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ORIGINAL ARTICLE

From cattle to camels: trajectories of livelihood adaptation and social-ecological resilience in a Kenyan pastoralist community

Gabriele Volpato [1,2] · Elizabeth G. King [1,3,4]

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Abstract

In drylands across the globe, natural resource-dependent societies are experiencing rapid rates of environmental change as well as transforming social, economic, and political contexts. When novel adaptation strategies are adopted in response to changing climatic and environmental conditions, outcomes are often contingent on individual households' adaptive capacities as well as broader environmental, social, economic, and political contexts. Understanding the heterogeneous and context-dependent outcomes of adaptation strategies is critical information for dryland sustainability policy, and is a burgeoning focus in climate adaptation science. We evaluated the 30-year process of novel adoption of camel husbandry by a group of Kenyan pastoralists, using a five-stage analytical approach that disaggregated dynamics in three ways: at the level of each individual who adopted camel husbandry; at the processual level by distinguishing assets that influenced decision-making, enactment, and streams of livelihood benefits; and at the temporal level by assessing changes in broader social-ecological contexts that occurred over the 30-year period. Our study revealed that adaptation unfolded as a heterogeneous, multi-phase process, contingent on individuals' different sources of adaptive capacity utilized at different junctures in their adaptation experience, as well as on temporal shifts in the broader social-ecological context. Synthesizing the findings using a multi-dimensional vulnerability framework, we concluded that because of inequality in access to assets among households and a concomitant weakening of social norms of reciprocity and social cohesion, the livelihood adaptation is generating contradictory effects on household-level and community-level resilience.

Keywords Camel adoption · Diversification · Dromedary · Kenya · Laikipia · Livelihood trajectories

Introduction

Natural resource-dependent societies exist as social-ecological systems (SES), in which people derive their livelihoods directly from local ecosystems. Across the world today, such societies face heightened vulnerability as they cope with climatic and environmental changes (Nori and Davies 2007; Agrawal and Perrin 2009; Thornton et al. 2009). These societies are often undergoing profound policy, governance, sociocultural, and economic changes that also shape and constrain livelihood pursuits (Adger et al. 2005; Fawcett et al. 2017). In order to continue meeting livelihood needs, households and communities may seek ways to adapt their resource use systems to multiple stressors, including the adoption of novel strategies (Quinn et al. 2011). Novel adaptation strategies are particularly likely to elicit transformative (as opposed to incremental) change, because the introduction of a new production system can alter so many existing variables and interactions in the SES, making the range of possible outcomes especially broad and hard to predict (Chapin III et al. 2010; Kates et al. 2012). Furthermore, households have heterogeneous capacities for adaptation, which constrain, enable, and shape choices and outcomes (Bebbington 1999; Ribot and Peluso 2003). Thus, the broader trajectory of adaptation is governed not only by the nature of an adaptation strategy

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✉ Elizabeth G. King
egking@uga.edu

[1] Center for Integrative Conservation Research, University of Georgia, Athens, GA 30602, USA

[2] University of Gastronomic Sciences, 12042 Pollenzo/Bra (Cuneo), Italy

[3] Present address: Odum School of Ecology, University of Georgia, 140 E. Green Street, Athens, GA 30602, USA

[4] Warnell School of Forestry & Natural Resources, University of Georgia, Athens, GA 30602, USA

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itself, but also by the diversity of household capacities, the complex and shifting contexts, and the interactions and feedbacks that occur as a strategy is pursued over time (Adger et al. 2012; Amaru and Chhetri 2013; Nelson et al. 2016; Simonet and Fatorić 2016). Because of these complexities, theoretically viable policies to stimulate or support adaptation may not result in the anticipated livelihood outcomes (Smit and Wandel 2006; Scoones 2009; Biggs et al. 2015). Methodologies and studies that address adaptation dynamics at multiple levels from individuals to communities, and evaluate contingencies due to temporal shifts in contexts, can provide nuanced insights to strengthen the role of climate adaptation science in sustainable development policy (Adger 2003; Roncoli 2006; Nielsen and Reenberg 2010).

Pastoralism is a common natural resource-dependent livelihood system in dryland regions across the globe. Dryland pastoralists have numerous strategies—including mobility, polycentric governance, and reciprocity-based norms and institutions—to buffer against the regions' characteristic spatial and temporal variability and unpredictability of rainfall and grazing resources (Niamir-Fuller 1998; Scoones 1998; Agrawal 2010). Yet today, many pastoralist systems are experiencing profound and rapid environmental, socioeconomic, and political change (López-i-Gelats et al. 2016). Mobility has been compromised by landscape fragmentation, loss of land, and increased sedentarization in many pastoral contexts, all of which reduce the capacity of herds to survive dry seasons and droughts (Galvin et al. 2008). Current and projected climate trends across many global dryland areas may further exacerbate sensitivity to drought (Hobbs et al. 2008; Thornton et al. 2009). Broader market integration (Lesorogol 2008), formal education (Bishop 2007), and exogenous conservation and development initiatives (German et al. 2017) affect households and groups within pastoralist communities differently, and as a result, these forces may increase inequality (Galvin 2009; Watson et al. 2016) or reduce social cohesion and cooperation within communities (Vollan 2012; Kaye-Zwiebel and King 2014).

Pastoralists often adapt to changing resource conditions by altering the composition of livestock species in household herds (Valdivia 2004; Homann et al. 2008; Seo et al. 2010; Watson et al. 2016). In Africa, the adoption of dromedary camels by cattle-keeping pastoralists in Sahelian and East African drylands has been increasing in the last decades (Krätli 2008; Faye and Bonnet 2012), bringing concomitant land use, economic, and socio-cultural changes (Faye et al. 2012). Adopting camel husbandry holds promise as an adaptation to environmental change, but is fraught with challenges: it requires costly initial investments, acquisition of multiple forms of new knowledge, and it may pose tradeoffs in household labor (Sperling 1987). However, there has been little research on the way camel adoption unfolds or the key factors involved (Fratkin 2004). Furthermore, when novel livelihood strategies such as camel husbandry are adopted over time by members of a rapidly-changing social-ecological system (SES), the contextual conditions that influence motivations and outcomes may also shift and change (Spielman et al. 2009; Triomphe et al. 2013). Studying adaptation experiences embedded in a timeline of shifting contextual factors offers a more comprehensive understanding of the interplay between contexts and experiences (Dearing et al. 2010; McDowell and Hess 2012), and can help address limitations that arise from inferring future trajectories or intervention responses based on current livelihood and contextual conditions (Adger et al. 2005; Fawcett et al. 2017; Adamson et al. 2018).

