Hum Ecol (2009) 37:589–612
DOI 10.1007/s10745-009-9271-0

Efficacy of Integrating Herder Knowledge and Ecological Methods for Monitoring Rangeland Degradation in Northern Kenya

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Published online: 31 July 2009

Abstract The world-wide debate on land degradation in arid lands, usually linked to local land use practices, does not reflect methodological advancements in terms of assessments and monitoring that integrate local communities' knowledge with ecological methods. In this paper, we evaluated the efficacy of three different methods related to herder assessments and monitoring of land degradation; herder knowledge and ecological methods of assessing impacts of livestock grazing along gradients of land use from settlement and joint monitoring of selected marked transects to understand long-term vegetation changes in southwestern Marsabit northern Kenya. The performance of each method was carefully evaluated and interpreted in terms of the indicators used by herders and ecologists. Herder interpretations were then related to ecologists' empirical analysis of land degradation. The Rendille nomads have a complex understanding of land degradation which combines environmental and livestock productivity indicators, compared to conventional scientific approaches that use plant-based indicators alone. According to the herders, the grazing preference of various livestock species (e.g., grazers versus browsers) influences perceptions of land degradation, suggesting degradation is a relative term. The herders distinguished short-term changes in vegetation cover from long-term changes associated with over-exploitation. They attributed current environmental degradation around pastoral camps, which shift land use between the alternating wet and dry seasons, to year-round grazing. We deduced from long-term observation that herders interpret vegetation changes in terms of rainfall variability, utilitarian values and intensification of land use. Long-term empirical data (23 years) from repeated sampling corroborated herder interpretations. Land degradation was mostly expressed in terms of declines in woody plant species, while spatial and temporal dynamics of herbaceous species reflected the effects of seasonality. The efficacy of the three methods were inferred using explanatory strengths of ecological theory; insightfulness of the methods for describing land degradation and the likelihood of using the methods for promoting local community participation in the implementation of the UN Convention on Combating Desertification (CCD) and the Convention on Biological Diversity (CBD).

Keywords Ecological indicators · Herder knowledge · Land degradation · Monitoring · Northern Kenya · Rendille

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Introduction

In the arid lands of the world, the land degradation and desertification debate has taken central stage for some time and resulted in international conventions such as the UN Convention on Combating Desertification (CCD) and the Convention on Biological Diversity (CBD) (Thomas and Middleton 1994; Arnalds and Archer 2000; Oba *et al*. 2000a; Geist 2005). However, the development and implementation of frameworks for integrating indigenous knowledge of local communities and ecological methods have made limited progress (Oba *et al*. 2008a, b). Environmental assessments and monitoring concerned with combating desertification and land degradation have, for the most part, excluded local pastoralists, and considered scientific methods exclusively (Warren 1992; Oba *et al*. 2008a). The scientific bias of viewing pastoralists as the 'villains' of environmental degradation, due to common perceptions held by researchers that herders overexploit natural resources (see O'Leary 1984; Dahlberg 2000), has hardly created a constructive environment for collaboration between herders and ecologists.

In our view, the main problem might lie in the academic training of natural scientists whose analysis and understanding of land degradation are influenced largely by scientific methods and theories that make strong links between land degradation and the types of land use practiced by herders (e.g., Behnke and Scoones 1993; Lamprey 1979, 1983; Thomas and Twyman 2004). The equilibrium ecological theory that strongly associates the debacle of rangeland degradation with greater stocking rates of livestock by pastoralists (e.g., Hardin 1968) for example appears to ignore the potential use of indigenous knowledge that manages the rangelands for variability as opposed to stability.

