end at 7:00 pm to standardize the length of the day. These times were based on observation of regular herding hours. This helped make up for days that lacked early and ending GPS location points even though they normally collected location data every ten minutes. However, this time adjustment could potentially overextend the NDVI value that the herd was accessing during that day. When this length of day adjustment changed the integrated daily NDVI value more than 50% than what would have otherwise been calculated, we dropped this individual day from the study. We calculated the average integrated daily NDVI-accessed for each herd over the 10-day monitoring period and this value is what is presented and used in our results.

– *Vegetation cover in preferred grazing locations*

Research assistants also conducted vegetation cover assessments for the locations that the shoat herds grazed in each community to access how vegetation available to these herds changed between monitoring periods and village. We evaluated vegetation cover using the phone application created by the Land Potential Knowledge System (LandPKS). This follows the 'Stick method' in the Monitoring Rangeland Health manual (Herrick et al., 2017). Each day two research assistants followed one of the shoat herds monitored with a GPS logger in each of the three villages. Once the sheep and goats began to slow down and feed in earnest, the research assistants would select a location in the center of the herd activity and conduct a vegetation cover

plot assessment. These plots were 50 x 50 meters and evaluated through 25 subplots, 1 m^2 each. Research assistants measured 2-3 vegetation plots each day for a single herd. The following day our research assistants followed the herd of a different household in the study, until they completed 10 days of herd follows (typically out of eleven herds available to follow). Following data collection in December, two of our phones were stolen (or lost) and our vegetation cover data for Naisunyai and Ngutuk Engiron communities were lost. We thus only present changes that occurred in Laresoro in December.

– *Main herder age and gender*

Samburu research assistants conducted a survey with each headwoman in charge of the sheep and goats in the household corral at the conclusion of each 10-day monitoring period to identify who herded each day of the monitoring period. These surveys were conducted in the Samburu-Maa language after they were piloted in other Samburu villages. Responses were translated into English but were mostly numeric (Appendix 1.4). Our surveys collected information on household characteristics and herder characteristics including herder(s) age and gender. In a minority of cases, households had more than one herder or switched herders over the course of the monitoring period. We present results for the eldest herder that herded the majority of the ten days.

– *Data Analyses*

We ran descriptive analyses and performed nonparametric, and parametric tests to interpret our data and relationships between variables ($\alpha = 0.05$). We conducted our statistical analyses using Statistical Package for the Social Sciences (SPSS) software version 26, IBM.

Significant differences were identified between each of the communities across monitoring periods through an independent-samples Kruskal-Wallis test followed by pairwise tests with a Bonferroni adjusted *p*-value. To test between subject effects in community and monitoring period, we natural log transformed variables to obtain normal distribution and then conducted a two-way ANOVA. We calculated the multiple linear regression analyses with AIC stepwise model selection (*p*-value entry = 0.05, removal = 0.10) using sheep and goat market values as two separate dependent variables for each species and four independent variables: the proportion of sheep in herd, total herd size, average daily NDVI-accessed, and average daily herding orbital distance. We separated these analyses for three monitoring periods, August, October, and December to determine what factors predict drought impacts on sheep and goat market value at the different stages of drought. All variables were natural log transformed to obtain normality. The May monitoring period was dropped from this analysis because normality was not obtained for some of the variables even after natural log transformation.

4.3. Results

Household shoat herd size (production)

We counted the number of sheep and goats for all GPS-tracked herds in the three villages and present their average, minimum, and maximum for all monitoring periods to show the variation in shoat herd size and composition among households (Table 4.2). This descriptive information provides context for understanding sheep and goat husbandry in this region. On average goats make up 61% of a household's shoat herd. In Table 4.2, the minimum or

maximum numbers of sheep and goats do not sum to the shoat herd minimum or maximum value because different families had different herd compositions.

Table 4.2. Household sheep and goat herd sizes averaged for all villages across all monitoring periods. Shoats-home is the shoat herd size that the household representative reported in our survey. Shoat-herd is the shoat herd size that the researcher counted. Goats-herd is the number of goats in the herd. Sheep-herd is the number of sheep in the herd.

	Mean	Std. Deviation	Minimum	Maximum	Sample Size	How Measured
Shoats-home	53.3	57.1	3	400	126	Household reported
Shoats-herd	66.0	75.7	3	549	129	Researcher counted
Goats-herd	40.3	55.4	1	430	129	Researcher counted
Sheep-herd	25.7	29.7	0	250	129	Researcher counted

We found that household reported shoat numbers of their herd size ('shoats-home' in Table 4.2) kept in the village were unreliable because they did not consistently match with researcher counted shoat herd numbers ('shoats-herd' in Table 4.2). We surveyed households to record the number of sheep and goats kept in the village at home. Research assistants also counted the number of shoats in the household herd kept in the village. We are confident they did this accurately based on practiced methods. A correlation test between household reported shoat numbers kept at the household and researcher counted shoat numbers found a significant (Spearman's rank correlation coefficient; $p < 0.008$), but not particularly strong Spearman Correlation value = 0.237. This indicates that household reported livestock numbers are likely not reliable. However, the household reported average, minimum, and maximum shoat numbers were similar to the average, minimum, and maximum researcher counts of shoat herds. This

indicates that households report both higher and lower numbers than they actually had in their herds but do so in a range somewhat consistent to village shoat herd size levels.

We found one village with a drought effect on households' shoat herd size. There were significantly (Pairwise Mann-Whitney U test; adj p = 0.006) fewer shoats in the village Ngutuk Engiron in October compared to December (Figure 4.2). No other shoat herd size differences existed among monitoring periods. However, this finding might be misleading because we learned some households moved their herds out of the settled village area to distant forage and does not necessarily mean shoats in Ngutuk Engiron died or were sold in significant numbers.

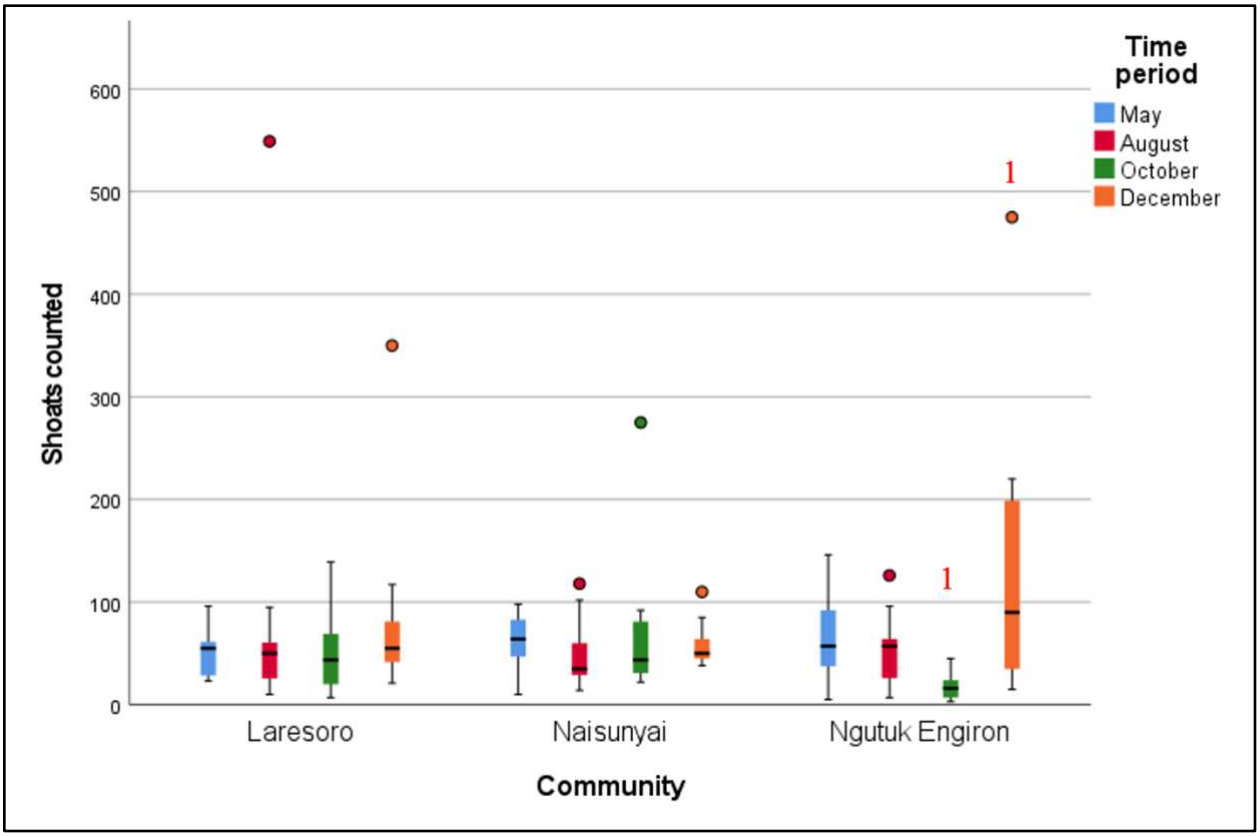

Figure 4.2. Shoat herd size ('shoats counted' by researchers) by village and monitoring period. Boxplots with the same red numbers are significantly different (adj p < 0.05, Pairwise Mann-Whitney U tests) comparing a village between two different monitoring periods. There were no differences comparing across the villages within the same monitoring period.

We found no effect of drought forage reserves on either conservancy or household shoat herd size (based on Pairwise Mann-Whitney U tests). There was not a significant difference in sheep and goat herd sizes among any of the three villages (two with access to a conservancy drought forage reserve, one without). This indicates that conservancy drought forage reserves did not have an effect, during or after the drought, on shoat herd size for those shoat herds that remained in the villages.

Sheep and goat body condition and market value (production)

Body condition and the market value of sheep and goats declined over the course of the drought but rebounded in December (Figure 4.3). These production measures were lowest in the October drought monitoring period (before rains) and recovered in the December monitoring period (post rains). Between these two periods aggregated by village, sheep market value increased from 1740 KSH to 3780 KSH (117%); sheep body condition score increased from 1.9 to 3.4 (79%); goat market value increased from 2450 KSH to 3660 KSH (49%); goat body condition score increased from 2.3 to 3.3 (43%) (all differences are significant, Pairwise Mann-Whitney U tests, adj $p < 0.05$). The drought affected sheep body condition and market value more than goat body condition and market value, as can be seen by comparing October and December measurements for each species.

There was no difference in either body condition or market value for either species comparing among the three villages within a given monitoring period. This indicates that access to conservancy drought forage reserves did not have an effect, during or after the drought, on these production measures. However, we did find for Ngutuk Engiron (with access to a drought

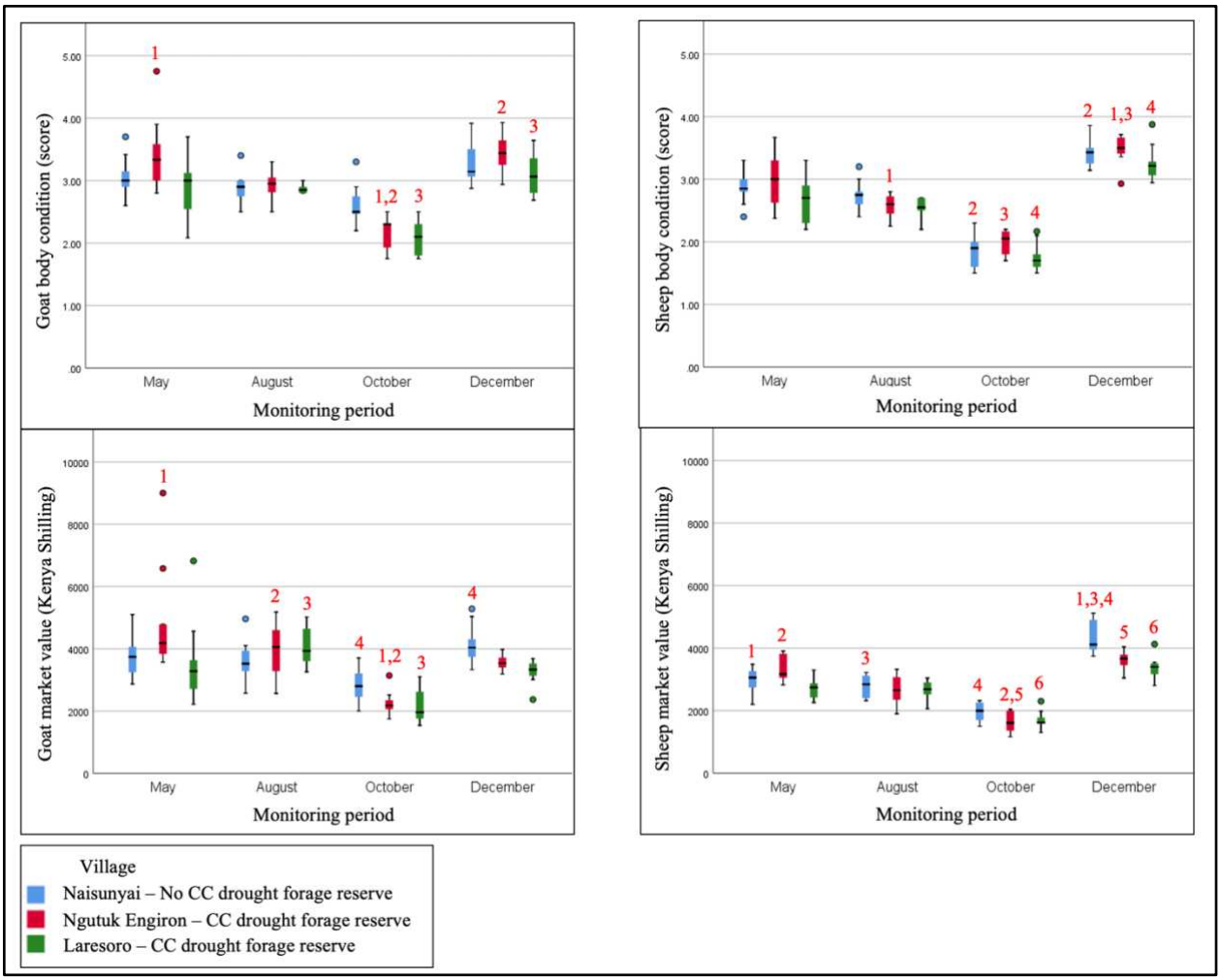

Figure 4.3. Sheep and goat production measures by monitoring period and village. Boxplots with the same red numbers are significantly different (adj $p < 0.05$, Pairwise Mann-Whitney U tests) comparing a village between two different monitoring periods. There were no differences comparing across the villages within the same monitoring period (CC stands for community conservancy).

forage reserve) that there was a significant interaction ($p < 0.05$; Two-way ANOVA, tests of between-subjects effects) between monitoring period and community for goat body condition, goat market value, and sheep market value. Ngutuk Engiron shoat herds dropped more in these three measures between the May and October periods compared to shoat herds in Naisunyai (without a conservancy drought forage reserve). This indicates that the conservancy drought forage reserve in Ngutuk Engiron may have had a negative effect on goat body condition, goat

market value, and sheep market value. However, this was not the case for the village shoat herds Laresoro (which also had access to a different conservancy drought forage reserve) that experienced similar effects to Naisunyai.

How did the 2015 - 2017 drought affect landscape vegetation greenness?

In order to understand how the drought impacted livestock access to forage, we examined and compared vegetation greenness over time based on remotely sensed NDVI. The geographic scope of our analysis included the area of Kalama and Westgate community conservancies; this area represents what is most easily accessible to all households in the three villages studied. Historically, there was a decreasing trend in NDVI mean from 2004 to 2017 of about 18% (a drop from 0.337 to 0.275, based on a best fit line) (Figure 4.4). The 2004 - 2017 NDVI mean was 0.307, with a 95% confidence interval from 0.299 - 0.316; we use this overall mean to understand relative vegetation greenness during our monitoring periods. The drought in 2017 severely limited vegetation greenness across the lowland grazing area accessible to all three villages. In these areas, the year of 2017 was when NDVI hit its lowest values since the MODIS measures began in 2004. These lowest values occurred briefly in February (NDVI = 0.21) and then again in July-August (NDVI = 0.201 – 0.207) before reaching average levels again by late October 2017. Even though August (NDVI = 0.201) had the lowest NDVI values since 2004, our communities said (Chapters 2) that the May, August, and October had drought conditions and December was a post-drought recovery period. However, May (NDVI = 0.284) and October (NDVI = 0.278) had close to average NDVI levels, while December (NDVI = 0.329) had a slightly above average NDVI level. We will use the community description of pastoral drought

here (not the vegetation drought shown by NDVI), naming all our monitoring periods as drought except December.