In this study, we examined the adoption of camel husbandry in a dryland pastoralist community in Laikipia, Kenya, over the last 30 years. The study area manifests patterns of ongoing declining livelihood sustainability seen in many dryland pastoralist systems, where complex suites of social, political, and environmental change are undermining customary social-ecological systems (Galvin 2009; Unks 2017). We utilized and integrated five analytical stages (Fig. 1), which have complementary theoretical approaches and methodologies. This allowed us to evaluate: individuals' heterogeneous experiences, perceived capacities, constraints, and outcomes; how the social-ecological context changed over time; and the ways that contextual changes influenced adaptation dynamics generally and for different households. By focusing on factors that afford adaptive capacity, the analytical approach allowed us to

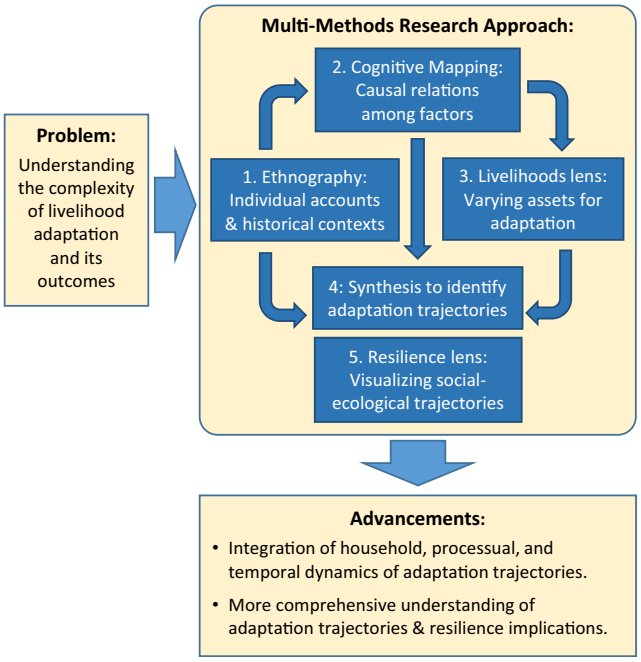


Fig. 1 Summary diagram of multi-methods research approach used for evaluating the novel livelihood adaption of camel husbandry

assess the consequences of camel adoption for household- and community-level resilience, defined as the ability to adapt and maintain livelihoods under changing conditions.

Theoretical frameworks

Ethnography and history of livelihood adaptation (step 1)

Different individuals' personal accounts of a period of adaptation can reveal (1) the importance, meaning, and relationships between factors that affected their personal experience with a novel adaptation (Bagchi et al. 1998), and (2) key contextual factors that may have influenced the longer history of an adaptation process (Roncoli 2006). The contribution of ethnographic methods is grounded on the theoretical tenet that culture frames the ways people perceive, understand, and respond to changes in their environment (Roncoli et al. 2009). Households' and communities' adaptations are shaped by what they perceive as feasible and desirable in different contexts (Adger 2003; Artur and Hilhorst 2012). Thus, people's responses to change are embedded in the dynamic localized context of the historical, cultural, and natural environments they inhabit, contexts which ethnographic methods seek to elicit while minimizing the influence of their own framings and understandings (Ford et al. 2013). Importantly, as people relate their experiences over years and decades, ethnographic approaches can reveal temporal shifts and periods in the broader *social-ecological contexts* that influenced individual livelihood decisions and their perceptions of outcomes (Nielsen and Reenberg 2010; McDowell and Hess 2012).

Inferring causal relationships through social cognitive mapping (step 2)

Cognitive mapping techniques can be used to examine the multiplicity of factors, and causal relationships between them, which influence the course of an adaptation process. By graphically representing these variables and their relations through a set of nodes and connecting arrows (Özesmi and Özesmi 2004; Papageorgiou and Kontogianni 2012), these methods are particularly useful for integrating qualitative information collected through ethnographic fieldwork in order to understand and represent the complexity of, and the relations between, variables in a SES (Singh and Nair 2014; Voinov et al. 2016). Here, we used a cognitive mapping approach (modified from Vanwindekens et al. 2013) to create individual cognitive maps (ICMs), then combined them to build an aggregate social cognitive map (SCM). By applying social cognitive mapping to the narratives elicited in Step 1, we build a clearer picture of the range of *adaptation experiences* of camel adopters, which spans multiple stages of their process, including their motivations, decisions, perceived constraints, and livelihood outcomes of camel adoption.

Sustainable livelihoods approach and assets for adaptation (step 3)

In natural resource-dependent societies, adaptation is shaped by numerous institutional and larger-scale processes, yet is often pursued and enacted at the household level (Adger et al. 2005; Smit and Wandel 2006; Coulthard 2008; Amaru and Chhetri 2013). To gain analytical traction at those relevant scales, the Sustainable Livelihoods Approach (SLA) is a broad conceptual framing with multiple variations, sharing three main commonalities: the notion that livelihoods are shaped by access to multiple forms of assets; the classification of household assets into categories of human, financial, physical, natural, and social capital (Chambers and Conway 1992; Scoones 1998; Bebbington 1999; Carney 2003); and the recognition that livelihood outcomes are governed by feedbacks between people's access to assets and their political, social and environmental milieu (Ellis 1998). SLA can be employed with varying degrees of formality, from a heuristic framing to a formal analytical tool (Reenberg et al. 2008; McLean 2015). In Step 3, we employ the SLA concept in a heuristic way to categorize bundles of adaptation dynamics, identified through SCM in Step 2, in terms of the different forms of capital relevant to them. This overlay can reveal which forms of capital are most influential at particular junctures in the *adaptation experience* (e.g., decision-making, enactment, realization of benefits). The role and relative importance of different assets may shift through time as the broader *social-ecological context* changes. So identifying the forms of capital that are related to *adaptation experiences* provides a means for relating how those processes may respond to contextual shifts in Step 4.

Synthesis to identify heterogeneous adaptation trajectories (step 4)

Adaptation trajectories emerge over time as *adaptation experiences* unfold in *social-ecological contexts*. In adaptation and vulnerability research, assessing temporal trajectories rather than current conditions is increasingly advocated, in order to reveal more nuanced and dynamic insights into how and why people may have different patterns of vulnerability, and how and why they may respond differently in the future (McDowell and Hess 2012; Nelson et al. 2014; Zheng et al. 2014; Duvat et al. 2017). To identify the distinguishing characteristics of different adaptation trajectories, we synthesized the individual accounts and *social-ecological contexts*

provided by ethnographic histories (elicited in Step 1), the *adaptation experiences* of households during the process of adopting camel husbandry (charted in Step 2), and the role of access to different forms of capital that influenced those dynamics (overlaid in Step 3). Cultural and environmental contexts shift through time, posing potentially different constraints and opportunities for livelihood adaptation (Ribot 2010). Given the rapid cultural and environmental changes occurring in many natural resource depended SES, this temporal variability in broader contexts is surprisingly understudied in livelihoods approaches to studying adaptation (Nelson et al. 2014; Cinner et al. 2015). The case of camel adoption, where the same basic livelihood adaptation has been undertaken by different individuals over a 30-year time span, affords an excellent opportunity to examine how shifting contexts influence the adaptation process itself—in terms of the access to different assets that affect engagement, the trajectories of individuals' experiences, and the livelihood outcomes that result.

Resilience lens (step 5)

The final step evaluated adaptation trajectories and outcomes in terms of households' and communities' resilience. Both the vulnerability and resilience literatures draw on the concept of adaptive capacity; adaptive capacity reduces vulnerability and also represents the capacity of people to manage and influence the resilience of their SES (Walker et al. 2004; Nelson et al. 2007; Engle 2011; Maru et al. 2014). Fraser (2007) originally proposed a framework for characterizing the multidimensional nature of vulnerability using three-dimensional plots with axes representing environmental, socioeconomic, and institutional capacities. Its subsequent application in case studies illustrated its utility: for understanding heterogeneous levels of vulnerability within and across communities; for its departure from univariate thinking about adaptive capacity as something that just goes up or down; and for visualizing more complex temporal trajectories of vulnerability (Dougill et al. 2010; Sallu et al. 2010; Fraser et al. 2011; Li and Huntsinger 2011; Sendzimir et al. 2011). We adopt the Fraser (2007) analytical approach to explore resilience because the axes correspond to the livelihood lens that we used to assess capacities, and it draws attention to the multiple sources and potential tradeoffs in adaptive capacity as dynamics evolve temporally through shifting social-ecological contexts. By comparing the divergent trajectories of camel-based livelihoods to customary cattle-based livelihoods, the analysis can reveal tensions between resilience at the household versus the community level in a system where livelihoods depend upon both individualized and communal assets (Dougill et al. 2010; Li and Huntsinger 2011).