The usefulness of indigenous knowledge for assessing and monitoring land degradation is however, being acknowledged by the opposing non-equilibrium theory (Ward *et al*. 1998; Oba *et al*. 2000a; Illius and O'Connor 1999, 2000; Sullivan and Rohde 2002; Davis 2005), in which environmental variability as well as local management systems are considered to be important drivers of ecosystem dynamics. The non-equilibrium theory proposes, for instance, that changes in plant-based indicators in arid zones are influenced more by climatic variability and less by anthropogenic drivers (e.g., Oba *et al*. 2000a). According to this theory, shifts in vegetation cover and composition between the wet and the dry seasons represent not degradation, but rather evidence of fluctuating rainfall. Vegetation cover and species composition decline when grazing is heavy and sustained (Fynn and O'Connor 2000) and improve with increased precipitation and reduced grazing pressure. Such changes reflect what is called 'ecological resilience' (Berkes *et al*. 1998). In non-equilibrium ecosystems pastoral land use is closely tied to vegetation dynamics, which in turn are greatly influenced by climatic variability to which pastoralists respond using mobility (Niamir-Fuller 1998, 1999). Under excessive anthropogenic pressures, the resilience threshold is exceeded, resulting in land degradation (Binns 1990; Thomas and Middleton 1994). Thus, whenever it occurs, desertification of arid ecosystems represents a loss of resilience. Putting greater emphasis on short-term ecological assessments might, however, fail to capture the processes that lead to land degradation. In contrast to ecologists, local communities have developed in-depth knowledge of their environment over the long term, based on many years of livestock herding and environmental assessments. Their in-depth knowledge of key fodder species, as well as the grazing potential of different landscapes, forms an important basis for their pastoral practices (Roba and Oba 2008, 2009). Thus, the current thinking of most resource managers (albeit lacking universal agreement) is that the knowledge of local communities could make important contributions to better understanding of the mechanisms involved (e.g., Ellis and Swift 1988), and to developing frameworks for integrating indigenous knowledge and ecological methods for the assessment and monitoring of land degradation (Oba and Kaitira 2006; Oba *et al*. 2008a, b).

In this study, we examined the implications of different interpretations of land degradation, considering the perspective of local communities and their indigenous knowledge (hereafter referred to as 'herder knowledge'), as compared to ecological methods. 'Herder knowledge' can be defined as the experiences and perceptions of herding communities based on long-term observations and assessments of grazing lands. Such knowledge is used for making livestock management decisions. Although the importance of indigenous knowledge has been recognized by global environmental conventions such as the United Nations Convention on Combating Desertification and the Convention for Biological Diversity (CBD) (UNCCD 1994), its application has been ignored in monitoring work in environmental conservation in general, and in the implementation of the conventions in particular. The use of herder knowledge has also been constrained by the lack of clear protocols for integrating herder methods of resource assessment and monitoring with conventional scientific methods. Furthermore, reliance on ecological methods alone has not succeeded in understanding land degradation from the perspective of livestock production (Fraser *et al*. 2006), nor in capturing the perceptions and experiences of local communities (Krugman 1996; Oba and Kotile 2001). The analysis of land degradation would therefore be made considerably more fruitful if local knowledge and perceptions were taken into consideration alongside the scientific methods (Reed *et al*. 2007; Oba *et al.* 2008a, b). We expected that integrated assessment and monitoring of environmental change will improve understanding of the processes involved in land degradation by illuminating the causes and the trajectories of change. The combination of herder knowledge and ecological methods would improve the selection of more sensitive land degradation indicators.

Indicators of Land Degradation

Land degradation is a contextual concept and its definition varies according to the intended use (Warren 2002). For example, consideration in terms of biodiversity conservation is different from that for livestock grazing. While conservationists are interested in the total plant species present, for pastoralists, the emphasis is more on key fodder species (Roba and Oba 2008, 2009). Even in terms of particular grazing requirements, the feeding habits of livestock (browser versus grazer) influence the definition of land degradation (Roba and Oba 2009). The controversies surrounding the land degradation debate may therefore be resolved by linking the definition of the concept to the land use system, vegetation indicators and the types of livestock species managed locally.

In this study, we used two types of indicators—plant-based ecological indicators and livestock—based indicators understood by local herders for the assessment and monitoring of land degradation. Herder knowledge is developed, through mobile livestock management. Pastoral communities monitor livestock production performance and vegetation simultaneously in order to assess land degradation (Reed and Dougill 2002; Oba *et al*. 2000b; Roba and Oba 2009), using indicators such as vegetation cover, species richness and composition, soils, animal health and behavior (Fraser *et al*. 2006; Hambly 1996). Herders combine both ecological (plants and soils) and livestock production indicators (milk yields, mating frequency, calving rates and general animal health) as proxies for assessing degradation of the grazing lands.