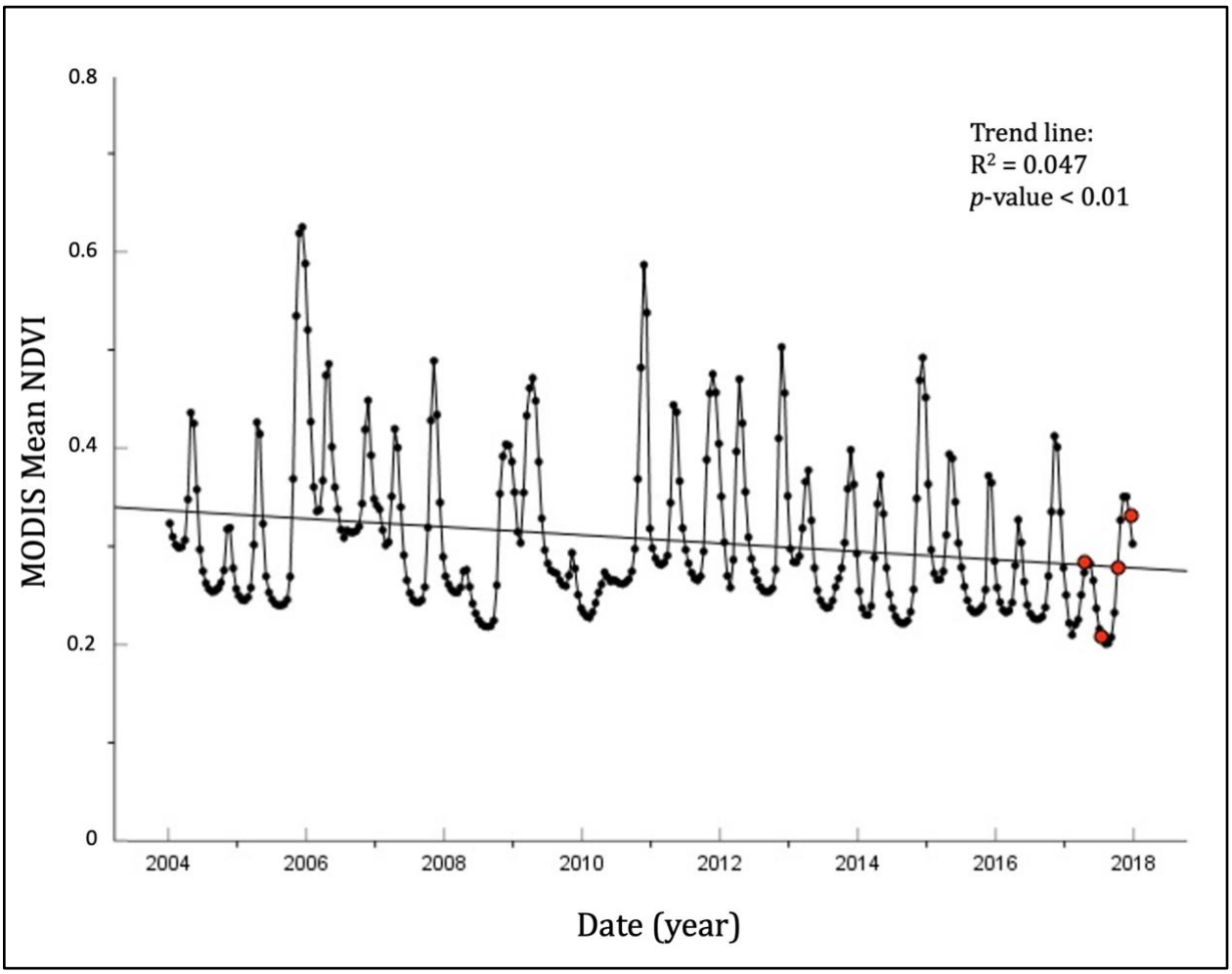

Figure 4.4. Mean NDVI (MODIS) by date for Kalama and Westgate conservancies. Red dots represent periods and images when sheep and goat monitoring took place (May, August, October, and December).

For livestock to recover from dry periods, it appears there needs to be extended periods of high vegetation production, measured here by NDVI greenness values. All of the community focus groups described the period from 2015 - 2017 as a drought that lacked livestock forage (Chapter 2). We observe that from 2015 - 2017 there were times when NDVI levels were at or

above average (with peak NDVI as high as 0.4), but these periods were not sufficient to be considered the end of a drought. This indicates that average NDVI levels in this environment do not necessarily mean it is not a drought, as Samburu pastoralists define it based on negative livestock impacts.

Shoat herd daily orbital distance traveled and NDVI accessed

Shoats travelled similar distances in all villages in the same time period, but they travelled longer distances during the drought periods than during the recovery period (Figure 4.5, top). At the village level, shoat herds moved less than half as far during the recovery in December (average daily herd orbital distance = 3481 m, SD = 749 m) compared with during the 3 drought periods in May (average daily herd orbital distance = 9326 m, SD = 1689 m), August (average herd orbital distance = 9469 m, SD = 1607 m), and October (average herd orbital distance = 8234 m, SD = 2507 m). Note that there was no difference comparing among villages, which means access to conservancy drought forage reserves did not affect grazing distances in any monitoring period, either positively or negatively. This also means that herds traveled shorter distances when the vegetation was greener, as we expected.

Shoat herds differed in the daily integrated NDVI levels that they accessed between some monitoring periods and between two villages (Figure 4.5, bottom). Daily integrated NDVI accessed measures the summed greenness of the locations each shoat herd traversed. This measure was significantly lower (adj $p < 0.05$; pairwise Mann-Whitney U-tests) during the August monitoring period compared to May, October, or December for both Naisunyai (with no conservancy drought forage reserve) and Ngutuk Engiron (with access to a conservancy drought

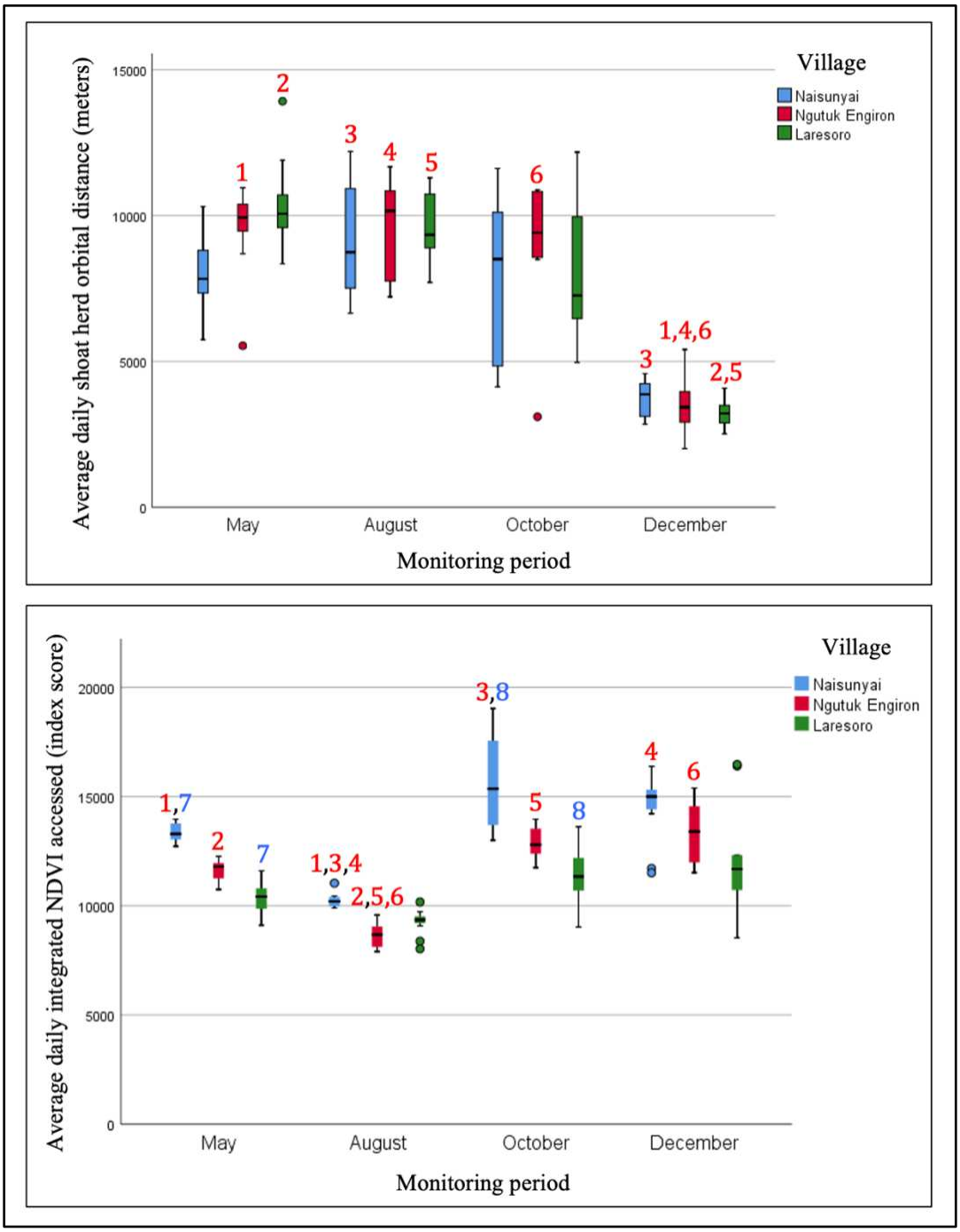

Figure 4.5. Clustered boxplot of average daily herding orbital distance of shoat herds by monitoring period (10-days) and village (top). Clustered boxplot of integrated NDVI-accessed by monitoring period (10-days) and village (bottom). Red matching numbers indicate pairwise significant differences (adj $p < 0.05$, Pairwise Mann-Whitney U tests) across monitoring periods within a village. Blue matching numbers indicate pairwise significant differences (adj $p < 0.05$, pairwise Mann-Whitney U-tests) across villages within a monitoring period.

forage reserve). Even though sheep and goat body condition and market value were lowest in October, herds in Naisunyai and Ngutuk Engiron were starting to access a pre-rain vegetation green-up that occurs in some woody plant species. Daily integrated NDVI accessed did not significantly vary between the monitoring periods for the Laresoro community shoat herds. Shoat herds in Naisunyai, which did not have access to a conservancy drought forage reserve, were able to access greener vegetation in May and October compared to shoat herds in the Laresoro community, which had access to the Kalama drought forage reserve. This shows that access to their drought forage reserve did not benefit Laresoro herds with access to greener forage during the drought.

The relationship between herd daily distance travelled and vegetation greenness accessed were either positive, negative, or lacked significance depending on the monitoring period. Using natural log transformed values for herding orbital distance and integrated NDVI variables to obtain normality, we found a significant negative correlation in May (Pearson's $R = -0.43$. $p = 0.012$) and a positive correlation October (Pearson's $R = 0.38$, $p = 0.036$), aggregated at the community level. NDVI levels in the overall area were close to average in both May and October; however, herds in Naisunyai and Ngutuk Engiron accessed greener vegetation in October, during a pre-rain green-up that might be limited to specific areas such as hills or riparian zones (Pickering pers obs). Being able to travel farther at these specific times might provide an advantage. In December, when NDVI levels were above average, or in August, when NDVI was well below average, traveling farther had no relationship to greenness accessed.

Vegetation available to shoats

Our next goal was to compare the amount of vegetation (of different types) available to sheep and goats in their preferred grazing locations in each community over the course of the 2017 drought. This allows us to understand the effects of drought over time, by comparing across monitoring time periods, and to also understand the effects of access to conservancy drought forage reserves by comparing among the three villages. To do this, we examined six measures of vegetation cover: (1) bare ground cover, (2) tree cover, (3) shrub cover, (4) perennial grass cover, (5) annual grasses and all forbs (other herbaceous cover), and (6) fallen herbaceous litter cover (Figure 4.6). Forage for sheep commonly includes both perennial grasses and annual grasses and all forbs, while forage for goats commonly includes annual grasses and all forbs, perennial grasses, shrubs, and sometimes trees. We observed, during the drought in the shoat herds we monitored, sheep consuming leaves from some shrubs and trees, and both species commonly consuming herbaceous litter cover (fallen usually dried leaves from trees and shrubs).

The forage available for sheep and goats differed from vegetation type to vegetation type over the course of the drought. Overall, the amount of tree cover available to these small ruminants did not change in response to drought, but was quite variable from plot to plot. Generally, as the drought continued from May to October, the availability of much of the other types of vegetation (annuals and forbs, perennial grasses and shrubs) declined, while the availability of herbaceous litter covered increased, as the vegetation dried out and bare ground increased. In the one community where we measured livestock access to vegetation in December, Laresoro, it was clear that there was more annual and perennial grass available to livestock at this time, as the vegetation recovered in the late year rains.

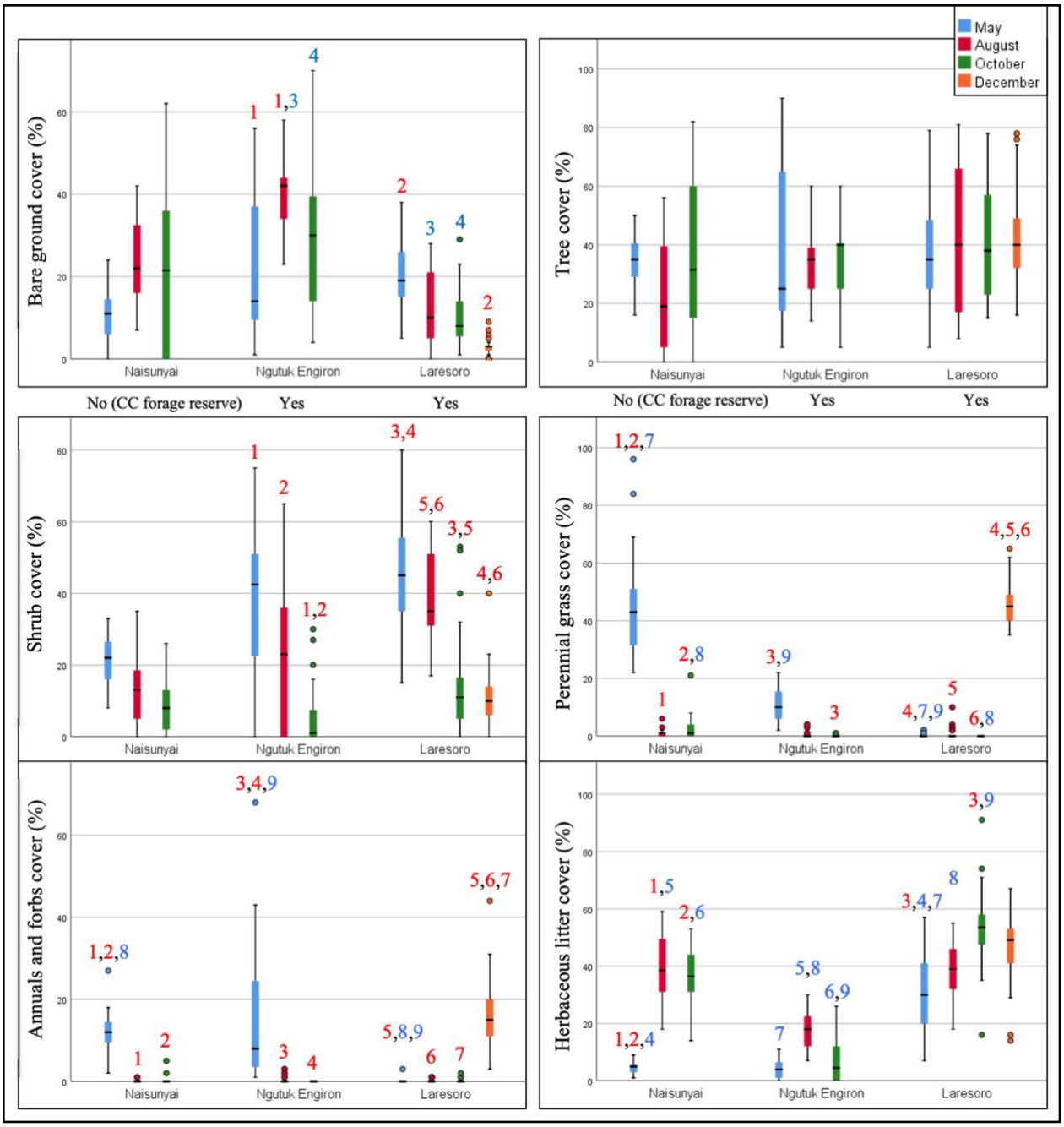

Figure 4.6. Clustered boxplots of the six types of vegetation cover by village and monitoring period. Within villages, boxplots with the same red numbers are significantly different (adj p < 0.05, Pairwise Mann-Whitney U tests) comparing between monitoring periods. Boxplots with the same blue numbers are significantly different (adj p < 0.05, Pairwise Mann-Whitney U tests) comparing between villages in the same monitoring period. 'No (CC forage reserve)' indicates the village (Naisunyai) without access to a community conservancy drought forage reserve.