Background

Camel adoption

Kenya, with 3 million camels or about 6% of the African camel population, is regarded as the southern limit in camel distribution in Africa (Hülsebusch and Kaufmann 2002). During the last few decades, Kenya's camel population has increased and spread as pastoralists had to adapt to an increasingly arid environment and recurring drought (Bollig 1992; Cecchi et al. 2010; Kagunyu and Wanjohi 2014). This includes recent camel adoption among the Maa-speaking pastoralists of northern Laikipia County, the location of this case study, where camel numbers rose from few to about 3000 in two decades (Jane et al. 2013).

Study site

The study site is Koija Group Ranch, located in Laikipia County, Kenya, and communally owned by Maa-speaking pastoralists (0° 33′ 25″ N, 36° 54′ 9″ E). Koija Group Ranch is 7605 ha with 2267 residents (in 2009). The area receives approximately 450 mm mean annual precipitation, and the vegetation is dry *Acacia* thorn scrub. Households tend to keep mixed herds of mostly cattle, goats, and sheep, which provide the dietary mainstays of milk and meat (Kaye-Zwiebel and King 2014), and selling livestock (particularly small stock) is the primary source of cash for other livelihood expenses. Other livelihood and income-generating activities include petty trade, beekeeping and honey sales, and external employment. In 2013, there were 225 households at Koija, with a total of 2577 head of cattle, 14,506 goats, 6365 sheep, and 139 camels (averaging 12, 66, 20, and 0.6 per household, respectively) (Unks 2017).

In recent decades, rainfall has become more erratic with more frequent and severe droughts (Franz et al. 2010), and residents' access to grazing outside the group ranch has also steadily decreased (Unks 2017; German et al. 2017). These factors have likely contributed to reported ecological changes, including severe soil erosion, decreased grass cover, thorny bush and tree encroachment, and increasing abundance of some succulent plant species (King 2008). Climate, access, and vegetation changes have reduced forage availability for cattle, sheep and goats, resulting in catastrophic losses during droughts (Letai and Lind 2013) and a 35% overall decrease in tropical livestock units (TLU) per capita from 1980 to 2016, to which the contribution of cattle decreased from nearly 90% to about 50% (Unks 2017). Today, vegetation is increasingly favorable for camels, which are adapted to feeding on trees, shrubs, and succulents (Rutagwenda et al. 1989), and camels can access forage and continue to produce milk during dry seasons and droughts when vegetation is severely limiting for other species.

Methods

Field research was conducted over 6 months during 2015 and 2016, primarily at Koija Group Ranch. We used open and semi-structured interviews, focus groups, and participant observation (Bernard 2017). We conducted in-depth (60–120 min) interviews with: 22 of the 23 active camel owners at Koija (20 men and 2 women), 6 of the 10 individuals at Koija who had camels in the past (all men), and six individuals who had never owned camels but expressed willingness to engage in camel husbandry (all men). Three focus groups were conducted with elders to explore the local history of livestock and camel husbandry. Interviews were also conducted with: 2 private ranchers engaged in camel safari, 4 members of the Somali community engaged with camel milk marketing, and 3 milk traders. Participants were given an explanation of the methodology and aims of the study, and informed consent was obtained verbally. Throughout the field study, the American Anthropological Association ethical guidelines (AAA 1998) were followed. Interviews were conducted in Maa by two local research assistants fluent in Maa and English, and in English by the first author. Interviews were recorded and transcribed with the research assistants to minimize translation errors and clarify information. Transcripts were entered into NVivo qualitative data analysis (Version 10 2012), and codes, concepts, and categories were generated during analysis. Data were analyzed using Excel to derive descriptive statistics. We used demographic data from Kaye-Zwiebel and King (2014) and Unks (2017).

To elicit ethnographic histories and adaptation experiences of camel adoption (Step 1), interviews and focus groups explored motives for wanting, having, or having kept camels; individuals' histories as camel herders, herd chronology and development, knowledge and management practices, use of camels and camel products, and constraints, costs, and losses. Interviews with other actors focused on their experiences and interactions with Koija camel herders and camel adoption over time.

For individual and social cognitive mapping (Step 2), herders' interview texts were parsed to identify and code all relationships mentioned between pairs of variables, where variables were concepts or elements of the system and relationships were directional linkages between them, as reported by the interviewee. NVivo was used to draw individual cognitive maps (ICMs) of variables and relationships for each interview (Vanwindekens et al. 2013). We generated a social cognitive map (SCM) by additively combining the ICMs from each interview, counting the number of interviewees that identified each relationship, and representing the frequency with arrow thickness in the SCM diagram. As the SCM evolved, thematic clusters emerged, broadly representing the topic prompts used in interviews: motivations for adoption, knowledge, constraints, advantages, social and cultural context.

To evaluate the SCM through the Sustainable Livelihoods lens (Step 3), variables were categorized in terms of pertinent types of capital assets. This allowed us to interpret the roles that assets and capabilities played in *adaptation experiences*. We then integrated the information yielded by the assets-based SCM (Steps 2 and 3) with the understandings of *social-ecological contexts* as people adopted camels over time (Step 1), in order to distill a synthesis of the salient trends in the adaptation process and the relative contribution of different asset bundles to the process (Step 4). Finally, in Step 5, we applied the framework on SES vulnerability and resilience from (Fraser 2007) and (Fraser et al. 2011) to the results of the synthesis, in order to characterize trajectories in terms of household capabilities, ecological conditions, and social roles of livestock, across the temporal span of the camel adoption process, and from this we made inferences about household and community level resilience.

Results and discussion

Timing and trends in camel adoption

There were no camels owned by Koija residents in 1980. In 2015, 23 households (about 10% of households) owned a total of 299 camels (Unks 2017). A total of 33 individuals at Koija had entered camel husbandry at some point, 23 of whom still had camels, and 10 had quit. We interviewed 22 and 6 persons in each group, respectively.

Of the 28 interviewees, 14 started keeping camels between 1985 and 1995, 7 started between 1996 and 2005, and 7 started between 2006 and 2014. These time periods were delineated based on trends and turning points in key *social-ecological context* conditions that influenced camel adoption, as reported by interviewees. Period 1 began in the early 1980s, when camels were first brought to Koija by a small group of Somalis who settled there. Influenced by the Somalis, the first few cases of camel adoption occurred in the mid 1980s, followed by the majority of Period 1 adoptions during the first half of the 1990s. Period 2 began with the departure of the Somalis from Koija in 1996 due to shifts in inter-ethnic alliances. This time period also marked the beginning of greater livestock market expansion in the area, which has continued to the present. Period 3 began in the mid 2000s when market demand and prices for camels and camel milk rose to levels that stimulated a more market-oriented period of camel adoption at Koija, from 2006 to 2014.

