Mobility and the Sustainability of the Pastoral Production system in Africa: Perspectives of Contrasting Paradigms

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Mobility and the Sustainability of the Pastoral Production system in Africa: Perspectives of Contrasting Paradigms

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Abstract

This paper explores the extent to which changes in pastoral herd mobility and impacts on the environment may be explained by four paradigms: (1) carrying capacity; (2) mobility; (3) modernization; and (4) resource variability, risks and governance (RRG). The carrying capacity paradigm has two contrasting components, the equilibrium and disequilibrium hypotheses. The equilibrium hypothesis assumes that animal densities in excess of the appropriate stocking rates cause land degradation in terms of loss of soils, vegetation cover and loss of biodiversity. It promotes intervention by regulating livestock stocking densities. The non-equilibrium hypothesis holds the opposite views by promoting mobility. The major weakness of the carrying capacity paradigm is its neglect of indigenous knowledge for rangeland management. Herd mobility under the traditional system of land use is based on a comprehensive knowledge of rangelands, where the stocking densities are varied according to the potential (which infers capacities to supporting stocking density) of the land and during different seasons of the year. The mobility paradigm is an attempt to explain this traditional system but is less suited in areas where external and internal pressures disrupt the traditional patterns of herd movements. The modernization paradigm advocates for the intensification of land use. It is promoted by peri-urban pastoralists, agro-pastoralists, commercial pastoralists and non-pastoralists. However, this transformed system suffers from a shrinking resource base and greater localized pressures on the land. The three paradigms are weak on social perspectives of mobility and in none is the role of policy clarified. The RRG paradigm can be understood from two perspectives: (a) pressure points and (b) loss of key resources. The latter paradigm is a tool for decision-making that gives equal weight to the policy makers and resource users. It also presents researchers with choices regarding different possible scenarios of the problems being tackled.

Key words: Carrying capacity, governance, herders, mobility, modernization, resources, risks

Introduction

In her edited book, *Maintaining mobility in Africa*, Maryam Niamir-Fuller (1999) asks a fundamental question whether `pastoral mobility [is] an archaic remnant of the past, or … the foundation for future sustainability`? Answer to the question will not be straight forward. The general principles are that pastoralists have from ancient times been able to exploit gradients of opportunities that linked mobility to alternative forms of land use. Mobility as an ecological rationality in arid and semi-arid lands is a response by herders to variable range production and animal nutritional needs. It relies on herder knowledge and local institutions for making decisions. It forms part of the society's genres and folklores. It serves as a source of memory about the past grazing patterns. Herd mobility is therefore an embodiment of time and space (Turner 1999). In this paper my aims are limited to discussing the scientific perspectives of the implications of loss of pastoral mobility and what sustaining mobility might imply. The paper is informed by increased settling down by pastoralists, loss of key resources to alternative forms of land use and transformation of pastoral land use in general.

This paper discusses four contrasting paradigms to explain the implications for changing pastoral mobility in Africa. It considers the carrying capacity paradigm that has for so long dominated discussions of rangeland management in the communal areas. It presents empirical evidence from three angles to show why this paradigm is inappropriate. Firstly, the claims made with regard to the drivers of land degradation are examined. Secondly, the consequences of the paradigm, ignoring the flexibility of the indigenous rangeland management is considered. Thirdly, its association of pastoral herd die-offs with pre-drought stocking density is questioned.

The second and third paradigms are the mobility and modernization (Moritz 2010; Butt 2010). The mobility paradigm, as the name implies, relates to the maintenance of pastoral herd movements. It is a continuation of the non-equilibrium hypothesis, which argues that pastoral production in arid and semi-arid areas would have better prospects if herd mobility is encouraged. The mobility paradigm has received much support from longitudinal studies that compared systems across regions and found that increased mobility enhanced production (Little et al., 2001). Maintaining herd mobility is one way of protecting the rangelands, thereby supporting the indigenous system (Moritz 2008). However, mobility has declined as the migration routes of the pastoralists have been altered by conservancies, ranches and the loss of floodplain pastures, among other forms of land use fragmentation.

The modernization paradigm argues that pastoralism under the changing land use systems needs to be intensified. The differences once again have to do with the impact of livestock grazing on rangeland under changing land use scenarios. The intensification of land use is likely to contribute to further degradation of the land (although studies have also shown that intensification can also bring about improvements). This is shown by the emerging forms of pastoralism in peri-urban and urban areas, which involve crop cultivation and mixed livestock systems that require different analytical approaches. By taking into consideration the growing human population and the decline in livestock per capita, proponents of the modernization paradigm argue for strategies to intensify and diversify pastoral production system, rather than relying on a mobile system (McCabe et al., 2010; Tache and Oba 2010). The proponents of the paradigm continue to doubt the future of pastoral peoples as intensification will not be sustainable under shrinking grazing lands (Mack 1996). The resources, risks and governance (RRG) paradigm provide an improved understanding of the problem that destabilizes pastoral herd mobility (see also Bollig 2006). The paper evaluates each of these paradigms in turn to gauge their suitability to explain the factors that undermine sustainable pastoral herd mobility.

The carrying capacity paradigm

The debates about African pastoral development in the 1980s focussed on the pastoral system as largely responsible for land degradation. This degradation was claimed to be so severe that it threatened the very survival of the system. Researchers and policy makers used the discussions of rangeland carrying capacity to regulate the problem of herd stocking rates. The impact of overstocking is gauged in terms of changes in composition of the herbaceous layer, shrub encroachment, a decline in the diversity of plant species and the degradation of the soil (Abel 1997). An additional assumption is that rangelands that are protected from livestock grazing will benefit from reversals of these conditions. The effect of biotic factors, such as grazing intensity, on plants is overemphasized, while the effect of overarching ecological processes linked to spatial and temporal variability (such as stochastic rainfall) is minimized (see discussions Ellis and Galvin 1994; Oba et al. 2000a; Angassa and Oba 2007). In arid environments, stochastic climatic events have a greater impact on rangeland production than grazing alone (e.g. Ellis and Swift 1988; Oba et al. 2000a, b). It is also assumed that pre-drought livestock densities can be used as indicators of density-dependent herd die-off. This implies that if the livestock density is high before the drought, the numbers of stock lost would be correspondingly high. If there are lower pre-drought densities, then a lower mortality rate would be expected. The paradigm does not say if mobility is a solution to regulate herd stocking density and if or not doing so would reduce herd die-offs.