Our three communities differed in their access to community conservancy drought forage reserves: Ngutuk Engiron and Laresoro had access, while Naisunyai did not. We expected that greater access to these drought reserves would translate into greater forage availability for the Ngutuk Engiron and Laresoro herds, and less for the Naisunyai herds. In our first monitoring period in May, Naisunyai (no access) and Ngutuk Engiron (access) had more annuals and perennial grass available to livestock than Laresoro (access). By October, Naisunyai sheep and goats grazed in areas with more perennial grass than the other 2 communities, even though these latter communities had access to their conservancy's drought forage reserve. This indicates that Naisunyai and Ngutuk Engiron started off with better forage availability compared to Laresoro in May during the early stages of the drought, but that Ngutuk Engiron ran out of available livestock forage before Laresoro. However, and importantly, Laresoro grazed in areas with more herbaceous litter cover in October than the other communities, and as shown below, these areas were in conservancy drought forage reserves. Across all monitoring periods, herds in all 3 communities had the similar access to tree and shrub cover.

Laresoro herds likely benefited from higher use of the Kalama drought forage reserve than Ngutuk Engiron herds that rarely accessed the Westgate drought forage reserve during our monitoring periods (Table 4.3). Since we measured vegetation cover plots where sheep and goat herds grazed, the number of plots in and out of the conservancy drought forage reserve measures how much shoat herds grazed in their drought reserves. Ngutuk Engiron herders only accessed livestock forage in the Westgate drought reserve in October and only in 2 of our 28 plots (7.1%). Laresoro accessed the Kalama drought forage reserve much more frequently, with herds accessing the reserve in 21 of our 27 plots (77.8%) in May, 12 of our 25 plots (48%) in August, and 9 of our 28 plots (32%) in October. This shows shoat herds from Laresoro decreased use of

the Kalama drought forage reserve as the drought progressed. These shoat herds did not access the drought forage reserve after the drought ended in December.

Table 4.3. The number and percent of vegetation plots measured inside and outside the Kalama and Westgate drought forage reserves accessible to Laresoro and Ngutuk Engiron communities, respectively. NS = No significant difference.

Villages with access to drought reserve	Monitoring period	Village area (out) Number of plots	Drought forage reserve (in) Number of plots	Village area (out) Percent of plots	Drought forage reserve (in) Percent of plots	Percent of shrub cover in village area (out)	Percent of shrub cover in drought forage reserve (out)
Laresoro	May	6	21	22.2	77.8	NS	NS
	August	13	12	52.0	48.0	NS	NS
	October	19	9	67.9	32.1	12	20
	December	29	0	100	0		
Ngutuk Engiron	May	20	0	100	0		
	August	27	0	100	0		
	October	26	2	92.9	7.1		
	December	Missing	Missing				

We can compare vegetation cover in preferred grazing locations that Laresoro shoat herds used inside and outside the Kalama drought forage reserve, but results are limited due to moderate sample sizes. Based on independent-samples Mann-Whitney U-Tests, there was no difference in bare ground, tree, perennial grasses, annuals and forbs, and herbaceous litter cover where shoats grazed inside and outside of the Kalama drought forage reserve in any of our monitoring periods. In October, the grazing areas in the Kalama drought forage reserve had higher shrub cover compared to other community grazing areas accessed; 20% vs 12% (p =

0.007) (Table 4.3). This increase in shrub cover, the greater herbaceous litter cover available (above) and the frequent use of the area by herds shows that there was some benefit to the Laresoro community of access to their drought forage reserve.

Herder age and gender

Herder age or gender did not significantly differ over the course of the drought or among villages but did show an important reliance on female herders and children. Across all communities and monitoring periods, 54.2% of herders were female and 45.8% were male. The average age of these herders was 16 years and ranged from approximately 6 to 67 years (n = 131). We were surprised to find that the percentage of male herders did not significantly increase during school breaks in May and December. There was no difference in the mean herder age comparing between monitoring periods (independent-samples Kruskal-Wallis test). In October, however, when the drought most affected sheep and goats (see below) there was an increase in the variance of age in Naisunyai and Laresoro communities for both genders (Figure 4.7). This may indicate that some households prefer to use older herders when times were most difficult. Note that there was no difference comparing among communities, which means access to conservancy drought forage reserves did not affect the age or gender of the herder.

We conducted independent-samples Mann-Whitney U-tests for each monitoring period to see if household herder gender related to daily herding orbital distance traveled. In August we found that female herders took their herds significantly ($p = 0.008$) farther distances, about 1.5 km more, than male herders, but no significant difference was found in any other monitoring period. We found no significant correlation between herder age and daily herding orbital distance in any given monitoring period (Spearman Correlation).

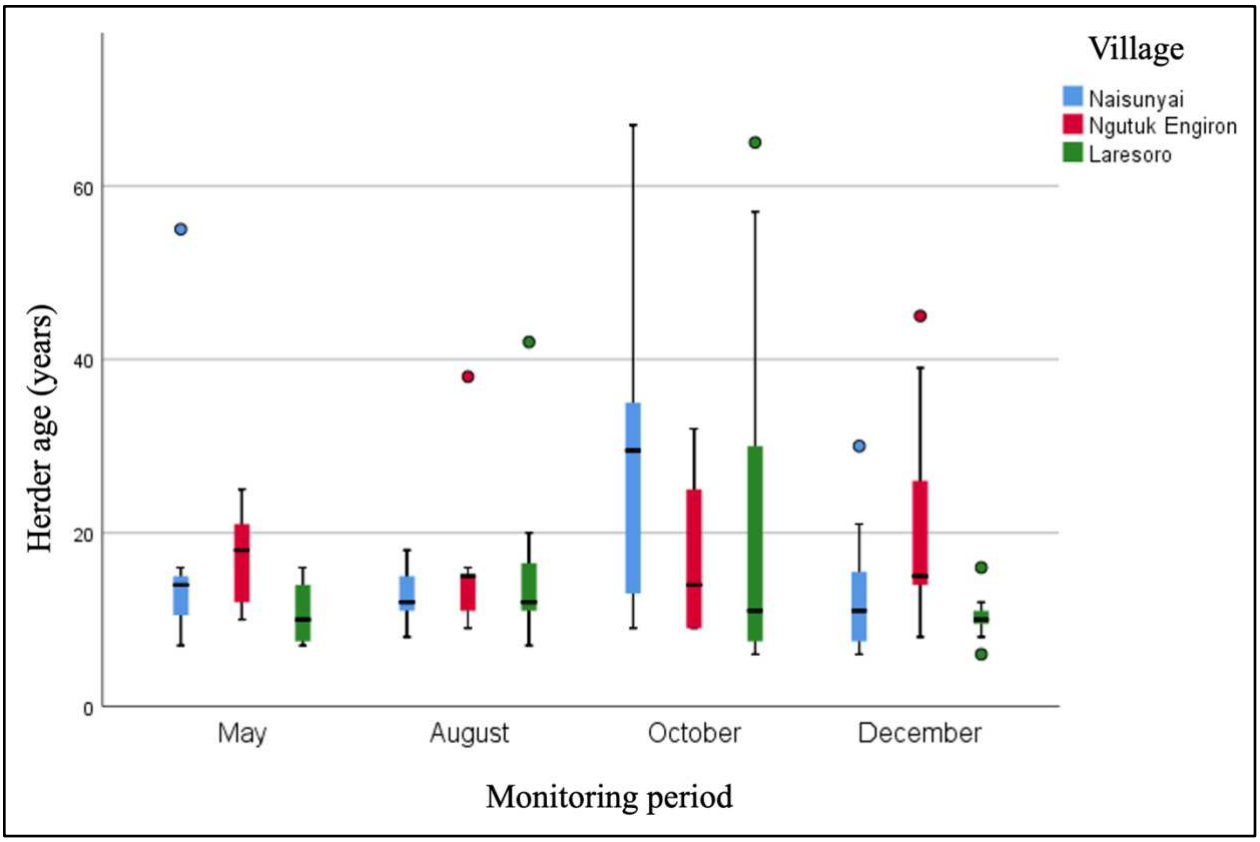

Figure 4.7. Clustered boxplot of herder age by monitoring period and by village. There was no significant difference in herder age comparing across villages or monitoring periods.

What determines sheep and goat market value?

In August, households with larger shoat herd size predicted both higher sheep market value and higher goat market value. Sheep market value increased in herds of larger size in August ($F(1,18) = 4.926$ $p < 0.05$, $R^2 = 0.215$, 'sheep market value' = 7.557 + 0.084 (herd size)). Goat market value increased in herds of larger size in August ($F(1,19) = 6.364$, $p < 0.05$, $R^2 = 0.251$, 'goat market value' = 7.789 + 0.112 (herd size)).

In October, shoat herds that accessed higher daily integrated NDVI predicted both higher sheep market value and higher goat market value. Sheep market value increased in herds that accessed higher daily integrated NDVI in the October monitoring period ($F(1,20) = 8.311$, $p < 0.01$, $R^2 = 0.294$, 'sheep market value' = 2.030 + 0.572 (NDVI-accessed)). Goat market value

increased in herds that accessed higher daily integrated NDVI in October ($F(1,24) = 11.037$, $p < 0.01$, $R^2 = 0.315$, 'goat market value' = 0.852 + 0.731 (NDVI-accessed)).

4.4. Discussion

Implementation of the two adaptations to rangeland fragmentation and drought

Sheep and goat husbandry is a rangeland fragmentation and drought adaptation widely used across Samburu villages and households. We found all households in these three villages owned goats, and almost all owned sheep. Ubiquitous shoat ownership is perhaps unsurprising given that others have documented the dramatic increase in shoat numbers since the 1970s in Samburu County (Ogutu et al., 2016). However, it is helpful to understand how widespread shoat herding is across all households. In our study, the average household herd size was 66 shoats, but this varied widely between households (SD = 75.7) and ranged from 3 to 549. In 2007, Westgate Conservancy (where two of our villages reside) households had much smaller shoat herds with a median shoat number of 18.4 (SD = 2.6) (Glew et al., 2010). This difference in shoat numbers between our studies likely indicates either a large increase in shoat numbers since 2007 or a difference in measurement methods. They used household reported numbers through interviews, and we counted herds, and we found household reported counts were 20% below our direct counts. Our findings also show that sheep and goat husbandry does support these settled households throughout a drought. Shoat herd size only significantly differed in Ngutuk Engiron between October and December. While no cattle were present in these village areas during the drought, many sheep and goats remained. However, we found some households moved a portion or all of their shoat herds out of their village area during the August and October drought

periods. We could not accurately measure how many households moved shoats or how many shoats left because we did not anticipate this coping strategy.

The establishment of conservancies is a second pastoral adaptation to rangeland fragmentation and drought. Conservancies have established drought forage reserves to benefit a limited number of villages within their greater community. Whether or not conservancies initially set up drought forage reserves to support shoat herds (as opposed to cattle), we found they benefit some shoat herds from a subset of villages during droughts. However, only villages alongside conservancy drought forage reserves have a real opportunity to benefit from them. We designed our study around villages with and without access to drought forage reserves and cover these nuanced differences later in this discussion. This current conservancy grazing structure has limited potential use for many shoat herds in villages too distant from the drought forage reserve. Conservancies in Kenya need to address shoat grazing management if they are to protect wildlife and benefit pastoral livelihoods (Løvschal et al., 2019). Current conservancy drought forage reserves may benefit more mobile cattle, but new drought grazing plans are likely needed if conservancies want shoats in all villages to benefit during future droughts. Our findings lead us to consider whether conservancies would have better success organizing additional smaller drought forage reserves separated for each village (not for multiple villages across a conservancy) when possible. It might be easier for a single community to trust and monitor one another's access to a drought forage reserve than coordination across multiple communities (Agrawal, 2003).

Herding shoats requires valuable household labor, and this represents an adaptation opportunity cost. Herders are a labor cost to all households that manage sheep and goats. We found herders, on average, were 16 years old, and they ranged from 6 – 65 years. A slight

majority of them were female (54.2%). This labor investment shows many households suffer an opportunity cost by not sending some children to school, at least a portion of their youth. Few studies have captured herders' ages of African pastoralists. Among the Datoga of northern Tanzania, the age of those who herd shoats averaged 12 years and ranged from 3 – 52 years; there was an equal divide between girls and boys herding shoats (Sieff, 1997). In the Fakara region of Niger, herders of all livestock species were much more likely to be male, and those younger and female herders were more likely to herd sheep and goats (Turner and Hiernaux, 2008). Samburu pastoralists often use income from sheep and goats to send children to school (Chapter 3), but they accomplish this by keeping some children herding.

Shoat herding requires large areas of unfragmented rangelands around villages during droughts. Practitioners and scientists can use our mobility data of shoat herd daily distance travelled from villages in this region to understand the accessibility of drought forage reserves and fragmentation threats. Herders in our study moved their shoats on average 3.5 km in an orbit in the wet season, but up to 9.5 km on average during the drought. This distance shows the hard work involved in traveling during droughts, especially for younger children that had to keep up with their elder peers (we found no correlation between herder age and distance traveled). Shoat herds commonly used areas 6 km away from their corral during a drought. This distance may be the upper mobility range that a drought forage reserve can be located from a household and still be accessible without temporary herd relocation or significant extra effort. These distances also indicate the radius around a household required for grazing. Thus, if pastoralists fence or privatize areas that encroach this village grazing area, this rangeland fragmentation will likely impact settled shoat herding.

Drought impacts on shoat production, access to vegetation, and management

The lack of drought impact on shoat herd size is somewhat unexpected given the rates of shoat loss reported during different droughts in two other regions of Kenya and three regions of Ethiopia. Few other studies have examined drought impacts on sheep and goat production among East African pastoralists. Samburu pastoralists defined the 2015 – 2017 time period as a drought because cattle suffered and died over this period. The Samburu are a cattle-centric pastoralist culture that has come to rely on sheep and goats in their settled villages, mainly since the 1984 drought (Chapter 3). We found no evidence that shoats died in significant numbers during the 2017 portion of the drought (April – October). Herd size did not significantly vary between our drought monitoring periods or the recovery period (December 2017). Shoats possibly died during this period, but this mainly occurred in shoat herds that families moved out of the village to distant forage. We were not able to accurately track these herds and record changes in herd size. Only a few other studies have described shoat mortality during a drought in East Africa. For example, in southern Kenya and northern Tanzania during the 2005 – 2006 drought, 11 – 47% of sheep and 22 – 35% of goats died in four different community areas. These researchers recorded this change using household surveys (Nkedianye et al., 2011). In Turkana, during the 1979 – 1980 drought, the researcher counted a 55% decrease in shoat numbers among three representative households (McCabe, 1987). In the Afar, Borana, and Somali regions of Ethiopia during the 2001or 2005 – 2006 drought, excess shoat mortality was 23.3%, 8.4%, and 6.5% higher, respectively (Catley et al., 2014).

We speculate research methods may account for some of the difference between our study and others that measure changes in shoat herd size or mortality during a drought, along with other social and environmental factors that determine shoat mortality. We found that

households did not report their shoat numbers accurately in surveys compared to researcher counts. There are several hypothetical situations pastoralists may have for reporting inaccurate livestock numbers. For example, they may perceive a potential penalty for having too many livestock (perhaps affiliating us with conservation NGOs in the area), or they may under-report livestock taken from other ethnic communities, or report higher drought mortality to some researchers because they have expectations of compensation for loss. Alternatively, because these studies are in different social-ecological systems, there may be other social and environmental explanations. For example, perhaps shoat numbers are not at levels in Samburu communities that put them at high risk of starvation during droughts. If sheep and goat numbers continue to increase rapidly in Kenya (Ogutu et al., 2016), it will be useful for scientists to get accurate counts and assessments of drought impacts on their populations.

During the drought, sheep and goat body condition and market value significantly decreased with differences in effects between species that indicate there are likely trade-offs to herding these species together. Since goats on average make up 61% of Samburu shoat herds, herders may favor moving herds to places with shrubs or small trees and areas with fallen dried leaves (herbaceous litter) during droughts. These locations may not be suitable for sheep that are more productive when they feed on small grasses and forbs (Coppock et al., 1986; Schroeder et al., 2019). Anecdotally, we observed that a minority of households with enough herding labor moved sheep to the distant forage, often in the Samburu highlands, and kept goats around the village during the 2017 drought (Pickering and Yasin pers obs.). This herd splitting may require more labor than these households can spare. We found the average shoat herder was only 16 years old and most were female. These female herders may take additional safety risks traveling outside of their community compared to older males. These trade-offs seem to be at play in our

study, we found greater increases in these sheep production measures during the recovery period than goat production measures. Sheep market value increased from 1740 KSH to 3780 KSH (117%); sheep body condition score increased from 1.9 to 3.4 (79%); goat market value increased from 2450 KSH to 3660 KSH (49%); goat body condition score increased from 2.3 to 3.3 (43%). Therefore, the drought impacted goats less than sheep (body condition scores lower in sheep), or sheep were prioritized for grazing following the drought (greater recovery), or both.