While most interviewees mentioned a broad pattern of environmental change in the last three decades, there were pulses of camel adoption following each of the historic droughts that occurred in recent decades, during which households frequently lost much of their cattle (Herren 1991; Letai and Lind 2013). Camel adoption was related to loss lack of milk

from other livestock for household consumption. The earliest Period 1 adoptions followed the drought of 1983–1984, with additional post-drought adopters after the 1991–1992 drought. Most Period 2 adoptions were motivated by cattle losses during the severe 1999–2000 droughts, and Period 3 adopters mentioned drought, cattle losses, and/or the devastating 2009–2012 droughts specifically as motivators.

All 28 past and present camel owners interviewed obtained their first camel(s) by exchanging cattle or using income from other jobs, livestock sales, or honey selling. None obtained camels through social means, redistributive networks, or development schemes. The dominant means of acquiring camels changed over time. Exchanging cattle for camels was dominant during Period 1, but at the end of the 1990s, with increasing market integration and demand for camels, camel prices started increasing—tripling in the last 20 years. Hence, the means of acquisition in Periods 2 and 3 typically included cattle and cash procured through other activities.

The number of camels originally purchased ranged from 1 to 20 animals. Initial herd size tended to increase through time, with concomitant shifts in expected use of the animals, from few camels (1–3) for subsistence purposes in Period 1, to the present average of 8 initial camels with increasingly common purposes of income generation. Later adopters, whose intention was to use camels to generate income, paid larger costs of initial investment due to both higher prices of camels and bigger initial herds.

After initial acquisitions, camel herd size and structure tended to fall into three categories, which related to herders' main use of camels. Small herds (1–6 camels) tended to be mostly females, and were usually oriented toward milk production for family consumption. Medium herds (7–19 camels) tended to have either relatively high number of males (up to 50%) when owners are involved in camel safaris, or a predominance of females when owners were oriented toward milk production for home consumption and for trade. Large herds (20–35 camels) were usually involved in camel milk marketing and had a prevalence of females, while males and bulls were sold at markets to generate further income.

Dynamics of camel adoption: social cognitive mapping

The social cognitive mapping (SCM) aggregated individual cognitive maps of 28 interviewees, and included 68 different concepts and phenomena associated with camel adoption (Fig. 2). Concepts in the SCM clustered into five main themes, which we elaborate below with nuances from interviews. Overall, the most frequently mentioned variables and connections involved: drought, environmental change, reduced cattle survival, lack of milk at home, influence of established camel owners, knowledge acquisition, camel diseases, herd management, predation and other camel losses, social aspects of camel adoption, family needs, milk availability, market involvement and income generation. An important caveat is that there were only two women who owned camels, and thus the SCM may not capture the diversity of motivations, experiences and perceptions held by women. In pastoralist systems and beyond, gender disaggregation and gendered research perspectives can reveal consequential dynamics and nuances for livelihoods and adaptation policy (McPeak and Doss 2006; Carr and Thompson 2014; Ravera et al. 2016), and are thus an important future research direction.

Drivers and motives for camel adoption

For dynamics leading to camel adoption (Fig. 2, red boxes in upper left), three main clusters of concepts emerge. The first includes livelihood consequences of environmental changes and resource access, which made local vegetation composition and structure more favorable for camels, and drove cattle losses and increased durations of cattle treks to distant grazing areas, both of which created household-level shortages of fresh milk. Twenty-four herders (86%) attributed their motives to vegetation change, cattle losses, and/or inadequate provision of fresh milk.

The second cluster related to increasing awareness of camel-keeping's potential benefits through the influence and example of local Somalis, nearby Samburu camel-keepers, and neighboring private ranches where they saw camels' potential for transport, workload, and generating income through tourism. The third cluster related to financial resources that enabled adoption. Here, people related how the cash needed to invest in camels was provided or constrained by their other livestock holdings and other income generating activities. Interviewees repeatedly stated that camels were out of the price range for many households.

Benefits of camel adoption and uses of camels

Respondents identified two main flows of benefits from camels (Fig. 2, blue boxes on right): they helped meet households' subsistence needs, and were used to generate income. In realm of subsistence uses, 100% of camel-owners used them for home milk consumption, which was the dominant motivation for diversification into camel husbandry. Camels were used by 55% of owners for transport and work, and only for meat consumption following predation or injury. Similar values for milk production and transport has been reported among pastoralists of Kenya and Eastern Ethiopia (Seifu 2011), and camel milk is increasingly important to the livelihoods of several pastoral groups of Kenya (Elhadi et al. 2015).

In terms of market-oriented uses, about 75% of the 22 current camel-owners obtained cash from camels, with most owners engaged in more than one of three main ways: 14 sold

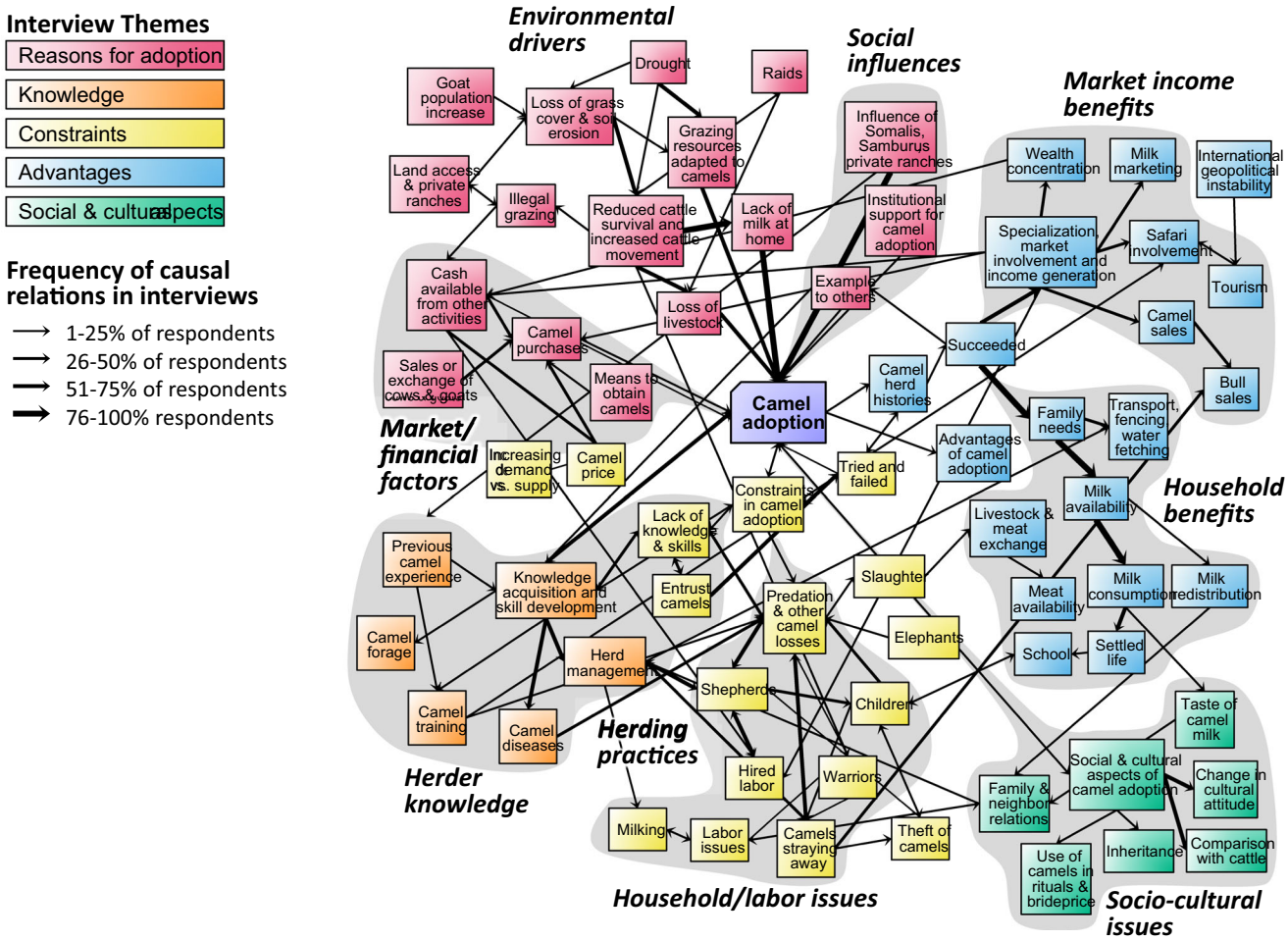


Fig. 2 Social Cognitive Map (SCM), characterizing individuals' aggregated *adaptation experiences*. Box colors correspond to themes explored in semi-structured interviews. Clusters in gray represent closely linked processes discussed in the text ("Drivers and motives for camel adoption" through "Social and cultural change")