Livestock production indicators can be documented through interviews, while joint field assessments would improve understanding of the rationale used by herders in terms of their decisions based on environmental indicators such as plants and soils. In terms of rangeland plants, herders are more concerned with key forage species, which are specific for different rangelands and are key indicators for determining if rangelands are sustainable or degraded. Herders monitor key forage plants in relation to livestock productivity indicators. Accordingly, they perceive that some plant species do not tolerate overuse in the long term and these species thus decrease in grazing landscapes (hereafter referred to as ‘decreasing species’). Unfortunately, these are usually the most valuable forage species. Weedy species increase (‘increasing species’) in landscapes that have been subjected to sustained heavy use, while other species are tolerant to grazing pressure (these are known as ‘stable’ species) (Roba and Oba 2009). The different responses of plants to grazers are inferred from historical knowledge of livestock herding and continuous range assessments (e.g., Oba *et al*. 2008a, b; Reed *et al.* 2007). According to herders, however, grazing impacts alone do not change plant species composition, while low rainfall, coupled with heavy grazing would do so (Oba *et al.* 2000a; Oba and Kaitira 2006). The traditional practice of grazing movements across landscapes avoids overuse of the range, except around settlements where over-exploitation becomes inevitable due to the concentration of stock and humans (as investigated in this study).

The same plant-based indicators could be used by trained ecologists. Plant-based indicators improve information on spatial and temporal coverage and are therefore necessary for comparing changes in different land units over time (Havstad and Herrick 2003; Spellerberg 2005). In terms of grazing lands, plant-based indicators commonly used by ecologists include composition and cover. Repeated samplings (e.g., Kraaij and Milton 2006) may be used to infer indicator dynamics. The spatial scale for monitoring requires careful consideration in order to differentiate between management-induced changes and changes related to environmental variability (e.g., Oba *et al*. 2008a, b). Such careful consideration is necessary in arid zone ecosystems where changes in vegetation indicators are highly dynamic in response to variable rainfall as well as anthropogenic pressures. For this reason, changes monitored over time should only compare a wet versus another wet period, or a dry versus another dry episode, in order to control for seasonally related changes. This is the approach used in the present study in southwestern Marsabit, northern Kenya where scholars in the past linked land degradation and desertification to pastoral sedentarization, heavy livestock grazing pressure and overutilization of woody plants (e.g., Lusigi 1981; Lamprey and Yussuf 1981).

The main objectives of the study were (a) to assess and monitor rangeland degradation using three methods: (1) herder knowledge of assessments and monitoring of land degradation; (2) herder knowledge and ecological methods of assessing impacts of livestock grazing on plant-based indicators along gradients of land use from settlement and (3) jointly with herders to monitor selected IPAL (Integrated Project on Arid Lands) marked transects to understand changes in plant-based indicators over 23 years. (b) To evaluate the efficacy of integrating herder knowledge and ecological methods for assessing and monitoring rangeland degradation. The efficacy of the methods were evaluated in terms of three criteria. Firstly, the relationship between the indicators and ecological theory; secondly, the insightfulness of the methods in describing land degradation and thirdly, the likelihood of using the methods to promoting community participations in the implementations of the Convention on Desertification and Convention on Biological Diversity.

Southwestern Marsabit, Northern Kenya

The region of southwestern Marsabit District is semi-desert, receiving less than 200 mm annual rainfall (Pratt and Gwynne 1977) with frequent droughts (Bake 1983). Detailed anthropological studies in northern Kenya, particularly in relation to pastoral sedentarization, modes of land use, and responses to drought and development have been dealt with exhaustively by others (e.g., Fratkin 1991, 1994; Fratkin and Roth 1990; McPeak 2005; Roba and Witsenburg 2004).

Scholars in the past (e.g., Lusigi 1981; Lusigi *et al*. 1986; Lamprey and Yussuf 1981) linked land degradation around pastoral settlements (*gop*) to home herds that continuously overgrazed, while herders over-harvested woody plants around pastoral settlements to build livestock night enclosures against predation by large carnivores (Roba and Oba 2008). The general concern is that in addition to progressive pastoral settlements, the overall grazing home range of the Rendille has been shrinking since the 1920s due to administrative and insecurity pressures. Prior to the 1930s, the Rendille nomads had expansive grazing lands that allowed seasonal livestock mobility (Sobania 1979). According to Dollan (1980), there was a drastic reduction in the extent of the homeland range from 1923 to 1978. Dollan attributes this reduction to development interventions by missionaries, the provision of famine relief, and the government policy of settling nomads. The insecurity problems that began with banditry in the 1960s through to the 1980s were transformed into armed conflicts with other neighboring pastoral groups, which squeezed the Rendille into a fraction of their original home range. The consequence was heavy grazing, particularly around pastoral settlements (Lusigi 1981).