The most obvious weakness of the carrying capacity paradigm is that it is based on average values and assumes homogeneity of rangelands and that stocks managed by herders are restricted to individual grazing landscapes, contrary to the counter evidence (Hary et al., 1996). Average productivity values ignore the high degree of variability in terms of space and time. This paradigm also fails to take cognizance of evidence that in multi-species livestock management systems, such as those of African pastoralists, there is no fixed carrying capacity. Multiple capacities exist, reflecting the different nutritional requirements of different livestock species during different seasons of the year. The range carrying capacities of the wetter years will be greater than that of the drier years. This paradigm also fails to acknowledge that land degradation is the product of settling formerly mobile populations by development (Fratkin 1998) and the loss of key grazing resources (Hary et al., 1996; Scoones 1995). The carrying capacity paradigm, while focusing on the protection of grazing, or on balancing grazing pressure with forage, does not consider the ecological sustainability of indigenous rangeland management. In particular, it does not take into account the value of herder indigenous knowledge in promoting mobility (see below).

However, by the 1990s, the discussions had moved from an ecological to an interdisciplinary dialogue. The equilibrium hypothesis (which looks at the carrying capacity) and the non-equilibrium hypothesis (which looks at the alternative variability) were taking central stage in the ecological and pastoral development debates (Behnke et al., 1993; Scoones 1995). The "variability" for which, the non-equilibrium hypothesis advocates was gaining wide currency in dispute of the "balance of nature" paradigm (e.g. Behnke at al., 1993). What are the evidences in support or rejection of the paradigm? The following sections of the paper consider evidences on impacts of stocking densities (i.e. the proxy grazing pressure) on soil and vegetation indicators. I begin with the impact of grazing on soil condition (Box 1.1).

Box 1.1. Soil degradation

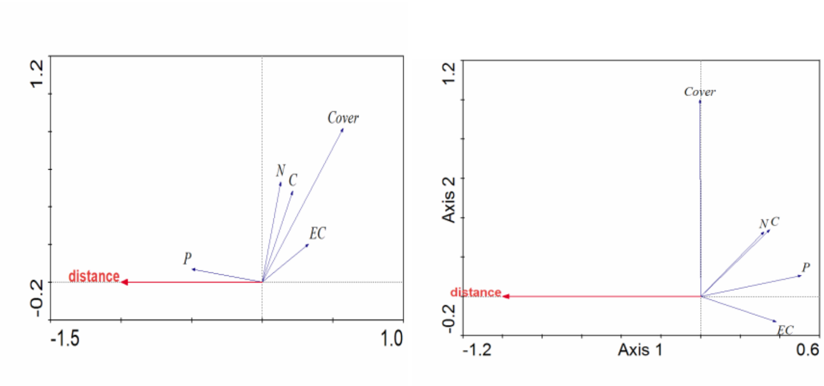
Discussions on processes of land degradation associated with livestock grazing remain speculative and superficial. The impact of livestock grazing pressures (as surrogates of stocking rates) on soil indicators was evaluated in north-eastern Tanzania. Soils were sampled along a chronosequence of grazing pressure gradients (i.e. from non-heavy to very heavy), and soil erosion and bush cover were investigated as drivers of loss of nutrients. The interactions between grazing pressure, soil erosion indices and bush cover and soil biochemical activities in terms of pH, cation exchange capacity, percentage total N, soil organic matter, soil bulk density, available phosphorus and exchangeable cations at landscape scales were examined. Grazing pressure gradients did not significantly impact on the spatial distributions of soil nutrients. Grazing influenced the bulk density of soil but had no significant influence on the concentrations of soil organic matter or concentrations of cations. Soil erosion influenced cation exchange capacity, soil bulk density and exchangeable cations (i.e. Na^+, Mg^{++} and Ca^{++}). Bush encroachment influenced soil water holding capacity and soil bulk density but had no effect on other soil nutrient pools. Grazing pressure had no influence on soil water, soil organic matter, exchangeable phosphorus, and cation exchange capacity when soil physical structure (i.e. in terms of proportions of sand, silt, and clay) was accounted for in the analysis. The research showed that land degradation is a complex phenomenon involving interactions of grazing pressure, bush cover and soil structure (Oba et al., 2008 a).

Impacts on soil indicators

The evidence shows that grazing pressure has less effect on soil nutrients than other drivers (Rutherford and Powrie 2010). Site factors pointed to far greater effects on soil nutrient variability than that caused by grazing pressure (Tefera et al., 2010) despite the oft claims made that associated livestock grazing with processes of desertification (Box 1.2).

Box 1.2 The impact of desertification on soil nutrients

The research selected the settlements of Kargi (N 02 31 275` E 037° 34`) and Korr (N 02 00° 200` E 037° 30`) that were associated with *in situ* desertification by sedentary Rendille pastoralists (Lamprey and Yussuf 1981). We established 4 km transects set in four compass directions from the centres of the two settlements. The settlements showed different patterns of pastoral camps. In Kargi, the pastoral camps formed a central cluster within a 1 km radius of the settlement, while at the Korr site; the pastoral camps were located more than 4 km from the settlement. In Kargi settlement there was evidence of sand dune movements in some areas of the pastoral camps, while in Korr soil movements were evident 4 km from the settlement. Soils were sampled along land use gradient transects at 200 m intervals from 0-20 cm depth (n = 80 samples for each site) and mixed. About 250 g of soil was analyzed for total nitrogen (% N), total organic carbon (% C), extractable phosphorus (% P) and electro-conductivity (Ec) using the standard laboratory methods. Woody cover was also estimated. Soil nutrient gradients and woody cover were analysed using linear constrained ordination in CANOCO. Redundancy Analysis (RDA) was used with soil nutrients and woody cover as response variables and distance as an explanatory variable.