camels, 7 sold milk, and 6 hired camels for transport and safaris. Koija herders have become progressively more integrated in emerging camel milk marketing networks, whose agents encourage them by delivering milk to processing facilities in towns. About 25% of current camel herders do not engage in any cash generating activity with their camels, either because they have too few or because they "use them as cows," kept for milk provision and as wealth on the hoof. Income obtained from camels was used to: 1) buy other livestock to rebuild herds after droughts; 2) maintain and increase the camel herd through purchasing additional camels, veterinary medicines and salt; 3) pay family expenses such as secondary school fees and hospital costs; and 4) support cattle herds by paying for veterinary medicines and private grazing fees.

Constraints in camel adoption

Beyond the high cost of acquisition, herders recounted several constraints on successful camel adoption that commonly led to camel deaths and losses (Fig. 2, in yellow, lower middle of diagram), echoing the statement by Sperling (Sperling 1987), "there is nothing easy or natural about cattle pastoralists adopting camels." Losses due to straying and subsequent predation or theft were mainly the outcomes of herd management practices, and the interplay of three factors: labor, entrustment, and small herds.

1) Labor. Any diversification process must pass through the filter of labor demand and availability (Barrett et al. 2001). Given the experimental nature of earlier camel adoption attempts, owners sought to avoid diverting adult family labor from cattle husbandry and other tasks. Many did this by using inexperienced children as camel herders, who were unable to prevent straying: "kids would come home and announce that the camels had left." Cultural identity also contributed to this, as warriors are charged with the esteemed role of herding cattle. Over time, however, more households began to see camels as being worth the labor of warriors, adult men, or hired shepherds, which reduced

losses: "both thieves and lions think twice before preying on a herd defended by warriors and grown men."

2) Entrustment. Given the attempt to spare labor and the presence of Somali households in the ranches, about 25% of Period 1 camel adopters entrusted their camels to Somalis. By doing so, herders sought to have fresh milk without the need to manage and learn about camels. When the Somalis departed in 1996, these owners struggled because they had not built knowledge, skills, or commitment to camel husbandry. Half of those owners lost all their camels thereafter. Most regretted the choice, stating that entrustment went against the widespread belief that "nobody can take care of your livestock better than yourself." Sperling (1987) reported similar difficulties for Samburu assuming care for their camels after entrusting them to Rendille counterparts.
3) Small herds. Due to lack of financial means and experience with camels, most early adopters began with few camels. Adopters with very small herds (1–5 camels) tended to lose more camels due to straying than adopters with larger herds. According to herders, camels tend to stray away looking for mates or for bigger herds when they do not feel safe and reproductively satisfied where they are. Camel straying events are especially troublesome as camels tend to cover huge distances, exposing themselves to predation and theft, as well as forcing herders to deploy time (days and weeks) and resources in their search, at times moving into ethnically contested areas.

Knowledge

Informants widely recognized that acquisition and development of knowledge and associated skills were keys to successful camel adoption (Fig. 2, orange boxes, lower left of diagram). Interviews revealed three processes through which knowledge was developed: 1) acquiring new knowledge from external sources, such as camel herders of other tribes and institutional sources; 2) self-generating knowledge through trial-and-error, observation, and discussion with other new herders; and 3) translating and adapting existing knowledge of other livestock species to camels. Herders used a combination of all three modes of knowledge acquisition.

Herders noted that prior herd management and externally-acquired veterinary knowledge was an advantage, and was usually obtained through experience working on private ranches and, more importantly, from the initial Somali residents. Yet both prior to and after the Somalis' departure from Koija, interviewees regarded knowledge as a persistent limiting factor in camel adoption.

In the SCM, two main domains of knowledge-related factors imposed constraints and led to camel losses: herd management (discussed above in the "Constraints in camel adoption" section) and veterinary care. Interviews frequently revealed efforts to adapt and translate veterinary knowledge from cattle, and secondarily goats and sheep, to camels. For example, several informants reported using cattle medicines on camels, assuming they would have similar effects on similar symptoms. While herders do build knowledge through these efforts, this approach can be challenging and costly in terms of camel losses, especially in the case of trypanosomiasis, considered by herders across the Horn of Africa to be the main disease constraining camel husbandry (Schwartz and Dioli 1992; Seifu 2011).

Social and cultural change

Livelihood adaptation entails social and cultural change, which can feed back to impel or impede the adoption of a novel strategy (Adger 2003). Sociocultural aspects of the adaptation process are shown in green in the lower right of Fig. 2. During the 30-year process, camels broadly shifted from unknown to meaningful, while inducing social and cultural change and resistance on the way. We highlight three kinds of changes discussed by informants: 1) shifting perceptions and narratives around camels; 2) increasing inclusion of camel products in food practices; and 3) evolving roles of camels in their social fabric.

1) As adopters (and a portion of non-adopters) increasingly perceived and valued camels' potential for milk and income and their importance under current environmental change, their narratives around camels have shifted from foreignness (i.e., camels regarded as wild, useless, or likened to elephants), to appraisal (i.e., an interesting option particularly for milk production for home consumption), to praise (i.e., very important to complement cattle and small livestock, providing milk and generating cash).
2) The growing acceptance of camel products and their taste seems to be increasing with use and familiarity, but has not been straightforward or uniform throughout the community. Attitudes tended to change for people who became more exposed to camel products (through neighbors, relatives, or friends) or were motivated by need for fresh milk, rather than preference for camel milk. Acceptance also varied with age: all children were seen as real or potential consumers of camel milk, but adults and elders have been slower to value camel products, and many of them dislike and avoid camel milk. Similar heterogeneous processes of cultural change have been documented in other camel-adopting cultures, e.g., the Borana (Kagunyu and Wanjohi 2014).
3) For Maa-speaking pastoralists, cattle have traditionally been at the center of cultural identity, social status, ceremonies, and norms of reciprocity. Cattle-owners

are beholden to participate in social interactions that temporarily or permanently redistribute cattle to other households, including loaning and paying bride prices in cattle. Thus cattle constitute a form of social wealth that contributes to the maintenance of social organization and cohesion. Camels are largely excluded from these practices. We found only one case in which part of a bride price was paid with camels. The cattle customarily paid as bride price are ceremonially blessed. Currently, until the elders officially declare it admissible, camels cannot be blessed. Likewise, camels are thus far not incorporated into norms of reciprocity and livestock redistribution; only one informant reported loaning camels. These constraints stem from cultural adherence to the roles of cattle on the side of elders who maintain customary institutions, but are reinforced by camel owners who use camels for income generation and perceive them, in contrast to cattle, as private wealth: "like money, they are yours, you don't have to give them in loan."