The settlements of Korr and Kargi (the focus of the current study), had their vegetation cover over-exploited from 1971 to 1978. The period marks the initial stage of land degradation characterized by high rates of over-exploitation of woody vegetation and heavy grazing in and around pastoral camps. Despite the perceived environmental degradation, Rendille pastoralism appears to be resilient (see also Fratkin 1991). Compared to neighboring pastoral communities, their production system has remained fairly robust. At the time of the study in 2005 and 2006, most of the pastoral camps were located within 4 to 15 km of Korr and 1 to 2 km from the Kargi urban settlements (Fig. 1). The transfer of excess and non-milking livestock between the mobile *fora* herds which are managed in distant camps and the home-based herds, allows the Rendille systems of land use to be dynamic (O'Leary 1985). The *fora* herds tracked grazing within 18,000 km^2 of the current home range, and occasionally across into the neighboring Samburu District by responding to seasonal rain pools to exploit the patchy wet season rangelands. Additionally, during the wet season, the Rendille people have a tendency to return to the home-based camps. This practice is associated with rituals that require the coming together of the herds and people at least for some few days once a year (O'Leary 1984; Fratkin 1986, 1994). They then return to the dry season grazing areas that are waterless and travel long distances to reach water, a common strategy used by camel owning families.

The Rendille rangeland was the focus of research by the UNESCO Integrated Projects on Arid Lands (IPAL) about 23 years ago. The IPAL research was concerned with human impacts on the environment (e.g., Lamprey and Yussuf 1981; Lusigi *et al*. 1986) and initiated rangeland monitoring programs in the early 1980s in order to understand the dynamics of land degradation (Lusigi *et al*. 1986). The Rendille rangelands were mapped into 25 vegetation types (hereafter referred to as 'range units') used as grazing resources (Fig. 2). The objective was to monitor land degradation and expansion of desertification from centers of heavy use into the distant rangelands, thereby comprehending the spatial and temporal variation of vegetation production (Lusigi *et al*. 1986). The monitoring was built on plant-based indicators but ignored livestock production-based indicators used by herders (Lusigi *et al*. 1986). We selected the Kargi and Korr settlements (Figs 1 and 2), which form the core grazing lands of the Rendille pastoralists. The vegetation and land use have been described elsewhere (Lusigi *et al*. 1986). The rangeland is used mainly for communal grazing by multi-species herds comprising camels, cattle, goats and sheep. The mean livestock holding per household during our survey was about 38 Tropical Livestock Units (TLU; Roba 2008). In order to understand the long-term impacts of land use systems (particularly livestock grazing), four IPAL grazing range units were chosen (Fig. 2), with areas varying from 23.5 to 3,011.2 km^2.

Methods

We used the performances of the three different methods in order to evaluate the efficacy of integrating herder knowledge and ecological methods for assessing and monitoring rangeland degradation and the results interpreted in terms of deductions and inferences made from the outcomes of joint assessments and monitoring.

Method 1: Herder Perceptions of Land Degradation

Experience from working with different pastoral groups in East Africa (Roba and Oba 2008; Oba and Kotile 2001; Oba and Kaitira 2006; Oba *et al*. 2008a, b; Mapinduzi *et al*. 2003) shows that members of the community possess knowledge of landscape and vegetation assessment and monitoring through herding experiences over many years. With the help of the communities we selected and interviewed a total of 38 herders, the majority being men, with 21 from Kargi and 17 from the Korr pastoral camps. We interviewed the herders with the aim of understanding terms and concepts, as well as the methods they use for assessment and monitoring of rangelands.