A B

Figure 1 *Soil nutrients and woody cover ordination from the settlements: (A) Kargi and (B) Korr in Northern Kenya*

Total nitrogen, total organic carbon and Ec were negatively correlated with distances from the settlements, but the correlations were not significant (p>0.05) (Figure 1A-B). Extractable phosphorous was negatively correlated for the Kargi but positively for the Korr settlement (p<0.05). In Kargi woody cover showed no spatial patterns, while for Korr, woody cover decreased with increasing distance from the settlement. Woody cover showed no correlation with soil nutrients except for Ec at the Korr site (r = 0. 20, p<0.05). In both settlements, the patterns of extractable Phosphorus varied according to the locations of the pastoral camps, suggesting that the changes were related more to livestock activities than to losses attributable to degradation. The distributions of total nitrogen and total organic matter were also greater around the settlements, albeit insignificant (p>0.05). The results showed that soil nutrients in the settlements did not directly reflect the losses often linked to the processes of desertification. The responses of different nutrients along degradation gradients appeared to reflect the positive roles played by livestock in nutrient transport (Roba and Oba 2009a).

Impacts on herbaceous biomass

The discussion can be extended to the impact of livestock grazing pressure on changes in herbaceous vegetation indicators. When rainfall is sufficient, some levels of grazing promote plant productivity (Illius and O'Connor 1999; Oba et al., 2000a). Contrary to this Rahlao et al. (2008) considering vegetation protection for 67 years reached conclusion that grazing control had more benefits for biodiversity conservation than often acknowledged. This study did not however have a grazing control. The cause of disagreements between the equilibrium and non-equilibrium hypotheses is therefore reliance on short-term studies or lack of control studies. Most studies coincided with favourable or unfavourable climatic periods but fail to capture the sequence of wet and dry years (Oba et al., 2000b). The persistence of the systems at spatial and temporal scales (Pickup 1995) may imply that climate variability is the main driving force (Oba et al., 2000a, b). In northern Ethiopia and northern Kenya, researches showed that extended periods of protection from grazing do not necessarily promote biodiversity but might increase biomass (Oba et al., 2001; Asefa et al., 2003; Abebe at al., 2006).

Another equally important source of disagreement is the scales at which impact of grazing can be evaluated (Oba et al., 2008a,b). In northern Kenya, spatial data sets was used to understand the scales at which degradation in response to grazing pressure occurred, thereby testing the efficacy of the equilibrium and non-equilibrium hypotheses. Degradation was detected at fine scales (described by the non-equilibrium hypothesis), but not at the coarse scale (described by the equilibrium hypothesis). Increased grazing pressure at a fine scale did not result in a concomitant decline in plant cover, species richness or biomass (Oba et al., 2003). Furthermore, the impact of grazing can be observed at scales of individual forage species. Plant productivity is optimal under repeated grazing at moderate levels; this is not the case with complete exclusion from grazing (Oba et al., 2000a). Over-resting induced a loss of plant cover and productivity in dwarf shrub rangelands (Box 1.3).

Box 1.3. Adaptations of key arid zone forage plants to herbivore grazing

In central Turkana, a five-year monitoring period (1986-1990) comparing traditional management with grazing exclusion in *Indigofera spinosa* and *I. Cliffordiana*-dominated rangelands was used to simulate impacts of long-term grazing on dwarf shrub rangelands. The simulation of severe levels of overgrazing by herbivores was used to understand how the species responded to over browsing. The treatments were repeated during wet and dry seasons to correspond with local systems of land use. The experiment showed that the dwarf shrubs were tolerant to herbivory with optimum biomass produced and survival achieved at moderate levels of grazing; however, very heavy levels were detrimental to plant production. Plant production performances were dependent on the residual biomass. The results showed that *I. spinosa* pastures could be grazed by up to 30% of the total crown biomass without causing overbrowsing. This level of utilization corresponded with the impact of livestock in the field, while the heavy and the very heavy levels achieved through artificially simulated herbivory were rarely achieved under the traditional system. In both protected and grazed pastures dry matter was more strongly influenced by rainfall variability than by grazing. Protection did not increase the rates of new biomass production (when compared to the grazed pastures). During drought years the shrubs in the protected area accumulated most dead fractions than the browsed system (Oba 1992, Oba et al., 2000a,b).

Impacts on plant species richness

In grazing exclosure studies, doubling the chronological age of protection do not necessarily promote plant species diversity (Abebe et al., 2006). The exclosures promote biomass accumulation but do not reduce regeneration of bush encroachment (Angassa and Oba 2010). The impacts were influenced by climate variability rather than by grazing (Oba 1998; Oba and Post 1999). From conservation points of view, therefore, stocking rates can be measured in terms of outcomes related to biodiversity. But as with plant biomass, biodiversity is perceived by ecologists to be better conserved if grazing pressure is reduced. A common perception by researchers and policy makers is that grazing exclusion over long periods will result in improved conservation of forage plant species. However, this does not always disclose the expected results. If we take the example of time of protection, even if extended for over 25-30 years there was no evidence of favourable responses in terms of the conservation of biodiversity (Oba et al., 2001b; Abebe et al., 2006; Angassa and Oba 2010). Favourable responses were more likely if management were to take the types of topography, soil types and time into consideration, rather than protection or grazing pressure alone (Table 1). These are what Anderson and Hoffman (2011) recently referred to as "fuzzy" results. In addition, if one uses the common assumption that private ranches that are conservatively stocked perform better than the communal grazing land; the results appear to be inconclusive. Contrary to the expectations grazing on private compared to communal grazing areas (the latter tends to be more heavily stocked) equally responded to the variability of rainfall (see Kraaij and Milton 2006) suggesting that the data that does not take into account rainfall variability might be meaningless to management. Whatever the stocking density, the observation of very wet years differ from those of very dry years on ranches stocked conservatively compared to communal rangelands (Hein 2006; Anderson and Hoffman 2011).