Adaptation assets and the SCM

Drawing from Sustainable Livelihoods studies, we conducted a post hoc analysis of the SCM to evaluate the relationship between adaptation assets and the decisions, constraints, and outcomes of camel adoption. In Fig. 3, we distinguish eight clusters related to access to different forms of adaptation assets, which aligned with the causally linked clusters of dynamics described above. As households varied in their access to most assets, this analysis helped us to understand the different adaptation decisions, experiences, and outcomes that were realized by different households.

Herders' motivations to adopt camels can be framed in terms of natural, social, and financial capital. Ecological changes on the group ranch affected natural capital by simultaneously decreasing the capacity to support cattle and small stock while increasing the environmental suitability for camels. These changes, as well as social capital vis a vis facilitative interactions with the Somalis, were common motivators, while differential access to financial capital strongly

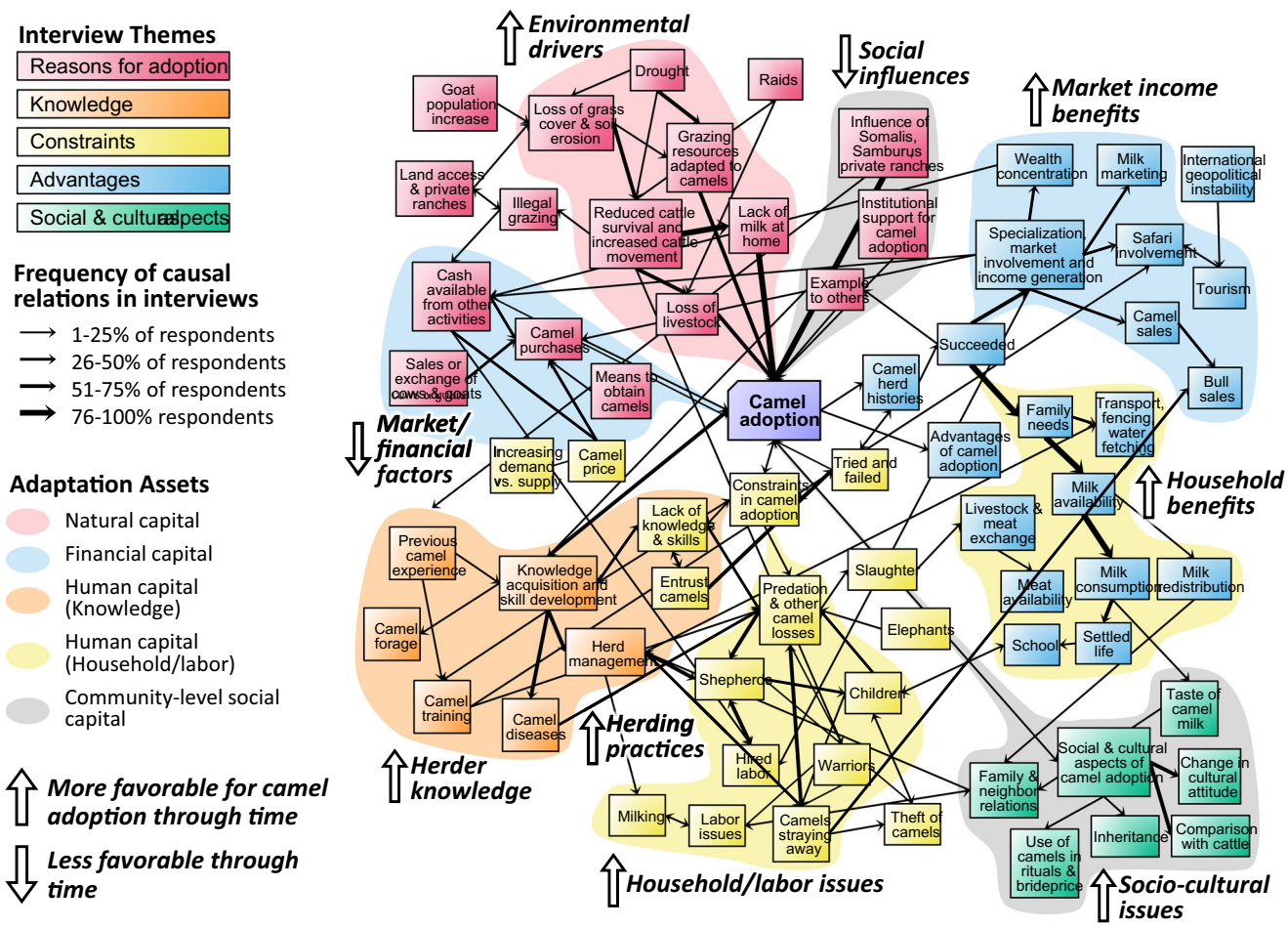


Fig. 3 Social Cognitive Map (SCM) of *adaptation experiences*. Colored envelopes correspond to the forms of assets that were central to the dynamics in the cluster (see "Adaptation assets and the SCM"). Upward and downward arrows capture the general temporal change in social-ecological contexts over the 30-year duration of camel adoption ("Synthesis of salient trends through time")

governed individuals' capacity and outcomes for camel adoption. Once adoption occurred, the critical assets for adaptation shifted to human capital, in terms of camel-related knowledge and herding skills, and labor allocation for herd management. Herders' narratives also revealed the evolving interplay between knowledge and labor allocation as a key dynamic in successful adaptation.

Outcomes were expressed in terms of livelihood benefits that contributed to different forms of human and financial capital. While a lack of financial capital prevented many households from engaging in camel husbandry, most camel owners generated financial capital through milk, animal sales, and involvement in safaris. Camels are not yet incorporated into the redistributive practices and norms that support the community-level social capital. Broadly, camel adoption is increasingly building human and financial capital for adopters, but does not contribute to social capital in the way that customary livestock species do. In the absence of redistributive mechanisms, and with a steady flow of income from camel milk commercialization, camel husbandry may increase wealth inequality in the community, and may also afford camel owners greater adaptive capacity via a wider range of coping strategies when droughts strike.

Synthesis of salient trends through time

We aligned and synthesized our findings regarding: (1) *social-ecological context* periods over the last 30 years, (2) individual accounts of herd histories and *adaptation experiences*, and (3) asset-related clusters of variables and dynamics in the SCM. This allowed us to denote general trends over the 30 year period in each of the asset-related suites of dynamics, in terms of their favorability for camel adoption (Fig. 3, arrows next to cluster labels). Seven of the nine trends were positive, except social support once provided by the Somalis, and financial assets needed to adopt camels. The natural capital shifts in forage and access to distant areas increased the ecological suitability for sedentary camels versus cattle. The four bundled dynamics relating to human capital all gradually improved among camel owners, which fed back to strengthen the array of household benefits. However, in terms of dynamics related to financial capital, rising purchase prices became less favorable for decisions to adopt camels, yet those market conditions simultaneously increased the privatized benefits garnered by those who were able to adopt. Likewise, dynamics relating to social capital became less favorable for initial decisions to adopt with the departure of the Somalis and their social support, but became more favorable for those who did adopt as the social acceptability and thus markets for camels and camel products gradually increased. By viewing these changes over time, we can see that social and financial factors underlay a community-level trend toward increasing inequality, whereby fewer residents had access to assets that afforded capacity to adopt camels, yet those few adopters were able to garner greater relative benefits from doing so.