During the discussions, the herders described their reasons for assessing and monitoring the rangelands, as

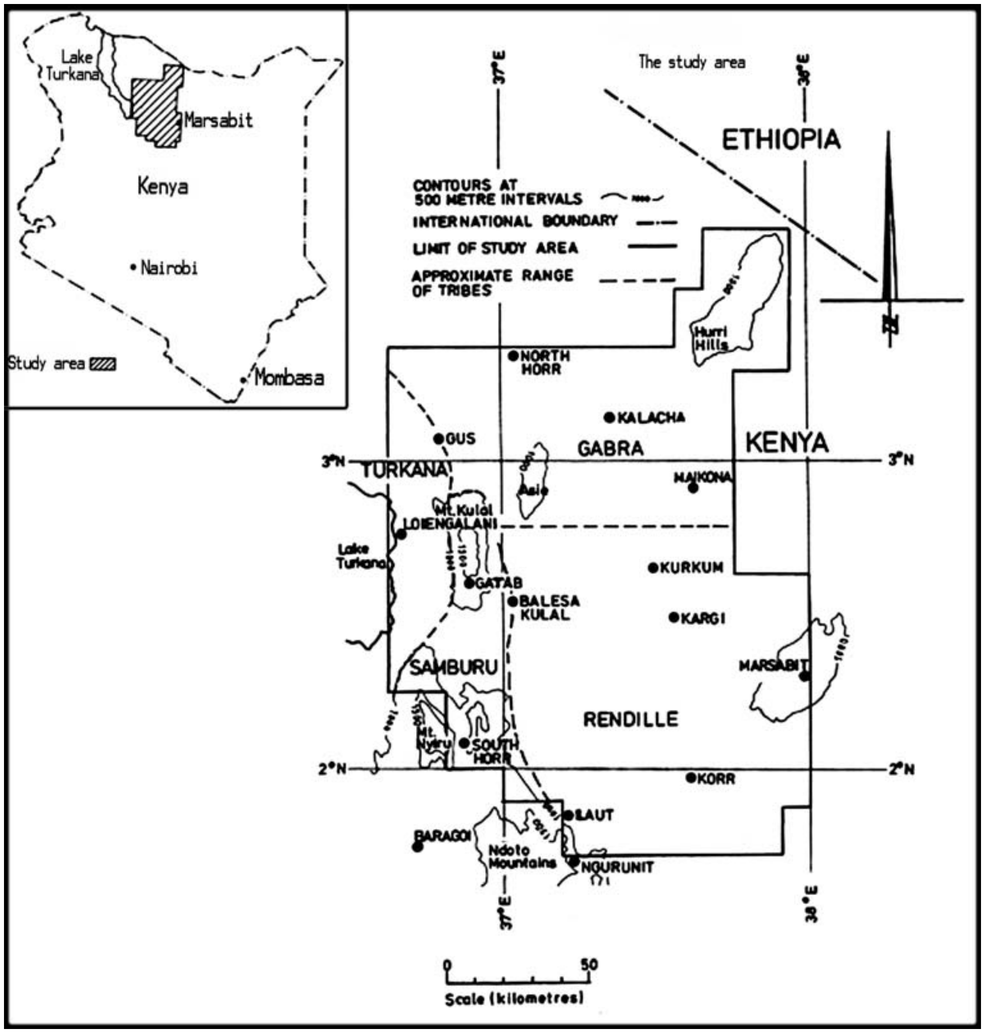

Fig. 1 Location of Kargi and Korr in inset map of Kenya, showing the location of the former UNESCO-IPAL study area, modified from Map 2 in Lusigi (1984)

well as the livestock production performance indicators and plant-based indicators they use. We also analyzed the terminologies herders use for describing changes associated with rangeland degradation and livestock grazing suitability of different landscapes. The discussions concentrated on what the herders considered as 'good' (*mirr qabdo*) and 'bad' (*mirr maqabdo*) rangelands, and what indicators they use for monitoring changes. Herders' perceptions were used to capture a broader understanding of environmental change, encompassing livestock production and environmental indicators. The next task was to understand the herders' perceptions of the trends in vegetation-based and livestock productivity indicators over time. These perceptions were then applied to the joint field assessments of the impacts of land use gradients from settlements on vegetation.

Method 2: Impacts of Land Use Gradients on Vegetation

For the second method, we selected the settlement of Korr for joint field surveys with seven of the most knowledgeable herders selected from the groups interviewed earlier. There were four reasons for selecting the Korr rangelands (Fig. 1). Firstly, the area is centrally located in the Rendille home range and was reported as being highly degraded (Lusigi 1981). Secondly, the settlement had been monitored earlier in terms of understanding changes in vegetation composition and land cover along radial distances from the settlements (Walther and Herlocker 1980). Thirdly, the Korr site is the main source of water in the region. The numerous hand-dug wells along the dry riverbed attract livestock for watering from the surrounding areas during the dry season. Fourthly, in a separate study, we focused on the regeneration of woody vegetation around Korr, but did not include assessments of the pastoral camps located 5 to 6 km from the town centre (H.G. Roba and G. Oba unpubl).