Table 1. The impact of grazing and site factors on the diversity of plant species.

	Species richness		
Total species richness	Lowlands	Uplands	Source
Communal	42.5±11.7	49.8±9.2	Anderson and Hoffman 2007
Private	42.5±13.3	46.2±7.6	Succulent Karoo, S. Africa
	River landscape (1)	River landscape (2)	
Light grazing	12.44±2.09	1.2±3.45	Allsopp et al. 2007
Heavy	9.67±1.10	14.8±2.42	Karoo, S. Africa
	Effect of enclosures on species richness		
	Red soil	White soil	
Grazed (1992)	4.8-9	4.0-7	Dahlberg 2000
Grazed (1994)	8.7-15	7.0-11	Botswana
Ungrazed (1992)	4.8-11	6.0-15	
Ungrazed (1994)	7.9-15	9.1-17	

Climate and grazing interact to influence vegetation production (Pickup 1995). At landscape scales in northern Ethiopia, where several centuries of crop cultivation and grazing have resulted in loss of soil and vegetation cover, restoration of a biodiversity of herbaceous species was achieved after three years of protection, but continuous protection resulted in a decline. Tree species richness in protected areas showed a gradual increase (from 3-8 years), while shrub species richness showed little response compared to the areas which were open to grazing (Asefa et al., 2003). In northern Tanzania, the diversity of plant species was greater in the grazed areas than in the agro-pastoral landscapes (Mapinduzi et al., 2003). At larger scales the role of human agents in environmental changes in relation to sub-continental level expansion of desertification is disputed, while the role of global environmental variability is supported (Box 1.4).

Box 1.4 Impact of large scale variability on sub-Saharan rangelands

Large-scale global climate variability dominated by the North Atlantic Oscillation (NAO) and El Niño Southern Oscillation (ENSO) were used as predictor variables for the expansion and contraction of the Sahara desert. Time series environmental data (11 years) was used to analyse the role that large-scale climate variability played by correlating the indices of the NAO with rangeland production and vegetation NDVI across sub-Saharan rangelands. It showed that the combined effects of NAO and ENSO accounted for 75% of the inter-annual variability of the expansion and contraction of the southern borders of the Sahara Desert and 40% of the variability of range production in Africa, with most of the variances explained by NAO alone. The study contradicted the common perception that the southern expansion of the Sahara Desert indicates a progressive trend. On the contrary, the fluctuations of the southern borders of the Sahara Desert and fluctuations in rangeland productivity were a response to the cyclical dry and wet episodes; these are more strongly influenced by global climate variability than by human agency. The significance of the findings is that large-scale climate variability might be superimposed on the effects of local land use in the sub-Saharan rangelands (Oba et al.,2001b).

Stocking density and drought induced herd die-off

Ever since the study by Dahl and Hort (1976) on long-term herd growth, there has been less research that tested the hypothesis that pre-drought livestock density is related to herd die-offs (see Oba 2001; Angassa and Oba 2007). The equilibrium hypothesis assumes the stability of livestock stocking density at a fixed carrying capacity. The non-equilibrium on the other hand assumes dynamic processes where multiplicities of drivers influence the system (Walter 2008). The latter model implies that livestock numbers in highly variable environments seldom exceed carrying capacity because frequent die-offs maintains the stocking density at lower levels (Moritz 2008). These are being disputed but let us examine the different evidences.

The opponents suggest that most studies reporting herd mortality in relation to stocking density are conducted after the drought effects while monitoring of the herd dynamics (either through direct recordings or through herder recalls) over longer periods failed to establish clear patterns between pre-drought density and herd die-offs (see also Oba 2001; Angassa and Oba 2007; Tache 2008). Using the relationships between pre-drought livestock population densities and drought die-offs a number of important findings were observed. Firstly, herd die-offs influenced herd structure more severely, with immature and the reproductive females being most affected and males and steers least affected (Oba 2001; Angassa and Oba 2007; Tache 2008). Secondly, different droughts caused different patterns of herd die-offs. The increase in mortality recorded during some droughts was often a result of a combination of feed scarcity and animal diseases (Oba 2001; Tache 2008). Thirdly, mortality patterns between ranches and herds on communal rangelands were comparable (Angassa and Oba 2007). Fourthly, drought recovery rates were related to the relative levels of herd die-offs and therefore the residual stocks but not related to pre-drought stocking density. Livestock population variation is more related to rainfall variations (using time lags) (Ebei et al. 2008). Alternative views also used long –term data in support of the density dependence effects on herd die-offs (Desta and Coppock 2004). However, the greater majority of the case studies from East Africa appear to confirm that stocking densities are driven by rainfall variability and the quality of food more than pre-drought livestock densities (Box 1.5).

Box 1. 5 Impact of droughts and herd recovery

In south-eastern Ethiopia, rainfall variability meditated through livestock food quality accounted for large livestock die-offs during multi-year droughts (Zerihun and Oba, 2004). In northern Kenya, long-term (14 years) livestock population data used to develop a herd growth model for predicting regional herd recovery following multiple drought periods showed that the links between pre-drought populations and post-drought populations were weak, while recovery rates varied from one drought to another (Oba 2001). The relationships between long-term rainfall variability and livestock population variations showed no cause-effect relationship between pre-drought and post-drought densities on the communal rangelands – similar to the government ranch, where stocking densities were fixed (Angassa and Oba 2007). For the case studies in northern Kenya and southern Ethiopia, the lack of a clear relationship between pre-drought and post drought livestock populations implies that the dynamic drivers of herd density are probably influenced by varieties of factors such as declining forage nutrition. Large livestock die-offs and slow herd recovery are the characteristic features of these systems. Thus in the pastoral systems of southern Ethiopia and northern Kenya livestock population recovery depends on whether droughts occur within 10-15 year intervals (Coppock 1994) or whether the droughts return time is 3-5 years (Oba 2001). While we lack information on rates of human demographic growth, the herd per capita decline implies that the human population growth is not matched by livestock population recovery (Ebei et al., 2008, Tache 2008; Homan et al., 2008). This might explain the high rates of drop out by households moving from the pastoral system into alternative livelihoods.