We also found that these general trends unfolded in three phases—exploration, consolidation, and specialization—which partially coincided with *social-ecological context* periods characterized in the "Timing and trends in camel adoption" section, and were most influenced by the following variables: loss of grass cover and soil erosion (related to natural capital); terms of trade to purchase camels, average initial size, income generation, and hired shepherds (related to financial capital); and knowledge and entrustment cases (related to human capital). These combined to influence the numbers of adopters and numbers and asset profiles of herders that failed over time. This synthesis is illustrated in Fig. 4.

Exploration phase (1984–1995; includes period 1 of camel adoption)

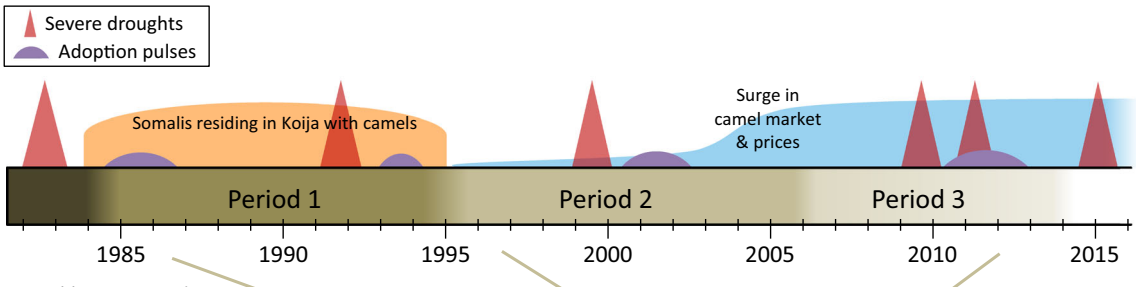
This first phase of camel adoption started after the drought of 1984–1985 during the period of facilitative social conditions offered by the presence of the Somalis, when camel purchase prices were relatively low. The lack of human capital in terms of knowledge led many early adopters to entrust their camels to more experienced herders, which further inhibited the development and acquisition of knowledge. As a consequence, this phase resulted in a high number of early adopters with just a few camels each, but also a high number of dropouts, largely due to lack of knowledge and poorly informed choices regarding the size and management of camel herds.

Consolidation phase (1996–2014, includes periods 2 and 3 of camel adoption)

The consolidation phase was characterized by progressive change in natural capital, and increasingly higher stakes in terms of financial assets: higher investment costs, larger optimal starting herd sizes, and also greater market opportunities and prices for animal and milk sales. New and continuing adopters also had more developed human capital in terms of knowledge, social networks for sourcing knowledge, and fewer cases of entrustment. Because of these factors, camel adoption fed back to increase human and financial capital for camel keepers. There were fewer adopters because of the high costs of entry, but they enjoyed higher success rates and profitability.

Specialization phase (current and emergent)

The third is an emergent phase of specialization in two directions: toward camels as a milk business enterprise, and as the main species in the livestock portfolio. Specialization is reflected in the heightened degree of investment of human capital in the



Variables associated with adoption phases	Exploration Phase	Consolidation Phase	Specialization Phase
Loss of grass cover	+	++	+++
Terms of trade to purchase camels	+++	++	+
Average initial herd size	+	++	+++
Income generation	+	++	+++
Hired shepherds	+	++	+++
Knowledge of adopters	+	++	+++
Entrustment cases	+++	+	+
Number of adopters	+++	++	++
Number of herds failing	+++	+	+

Fig. 4 Synthesis of adaptation trajectories. Above the timeline, some key factors associated with periods of *social-ecological contexts* are illustrated: presence of Somalis in the community (orange), changing terms of trade surrounding camels (blue), severe droughts (red), and pulses of adoption (purple). Below the timeline, we characterize *social-ecological contextual* factors associated with three phases of *adaptation trajectories.* Row colors indicate relevant forms of capital: red = natural, blue = financial, orange = human

endeavor: with adults and paid shepherds tending herds, and more sophisticated veterinary and herding knowledge. The trend is toward greater emphasis on financial assets, both in terms of asset investments and expected outcomes of camel husbandry. However, many potential adopters are prevented from entering due to camels' high purchase prices.

Camels, household-level, and community-level resilience

The study revealed that adaptive capacities varied between households and in accordance with available assets, and this variation defined the trajectories of the camel adoption process. Here, we evaluate those temporal trajectories, comparing camel-diversified livelihoods pursued by about 10% of households in Koija, to customary cattle-based (which we mean to include mixed cattle, sheep and goats) livelihoods, in terms of three forms of capacity that influenced adaptation experiences: household-level capacities afforded by human capital, the ecological suitability of natural capital for livestock production, and the social capital maintained through cultural roles of livestock. To do so, we draw on additional scholarship that has examined the decline in household herd sizes and the proportion of cattle in customary herds over recent decades (Herren 1990; Letai and Lind 2013; Unks 2017). We also draw from our ethnographic work, in which several people noted a general decline in customary practices of interhousehold cattle transfers, in a changing socio-economic context in which livelihoods are increasingly more reliant on exchanges of money rather than on livestock.

In Fig. 5a, we represent the different trends for cattle-based and camel-based households through a three-dimensional space along those axes of capacity, following Fraser (2007). In it, we see that cattle-based livelihoods (in red) have become increasingly difficult to sustain due to changes in local environmental conditions and socio-political restrictions to grazing access outside the group ranch. As a result, cattle herds have continued to decline, especially due to deaths during drought, leading to greater reliance on small stock and overall fewer tropical livestock units per person, which feed back to decrease household-level capacities (Herren 1990; Unks 2017). Cattle have retained their cultural importance for wealth, status, marriages, and other customs, but as herds dwindle, households are experiencing greater difficulties and declines in maintaining social obligations through cattle exchanges. Together, these dynamics are driving cattle-based households from the upper front left region of the resilience space in Fig. 5a toward the mid right rear.

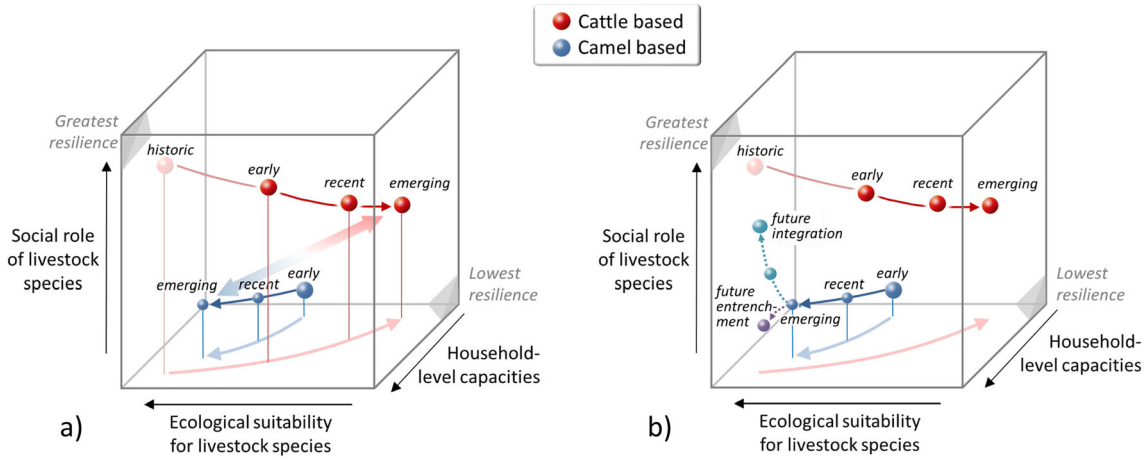


Fig. 5 Adaptation trajectories projected in three dimensions representing different types of capacities that afford resilience, using framework adapted from Fraser (2007) and Fraser et al. (2011). The trajectories for camel-adopting households (blue) are inferred from this study; the trajectory for cattle-based (or with goats and sheep) households are inferred from broader literature (Herren 1990, 1991; Galvin 2009; Unks 2017) and observed trends. **a** Trends over the 30-year duration of camel adoption at Koija, showing a widening disparity in resilience and capacities between the two livelihood strategies (blue-red arrow). **b** Considers two potential future trajectories for camel based livelihoods: one in which camels become integrated into cultural practices of reciprocity (upward dashed blue arrow), and one in which the current trend toward privatized accumulation of assets becomes entrenched (downward dashed gray arrow)