We do not know of other studies that describe drought impacts specifically measuring sheep or goat body condition or market value; however, our production findings match with what other studies have observed regarding drought and livestock mortality relationships. Sheep tend to be somewhat more sensitive to droughts than goats, though in some environmental conditions perhaps where grasses are plentiful, less sensitive (McCabe, 1987; Nkedianye et al., 2011). Sheep and goats usually feed on different vegetation types (Samuels et al., 2016), but goats occasionally prefer grasses in some environments (Schroeder et al., 2019). We speculate pastoralists may avoid the drought impact difference between species if they can move sheep to pasture outside the drought zone and keep goats around the village, supporting the settled family.

Our MODIS NDVI assessment of the 2017 drought aligns with pastoralist descriptions (documented in Chapter 2) of the 2017 drought, and this leads us to consider new ways to better evaluate drought patterns. In Chapter 2, we determined through a separate NDVI assessment at the Samburu County scale (rather than the Westgate and Kalama conservancy aggregated scale presented in this Chapter) that 2011, 2009, and 2005 were the top three most severe NDVI anomalies from 1981 to 2013. These three vegetation droughts also appear as periods when Kalama and Westgate conservancy MODIS mean NDVI levels (presented in this Chapter) fell below the average index score (0.3) for several months at a time (Figure 4.2). While the 2017

drought saw the lowest absolute NDVI value (0.201 in August) since 2004, the duration of time NDVI levels remained below the average greenness level was shorter than in either the 2005, 2009, or 2011 droughts. Many communities considered the 2017 drought one of the most severe in their lifetimes (Chapter 2). Interestingly, this drought was named *Loidikdike* in Samburu-Maa, which means a drought that continues, but little bits of rain interrupt it (Chapter 2). This commonality indicates that scientists can match pastoralist drought perceptions with NDVI measurements in useful ways to understand pastoralists' drought experiences better. In Chapter 2 we measured NDVI anomalies at seasonal scales and in this chapter at 16-day intervals. Both appear suitable for comparison with perceptions of pastoralists about drought that generally were described at seasonal scales, months to years (Chapter 2).

Samburu herders increased the daily distance traveled by their shoat herds during the drought periods, as expected. Still, we were surprised to find farther distances did not correlate with herder gender or herder age. We found that the average daily distance traveled in different seasons varied between 3.5 and 9.5 km. These are generally shorter distances on average compared to other studies of shoat herd mobility. In Niger, one study found herders move their shoats between 10 and 12 km (Schlecht et al., 2006). In Turkana County, Kenya, a drier environment than Samburu County, another study found shoats moved between 12 and 15 km in a day (Coppock et al., 1988). In Burkina Faso, shoat herders move 4.5 and 18.8 km (Zampaligré et al., 2013). Some pastoralist societies consider female and younger herders less capable of herding far distances (Turner and Hiernaux, 2008). However, at least for shoat mobility, the herder's age or gender did not make a difference in our study. In fact the opposite may be true: we found female herders took their shoat herds farther distances in one monitoring period (August) than their male counterparts.

Pre-rain vegetation green-up periods might be brief but valuable periods for pastoralists to improve shoat health before seasonal rains. To our knowledge, no other studies have examined the connection between NDVI-greenness that herds access and livestock production. Other studies have used livestock NDVI accessed to assess grazing intensity (Butt, 2010), understand livestock distribution patterns (Moritz et al., 2014), or compare livestock access to different vegetation types (Spiegal et al., 2019). Our analysis of shoat daily access to vegetation greenness generally did not predict sheep and goat production differences. However, we did find a significant relationship between greenness accessed and sheep and goat market value for one monitoring period during early pre-rain green up in October 2017. We observed this green-up on the MODIS satellite imagery in some areas, especially around the Naisunyai village. We reconfirmed with Samburu research assistants that no rainfall had occurred before our October monitoring period (Pickering pers. obs.). Scientists have documented widespread pre-rain green-up in Acacia savanna (and other environments) weeks to months before wet season precipitation in southern Africa (Ryan et al., 2017; Reid pers obs). *Vachellia* (*Acacia*) *spp* and *Commiphora spp* are examples of common types of vegetation in the Samburu lowlands that begin to put out leaves at least a few weeks before the rainy season (Pickering pers. comm.). During our study, these pre-rain green-up locations likely occurred in the hills and along with the riparian areas where trees are more common (Pickering pers. obs.). Not all herders were able to access these greener areas. We speculate accessing these greener areas might have required more directed herding strategies, knowledge of locations where forage from trees was accessible to sheep and goats, or the ability to climb and cut tree limbs. Samburu pastoralists previously described that cutting *Vachellia tortilis* limbs is a common and sometimes regulated practice to feed livestock (Chapter 2). This ability to access early green-up grazing areas might be valuable to households

to help them recover and end a drought situation more quickly. If shoat herds have access to green forage before the rain, herders may avoid the difficult period at the beginning of the rainy season when livestock are weak and do not have enough food resources to prevent exhaustion from cold or increased diseases, like diarrhea and pneumonia (Little et al., 2001). However, we found that two months later, in the December monitoring period, there was a slight variation in livestock health, and thus we do not know how much access to pre-rain green-up mattered in the long term for shoat production.

Herd size was the only other management practice that showed any relationship to improving shoat production during the drought besides access to pre-rain green-up (described above). In August, larger herds also indicated higher sheep and goat market values in the herd. We do not know why. Perhaps the owners of larger herds could afford to provide more veterinary care, which can help with post-drought diseases (Catley et al., 2014), or had more skilled herders that help resist drought (Salomon et al., 2013). Households in our study area typically do not like to combine herds with other families' herds because they are worried about livestock diseases and therefore are unlikely to be able to quickly manage their herd size for improved drought resistance (Pickering pers. obs.). Yet because larger herds could free up more children to go to school, it might be worth reducing disease risk through increased veterinarian care to allow herd amalgamation across households. We suggest others might study this possible drought coping strategy.

Pastoralist households in settled villages appear to have limited coping strategies within current household herding practices to resist drought impacts on sheep and goat production. We found no evidence that the effects of drought varied across households despite variation in herding practices like mobility, herder age, and herder gender. Skilled herders make a difference

in some aspects of shoat husbandry, like protection from predators and reducing lost livestock (Jablonski et al., 2020; Salomon et al., 2013). However, the skill of herders is not easily measured and does not appear to match with herder age or gender for shoat herds in our study. However, we did see a small number of households use an older herder (observed through greater variation in herder age) in October. Our analysis indicates that sheep and goat production more readily depends on vegetation availability than household herding practices.

Do conservancy drought forage reserves benefit livestock during droughts?

Conservancies' drought forage reserves (at least in their early stages of establishment and current management) provide some shoat benefits but do not improve household drought resistance. We found no difference in shoat production in any monitoring period between the two villages with (Laresoro and Ngutuk Engiron) and one village without (Naisunyai) access to conservancy drought forage reserves. We found a significantly greater decrease in three measures of shoat production as the drought progressed in Ngutuk Engiron (with access) compared to Naisunyai (without access). However, Ngutuk Engiron decided not to access their drought forage reserve during our monitoring periods for reasons we explain below. Laresoro did access their conservancy drought forage reserve regularly during the drought, and those herds benefited from increased available shrub cover. Laresoro shoat herds also accessed areas with higher herbaceous litter cover during the two later drought monitoring periods than Naisunyai and Ngutuk Engiron. However, Laresoro herds accessed less grasses and forbs than the other two villages in the early drought period (May). Laresoro herders' decisions to graze in the conservancy drought forage reserve also likely indicates this area had higher nutritional quality than other Laresoro grazing areas (Schlecht et al., 2006). We found no differences in daily

distance traveled or vegetation greenness accessed (NDVI) between villages. However, there was less variation in NDVI accessed between monitoring periods in Laresoro (no significant differences throughout the drought and recovery periods). Other studies have documented pastoralists' perceived benefits from access to conservancy drought forage reserves during droughts (Bedelian and Ogutu, 2017). No other studies to our knowledge have reported specific outcomes. Our study is a case comparison and does not prove cause and effect between conservancy drought forage reserves and benefits but identifies differences for potential further research.

There may be a risk of establishing a drought forage reserve but not successfully restricting access before a drought. We found greater drought impacts on sheep and goats in Ngutuk Engiron, the Westgate village with access to, but did not choose to use, their conservancy drought forage reserve. This choice likely indicates that sheep and goat forage inside the Westgate drought forage reserve was not better in livestock nutritional value than outside in the Ngutuk Engiron village grazing areas during our monitoring periods (Schlecht et al., 2006). If it were better, herders would have likely accessed and moved their livestock into the drought forage reserve when the conservancy administration gave permission. Based on our conversations with conservancy staff in 2017, we speculate the lack of forage in the Westgate drought forage reserve was likely because some households in Ngutuk Engiron and from other villages had grazed the forage before the conservancy staff officially opened it to villages in June 2017. This pre-drought grazing might explain why we saw larger shifts in vegetation cover in Ngutuk Engiron's preferred grazing locations during the drought compared to Laresoro–the other community with a drought forage reserve. Ngutuk Engiron in May had more grasses and forbs but more bare ground and less herbaceous litter in August and October compared to Laresoro.

This vegetation difference did not likely affect sheep and goat production but shows there is possibly some risk of unwanted drought forage grazing when establishing a drought forage reserve, particularly when multiple villages are involved.

The establishment risk and cost of a drought forage reserve may be worth it because they provide multiple types of benefits, not just to livestock. In the short term, regulation of drought forage reserves likely defers livestock grazing, and returns some of these initial costs of deferred grazing during droughts to livestock (Angassa and Oba, 2008; Bedelian and Ogutu, 2017; Glew et al., 2010). However, the establishment of these reserves also allows pastoralists to create wildlife conservation areas, which have different household benefits (usually through tourism) and can rehabilitate rangelands by allowing periodic rest of the rangeland (Kieti et al., 2013; Kimiti et al., 2017; Odadi et al., 2017; Ogutu et al., 2017). These areas could potentially improve rangeland conditions by not removing livestock completely from the conservation area but developing a dynamic system of rest and rotation (Curtin, 2002). Grazing areas with dynamic rest and livestock rotation, similar to customary herding practices, may also have the dual benefit of supporting a greater diversity of wildlife species (Augustine et al., 2011; Augustine and McNaughton, 1998). Rangeland heterogeneity, which can reduce the effects of rangeland fragmentation, can be maintained or improved through actions such as dynamic livestock management, intentional livestock impacts, burning, reseeding, and clearing unwanted species (Briske et al., 2020; Kimiti et al., 2017; Liao et al., 2020; Odadi et al., 2017). These are opportunities that many Kenyan communities want when livestock production is not put at risk (Cockerill and Hagerman, 2020), although these different opportunities can create substantial trade-offs between livestock production and wildlife conservation, such as during times of drought when remaining forage can be protected for wildlife or for livestock.

Community conservancies likely have an opportunity to reduce drought impacts on household sheep and goat husbandry in Kenya. Sheep and goat production provides essential resources to many pastoralist households across Kenya and much of East Africa. It is an adaptation that is likely here to stay, at least until other livelihood activities can meet the food and income security roles these sheep and goats provide, particularly to women and youth (Degen, 2007; Little et al., 2014; Chapter 3). Community conservancies have the option to better support, regulate, and advise sheep and goat grazing practices so that they prepare for these livestock demands and increase benefits to the communities within each conservancy (Løvschal et al., 2019). Whether conservancies can accomplish this without sacrificing conservation goals is largely unknown. Dual conservation and shoat husbandry goals are challenging because of sheep and goats' potential negative grazing impacts (Keesing et al., 2018; Riginos et al., 2012). Some grazing methods might allow small stock and wildlife to coexist if pastoralists rest livestock grazing areas for recovery and wildlife occupation (Lalampaa et al., 2016; Tyrrell et al., 2017). Here, we explored the option of allowing shoats access to conservancy drought forage reserves to support these small ruminants during droughts. The alternative option, where conservancy actions aim to constrain sheep and goat husbandry, is not ideal because women and youth receive considerable benefits from sheep and goat husbandry, such as income and food to support settled life with access to schools (Bedelian and Ogutu, 2017; Jandreau and Berkes, 2016; Chapter 3).

Limitations and future research considerations

We used our study methods to compare drought impacts on sheep and goats at the village level. This design limited how we measured and were able to compare outcomes at the

household level. We chose to use our restricted number of GPS units (34 at the beginning of the study) to assess three villages to capture differences between drought forage reserve access. Still, we did not expect drought impacts to be so strikingly similar on sheep and goat body condition and market value across these villages. To better understand and compare the effects of different household herding practices on livestock production, we recommend future studies first assess livestock production in each stage of a drought and then selectively monitor herds at different production levels (e.g., body condition scores, or market values) to increase variation in the dependent variable of interest. This would not be representative of the community but would help with understanding what variables influence production. Despite these methodological limitations, our results clearly show that for most households with fixed camp mobility in a village, climate primarily dictates livestock health and production in any given period. There are few individual-level herding decisions that families can make to avoid drought impacts once a drought begins. There might be community-level actions that can make a difference, like establishing drought forage reserves or communal reductions in livestock numbers; however, this is speculation. Another limitation is that in this research, we only looked at the ability of conservancies to provide drought forage; there may be other customary institutions that are more appropriate to accomplish this goal.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

In this chapter, I describe the conclusions and make recommendations from my research and Ph.D. experience in three sections. First, I provide a synopsis of the main research conclusions from the three previous research chapters. I reflect on the significance of these findings based on the scientific literature and make recommendations for future studies. I then describe the implications of this work for community-based rangeland management efforts. I focus my recommendations on non-government organizations (NGOs) and government development agencies working with pastoral communities in dryland regions. In the final section, I describe my actions to make my research a collaborative effort with stakeholders of community-based rangeland management. I then reflect on how well these actions accomplished their goal of improving how science serves society. In this process I make conclusions about how I might improve my future collaborative scientific approach.

5.1. Main Research Messages

Chapter 2: A Samburu pastoral perspective on drought crises and their causes

Conclusions. Pastoralists regard severe droughts as crises that significantly impact their lives. I found that the Samburu people have two words, *ngolong* and *riai*, that refer to dry periods that meet a scientific definition of socio-economic drought (Kallis, 2008; Wilhite and Glantz, 1985). *Riai* are severe droughts and are categorized as periods when livestock die and people significantly suffer. For the Samburu people these severe droughts were crises, that is a period

that necessarily has negative consequences, and they did not think all low-precipitation anomalies were severe droughts. Respondents identified nine severe droughts that occurred between 1970 and 2017, on average every five years. The 1984 drought was ranked 1st with the worst impacts, followed by the 2009, 2017, 1996, 1993, 2005, 1981, 1976, and 1982 droughts.

I described how Samburu pastoralists understand drought in relation to livestock forage sufficiency and its diverse determinants, such as lack of rainfall, violent conflict, livestock competition, and environmental conditions. The Samburu regard lack of rainfall as a major cause of a drought crisis. However, livestock forage sufficiency (whether forage was sufficient) largely determines how they categorize and rank dry periods. The amount of forage–but also water and disease–will determine livestock suffering during droughts. Livestock suffering (or well-being) during a dry period determines how Samburu pastoralists categorize these dry events. To Samburu pastoralists livestock forage sufficiency is dependent on availability (including abundance and accessibility) and demand from livestock (species and numbers). Determinants of availability and demand include grazing practices, violent conflict with other ethnic groups and the Kenyan army, cultural practices (including the need to propitiate God through good internal social relations and women-led rituals), climate change, the environmental context (status and drivers of current vegetation species and abundance), as well as lack of rainfall.

Samburu pastoralists also perceived environmental conditions in which droughts occur changed over their lifetimes and these changes affected their drought vulnerability, potential livestock production, and need for livelihood adaptations. Samburu pastoralists understood livestock forage growth patterns depended on the plant species present. They described how the 1984 drought caused and began a trend of significant unwanted environmental changes. Over their lifetimes, study respondents observed significant reductions in grass species and abundance

and increases in undesired, non-palatable, plants. This co-occurred with heavy soil erosion, which changed the soil color in many areas, and a major loss in the number and kinds of large mammalian species present. After 1984, pastoralists perceived that vegetation shifts made cattle more vulnerable to droughts and decreased overall cattle production. They viewed the changing environment and the impact from specific droughts as interconnected, creating the need for Samburu pastoralists to change their livelihood practices.