Mobility paradigm

Pastoral mobility refers to the time-space behaviour of herds and their handlers in response to variations in pasture and the distribution of water. The patterns of mobility can be regular (in relation to gradients of grazing resources) or guided opportunistically (by herders using indigenous systems of management). Grazing mobility, with the exception of the more ordinary landscape level movements, is responsive to situations of resource scarcity (Andriansen and Nielsen 2002; Butt 2010). But pastoral mobility has never been a one-way process; rather, it entails the rotational use of spatially varied resources by diverse species of livestock. Therefore, livestock species diversity is not only aimed at optimizing production but is also designed to promote different patterns of mobility. For families managing small stock, cattle and camels, each situation requires different patterns of mobility; the choices reflected by different livestock nutritional requirements (Oba and Kaitira 2006; Roba and Oba 2009b). Whereas mobility is associated with environmental variability, traditional herd mobility might also be a result of different socio-economic levels among nomads (Bassett and Turner 2007). Pastoral herd migration takes into consideration labour scarcity and the distances moved in space and time (Robbins 1998). Migration is a trigger to reducing herd losses (Homan et al., 2008). In annual migrations, movements might include regular transhumance between key resources such as floodplain pastures and the wet season rangelands. Later in the paper, I will present evidence that show how disruptions of these natural migratory pathways might expose pastoralists to much more severe stresses (for similar discussions, see Behnke et al., 2011).

Where environmental resource scarcity induces migration, the concept of “environmental refugee” is used. Environmentally induced migration is a safety-valve mechanism to escape stress and seek resources elsewhere (Bates 2002). However environmentally forced migrations can have spill-over effects (Charnley 1997). If it can be shown that environmental degradation is a trigger of pastoral migration, then one would want to identify the tipping point in the system, which when reached makes migration inevitable. The livestock population may have been under stress for a long time due to shortage of food (as in the case of animal deaths). If so, the tipping point is likely to be reached sooner rather than later. The timing is critical for “ecological migration”. This will depend on the degree of environmental threat needed for the tipping point to be reached (for other systems see Zi’an and Xiaolei 2006). An indicator that the tipping point has been reached is the mortality pattern in reproductive herds. Early mortality of calves, a shortage of forage and increased distances to reach watering points are all important early warning signs that herders should heed. Any decision that herders take involves a risk factor that will influence the decision to migrate (Warner et al., 2010). Herders rely on their indigenous knowledge than the information provided by researchers to maintain mobility.

Indigenous knowledge and pastoral sustainability

The paper has so far considered the ecological drivers relevant to the ecological sustainability of mobility. Herders and ecologists react differently to the impact of grazing on rangelands. Migration is traditionally preceded by herder assessments of rangelands which are usually conducted at a landscape scale (Oba et al., 2008 b, c; Roba and Oba 2008, 2009b). The scales of movement vary enormously between locality and region. In traditional systems, migration might not be driven by scarcities alone but by herder preferences or the dietary needs of livestock (Behnke et al., 2011). From what we can infer, herders have developed systematic epistemologies of landscape classification according to grazing resistance gradients (Bauer 2009; Roba and Oba 2008; Oba et al., 2008c). Herder knowledge of stocking rates that can be supported by the landscape is based on an assessment of soils and vegetation types (Bruke 2001; Oba et al., 2008b). Unlike ecologists, herders can distinguish between landscapes that are vulnerable to heavy grazing and degrade rapidly, and those that resist degradation. Herders deliberately overstock landscapes that resist degradation (i.e. such landscapes have greater land use potential). Where there is greater risk of degradation, landscapes are grazed for brief periods during the wet season (e.g. Oba et al., 2008a, b; Roba and Oba 2008). Understanding the landscape patterns of herding is therefore critical to appreciating herders' knowledge of mobility ecology. Bollig and Shulte (1999) for example, showed that the Pokot herders have a good understanding of the interplay between changes in vegetation and livestock grazing patterns. Herder knowledge of vegetation changes is based on historical observation. The herders have a clear understanding of the stable species compared to the decreasing and increasing plant species. They are also able to tell how the changes affect the rangeland ecology and influence grazing patterns (Oba and Kotile 2001; Roba and Oba 2008; Angassa and Oba 2008). Using the trajectories of vegetation change, herders are able to alter their herd composition and modify grazing movements. The shift in ownership from cattle to camels is one such example. For the herders, extensive bush cover that reduces herbaceous biomass production would be considered undesirable for cattle management (Oba et al. 2000c; Angassa and Oba 2008). Camel pastoralists would consider bush encroachment to be desirable.

These knowledge systems are central to sustainable pastoral herd mobility. They help to determine the distribution of spatial and temporal resources. They are based on knowledge of animal nutritional needs during different seasons of the year. The indigenous knowledge system links the ecological and production systems and is better able to respond to changes than suggested by ecologists. As suggested throughout this paper, in the indigenous system, it is the variation in pasture and water that drive herd mobility. However, different cultural specializations and individual migration topologies do exist (Henry et al., 2004). The Gabbra and the Borana, who are neighbours in northern Kenya, for example, rely on different systems of mobility. The Borana with their cattle practice orbital mobility where the distribution of water points determines the seasonal movements and the distances moved, while the mobility of the camel-owning Gabbra is influenced by access to pastures rather than by distances to water. Their camels are able to tolerate thirst for as long as 14 days, allowing them to trek nearly 100 km to water (Roba 2010). For the Borana, the distance to water during the dry season can hardly exceed 20 km (Helland 1982; Tiki et al., 2011).