We conducted joint herder and ecologist assessments using road transects, each 20 km long, in three compass directions from the centre of the Korr town (Fig. 1). To the south of the settlement we selected the Korr−Ngurunit road, to the southwest, the Korr−Ilaut road and to the north, the Korr−Kargi road. The road transects traverse the IPAL Range Units 2, 13, 20 and 24 (Fig. 2). We used vehicle

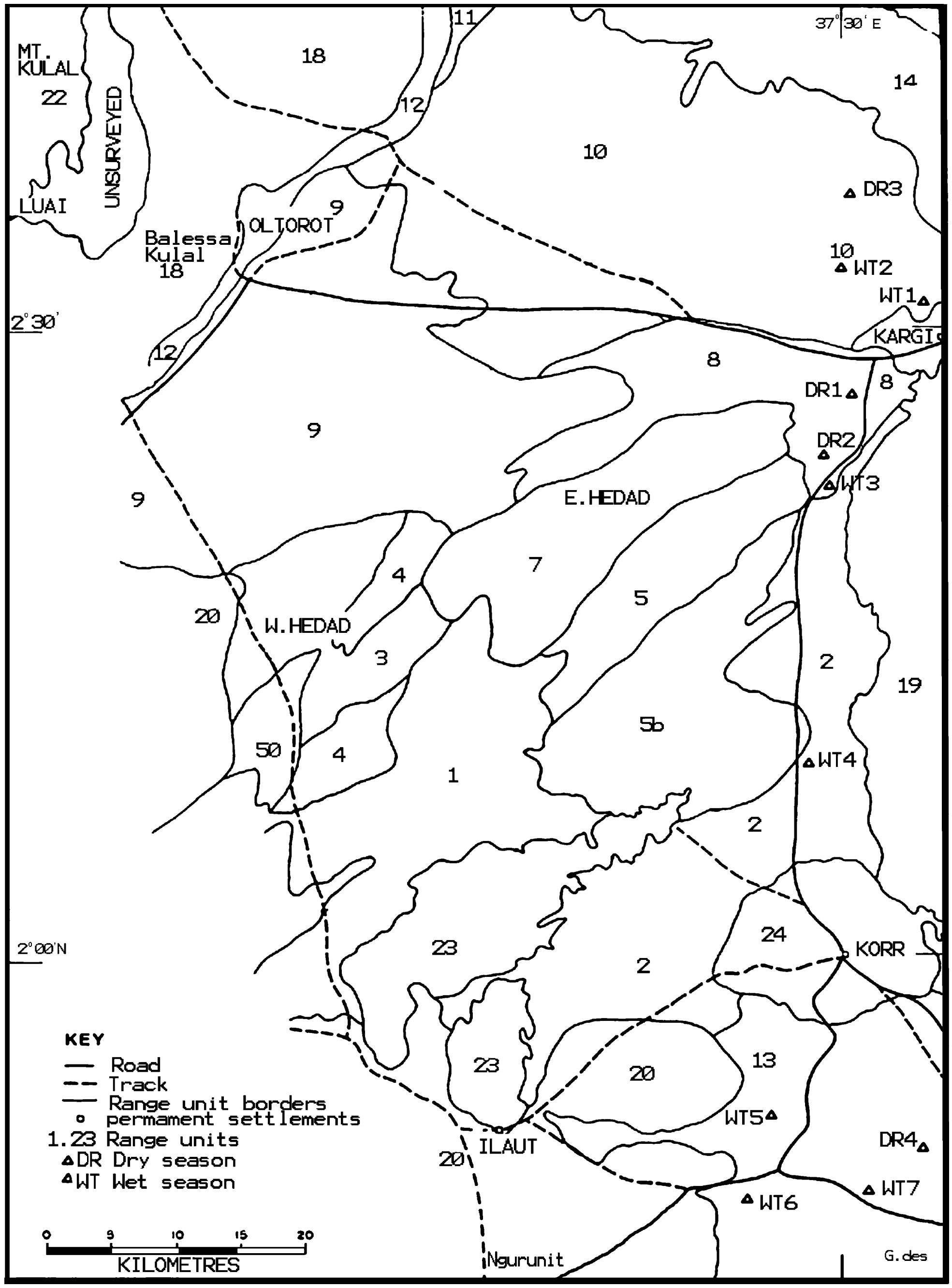

Fig. 2 Map of the UNESCO-IPAL range units showing the location of re-sampled transects, modified from Map 7 in Lusigi *et al.* (1986)