Scientific recommendations and reflections. There is significant value in ethnographic scientific approaches for the study of drought and climate change in pastoral systems that others have called for, but few have conducted (Conway et al., 2019; Galvin et al., 2020). More studies are needed that describe pastoral perspectives of drought and its causes. My findings provide a basis of understanding drought as a problem that leads to significant suffering and livelihood adjustments. The results in Chapter 2 on pastoral definitions of drought fills a significant gap in the literature. One notable exception is the work describing how Mukugodo-Maasai from central Kenya define and experience droughts. They appear to have similar ideas as the Samburu: drought is a crisis period, but they have a less nuanced terminology that does not include distinct thresholds to categorize dry periods and crises (Herren, 1991). More recent studies rarely, if ever, present pastoral definitions of drought. They may present timelines of perceived droughts but with no explanation why certain events are included or excluded (Ifejika Speranza et al., 2010; Miller et al., 2014). These studies are valuable, but to understand drought decision-making or how experiences are changing, it is necessary to take a careful ethnographic perspective.

There is a growing opportunity to understand drought vulnerability by comparing drought exposure and the coping strategies that pastoralists implement in response to drought. Other studies created drought timelines with pastoralists but do not clearly identify what qualified as a

drought from a pastoral point of view (e.g., Huho et al. 2011; Ifejika Speranza et al. 2010; Miller et al. 2014). Vulnerability is exposure plus sensitivity (Adger, 2006). Without additional information, researchers cannot answer whether changes in the frequency or severity (measures of vulnerability) of pastoralist-perceived droughts are from changes in exposure or sensitivity. Likewise, assessments that are solely based on remote sensing of forage availability are limited in their ability to identify drought-crises (pastoralist perceived droughts) because they do not include an assessment of forage accessibility and demand. These studies only indicate that pastoralists were exposed to a drought. I identified nine perceived severe drought events in which livestock died from the 1970s to 2017, this represents times when pastoralists were vulnerable to drought. I was also able to measure and rank vegetation greenness (NDVI) anomalies from 1981 to 2013, these events measure exposure to drought conditions. I was then able to compare Samburu perceived droughts and their ranked impacts to ranked vegetation greenness (NDVI) anomalies to better identify periods of high resistance and vulnerability to low forage production, a vegetation drought. This method identified that there were periods like the 1984 drought when pastoralists suffered more than would be expected from the measured lack of forage production. There were also periods, like 2011, when pastoralists resisted the impacts of a severe lack of forage production. This helps identify topics and specific time periods for further discussion with pastoralists about what causes a drought crisis. I suggest that other studies use this method to improve our understanding of the effects of climate change and social-ecological development in relation to droughts.

Chapter 3: The drought adaptation process of Samburu pastoralism

Conclusions. In chapter 3, I show that Samburu pastoralists accelerated an anticipatory adaptation process (as opposed to maintaining existing coping strategies) to diversify their livelihoods from cattle-centric husbandry to reduce suffering during droughts. Pastoralists use anticipatory adaptations to prepare for future droughts (there have been five more severe droughts since 1984) and to adjust to new social and environmental circumstances (Thornton and Manasfi, 2010). Samburu pastoralists remembered that the 1984 drought killed many cattle and people. Following this drought, Samburu families began sending their children to school in much greater numbers. Women increased their roles and provided more labor to replace the lost child labor and to help raise increasing numbers of sheep and goats. Women are what ultimately facilitated the diversification of livelihoods away from cattle-centric production after 1984 and later droughts. Pastoralists used other anticipatory adaptations at the same time, such as diversification of livestock holdings to include camel husbandry. And schooled youth brought more diverse knowledge into families and students, once adults, created many new adaptation strategies. For example, they contributed to greater income diversification by starting small businesses and using new technologies to assist with livestock movements during the 2017 drought. These adaptations provided pastoral families more coping strategies that they thought reduced drought impacts on their well-being. However, they did not necessarily increase cattle well-being because of the concurrent (and negative) vegetation shifts since 1984, during more recent droughts. These more recent pastoral adaptations also allowed them to more easily recover livestock numbers following the 2017 drought compared to previous drought recovery periods.

Scientific recommendations and reflections. Understanding the drought adaptation process, in relation to specific drought events over time, allows us to assess how adaptation

strategies are interconnected with one another and to drought vulnerability. I classified these strategies according to when they occurred in relation to drought occurrences: anticipatory (before), coping (during), and recovery (after). This simple structure showed how adaptation decisions were highly interconnected and supported each other through time. It became harder to judge any adaptation (e.g., increase in sheep and goat husbandry) as a maladaptation, because even if the Samburu perceived negative consequences, they also understood how it supported other essential, positive adaptation strategies. Adaptation theory and research would better support social-ecological well-being during droughts if it helps CBRM stakeholders see relationships among adaptation strategies. In the context of science to support CBRM organizations, this may allow people to more carefully consider adaptation strategies in a greater adaptation process context. This understanding allows better evaluation of when benefits and costs accrue from adaptation strategies and how benefits from one strategy support implementation costs of another strategy over time. This knowledge can help identify ways CBRM can support the pastoralist drought adaptation process. For example, CBRM programs might increase education bursaries for families that reduce shoat numbers or follow grazing programs to make up for the lost benefits from household shoat production.

Livestock recovery is an essential part of the drought adaptation process in pastoralism, and I recommend it should be better emphasized in adaptation theory. The Samburu communities described how a strong livestock recovery process was heavily reliant on good social networks and relations and gifts from those with larger herds, but also recovery was easier if they also used some anticipatory adaptation strategies. For example, when women raise sheep and goats, pastoral families built up livestock wealth faster by breeding or buying and selling shoats at stock markets. Also, families used income from new businesses or their schooled children with

employment to purchase livestock at markets following droughts. Livestock recovery is part of the adaptation process because it is part of the same decision-making process. It is an action to reinvest in a livelihood that matches the improving environmental conditions following a drought. Livestock recovery requires resources that otherwise could support different anticipatory adaptation strategies; it has trade-offs. Therefore, livestock recovery should be included in pastoral adaptation assessments.

Chapters 2 and 3 serve as a drought baseline assessment of severe droughts since the 1970s in the Samburu southeastern lowlands. As future dry periods occur in Samburu County, using this study will make it easier to compare how pastoral drought vulnerability is changing over time. If the current apparent trend of more frequent and severe dry periods continues in this region (Ouma et al., 2018), this baseline information may help compare how pastoralists perceive their suffering and better assess what adaptations or adaptation processes help make them less drought vulnerable. More ethnographic studies are needed to capture different pastoral group experiences with drought to understand the effects of ongoing climate change and adaptations in different social-ecological systems. Other datasets will allow us to compare how different pastoral groups adapt to drought over time.

Chapters 2 and 3 show that Samburu pastoralists perceive that their drought coping strategies have reduced their suffering during drought. Even though the meteorological droughts and vegetation droughts are likely becoming more severe (Ouma et al., 2018; Pricope et al., 2013; Chapters 2 & 3), their impacts are not. This disconnection occurs because people do not 'feel' the impacts of drought as strongly because they are less reliant on cattle and have more diversified incomes. Droughts are still a major issue and perhaps the greatest issue to address in this region, because they are the pivotal periods when people suffer and their coping capacity is

tested. Reduced drought vulnerability does not mean cattle are necessarily less vulnerable to death during drought. Dry periods with cattle death are still occurring frequently despite that fact that average cattle numbers have dropped approximately 25% since 1977 (Ogutu et al., 2016). This might indicate that the decrease in cattle numbers matches changes in forage production (vegetation shifts) or accessibility (fragmentation); otherwise, reduced cattle numbers would have likely resulted in greater cattle drought resistance and less frequent pastoral droughts. It appears that diversification of livelihoods has reduced drought impacts on pastoralists, but, so far, none of the pastoral adaptation strategies have solved some of the rangeland management and environmental challenges. This might be changing with the advent of community conservancies, but pastoralists did not perceive that conservancies created major improvements in drought vulnerability as of yet.

Chapter 4: Effects from drought and conservancy forage reserves on sheep and goats

Conclusions. I found that following the 2017 drought sheep and goat body condition and market value (four variables) each increased 43 – 117%, but, generally, differences in household herding practices had little influence on these drought impacts. Among households, herder age, herder gender, herd size, and daily distance traveled varied considerably. I therefore found it surprising that herder age, herder gender, herd size, and daily distance traveled had little influence on the vegetation greenness that sheep and goats accessed, or sheep and goat body condition or market value. However, there were two exceptions. First, herd size was a significant predictor of sheep and goat market values during a peak drought monitoring period, with larger herds having higher market values. It is possible larger herds were receiving better veterinary care, but I am unsure of the causal mechanism in this case. Second, herds that accessed greener

vegetation during a pre-rain green-up period (very end of the drought) were more likely to have higher sheep and goat market values. I suggest this was the only period when careful directed herding could result in significant differences in forage accessed. These findings were true for households that kept sheep and goat herds within the permanent community settlement and did not move them to new corrals to access better forage. My findings may show the importance of community rangeland management because forage availability and accessibility at the village scale appears to be what determines sheep and goat production for all households, not current herding practices. The only other management option is to support large scale sheep and goat herd movements, but the trade-off is that sheep and goat production who travel far away would not be nearby to support settled families.

I found, during the 2017 drought, that drought forage areas regulated by community conservancies had minor benefits for sheep and goat herds. Better management of drought forage reserves may improve these drought benefits. I did not assess how these conservancy drought forage reserve benefitted cattle or wildlife (their primary purpose) but community members also used these areas for sheep and goat grazing. Drought forage reserves provided access to higher shrub cover than in the village grazing areas. This did not reduce drought impacts on sheep and goat condition or market value compared to the village without access to a drought forage reserve. However, there may be a risk for pastoralist villages that attempt to establish a drought forage reserve. One village (Ngutuk Engiron) neighboring a conservancy drought forage reserve did not access it (likely because other villages had ‘robbed’ the grass earlier). This village suffered slightly higher drought impacts on sheep and goat production than the village without access to a drought forage reserve (Naisunyai).

Scientific recommendations and reflections. Rangeland scientists working in CBRM should monitor and evaluate livestock forage sufficiency and its determinants: forage availability, forage accessibility, and livestock forage demand. This will help them better understand what causes drought from the pastoralist perspective. Some of the techniques used to make measurements in Chapter 4 may be helpful in this process. This recommendation is made because forage sufficiency, particularly availability and accessibility, was the Samburu pastoralists' main indictor of drought severity. To them, drought was caused by more than lack of rainfall (Chapter 2). A focused monitoring and evaluation of forage sufficiency may improve our understanding of what causes a drought crisis from a pastoral point of view. Knowing and predicting the status of forage sufficiency could help assess what drought adaptations might be most effective in CBRM, for example. Pastoral customary practices rarely, if ever, put limits on livestock numbers. If livestock mobility continues to be constrained from land fragmentation and sedentarization (Galvin, 2009; Reid et al., 2014), it might be helpful to learn with pastoralists how livestock populations could be controlled to reduce drought vulnerability. Alternatively, is the establishment of drought forage reserves sufficient to prevent livestock death without livestock limitations? Monitoring tools like satellite remote sensing combined with ground verification of forage availability and GPS tracking of herd movements to understand forage accessibility is valuable for assessing forage sufficiency and answering these kinds of questions. This is particularly informative when these technical tools are also connected with community qualitative descriptions of livestock populations and vegetation availability or accessibility. A cautionary note, we did find that household reported shoat numbers were somewhat unreliable. Thus, a combination of research methods is helpful to study rangeland dynamics and drought vulnerability

Research is needed to understand how to increase rangeland plant heterogeneity to help reduce mobility requirements and drought impacts on sheep and goats (Fuhlendorf et al., 2017). Functional heterogeneity in rangeland natural resources can help reduce seasonal drought forage variation and thus reduce livestock mobility requirements (Fuhlendorf et al., 2017). For example, CBRM practitioners in Samburu focused on cattle grazing, might manage wet season grazing areas for annual grasses and manage dry season grazing areas to include more perennial grasses and small shrubs that are likely to maintain greenness into the dry season. Or, they could manage some areas to include *Vachellia tortilis* or large shrubs that provide forage for goats during dry and drought periods. However, I am aware that the idea that pastoralists have high degrees of control over dryland plant communities may be limited in some settings (Vetter, 2005). In chapter 3, I concluded that sheep and goats, from the Samburu perspective, were essential to supporting other drought adaptation strategies associated with sedentarization like schooling youth or diversifying non-pastoral incomes. I concluded in chapter 4 that households had limited herding practices to avoid drought impacts on sheep and goats, but that community conservancy drought forage reserves (for cattle and wildlife) could benefit sheep and goats during droughts. While CBRM is designed to support cattle mobility at larger scales during droughts, conservancies should also seek to support sheep and goats during droughts to help sustain settled families. I found some evidence that if conservancies current restoration programs in drought forage reserves are able to increase rangeland plant heterogeneity (Kimiti et al., 2017; Odadi et al., 2017), it would likely reduce the negative impacts on livestock during drought periods. My research indicated shrubs and dried herbaceous litter may be an important source of drought buffer forage, but more investigation is needed about what plant species may serve sheep and goats best, ideally with limited effects on cattle forage. While sheep and goats were moved far

away from settlements in the 2017 drought to find forage, this meant these herds could not support settled families. More research is needed to examine how to develop rangeland plant heterogeneity, in drought reserves or other locations, to reduce the need for sheep and goats to move outside of conservancies during droughts (Briske et al., 2020; Løvschal et al., 2019).

5.2. Implications for Community-Based Rangeland Management

In this section, I make recommendations for community-based rangeland management (CBRM) efforts. Within CBRM, I address non-government and international development organizations working with pastoral communities in dryland regions. I do this because institutions, like the Northern Rangelands Trust, were the major actors supporting community conservancies in Samburu County. Both pastoralists and non-pastoralists administer these organizations and funding largely comes from non-pastoralist supporters of CBRM. My recommendations are likely more useful for non-pastoralists involved in CBRM efforts. My recommendations could also apply to county or national government agencies that are engaged in CBRM. My research, and my knowledge of the scientific literature, is focused on Samburu pastoralism and thus my recommendations may not apply elsewhere. Even so, I try to make the following eight recommendations at a scale that applies more broadly and can be adapted to different pastoral areas in East Africa and perhaps more widely.

1. *CBRM supporters should conduct research to understand the community's cultural drought definition(s), causes, and experience(s) to improve drought monitoring and management, including supplemental food.* Pastoral knowledge can provide an essential, direct understanding of drought. This perspective is necessary to properly discuss and respond to

drought in a CBRM setting that includes non-pastoralist and pastoralist decision-makers. This information would enhance CBRM drought monitoring and evaluation practices because it would not rely solely on environmental indicators. Integrating local knowledge with academic knowledge about drought can improve environmental management and drought adaptations to better serve CBRM goals (Bennett et al., 2016; Galvin et al., 2020; Thornton et al., 2019). For example, a pastoralist informant network across regional rangelands in Kenya could help keep track of forage sufficiency, livestock production, and human food security needs. This type of monitoring may better alert government institutions of when supplemental food relief is needed when social causes, such as violence, are likely to prematurely limit pastoralists from moving their livestock to needed pasture. Furthermore, pastoral knowledge could help identify future learning opportunities for both communities and scientists about drought environmental management (Oba, 2009; Raymond et al., 2010). Drought definitions and perceived drought impacts may differ between different cultural groups with overlapping rangeland management systems. Identifying these differences in drought perspectives may help identify areas for ethnic collaboration or conversations about effective, non-violent, rangeland management for drought grazing (McPeak and Little, 2018).

2. *CBRM supporters should evaluate the adaptation process and work to understand relationships among different types of adaptations from a community perspective to improve adaptation efforts.* Understanding the adaptation process is effective for evaluating drought adaptation strategies and vulnerability (Thornton et al., 2019). Pastoralists' descriptions of the drought adaptation process include the effectiveness of adaptation strategies, the adaptive capacity that supports adaptations, and how adaptations support one another. This helps CBRM supporters understand drought adaptation strategies in the context of the social and

environmental situation, including the most recent drought impacts. Pastoral knowledge about the drought adaptation process may help identify strategies that cause unintended harm but also benefit other desired adaptation strategies. These adaptations are sometimes labeled as a maladaptation (Magnan et al., 2016), but this label may be misleading because some harm may be required to achieve other desirable ends. There may be an opportunity for CBRM to reduce negative impacts from certain adaptation strategies (like sheep and goat husbandry). If discouraged, CBRM should help ensure the adaptation strategies or outcomes these undesired activities do support are still benefited in other ways.