When herd movements are in response to environmental stress, different families may adopt different strategies with regard to mobility. The wealthier herd owners are likely to be the first to respond. For these families, one way of spreading the risk would be to diversify their herds. On one hand, management of different types of livestock pose an additional constraint to the family mobility. Thus, for a wealthy family, spreading the risk may be an optimal strategy if it creates a safety net for herd survival. Logically, the wealthy herders do not act alone, but would build networks with the less wealthy in order to obtain extra labour. On the other, if the risk of losing herds is the reason for mobility, less wealthy herders may choose to adopt local management strategies rather than resort to long-distance migration. Small herd owners pay attention to individual animals: the weakest ones are nursed by hand-feeding with bundles of grass or tree branches, while the stronger ones are allowed to fend for themselves. This cannot be done by wealthy herd owners. In order to maximize the survival of the reproductive females, wealthy herd owners kill off the calves during periods of severe stress, thereby ensuring the survival of the dams (Tache 2008). The functioning of this flexible traditional system has been reduced, so that different analytical tools are needed to understand the herders' responses.

Modernization paradigm

In response to risks posed by changing land-use systems – such as increased sedentarization, the practice of agro-pastoralism, non-herding pastoralism, commercial pastoralism and peri-urban pastoralism – are promoting different forms of mobility (see also Moritz 2010). The argument of the modernization paradigm is that pure forms of pastoralism (where families rely entirely on livestock produce for their livelihoods) are diminishing. Some research suggests that the transformation from pastoralism to livelihood diversification is triggered by declining livestock per capita (Desta and Coppock 2004; Homan et al., 2008). The system is pulled into alternative modes of resource exploitation, while at the same time not completely divorced from the push factors that helps them to hang on to the traditional system of mobility. Among the new livelihood possibilities, agro-pastoralism has offered traditional pastoralists new opportunities to integrate the production of herds and the cultivation of crops (Pedersen and Benjaminsen 2008; McCabe et al., 2010; Tache and Oba

2010). Yet, they face different problems from those which confront the traditional herding families. While agriculture provides alternative livelihoods, it has not necessarily reduced the need for herd mobility. Agro-pastoralists are moving towards the exclusive use of resources, especially where this concerns the exploitation of grazing reserves (used by settled families) that excludes their mobile neighbours. The conversion of the grazing lands into land used for semi-private crop cultivation is undermining traditional systems of herd mobility (Angassa and Oba 2008; Haman et al., 2008). Crop cultivation takes up quality grazing land that is traditionally set aside for dry season grazing (Coppock 1994), thereby exposing pastoralists to greater risks.

The integration of pastoral herding with crop cultivation can be an advantage, especially where livestock/farm owners use crop residues as grazing reserves. Where such agro-pastoral families developed new strategies, they put their livestock on the communal pastures during the wet season, before returning to their enclosure reserves, for which they have exclusive access during the dry season (Angassa and Oba 2008; Fabusoro 2009). Nonetheless, because of their smaller sizes, crop plots and range enclosures have not offset the need for herd mobility although the regularity of the transhumance has been significantly transformed. This can be compared to systems where Pastoralism dominates that had shown mobility to be stable overtime (Samuels, et al., 2008).

In several areas of the Horn of Africa where agro-pastoralism, conservancies, and private range enclosures obstruct migratory routes, however, the changes have brought about new ways of negotiating access to private pastures. Commoditisation of forage in private ranches and grazing fallows has forced the migrating herders to pay grazing fees (Lengoiboni et al., 2011). There are therefore familiar narratives of modernization paradigm in terms of pastoralists' environmental impact, land use competition and conflicts. The settled pastoral population in addition to crop cultivation managed small herds. The scarcity of grazing resources (Ying et al. 2002) in the settled system becomes increasingly difficult to make environmental predictions because of the erosion of local resources. Minor environmental stresses will have a disastrous effect on local economies. In this scenario the capacity of the human population to cope with risk is reduced. Rather than engage in long-term planning, people in this situation may resort to short-term decision-making (Angassa and Oba 2008; Roba 2010).

Commercial pastoralism by comparison is a capital accumulation in non-reproductive herds which are sold when the market environment improves. Commercial pastoralists have two options if their investment is threatened by droughts. They can invest in trucking to ferry their herds to commercial ranches, or they can rent grazing reserves during periods of stress (Mahmoud 2006). However, commercial pastoralists will not risk long-distance migration (Adriansen 2006) because of a greater risk of huge financial losses when the herds are lost as a result of environmental stress. The rapid turnover of the herds offsets such risks. The participants are often wealthy urbanized pastoralists or other commercial traders, rather than subsistence herders. This type of pastoralism has strong links to consumer markets in cities and rural towns and is less regulated by the need for mobility.

An interesting aspect of the new pastoralism is the non-herding families who live in peri-urban and urban environments. These families engage in retail trade or have regular jobs. They also maintain herds on the rangelands. They often hire labour to herd their livestock in that way maintaining the traditional herd production system but with a difference. They use non-pastoral and pastoral economies to protect their income (Khalif 2010). Peri-urban pastoralists use their past herding experience to guide them in making critical decisions. The emerging trends in these new forms of pastoralism therefore contradict the assumption that pastoralism ends when families stop practicing mobile herd management. The rapid transformation of former herders, who even after leaving the pastoral environment still consider themselves to be pastoralists, disclose that pastoralism is not a dying system (Moritz 2010). The novelty of this new strategy is that it builds linkages between urban consumer markets and mobile herds. In northern Kenya, dairy camels present an economic opportunity for non-herding urban households: their role in supplying milk to urban residents has promoted a new way of tapping into the pastoral economy, although the mobility of the dairy herds has been reduced (Khalif 2010). It is likely also that the hiring of labour by the non-herding pastoralists creates employment opportunities for young herders who use the opportunity as transitional employment before relocating to rural towns and cities as watchmen for urban businesses and elites (Doti 2005). The modernization paradigm thus offers many new opportunities but fails to explain how individuals involved in strategic land use make strategic decision to confront problems of herd mobility. This is attempted by the resources, risks and governance (RRG) paradigm.