odometer readings to mark the distances of each transect and made stops at 2 km intervals. Along each route the impacts of land use gradients were assessed jointly with herders in terms of changes in plant indicators (i.e., plant cover, composition, range condition and trends) in relation to the history of land use. In total 30 survey points were used (three road transects × 10 stops each). At each stop (always on alternating sides of the road) the joint team walked 100 m away from the road and the herders were requested to make their assessments at landscape level. They did this by walking about the surveyed landscapes, examining plants, considering evidences of recent and past land uses, grazing intensities of different plant species and discussing among themselves to reach consensus. The final decisions on their assessments were presented by the more elderly among the herder Team. Herders explained the hierarchy in terms of how they usually reach decisions.

Herders traditionally classify landscapes by considering soils and dominant plant species (Oba *et al.* 2000b). For each of the landscapes surveyed, the herders were asked questions about seasons of grazing in the past and if the use of the grazing season had been altered in recent years. Reference was made to the herding years since the settlements, which was about 45 years. Herders identified key forage species preferred for grazing by different livestock species. Camels and goats prefer dwarf shrubs, while cattle and sheep prefer forbs, annuals and perennial grasses. Using this a priori, the herders determined whether the key forage species (compared to historical knowledge) were 'present' or 'absent.' The absence of the key forage species during the wet season was used as evidence of degradation. With reference to the dry season which is a dormant period, the herders, when asked about key species stated that "...they [plants] would be back with the rains". Thus, absence during the dry season did not necessarily imply degradation for annual plant species, because of their fluctuating habits but did so for perennial grasses and woody species (i.e., shrubs and trees).

Simultaneously with herder assessments at each stop, the ecologists randomly located nested 1×1 m plots for assessing herbaceous species, 2×2 m plots for assessing dwarf shrubs and 5×5 m plots for counting tree species. Eight plots were used per stop $(8\,\text{plots} \times 10\,\text{stops} \times 3\ \text{transects} = 240\,\text{plots})$. Since the plots were nested within landscape patches, herder and ecological assessments were interpreted in the context of the grazing condition at landscape scale. For all plants present in the plots, the herders reported suitability for grazing by different livestock species. The herders evaluated the trends of individual plant species using their historical knowledge of land use, and then considered whether the species increased, decreased or remained stable compared to their knowledge of the past for each landscape. The herders did this by responding to the simple question: "Has this or that species changed compared to the past?" We asked the herders about the preferences of different livestock species for different categories of plant species, and how changes in plant species composition could influence the food supply for the livestock species concerned. The herders were also asked what they considered as being preferred (i.e., good) or not preferred (i.e., bad) about particular landscapes. The process was repeated for all the landscapes that were surveyed. Altogether jointly with the herders we surveyed three traditionally classified landscape types referred to as *tori*, *kuya* and *thobos*[1] that recurred throughout 630 km^2 of the rangelands around Korr town.

Methods 3: Monitoring the IPAL Transects

Long-term trends in vegetation indicators may be evaluated either in relation to herders' historical knowledge of land use (as in the second method), or by monitoring fixed transects. In order for us to give a historical dimension to the monitoring of the Rendille rangelands, we selected four of the Range Units that IPAL had earlier marked for long-term monitoring of vegetation changes. The Range Units were subjected to grazing during different seasons (wet and dry seasons). At the time of our survey in 2005 and 2006, the land use for most Range Units had shifted to year-round grazing, similar to that around the settlements. The baseline surveys were conducted by IPAL during the wet season in 1982 and during the dry season in 1983.