The trajectory for camel-keeping, shown in blue in Fig. 5a, is quite different. Camels can thrive under current environmental conditions and do not require seasonal access to distant foraging areas. The most serious camel disease, trypanosomiasis, is most prevalent during wet periods, so increasing aridity may actually improve the ecological conditions for camel husbandry. For those households that were able to develop appropriate human capacity for husbandry, camels provide food security and economic benefits to re-invest in camels, creating a positive feedback between human capital and assets garnered from camels, which together built household-level capacity. These feedbacks generate the blue trajectory in Fig. 5a, of increasing environmental suitability and household-level capacity. However, the social role of camels remains low as they are not fully accepted or enmeshed in cultural practices. Their contribution to household social capital appears to have increased slightly; there has been one instance of camels used as bridewealth, and there is increasing inter-household milk sharing and sales, with growing appreciation of camel milk particularly for children's nutrition.

This visualization of trajectories highlights the multidimensionality of resilience in pastoralist social-ecological systems. Camels clearly offer an ecologically-suited livelihood strategy that can improve household-level resilience. But increasingly, that livelihood is only accessible to those households that already have the capability to invest in camels, and can acquire and afford appropriate husbandry practices. Furthermore, that livelihood strategy is decoupled from the customary modes of maintaining community-level social capital that still rely on cattle. Also, overall, the role of livestock in cultural practices and as a mode of economic redistribution has declined over time (Unks 2017). Thus, what we see emerging in Koija is increasing inequality in terms of household assets, social connectivity, and environmental resilience, indicated by the blue-red arrow between emerging states in Fig. 5a. These conclusions are consistent with findings that unequal assets lead to unequal capacities for adaptation in other pastoralist systems (e.g., Goldman and Riosmena 2013; Fernández-Giménez et al. 2015; López-i-Gelats et al. 2015).

Based on the underlying dynamics and feedbacks that have created the current and emerging trajectories, we can also envision future trajectories (Fig. 5b). The first scenario is the entrenchment of the current trends. If wealthier families, with their greater household-level adaptive capacities, continue to specialize in the more lucrative and environmentally resilient practice of camel husbandry, we would expect that community-level social capital will erode even further, and we can anticipate an increasing divide and stratification between market-oriented camel keeping versus customary-oriented cattle keeping households that is not just economic, but also social (Fig. 5b, dashed gray line). The likelihood of this scenario may be strengthened by the present trends of increasing modernization, privatization, and market involvement in the community. Modernization vis a vis shops, roads, schools, a more settled life, a money-based household economy, is on the rise at Koija and neighboring group ranches, connecting them to regional and national trades and towns. These tendencies may compromise the collective level capacity for adaptation in the natural resource based dimensions of their livelihoods, which still revolve around communal land use and governance (Agrawal and Perrin 2009).

The second scenario involves the gradual integration of camels as a form of social wealth (Fig. 5b, dashed blue line). This could lead to social capital feedbacks that would include redistribution and also social cohesion through those

interactions, and could therefore facilitate the broader resilience of the community. Increasing the role of camels in social exchanges, however, would not necessarily mitigate the challenges of camel adoption. For instance, a novice household receiving three camels instead of the typical bride price of 10 head of cattle, may still face many of the difficulties of early adopters in terms of allocation of labor, veterinary knowledge, and straying. It is more likely that if camels are progressively integrated into social and cultural fabric, other smaller, incremental changes in attitudes, meanings, knowledge, practices, and decisions would emerge.

Conclusions

This study offers an important early and replicable endeavor to understanding adaptation experiences in a rapidly changing context, involving an adaptation strategy that may become increasingly attractive to climate-vulnerable dryland pastoralists across Africa. We have shown that adaptation experiences relied on access to different capital assets for decision-making, enactment, and benefit realization. Furthermore, those experiences were contingent and path-dependent on broader social-ecological contexts, which shifted over time. Many resilience and vulnerability assessments are based on current levels of capabilities, exposures, and sensitivities (Hinkel 2011). Yet information regarding *how* the current state emerged over time, and for whom, provides critical insights needed to understand prospects, constraints, and potential windows of opportunity for future adaptation (Nelson et al. 2014). The study illustrates a methodology that integrates diverse but compatible analytical lenses, each of which contributes to a more nuanced appreciation for heterogeneous adaptation processes that would not have been revealed by their application in isolation.

The documented dynamics created feedbacks that made camel adoption increasingly beneficial to those who can afford to engage, stimulating greater specialization and wealth accumulation by those few households. In doing so, however, the process exacerbates inequality as many potential adopters are economically unable to engage. Also, because it is emerging outside of the social reciprocity norms but within market opportunities, the increases in some households' wealth may come at a cost to cultural unity in the community. Sustainable Livelihoods approaches originally emerged to address unequal access to benefits of rural development initiatives (Scoones 2015); there is a growing call for a similar refocus on the heterogeneous impacts in climate vulnerability assessments and policy (Eakin et al. 2014; Dilling et al. 2015; Fawcett et al. 2017). While the usual argument is that climate adaptation policies often seek reductions in aggregate vulnerability with inadequate attention paid to individual vulnerabilities, this study offers a cautionary case of the converse: camel adoption may be promoted because of clear individual benefits, but in the absence of redistributive mechanisms, camel adoption may in fact erode collective resilience by decreasing social capital through a breakdown of traditional institutions and of cooperation.

This research is of relevance to policy makers, development institutions, and intervention programs that promote pastoralists' resilience to environmental change. In order to influence trajectories and adaptive capacity, policies should target assets that are lacking as possible leverage points to promote less risky transitions. In our case study, these may include improving camel-associated knowledge to reduce camel losses, and developing networks to reduce marginalization in markets. Policy could potentially seek to influence redistributive and cooperative norms to reduce inequality. However, this raises normative and ethical questions, and may run counter to increasing recognition and respect in the development sector for self-determination and autonomy in the arena of cultural and institutional processes (Adger et al. 2009; Crane 2010; Tanner et al. 2014). Further studies could employ future-focused methodologies, such as scenario planning, visioning, and the adaptation pathways approach (Wise et al. 2014; Bennett et al. 2016; Colloff et al. 2017; Prober et al. 2017), to explore not only the likely effects of interventions on adaptation dynamics, but also their diverse meanings and values to appreciate ethical implications from the perspective of local individuals and communities (O'Brien and Wolf 2010; Popa et al. 2015).

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