Resources, risks and governance paradigm

Why do we need a new paradigm? I have shown that the carrying capacity paradigm has limitations. Its major weakness is to de-link governance that allows the resource users to make myriads of contrasting decisions from the ecological drivers. The mobility and modernization paradigms both involve some aspects of decision making but both are less clear on how the system can be holistically used to guide management. The resources, risks and governance (RRG) paradigm provides a contextual framework for examining the socio-ecological, environmental and governance drivers that help to explain changes in pastoral mobility patterns in changing socio-political circumstances. It does this by disaggregating the drivers (the pull factors) and the counter actions (the push factors) that determine the trajectory of change in mobility. The drivers are the environmental risks and uncertainty and governance for decision making. The new paradigm provides an integrative holistic way of understanding how decision can influence the drivers of mobility. The natural resource base for human livelihoods, the risks associated with access rights and other external drivers that impinge on the environment and the governance instruments can help one to understand the functions of the new paradigm. Risk comes with opportunities – in terms of actions that may be taken by pastoralists. Risk infers with how societies practicing livelihood transformation cope with strategies of mobility. This means that coping with risks that undermine pastoral mobility requires systems of knowledge and chains of decisions, including institutional regulatory mechanism. The challenge is how to combine risk and governance to help one understand the dynamic nature of pastoral mobility.

The RRG paradigm should be able to allow users to understand the ecological dynamics, while at the same time capturing societal responses to changes in resource governance, in cases where the traditional pastoral mobility has been altered. The altered system has not reduced risks but increased the need for more vigorous risk aversion strategies with regard to herd mobility. As one might appreciate, risk is linked to time. For pastoral herders, each risky situation may elicit different strategies. For households, risk minimization may entail the diversification of livelihoods, so that herders are able to exploit varied gradients of economic and ecological opportunities – including crop cultivation (e.g. MacDonald 1998; Berhanu et al., 2007; Berhanu and Colman 2007). One usually regards risk as something to be avoided but risk may also provide a challenge and an incentive to develop new strategies. For example, those who are exposed to risk are likely to make attempts to seek new solutions than those less exposed to risks (Winterholder et al., 1999). In a system where risk is the product of the unpredictability, risk mitigation increases the chances of survival. Herders therefore consider various scenarios before making final decisions.

Survival mechanisms do not only operate at the level of individual households (although this is where decisions are often made) but are also cooperative in nature, and may involve the whole of society. This is a symbolic representation of the pastoral life where every act is linked to another in a complex social environment. Risk mitigation increases the reliability of the system, but this will not stop the system from collapsing if sufficiently weakened by external drivers. An important component of risk management is governance. The term has a broad meaning which includes the use of authority, both formally and informally. It implies a political process that permeates social life and environmental management (Palmujoki 2006). Governance focuses on the management of survival mechanisms and optimal use of the environment to reduce risks. Governance can be assessed in terms of performance and effectiveness. Governance includes both resources and risks as factors which have a powerful impact on decision-making. Governance also has a moral responsibility and accountability (Morton 2010). The RRG paradigm will make an important contribution to understanding how pastoralists adapt through decision-making that may be examined from two perspectives: (a) pressure points and (b) loss of key resources.

Pressure points

Resource pressure points are of various types, and may include environmental and political triggers. In the Horn of Africa, ethnic conflicts have increased the risk of political instability, and this has had a dramatic impact on herd mobility. Armed conflicts have displaced populations and separated them from their resources. Conflicts contribute to economic collapse and the appropriation of property. The immediate effect is the disruption of traditional migration patterns (Eriksen and Lind 2009). Conflicts reorder resource borders between conflicting groups (Johnson 1993). In the escape areas the populations of internally displaced peoples together with those of residents may exceed the capacity of the available resources. This makes the political stressors to serve as a trigger; whose effect is felt through the production system (Bell 2004). An obvious outcome of politically induced migration is changes in the ownership of resources (Unruh and Bailey 2009). There is however insufficient literature on the long-term consequences of conflict and the environmental changes associated with pastoralists forced migrations and their impact on the spatial distributions of resources. The causal drivers have not been sufficiently documented (Randall 2005). Political conflicts have the overall effect of forcing pastoralists to settle close to security centres. The loss or abandonment of the traditional grazing lands not only alter the traditional resource borders but overtime also cause major changes in vegetation structure and composition (Box 1.6).

Box 1.6 Impact of conflict on pastoral land use

The security centres provide a refuge for those displaced by political conflict. The Obbu Borana in northern Kenya were removed from their grazing lands by the *shifta* conflicts of 1964-1977. The population was removed from almost 95% of their traditional grazing lands and forced into security villages around Sololo. For nearly a decade livestock grazing was restricted to a radius of 10 km from the security centre. The previously mobile population was forced to settle. In the process they lost all their pack animals, thereby losing the means of mobility. Overgrazing around the security villages completely transformed the natural vegetation from perennial grasslands to bush encroachment over a period of three decades. Subsequent droughts caused the loss of herds, resulting in impoverishment of the families. The Obbu Borana began trials with crop cultivation but because their environment is not suited for growing crops, they ended up enclosing large areas of communal grazing lands as fodder reserves. Four decades later, with return of the peace, the Obbu residents have resumed mobile lifestyle into areas from where they were earlier displaced by insecurity. However, encroachments of the rangelands by bushes have made the former grazing lands worthless for sustainable livestock grazing (G. Oba, forthcoming).

Other drivers of settlements are voluntary or induced by development programs (Adano and Witsenburg 2005). In this evolving situation, local settled pastoral communities have succeeded in reversing land degradation through their involvements in environment management (Roba 2008). In this situation the external factors are limited to settlement process. The outcome might be different if pastoralists are displaced from their dependable and critical resources such as floodplain pastures. In the next sub-section I will examine the relationships between pastoral herd mobility and access to the river floodplain grazing resources and the role development (in the sense of economic investments as opposed to the modernization paradigm) play in endangering pastoral survival. Governance support is towards national economic interests as opposed to protecting systems of land use such as sustainable pastoral mobility.