3. *CBRM practitioners in northern Kenya, and likely many other East African rangelands, should prioritize the reduction or elimination of violent conflict to avoid drought crises.* A key finding from the Samburu perspective is that ethnic violence was the major contributor to livestock death and human suffering during periods that lacked rainfall, and thus caused them to experience lack of rainfall as drought. The Samburu identified ethnic conflict as a cause of all nine severe droughts since the 1970s; no other cause (besides lack of rainfall) so consistently played a role in causing a dry period (lesser drought) to become a severe drought with livestock death. CBRM efforts should support an adaptation process and rangeland management actions to prevent dry periods from becoming true droughts. They likely would find greatest success if they could help reduce ethnic conflict that occurs when the only remaining cattle forage is on or across ethnic boundaries. CBRM practitioners should also help oversee, if possible, when national armies are implemented as security to reduce ethnic conflict. These forces can contribute to a drought crisis themselves, through unintended or malicious actions, as occurred during the 2009 Samburu drought.

4. *CBRM should support women's adaptive capacity and thus their voices and involvement in CBRM.* Women were fundamental to beginning major drought adaptation processes in Samburu society. They were a critical source of drought adaptive capacity. While I do not encourage CBRM to undermine male-oriented customary institutions designed to promote rangeland management and pastoral well-being, it may be necessary to advocate for the inclusion of women in CBRM. Some women study participants expressed their desire to be involved in CBRM (and their frustration with men's limited roles in the drought adaptation process) and can explain how their participation should be encouraged. Our findings may help Samburu men better appreciate drought adaptations and livelihood improvements that women strongly influenced. While men and women perceived drought impacts similarly there are likely different actions that should be taken to support men and women to reduce drought vulnerability. The improved inclusion of women in CBRM will likely further their ability to improve the drought adaptation process and make sure a more equitable share of the labor burden is distributed to men. Collaborative studies that examine the drought decision-making process and well-being of women during droughts will help further equitable and just CBRM practices, which likely also improve drought adaptive capacity (Walker et al., 2021a, 2021b).

The four remaining points are made with less evidence directly from my research; they are based on my greater personal experience in Samburu County and the scientific literature. I include these points as suggestions for CBRM programs to discuss with pastoralists and to potentially enact for experimentation.

5. *CBRM practitioners and researchers could document drought suffering to better understand how to improve human well-being.* Studies and frameworks to describe cultural perceptions

of human well-being are valuable but may be difficult to develop and maintain as cultures change and may be less useful to CBRM practitioners. A focus on human well-being may delay or overcomplicate actions to reduce drought suffering. In the dissertation I was able to describe drought impacts related to suffering from a Samburu pastoral perspective. This kind of study may better identify areas for immediate action to alleviate suffering, without a more complicated assessment that culturally defines well-being. It is unclear whether studies that focus on describing what creates well-being, a more difficult concept to define, will better identify actions to reduce drought vulnerability than studies focused on suffering (for example, Woodhouse and McCabe, 2018). In my opinion, understanding what will make a person happy is complex, but understanding what creates suffering is simpler.

6. *CBRM practitioners might improve internal grazing regulations and the establishment of drought forage reserves (also used for wildlife conservation) by incentivizing desired household herding practices, not punishing undesirable practices.* It appears that common pool resource management theory and current CBRM efforts focus on punitive enforcement of grazing regulations (Ostrom, 1990). Samburu pastoralists knew they would be fined livestock if caught violating conservancy grazing rules. Based on anecdotal evidence during my dissertation research, many herders broke conservancy grazing rules. Herders also were unaware of grazing rules from these new institutions, and some did not want to interact and give legitimacy of power to community conservancies. Some of these grazing regulation challenges could be avoided, and increased herder engagement could be stimulated, if grazing regulations were made with incentives for specific herding practices and not punishments. For example, livestock vaccinations or other veterinary care could be provided to herds grazing in designated seasonal grazing areas. This may help reduce disease risk and

offset any livestock production losses from limited forage. The idea is that communities would set their rules and the conservancy would help create and administer the incentive programs. These programs might encourage conversations between herders and CBRM managers, without the threat of punishment. This might also allow conservancies to identify when or for whom certain grazing rules are too difficult to follow. Others have found that it is harder for pastoralists with small livestock herds to meet the mobility requirements of some grazing regulations (Glew et al., 2010; Pas, 2018). Community conservancies already have programs that disperse education bursaries or facilitate livestock markets and perhaps these programs could be reoriented to be administered to households that are able to graze in desired areas at designated times. This might be easier to monitor than scouting conservation zones or chasing herders in undesired locations.

7. *CBRM practitioners could support households to amalgamate herds with one another and reduce the use of young children herders.* The Samburu perceived livestock diseases as a major barrier to combining their herds with their neighbors' herds. There might be added benefits to CBRM administering veterinary care, especially during post-drought disease prone periods (Catley et al., 2014), that allows households to combine herds and reduce labor. I documented a large number of children as young as six years old that were primarily responsible for herding their family's sheep and goats. This could be avoided, and these children might be more likely to attend school, if households were able to avoid their fears of livestock diseases and work together to use older herders. Alternatively, elders could be incentivized through reward programs (lottery, randomly) to take up herding sheep and goats during school days (a low number of elders do currently herd sheep and goats so their children can attend school)

8. *CBRM practitioners might better support pastoralist households during droughts through a guaranteed basic income to encourage diverse drought coping strategies.* Part of the current drought problem seems to be that pastoralists are too livelihood and food insecure to take risks or make preemptive decisions to avoid drought consequences. For example, many households have livestock for subsistence needs including food. This makes it difficult to sell large numbers of livestock or move livestock away from the settled family even when they foresee the onset of an abnormal dry period. Based in large part on the work of NGOs (like GiveDirectly) and other development studies (e.g., Banerjee and Duflo, 2011), I suspect direct payments that secure a basic income to adults and herders during droughts may allow pastoralists the flexibility to pick coping strategies that work best for them. CBRM could do this in conjunction with community discussions to remind pastoralists of their diverse options as some options may be more appropriate for some households but not all. The option to move, sell livestock, or avoid conflict areas all become possible if basic needs are met and pastoralists know their families will have a secure income during a drought. These practices may also prevent livestock losses and allow for the better reinvestment of funds into recovery or diversification strategies.

5.3. Reflection on the Collaborative Research Process

In this section, I describe my collaborative research efforts with stakeholders of community-based rangeland management in the lowlands of Samburu County, Kenya. I introduced this collaborative approach, its intentions, and why I chose it in the dissertation's introduction chapter. I reserved describing specific actions until now so that I could reflect on

how well I accomplished my goal of improving how my science served society. My goal here is to reflect on how I might improve future collaboration with pastoralists and CBRM efforts.

I made an earnest effort to initiate collaboration in a Kenyan location that fit my research interests, where I was welcomed, and to identify rangeland management challenges that would serve the community. I first traveled to Kenya in June 2014. During this trip I visited different rangeland regions and I identified that working in northern Kenya would fit my research interests well. I felt initially welcomed to collaboratively build ideas and conduct research by community conservancy staff and the Northern Rangeland Trust that supported community conservancy work in Samburu County. In June 2015, I returned to northern Kenya and connected with Northern Rangeland Trust personnel, four community conservancies in Samburu County, rangeland scientists and managers in the region, and pastoralists in Laikipia, Samburu, and Marsabit Counties. I contacted many people through my initial friends from Samburu County, but I also made a concerted effort to meet others more randomly and learn from a range of CBRM stakeholders. For example, I traveled to villages or livestock markets with permission from local authorities and would ask to have conversations with different pastoralists, making sure to speak with adult men and women and *lmurran* (Samburu bachelor-warrior-herders). These discussions would last about an hour or so and were held with individuals but also often small groups. I was most interested in hearing what challenges they faced in pastoralism and trying to directly or indirectly identify challenges or research questions to address. Another collaborative learning practice that taught me a great deal was taking plant walks with local Samburu pastoral experts. They would take me on walks to identify plants, describe their uses and if they were unwanted or harmful, and describe how different plant species had changed in abundance over recent decades. This activity, that I repeated on several occasions, and related

discussions with pastoralists, helped me feel secure in understanding and developing a shared research goal: to understand how rangeland ecology for improved pastoralism and reduce suffering. In this way, we developed a shared collaborative purpose, and thus my research was not solely designed to answer questions for my personal or the scientific community's interests. I continued to follow up and refine my understanding of pastoralism in a third trip in January 2016 before developing a final dissertation research proposal. I felt welcomed in this process and developed an official collaboration and permission to do research in the area with Northern Rangelands Trust and the Samburu community conservancies. I also had created an unofficial collaboration with pastoralists–including friends–not directly involved in community conservancy activities.

During my initial trips to Kenya, it was a benefit to have some discussions with pastoralists without taking many notes or audio recording them, but this also hinders my ability to reflect on the collaboration process. I was advised to speak with them without these distracting activities and I think this helped pastoralists feel that I was listening better without a fixed agenda. There did appear to be a difference in how conversations flowed for the few discussions where I took copious notes or made an audio recording. However, even though this was not a part of my specific research study methods, I do regret now not documenting what meetings I had, the major lessons learned from each, and how they influenced my research questions. It is difficult to truly reflect and improve upon my collaborative research process without some reminders or analysis of how collaboration was established. For example, field notes in the style and practice of anthropologists would be an appropriate practice for me to implement.

Collaboration with CBRM stakeholders in northern Kenya helped my research remain flexible in the face of unavoidable barriers. In January 2017, I arrived in Samburu County with

the goal to study how community conservancy or village level cattle grazing regulations influenced livestock movements, forage accessibility, forage availability, and household livestock holdings. Cattle grazing regulations seemed to be the collaboratively identified management challenge to address. But when I arrived, a major drought was occurring, no community conservancy cattle grazing regulations were being implemented, and there was significant ethnic violence and conflict with the national army in the remaining cattle grazing areas. Through collaborative discussions, and advice from my academic advisors, I was able to reorient the project to focus on the obvious challenge, drought. Through discussions with pastoralist women and community conservancy staff, I was also able to quickly redirect my research questions to focus on sheep and goats that supported settled families, particularly women and children, during droughts. The collaborative process helped my research be flexible so I could shift my focus to the most relevant challenge (drought) that people were experiencing at an important moment.

The collaborative approach led to an ethnographic approach that had significant benefits. I also benefited from taking time to continue to learn from pastoralists and adapt my research as I learned more. I focused first on the sheep and goat grazing portions of my dissertation research while I continued to develop a better understanding of what additional research chapters would serve the Samburu community. This slow process gave me time to learn what many Samburu pastoralists wanted or needed most, which was for their voices to be heard. Samburu pastoralists wanted to have the community conservancies and supporting NGOs learn how they viewed their lived experiences with drought. I did not begin community focus group discussions to gain an ethnographic understanding of drought and drought adaptations until seven months into my fieldwork. I appreciate now that this long, slow collaborative process led to better research

questions that were more likely to serve the community. I also consider an important part of the collaborative process to include pastoralists in the interpretation of results process. My secondary community focus group discussions research was in January 2019, during which we co-interpreted some results with pastoralist participants. This led to some important findings about the livestock recovery process and perspectives on wealth inequality.

One of my larger mistakes was to not document my collaborative process. Therefore, I do not recall where some challenges arose and what exact process took place. I also failed to record where some ideas originated or how they influenced my research. This would help me understand how my knowledge and assumptions were altered over time and whether I was truly collaborating; that is, did I incorporate ideas too selectively from friendly sources or ignore ideas from any stakeholder groups too quickly? I do not mean that I believe all ideas must be included in collaborative research but that I should know how discussions meant for collaboration actually influenced the work, who might have been unintentionally marginalized, and who this collaboration really represents.

I am somewhat disappointed about how little I have currently shared results with the pastoralist communities or the community conservancies. During this work, Samburu pastoralists asked me repeatedly to make sure I shared my results back with their communities. I did this to some degree in January 2019, but it is a major regret of mine that between lack of planning to save funds and COVID-19 pandemic that I have not made a greater effort to return to Samburu County or create a study summary document that can be shared with the Samburu communities I worked with. I recently began a position with the San Diego Zoo Wildlife Alliance that will take me back to Samburu County on a regular basis, and thus I can revitalize this activity to complete the collaborative process in full.

Doctorate programs, and perhaps academic science more broadly, seem to disincentivize collaboration. The main value of collaboration to me was identifying and acknowledging my bias (described in the dissertation introduction) and improving the interest, quality, and applicability of my research questions to others. While there were many other personal benefits–for example greater personal learning and reward from working closely with Samburu pastoralists–there were few benefits that the Ph.D. program incentivized. Collaboration added significant time and expenses (many of them personally funded) to the research approach without officially distinguishing the work at the university level. In particular, there are few funding opportunities and little time granted or work encouraged to share results back with collaborators. There are also disincentives to giving collaborators control over some or all of the research questions or methods. If the project truly is meant to serve communities, then they should have a more direct say in how it is conducted, but this may threaten a student's ability to complete their Ph.D. For example, communities could require that certain research methods are conducted that are outside the capabilities of the student, or desire outputs outside the student's time available. I think academia might better support Ph.D. students learn and practice scientific collaboration if it allowed for more dynamic Ph.D. outputs, which may or may not include a standard dissertation. Additionally, I think that most collaboration should be developed through institutions, where trust can be developed with collaborators over longer periods of time. An institution can respond more dynamically to the needs of collaborators and are less threatened by changes to research goals or questions. I would encourage other Ph.D. students to learn community collaboration through a research institution that could support them and encourage relationships with the community beyond their study period.

In July 2020, I had a discussion with a Samburu assistant, collaborator, cultural ambassador, and friend about my collaborative research approach and we identified two practices that were beneficial, and he encouraged and two practices to improve upon. This individual worked with me throughout my entire Ph.D. in Samburu County, Kenya and knows me and my work very well. Through our discussion he identified two collaborative benefits, which I initially overlooked, that he encouraged: individual capacity building and diverse community member discussions. He thought some of the greatest contributions from my work (and other researchers in the area) came from hiring and training local Samburu research assistants. I worked with research assistants to train them how to collect environmental data and how to conduct surveys and focus group discussions. My colleague thought this not only helped him build skills and his desire to be a community leader but that some, if not all, of the others were similarly rewarded. He also explained how the collaborative efforts and research methods that formed many community group discussions with diverse community members had a strong (but difficult to measure) impact, because they brought diverse pastoralists together to share their knowledge with one another and discuss important social and environmental issues. These meetings helped bring people together that might not otherwise meet or take the time to talk, and these kinds of exercises made people happy to learn and consider changes needed in pastoralism. My colleague also helped identify two practices to improve: reduce pressure on Samburu to adopt foreign cultural norms and share results back with the community. He thought too often that I, and other foreign researchers, tried to encourage our own cultural morals or practices too quickly, even if unintentionally. For example, he suggested researchers pushed changing gender roles or even small customary practices like having guests sit in seats and not on the ground before researchers knew people well enough. He encouraged researchers to take more time to

build friendships and get to know people before they give direct or indirect pushback on cultural norms. Finally, he recommended that all researchers, including myself, should make a better effort to share and discuss results with the community. Still, too often, the findings, purpose, and follow up of scientific research is not given in full to the community and this diminishes their interest in science and collaboration. I hope and plan to improve upon my scientific collaborative approach in these ways and more.

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APPENDIX 1

1.1. Focus group discussion - Process and general questions

Questions and activities asked of all groups:

1. How do you (people in this community) define drought? What makes a drought a drought?
2. Has this definition of drought changed over time? Was it different in the past?
    a. Possible follow up question (PFQ), how was drought defined when you were a moran (or a young woman), or approximately 30 years ago?
    b. Why has this definition or the way they perceive droughts changed over time?
3. Since we are about to discuss droughts and how they have impacted your lives and community, what topics or issues do you think it is important we make sure to include?
4. What drought events have occurred in this community over your lifetimes, at least approximately the last 30 years?
5. (Activity) Create a timeline of these drought events for everyone to see, used as an aid for researchers' understanding and further discussion.
6. (Activity) Please rank in order these droughts in terms of which are considered the most severe in community impacts.

Process that varied by discussion groups:

Starting with the drought of the community's choice that they thought influenced them greatly and continued with additional droughts selected by researchers from the drought event

timeline the following questions were asked. The exact droughts discussed, and the questions asked varied, mostly by follow up questions.