Loss of key resources

The river basins are the life lines of rural economies based for cultivation of flood retreat crops, fishing and drought grazing reserves. Pastoral herd survival is dependent on the availability of these dry season pastures. The floodplains enable the annual transhumance of herds moving from their wet season pastures to their dry season pastures; where the fresh grass growth of the inundated pastures provide them with nutritious grazing (Scholte et al., 2006). Other users are sedentary agro-pastoralists who traditionally established mutual forms of land use with the herders during their annual visits (Binot et al. 2009). In the Nile River Basin of the Sudan, about 85% of the population directly relies on the resources of the floodplain (El-Tom Hamad and El-Battahani 2005). Van Breugel et al. (2010) calculated the water requirement of livestock within the Nile Basin and found a high correlation between Tropical Livestock Unit densities and water demands. In the Turkwel River in Turkana, Kenya, 30% of the total human and livestock populations are found within 5 km of the floodplain, showing the close dependence on floodplain by pastoral land use (Oba et al., 2002). The Turkana pastoralists who have customary ownership of trees (*ekwar* sing. *Ngekwarin* pl.) conserve pastures near the river during the wet season for use during the dry season (Barrow 1991; Stave et al., 2001). For the Orma the floodplain of the Tana River (*chaafa*) (Terer et al., 2004; Gufu Oba unpubl.) and for the Afar, the floodplain pastures (*kaalo*) of the Awash River (Getachew 2001), are critical resources during drought years.

The majority of these rivers are being regulated by dams for commercial irrigations directly competing with pastoral land use. Regulations of rivers have always been controversial despite the legitimate national development policies. Reconciling local interests with the greater national interests remain unaddressed. If one might take the example of dams, they are critical national sources of power without which government would not be able to provide basic human needs such as lighting in homes and providing modern amenities that contribute positively towards national development goals. Thus, governance is provided with different scenarios when constructions of large dams are recommended. The scenarios are however given unequal weight, often ignoring that the blocking river ecosystems have huge ecological implications. River floodplains are highly specialized ecosystems that are not dependent for their functions on the immediate rainfall but on sub-surface aquifers and flash floods that supports floodplain landscape ecology and their unique vegetation and animal biodiversity.

In Africa where river basins are considered as major sources of economic growth through the harnessing of power to generate electricity and use of dams to build headwaters for irrigated agriculture in the downstream, different competing interests are at play. Dam construction is likely to influence flooding regimes and the regeneration of the floodplain vegetation as the natural flash floods become regulated and over bank periodic floods cease (Stave et al. 2005). The greatest threats are to pastoral herd mobility, if the purpose is to develop commercial irrigated agriculture. Competition between irrigated agriculture and the flood retreat traditional farms will involve loss of sensitive floodplain landscapes (Oba et al., 2002). This means that the ecological system of the floodplain will be altered by regulation of the different types of flooding regimes, while the traditional transhumance system will be disrupted. In the long-term irrigated agriculture will restrict the access rights of the pastoralists to floodplain pastures (Randall 2005; Scholte et al., 2006). In most cases, alterations in land use systems modify patterns of land use, as there is no attempt to integrate seasonal grazing patterns with commercial agriculture (Unruh 1990). Commercial agriculturalists will prevent the pastoralists' herds from gaining access to their crop lands. On commercial agriculture where crops are grown all the year round, the nomadic herds no longer have access to the crop stubble, while the floodplain pasture loss adversely influence the traditional pastoral transhumance (Unruh 1990; Johnson 1993). Other sources of threats to the floodplain are invasive species (Stave et al. 2007). In the Tana River area in Kenya, 20 to 30% of the rangelands are currently infested with *Prosopis juliflora*. The species is aggressively spreading along all perennial and seasonal rivers in much of the Horn of Africa (G. Oba unpubl.).

The question still remains how the use of the new paradigm improves management decisions for a win-win scenario instead of the lose-win scenario. The scenarios to consider will not only be ecological but also political. Can the harnessing of river floodplain be used in ways that would not alienate indigenous systems of land use? Will governments be agreeable to scenarios that might be less ambitious where a compromise is made between protection of the ecology and indigenous resource use while still addressing national interests in terms of power generation and irrigation? Answers to these questions are more likely to offer the best chance of tackling the problem of sustainable pastoral mobility.

The loss of critical dry season grazing resources is due to a failure of governance. Thus, governance should be more concerned with practical decisions to promote resource management. In the case of irrigated agriculture, government policies have in general favoured plantation agriculture for the production of cash crops, while ignoring pastoral mobility. Government policies claim to create "non-exclusionary" agriculture that will cater for the needs of both commercial farming and traditional resource access by pastoralists. But in practice, this has seldom been achieved (Unruh 1990). But how do local communities respond to such disruptions. This presents another scenario of resource governance that governments might consider when dealing with conflicting interests. At the local level there are institutional arrangements between different pastoral and agro-pastoral groups to share resources that lead to inclusion of others in mutually beneficial arrangements (Beyene 2010). This is how "non-exclusionary" system of resource use operates where local institutions create entitlements shared with neighbouring pastoral groups (Bogale and Korf 2009). Policies that ignore these delicate social relationships would create a crisis for pastoral herd mobility (Johnson 1993).

Conclusions

This paper has examined different arguments employed by different paradigms related directly or indirectly to pastoral herd mobility. The carrying capacity paradigm is unable to explain the complex ecological and social factors that affect herd mobility. The mobility paradigm rationalizes the sustainability of the indigenous pastoral system but it does not explain the functional decline in mobility. The modernization paradigm appears to seek solutions in terms of a changed system. It shows that the pastoral system is a resilient system which is able to transform itself even where there are irreversible changes to settled lifestyles. In the complex scenario, the modernization paradigm seems unable to offer a long-term solution. The RRG paradigm is clearly more accessible and relevant to the policy makers. Yet, engaging the RRG paradigm requires good will and purpose from all the stakeholders. In particular the RRG paradigm has huge benefits where the indigenous system of governance is used to participate in the decision making. The key message of this paper is that sustaining pastoral herd mobility requires more than understanding ecological relationships between livestock grazing and changes in rangelands. It involves, reconciling competing resource use, it acknowledges that certain changes cannot be reversed and under certain circumstances pastoral land use transformation is permanent and the decision to return to mobility might not be justified.

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