7. How did this drought impact your community? What effects did this drought have?
    a. PFQ, what effects did this drought create on the health and survival of livestock owned by this community?
    b. PFQ, how did this drought impact the activities of the herders or the herding responsibilities of different family members?
    c. PFQ, how did this drought change how livestock were grazing (for example, where they were grazing, what they were grazing, herd movements)?
    d. PFQ, how did this drought change security and violence in the area?
    e. PFQ, how did this drought impact current grazing rules or restrictions made by the community or community conservancy? Were any areas or plants off limit and then this was changed because of the drought?
    f. PFQ, how did this drought impact the environment, vegetation, or wildlife? Were these short-term effects that were recovered or more long term or permanent changes?

Starting with the inter-drought period of the community's choice that they thought influenced them greatly and continued with additional inter-drought periods selected by researchers from the drought event timeline the following questions were asked. The exact droughts discussed, and the questions asked varied, mostly by follow up questions.

8. Following the previous drought, how did people in your community alter their behaviors and livestock management to better prepare for the next drought and its possible effects?
    a. PFQ, did the last drought change how you perceive or feel about droughts and their risk? Were you more, less, or unchanged in how you worried or felt about future droughts?
    b. PFQ, did people in the community change in which livestock they bought, sold, or desired more?
    c. PFQ, did people in the community change how they invested money in livestock or other business (income-generating) activities?
    d. PFQ, were the activities of herders or responsibilities of different family members changed to better handle the effects from future droughts?
    e. PFQ, were grazing practices altered or new community or community conservancy grazing rules created for any livestock that would better help with future droughts? Were any plants (livestock forage) restricted in how or when they could be used?
    f. PFQ, did the community change how they define, organize, or think about how they access land and areas for grazing?
    g. PFQ, were settlements (homes) in the community moved to help support changes in grazing practices?
    h. PFQ, were new water points created to better support livestock or people?

After questions 7 and 8 were asked of all drought events that the community and researchers thought important to discuss, given time. Some of the following questions were possibly asked.

9. What actions could your community take to better prepare or limit the negative effects from drought in the future?
10. Have community conservancies changed how you (and your community) think about what you have control over or are responsible for in your lives?
    a. PFQ, do you feel you have better control over preparing for drought because of community conservancies?
    b. PFQ, do you (and your community) think that the community conservancy could provide better control over preparing for drought, how and why?
11. Do current goat and sheep grazing practices in your community benefit, hurt, or have no effect the plants (vegetation) in your community?
    a. PFQ, do sheep and goat grazing practices (or their effects) increase, decrease, or have no effect on the likely impact from future droughts?
    b. PFQ, what changes could be made to livestock management to improve the environment (vegetation or wildlife) if that was the community's top priority (and they had full control to enforce those changes)?
12. How and why has your view of yourselves as pastoralists (their cultural view) changed over the last 30 years (since the first drought described)?
    a. PFQ, have droughts caused them to change who they are as a people and how they present themselves to outsiders?
13. How worried are you about droughts impacting your lives (and their community) in the future?

a. PFQ, do you think droughts will become more, less, or the same in frequency or severity in the future?
b. PFQ, are there things more important than drought (the weather) that shape pastoralism or your community?

14. Is there any other important information that you would like us to know, that you think we missed, or that you wanted to bring up related to droughts in our discussion (before we end)?

1.2. Codebook used for qualitative analysis

Broad research question with comparisons:

- In what ways are droughts perceived to have influenced changes and decision-making in Samburu pastoralism within the lowlands of eastern Samburu County, Kenya?
    - Are their distinct differences between how these changes are perceived between communities or gender groups?
        - CODES - "Case" code comparisons between responses from different focus group discussions (i.e., elders vs women; community vs community comparisons).
    - Are their distinct differences between how specific drought events caused changes or do all droughts have similar impacts and legacy effects?
        - CODES - "Case" code comparisons between responses referring to different drought events (i.e., Riai 1984 vs Riai 2017, etc.).

- Conceptual question for discussion (not answered directly) - How are these changes impacting livestock production and its contribution to society and well-being?
- Conceptual question for discussion (not answered directly) - How are these changes impacting livestock mobility, including their need and ability to move across the landscape?
- Conceptual question for discussion (not answered directly) - How has the adaptive capacity of the Samburu changed over time in their ability to respond to drought (and potentially other types of disturbance events)?

Specific research questions:

1. How do Samburu pastoralists in this area define drought and related times/events?
    - CODES - "Definition of Riai", "Definition of Ngolong", and "Definition of Mutai"
    - What are droughts perceived causes?
        - CODE - "God and drought" and (perhaps) "Conflict" (e.g., Elder-moran conflict)
    - What are people's lived relationship with drought and has it influenced ceremonial or spiritual practices?
        - CODES - "Ceremony and drought" and "Signs of drought or rain"

2. What drought events have shaped Samburu pastoralism in recent times?
    - CODES - "Case" codes from each drought event mentioned.

- How does the severity of drought events compare to one another? Are they getting more severe with time?
    - CODE - “Ranked severity of droughts” a “case” code to help keep track (but also, we have this in the excel we already created).

3. How do droughts impact Samburu pastoralism in the short-term (during a drought event)?
    - People effects?
        - CODES - “Livestock-people mobility”, “Leaving Samburu”, “Death, sickness, or hunger of people”, “Mental stress of people”, “Violent conflict”, and “Drought relief”
    - Cattle, and their forage?
        - CODE - “Cattle drought effects”
    - Sheep, and their forage?
        - CODES - “Sheep and goat drought effects” and if specifically stated “Sheep specific”
    - Goats, and their forage?
        - CODES - “Sheep and goat drought effects” and if specifically stated “Goat specific”
    - Water?
        - CODE - “Water effects”

4. How do droughts impact Samburu pastoralism in the long-term (legacy effects)?

- What are people's perceptions of long-term environmental changes due to drought (and likely also other causes)?
    - CODES - "Change in grasses and forbes", "Change in shrubs and trees", "Loss of wild-fruit", "Loss of wildlife", and "Decreased livestock productivity"

- How have people changed pastoralism to meet these new environmental conditions or prepared for future drought? What are their adaptive strategies?
    - CODES - "Shift to sheep and goats", "Shift to camels", "Income diversification and use of banks", "Increased formal education", and "Conservancies and community planned rangeland management and restoration"

- How have the changes the Samburu have made (see question above) been facilitated and/or what are the subsequent consequences of these changes?
    - CODES - "Women's changing roles", "Conflict", "Technology and transportation", "Improved social relations", and "Impact of sheep and goats"

5. What barriers exist(ed) to the way the Samburu want to change pastoralism?
    - CODE - "Barriers to adaptive strategies"

6. How have the social-environmental changes over this time period changed of the Samburu self-identify as pastoralists?
    - CODE - “Self-identity as pastoralists”

Table A1. Codes used and their descriptions to analyze Chapters 2 & 3 qualitative data, while using NVivo 12 Software program.

Name	Description
Cases - FGDs and drought events	Categorization to help with who or what is being referenced
2.1 - Drought event described	References to specific drought events, when given
Riai (2009)	
Riai (2015 - 2017)	
Riai 84	
Riai Elakira	
Riai Elkidaru	
Riai Elparna	
Riai Empurrwa	
2.2 - Ranked severity of drought	The ranked severity of each drought discussed in the drought-timeline. Need to query this against "Drought event described" to get variation of how each drought event was ranked in severity of impact. (This should match with information we

	pulled and put into excel files, i.e., perhaps this is unnecessary, duplicated.)
Conservancy	Notes referenced from particular conservancies
Kalama	Notes referenced from Kalama
Laresoro	
Lerata	
Meibae	Notes referenced from Meibae
Lekiji	
Nalepoboo	
Sera	Notes referenced from Sera
Ntilal	
Serolipi	
Westgate	Notes referenced from Westgate
Naisunyai	
Ngutuk Engiron	

Demographic	See subcodes... Notes that reference whether information came from elder men or women.
Elder men	Notes recorded from FGDs from elders (men)
Women	Notes recorded from FGDs with women
Codes (nodes)	All codes except those that are "case" classifications.
0.0 Difficult to code	A mixture of referenced notes where I (Tomas) have difficulty placing them in a single code. In these situations, I code them here and the single other code that I think best fits. I do not "double" code in any case and expect to see the relationships or similarities between codes to be analyzed later, perhaps through queries on NVivo.
1.1 - Definition of Riai	Comments that define or describe riai directly and/or compare riai to other time periods. This does include descriptions from their individual introductions that show how riai is personally thought about and how it has influenced people's lives. It does not include every comment about riai especially if it is covered by another code just how they answered the direct question about the definition of riai, from introductions, or very clear statements in which they define it.
1.2 - Definition of Ngolong	Comments that define or describe ngolong and/or compare ngolong to other time periods. Descriptions of ngolong compared to riai will by default go into "Definition of riai" unless the comment emphasizes more about what is ngolong.
1.3 - Definition of Mutai	Comments that define or describe mutai and/or compare mutai to other time periods.
1.4 - God and Drought	Comments that describe the relationship of God and drought. These comments often show how drought has been incorporated into spiritual beliefs and is a known disturbance. They also tend to identify God as the ultimate cause of drought.
1.5 - Ceremony around Drought	Comments that describe the ceremonial practices that have been developed to influence God, the rain, or drought.

1.6 - Signs of Drought or Rain	Cultural indications and/or local knowledge of drought or rain to come.
3.1 - Livestock-people mobility_Direct effect	Descriptions of how drought has directly impacted livestock (and at least their herders) and caused them to move for immediate drought mitigation. This can include broader descriptions of how livestock mobility has changed over time. It does not include comments about improved livestock mobility from transportation and technology which has its own code.
3.2 - Leaving Samburu_Direct effect	Descriptions of how drought directly caused people to leave Samburu and give up (most likely) connections to Samburu. These are descriptions of impacts during a drought, not general descriptions of people opening businesses or seeking education, but people who most likely lose connection to pastoralism in Samburu.
3.3 - Death, sickness, or hunger of people_Direct effect	Descriptions of droughts leading to the death, sickness (disease), and/or hunger of people. This includes the short-term impacts during a drought but does not include comments about long-term shifts in diet or livestock productivity (both of these are captured in two separate codes).
3.4 - Mental stress of people	Descriptions of the mental or emotional stress drought causes on people. This includes stress during a drought or even long-term worry.
3.5 - Violent conflict	Descriptions of violence (most often but not limited to ethnic violence) that increase risk to safety and/or decrease the ability to safely move (even if they do move) livestock. These can include descriptions of violence between drought events but are most often associated directly with a drought.
3.6 - Drought relief	Descriptions of organized help during a drought event from any institutional/government body. This includes county government, national government, missionaries, NGOs, and even the conservancies (if they come up).
4.1 - Cattle drought effects	Impacts, caused by drought, on cattle health and well-being. This includes short-term declines in forage specifically for cattle. It includes descriptions of diseases influenced-caused by a drought event.

4.2 - Sheep and Goat drought effects	Ambiguous as to which species or refers to the combined management (ndare)... Impacts caused by drought on sheep and goat health and well-being. This includes short-term declines in forage specifically for sheep or goats. It also can include comments about diseases influenced-caused by a drought.
Goat Specific	Impacts caused by drought on goat health and well-being. This includes short-term declines in forage specifically for goats. It also can include comments about diseases influenced-caused by a drought on goats.
Sheep Specific	Impacts caused by drought on sheep health and well-being. This includes short-term declines in forage specifically for sheep. It also can include comments about diseases influenced-caused by a drought on sheep.
4.3 - Water effects	Descriptions of how drought has impacted water resources. It also includes comments about diseases in water resources if these comments are not directly connected to a specific livestock type (i.e., cattle, sheep, goats, etc).
5.1 - Change in grasses or forbes	Descriptions of long-term changes in abundance of grasses or forbes (likely includes small-shrubs like lkitagesi) species and their causes. This does not have to be directly caused by drought, but is likely influenced by drought and subsequent human actions. Does not include short-term impacts on grasses and forbes during a drought event.
5.2 - Change in shrubs and trees	Descriptions of long-term changes in abundance of shrubs or trees species and their causes. This does not have to be directly caused by drought, but is likely influenced by drought and subsequent human actions. Does not include short-term impacts on shrubs and trees during a drought event.
5.3 - Loss of wild fruit	Descriptions of the loss of wild fruit that feed people. These changes highlight dietary shifts and shifts in environmental resources. This includes comments about general dietary shifts but does not include comments more aligned with decreased livestock productivity (though they are closely connected).
5.4 - Loss of wildlife	Descriptions of loss of wildlife or shifts in abundance of particular wildlife species. This does not have to be directly related to drought, but is likely influenced by drought and subsequent human actions.

5.5 - Lowered livestock productivity	Description of general trend of decreased livestock productivity. This does not necessarily have to be directly caused by drought (perhaps this can be coded out later) but does show increased challenge of relying solely on livestock for their livelihoods and the changing environment.
6.1 - Shift to sheep and goats	Descriptions of people shifting from management of cattle to increased reliance on sheep and goats.
6.2 - Shift to camels	Descriptions of people shifting from management of cattle or sheep and goats to increased reliance on camels.
6.3 - Income diversification and use of banks	Descriptions of increased reliance on business incomes, including tourism, or money sent from family members with jobs or businesses. This includes descriptions of people's use or planned use of banks. Mostly these are descriptions of changes in relation to drought but can describe the general trend.
6.4 - Increased Formal Education	Descriptions about how more children are going to school and its relationship to drought and livestock herding.
6.5 - Conservancies and community planned rangeland management and restoration	Descriptions of all conservancy or community planned rangeland management and restoration activities.
7.1 - Women's changing roles	Descriptions of the changing roles of women in pastoralism.
7.2 - Conflict	Descriptions of conflict (non-violent) most often between demographic groups within Samburu (e.g., women and elders, moran and elders, formally educated and elders). These conflicts are not necessarily caused by drought but are due to changes in the society and have a relationship to the changes surrounding drought. In some cases these conflicts might even be viewed as the cause of God's anger and the proximate cause of drought.

7.3 - New tools and methods	Descriptions of the use new tools and methods, especially transportation and technology, to move or make decisions about moving livestock especially during times of drought. This would include transporting in hay to feed livestock during drought, but does not include older practices of cutting branches or gathering fodder for livestock (which would be coded in "reliance and management of drought-forage")
7.4 - Social relations	Descriptions of changes to social relations, connections, social capital, etc. This especially is meant to capture changes in social relations regarding livestock movements, but does not include internal or external "conflict" or "violent conflict".
7.5 - Impact of sheep and goats	Descriptions of the long-term impacts of sheep or goats on vegetation. It recognizes the shorter-term benefits from shifting to sheep and goats but acknowledges the longer-term risks of further making it harder to keep cattle.
8.1 - Barriers to adaptive strategies	Comments that describe barriers to their ability to mitigate drought impacts in the short (during) or long-term (post drought).
9.1 - Self-identity as pastoralists	Comments that describe how changes to society or the environment have or have not changed the way the Samburu view or present themselves as pastoralists.

1.3. Chapter 2 supplemental material: Soil moisture anomalies, samburu pastoralists' descriptions of seasons, *riai* (drought) names, and age-set fortunes.

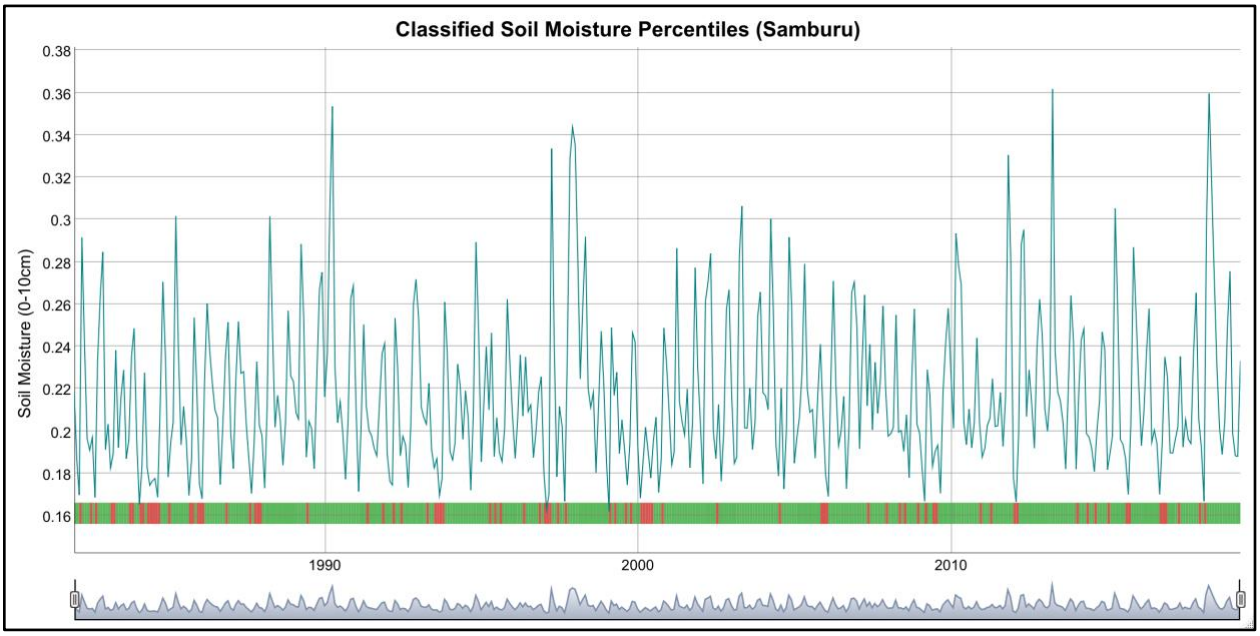

Figure A1. Soil Moisture (0-10 cm) anomalies aggregated for Samburu County based on NASA's Famine Early Warning Systems Network (FEWS NET) Land Data Assimilation System band for Soil Moisture (0-10cm) spanning from 1982 to 2019.

Seasonal descriptions

Informants also described terms for the two main rainy seasons (*lturumen* and *lgerngerwa*) and the small rains that occasionally happen in February or March (*somso orok* and *somso oibor*). Informants had terms associated with the positive impacts of rainfall, vegetation growth, and healthy livestock like *Nkupot,* when all the expected rains occur and there is food for livestock and people. They also use the term *Lari* to describe a rainy season with lots of livestock forage and food for everyone. At these times people might take their cattle for *Limmo*, early morning, before sunrise, grazing prior to milking. We did not discuss in depth with the groups

the terms associated with rainy seasons or plentiful times, and we did not assess whether these terms are widely used or how often these times of surfeit occur.

Referencing riai: *How are riai events named and commonly referenced?*

The way *riai* events are named and commonly referenced gives explanation to how people and communities think about *riai*. Almost all *riai* events were referenced by multiple names, except Riai Enaisicho and Riai Ekulu. In the process of developing the *riai* event-timeline we learned that while communities might have a more common way to reference a *riai* some people knew and used multiple names. Table 4 presents the different *riai* names and definitions and common descriptions for each of the nine *riai* events. *Riai* events were often named by the locations people moved their livestock during that drought, by contemporaneous events that were linked to the *riai*, or by the name of the *lmurran* (bachelor-warrior) age-set that was herding at the time of the drought. In one case Riai Loidikdike (2017) the name described the pattern of lack of rainfall, the drought itself. The name for Riai 84 (1984) came about because this is how outsiders providing drought relief at the time or shortly after referenced the event (the drought of 84). There were also small differences given in pronunciation of names.

Table A.2. *Riai* event names, meaning of names, and common reference-descriptions given.

Riai Name	Year	Also called	Meaning-Description

Riai Loidikdike	2012, 2015 to 2017	Riai Nachomieki Nkishu Ldonyo, Riai Lpurkel Enyokie, or Ngolong	This was the current drought and was often referenced as the current ngolong or riai and not by a specific name. The name "Loidikdike" refers to a series of droughts, which is how it was thought of in many communities. When asked when the current drought began most would say in 2015 but one group mentioned it began in 2012 and another said in 2013 because that is the last time their cattle were home and they had ceremonies with the cattle. They have gotten rain since then but never enough to fully relieve the pressure of the drought and bring the cattle home for a full season. The name "Nachomieki Nkishu Ldonyo" means the time when the cattle went to the highlands in Samburu and Laikipia. Once this drought was also called "Nachomieki Nkera Ldonyo" referencing the time when their children went to the highlands of Samburu and Laikipia. Women occasionally lamented the fact that they had not seen some of their children in years because they were out herding cattle. The name "Elpurkel enyokie" refers to the red and white soils of the lowlands which have been impacted by this drought; it was raining in the highlands. Two groups also said that this current event was not riai but ngolong and it was debated by other groups that concluded it was riai.
Riai Elpingwai	2009	Riai Nachomieki Serikali Nkishu or Riai Endeke	The name "Elpingwai" means springs, referencing those mostly around or in Buffalo Springs National Reserve which were used for watering livestock at this time. For communities along the main tarmac road this drought was referenced as the drought at the time of the road construction, which occurred in 2009. The name "Endeke" references the helicopters, which were around with the military rounding up cattle. The name "Nachomieki Serikali Nkishu" references the time the military came and took cattle. This conflict was often referenced and highlighted as making the effects from the drought much worse.

Riai Eldonyokeri	2005	Riai Elkidaru, Riai Elkishami, or Riai Elajingani	The name "Eldonyokeri" references the highlands of Mt. Kenya where some families took their livestock during this drought. The names "Elkidaru" and "Elkishami" are in reference to the *lmurran* generation that began their circumcision ceremonies in 2005 but these activities were interrupted due to the drought. “Elajingani” means flies, but we do not know the specific story behind this.
Riai Elparna	1995, 1996	Riai Elpurana, Riai Ekipindupindu, or Riai Enkeek	This drought was often referenced as the drought when the Samburu fought together with the Borana against the Somali people. The name "Elparna" is the Samburu term for the Borana people. It was concluded with the El Nino rains of 1997. When the rains first arrived they contributed to death of the livestock from cold, exhaustion, and then led to livestock skin disease outbreaks. This drought was also called "Ekipindupindu" in reference to cholera that killed people at the time. It was called by a few people "Enkeek" which means ladders; these were built and used at the time to climb trees to get birds nests and additional forage for livestock.
Riai Empurrwa	1992, 1993	Riai Engano, Riai Nanyekie, or Riai Elipis	"Mpurrwa" means sorghum which many communities remember being provided during the drought by then MP Lalampaa. This was a novel food at the time. “Engano” means wheat which was also was given as drought relief. “Elipis” is a type of livestock disease, East Coast Fever. “Nanyekie” means red, but we are unsure what story this referenced.
Riai 84	1984	Riai Eltirimin or Lamei Enkure	Community groups wanted to talk about this drought because they remembered it as a pivotal point with a severe impact that led to many permanent changes in the environment and society. It was called "84" by most people because they learned the English term from many of the organizations that provided relief during and afterwards whom called it "84". The name "Eltirimin", which was only used by one group, references a place called Ltirimin in the far north in Samburu where many people took livestock during the drought. One

			other group called this drought "Lamei Enkure". This means the dry season that was dusty. Despite this name it was still ranked by them as the second most severe riai.
Riai Enaisicho	1982		“Enaisicho” means honey, but we are unsure about the story it references. Riai Enaisicho and Riai Ekulu were remembered by fewer groups and there was sometimes confusion as to which came first. These droughts and earlier ones seemed to be where people's memories as a group started to conflict a bit more with one another and responses were not discussed as much.
Riai Ekulu	1980, 1981	Riai Ekulup	Riai Ekulu references a place called "Kulu" to the far east of Samburu in Isiolo County where people took their cattle.
Riai Elakira Elolkudongoe	1975, 1976	Riai Elkishili or Riai Elkidongae	The drought of the falling star or star with a long tail. This likely refers to a comet in the sky and based on the date provided by a few people might have been the Comet West. “Elkishili” is the name of the *lmurran* generation at this time.

Age-sets and patterns of good, moderate, and bad fortune, from Samburu culture belief

In the *siria* (good) periods people are thought to be happy, respect one another, and there is no conflict or fighting. The word *siria* means something that is straight and goes smoothly. The age-sets that belong to this *siria* period, in order from older to more recent, are: *Lterito, Lmekuri, and Lkuroro*. In the *lmaina* (moderate) periods things are not considered good or bad. The word *lmaina* means things go back and forth and are unpredictable. The age-sets that belong to this *lmaina* period are *Lmiricho*, *Lkimaniki*, and *Lmooli*. During the *lnyankik* time periods

people think that they will have many problems, lack respect for one another, and people will die from diseases and conflict. The word *lnyankik* means people eat poop. The age-sets that belong to this time period are *Lmarikon*, *Lkileku*, *Lkishili*, and *Lkishami*. The full list of age-sets back as far as one elder group member from Lekiji community could clearly remember was, in order from older to more recent: *Lmarikon*, *Lterito*, *Lmiricho*, *Lkileku*, *Lmekuri*, *Lkimaniki*, *Lkishili*, *Lkuroro*, *Lmooli*, *Lkishami*, then the future. As a note, the oldest individual elders we spoke with as part of the group discussions were in the *Lkimaniki* age-set and likely in their late 70s or older. The *lmurran* age-set in 2017 was the *Lkishami* and were connected to the *lnyankik* (bad) period. The next age-set of *lmurran* (not yet named) would be associated with the *siria* (good) period. Each *lmurran* age-set typically lasts around 10 - 12 years (the *Lkishami* were circumcised and initiated as *lmurran* mostly in 2006 and 2007). The name given to the age-set at the time of becoming *lmurran* stick with them for life though it might vary by region within the Samburu area. Time periods of rainfall and surfeit are needed to perform the circumcision and additional ceremonies required to initiate new boys as *lmurran* and advance the current *lmurran* to junior elder (marrigiable) status. Riai Elpingwai (2005) delayed the circumcision process of the *Lkishami*.

Table A.3. Comparison of the perceptions of men and women of r*iai* events and their severity in 16 focus groups in Samburu County, Kenya.

Riai Name, women or men	**Average of severity rank order**	**Standard deviation of severity rank order**	**Number of groups to identify it**	**Severity-area index score by gender**	**Gender Rank of riai by severity-area index score**	**Community Rank of riai by severity-area index score**
Riai Elakira Elolkudongoe, **Men, 1976**	5.57	2.44	7	0.80	**6**	8

Riai Elakira Elolkudongoe, **Women, 1976**	6.25	0.96	4	1.56	**8**	8
Riai Ekulu, **Men, 1981**	6.17	2.48	6	1.03	**8**	7
Riai Ekulu, **Women, 1981**	4.5	2.17	6	0.75	**6**	7
Riai Enaisicho, **Men, 1982**	6.00	1.83	4	1.50	**9**	9
Riai Enaisicho, **Women, 1982**	9.00	N/A	1	9.00	**9**	9
Riai 84, **Men, 1984**	1.38	0.74	8	0.17	**1**	1
Riai 84, **Women, 1984**	2.00	1.69	8	0.25	**1**	1
Riai Empurrwa, **Men, 1993**	4.71	1.60	7	0.67	**4**	5
Riai Empurrwa, **Women, 1993**	5.71	1.11	7	0.82	**7**	5
Riai Elparna, **Men, 1996**	5.29	1.89	7	0.76	**5**	4
Riai Elparna, **Women, 1996**	4.57	1.51	7	0.65	**5**	4
Riai Eldonyokeri, **Men, 2005**	5.00	1.22	5	1.00	**7**	6
Riai Eldonyokeri, **Women, 2005**	4.14	1.35	7	0.59	**4**	6
Riai Elpingwai, **Men, 2009**	3.00	1.31	8	0.38	**2**	2
Riai Elpingwai,	3.00	1.15	7	0.43	**3**	2

Women, 2009						
Riai Loidikdike, **Men, 2017**	3.33	2.58	6	0.56	**3**	3
Riai Loidikdike, **Women, 2017**	2.63	2.00	8	0.33	**2**	3

1.4. Surveys used in Chapter 4 methods

Survey 1: Record of households and participants in shoat monitoring

Date_____

Name of researcher(s)_____

Name of woman participant_____

Community Name_____

GPS Location of boma_____

GPS unit number_____

Sex and species of livestock attached to_____

Number of goats in herd (counted by researcher)_____

Number of sheep in herd (counted by researcher)_____

Number of goat kids remaining at home_____

Number of sheep kids/lambs remaining at home _____

Survey 2: Household, herder, and losses and gains

A researcher will conduct this survey and questions will be asked to the main woman of the household.

*Date (Ntarikini)*_____

*Researcher*_____

*Community*_____

*Woman's Name (Ngarna e ntomonani)*_____

*GPS unit number*_____

1. How old are you? *(Laritin aja iyata?)*_____
2. What are the gender and ages of your unmarried children and dependents and are they currently in school or herding? *(Aja ngera inonoo tanaa ngule kera niretito Laiyok o ntoiye nemeema naatii skul tanaa airitisho?)*
    a. How many girl children, too young to herd, 0 – 5 in age:_____*(Aja ntoiye niata ,keikuninii nemepuo airitisho naata laritin imet motodou?)*
    b. How many boy children, too young to herd, 0 – 5 in age:_____*(Aja Laiyok liata ,keikuninii nemepuo airitisho naata laritin imet motodou?)*
    c. How many girls, able to herd, typically above 6 years old: *(Aja ntoiye naidim airitisho naata laritin ile meiliapa?)*

i. In school:_____*(Naatii skuul?)*
ii. Herding:_____*(Nairitisho?)*

d. How many boys, able to herd, typically above 6 years old: *(Aja Laiyok naidim aritisho naata laritin ile mailiapa?)*

i. In school:_____*(Naatiii skuul?)*
ii. Herding:_____*(Lariteni?)*

3. What kind of livestock and numbers of livestock does your household have at home and 'away' from home (being herded elsewhere) and where are they currently located? *(Akwa siemi iata naa aja ne ngang ino,nalakwakuno ngang,nairititai tenalakwa,naa aji taata emanya?)*

a. Cattle: *(Ngishu)*
   i. Number at home: _____*(Aja naatii ngang?)*
   ii. Number away:_____*(Aja naatii lale anaa nkule ngoji?)*
   iii. Name of location:_____*(Aji emanya?)*

b. Camels: *(Ntamesi)*
   i. Number at home: _____*(Aja naatii ngang?)*
   ii. Number away:_____*(Aja naatii lale anaa nkule ngoji?)*
   iii. Name of location:_____*(Aji emanya?)*

c. Donkeys: *(Ngiron)*
   i. Number at home: _____*(Aja naatii ngang?)*
   ii. Number away:_____ *(Aja naatii lale anaa nkule ngoji?)*
   iii. Name of location:_____*(Aji emanya?)*

d. Goats and Sheep: *(Ntare, ngineji, o ngera)*
    i. Number at home: *(Aja naatii ngang?)*
        1. In herd: _____ *(Aja naapuo adaa?)*

        2. Kids/lambs that stay at home: _____ *(Aja lkuo lekineji o lekera natii ngang?)*

    ii. Number away:_____*(Aja natii lale anaa nkule ngoji?)*

    iii. Name of location:_____*(Aji emanya?)*

4. Who currently is the main herder of your shoats, relation to you, gender, age? *(Ngae Lchokuti le ntare inono,aji ingunakuno lochukuti?)*

    a. Relation to you_____*(Aji ingunakuno lo chokuti?)*

    b. Gender_____*(Layieni anaa ntitoo?)*

    c. Age_____*(Laritin aja eata lo chukuti?)*

5. How many shoats have been killed or lost, or born or gained in the last 30 days, since July 5th? *(Aja ntare naatara Loworu,naiminaite,naatiwaki tanaa naatapanunye teldo apa?)*

    a. Lack of food: _____*(Ntare aja ewata ngolong teldo apa)*

    b. Lost in the bush: _____*(Ntare aja naiminaite tesoro teldo apa)*

    c. Insecurity: _____*(Ntare aja etupuroyieki teldo apa)*

    d. Wildlife: _____*(Ntare aja etama loworu teldo apa)*

    e. Disease #1 – Name:_____ Number killed by disease:_____
    f. Disease #2 – Name:_____ Number killed by disease:_____
    g. Disease #3 – Name:_____ Number killed by disease:_____

h. Disease #4 – Name:_____ Number killed by disease:_____
i. Disease #5 – Name:_____ Number killed by disease:_____
(Ngarna e moyian: _____Ntare aja etara:_____)

j. Sold: _____*(Ntare aja naitimiraki teldo apa eima)*

k. Gifted away: _____*(Ntare aja ninchoiyie teldo apa eima)*

l. Ate: _____*(Ntare aja nitama teldo apo eima)*

****

m. Born:_____*(Ntare aja naatiwaki teldo apa eima)*

n. Bought: _____*(Ntare aja nainyengwaki teldo apa eima)*

o. Received as gift: _____*(Ntare aja naikinchooki teldo apa eima)*

Survey 3: Boma herd assessment

Household GPS number_____

Household name_____

	Goat or Sheep?	**Male or Female?**	**Health Score (1.0 to 5.0)**	**Estimate of value if sold in Archer's**
Livestock 1				
Livestock 2				
Livestock 3				
Livestock 4				

Livestock 5				
Livestock 6				
Livestock 7				
Livestock 8				
Livestock 9				
Livestock 10				
Livestock 11				
Livestock 12				
Livestock 13				
Livestock 14				
Livestock 15				

Overall Herd Rating (1.0 to 5.0):_____