Herder participation in monitoring of the range units is necessary because the range units have experienced different degrees of utilization over the monitoring period and the local knowledge of land use is necessary for interpretation of the observed changes. Our selection decisions of the Range Units were influenced by the availability of earlier assessment and monitoring records. Full descriptions of the four transects in the selected Range Units according to the IPAL classifications are given in Table 1. Four transects marked in Range Units 8, 10 and 13, and seven transects in Range Units 2, 8, 10 and 13 (Fig. 2) were re-sampled in September/October 2005 (dry season) and in May 2006 (wet season) respectively. Each re-sampling was conducted at two levels: using herder knowledge and the ecological methods as described in "Method 2." Firstly, we asked the herders to describe the past and current grazing seasons and the trends of the plant-based indicators in the landscapes of the marked transects. Similar to the procedure for "Method 2," we asked the herders to evaluate the trends of key forage species and the general changes in land use within the particular range units. Secondly, along individual transects, ecologists repeated the measurements using the same sampling procedures and ecological indicators used by IPAL, for purposes of comparison (Lusigi *et al*. 1986).[2] The 300 m long marked transects were each sampled by pacing, using a thin metal handle with a metal 'loop' measuring about 2 cm in diameter and placed at the end of the shoe of the pacer. At every step, the reading of the 'hit' by the loop served as a unit of measurement for herbaceous plant cover, bare ground, litter and rocks. The hits were then used to estimate the frequency of the different ground cover classes (CSU 1970). At 30 m intervals in each transect, we recorded all the plant species present using nested 1×1 m (herbaceous species), 2×2 m (dwarf shrub species), and 5×5 m (tree species) plots. In total, 10 plots of each category were used per transect. Plant species data (species frequency, composition and richness) collected at the plot level were compared with corresponding data recorded by IPAL for the wet season in 1982 and the dry season in 1983. All the species found in the

[1] All the grazing landscapes have comparable elevations at <500m a.s. l.

[2] Among the field team, two of the research assistants were involved in the earlier surveys. The assistants were responsible for sampling during the dry season in 2005 and the wet season in 2006.

Table 1 Descriptions of the UNESCO-IPAL Range Units and Transects in Northern Kenya

Transects code	Start location	Range unit	Range unit description UNESCO IPAL 1984
WT4	N 02° 1′ E 037° 2′	2	Mixed *Indigofera/Duosperma* bushed dwarf shrub land and *Dactylactinium* /*Sorghum* annual grassland): covering total area of 494 km^2. The main dwarf shrubs include: *Indigofera spinosa* and *I. Cliffordiana*. The main grasses and herbs are *Aerva persica*, *Aristida adscensionis*, *A. mutabilis*, and *Cenchrus ciliaris*. Trees commonly found in the unit include: *Acacia horrida*, A. *reficiens*, *A. seyal*, *Cadaba glandulosa*, *C. ruspoli*, *Cordia sinensis*, *Euphorbia cuneata* and *Lycium europaeum*. The carrying capacity of the unit is 2.6 camels, 2.6 cattle, 5.9 sheep and 5.5 goats. The Range Unit is heavily grazed and susceptible to degradation. It was described as being in 'poor' condition, both in terms of herbaceous and woody species. It is in use both in the dry and wet seasons by cattle, camel and small stock
DR1	N 02° 2′ E 037° 3′	8	*Acacia* with *Lippia/Duosperma* bushland: The unit covers an area of 244.7 km^2. The main dwarf shrubs are *Lippis somalensis*, *Duosperma eremophilum*, *Barleria eranthemoides*, *Indigofera cliffordiana* and *I. spinosa.* The dominant trees and big shrubs include *Acacia reficiens*, *A. mellifera*, *Cadaba farinosa* and *C. glandulosa.* The unit is used in the wet season by cattle and camels and in all seasons by small stock. The crop biomass was estimated at 790.6 kg/ha with a carrying capacity of 4.3 camels, 5.9 cattle, 12 sheep and 9.8 goats per km^2. The unit was rated as being in 'fair' condition, both for herbaceous and woody species cover.
DR2	N 02° 2′ E 037° 3′		
WT3	N 02° 20′ E 037° 27′		
WT1	N 02° 30 E 037° 34	10	*Acacia* bush land with *Duosperma* understorey: The unit occupies a total area of 1025.7 km^2. Dominant dwarf shrubs include *Duosperma eremophilum*, *Barleria eranthemoides*, *B. proxima*, *Euphorbia samburuensis*, *Heliotropium albohispidum*, *Indigofera cliffordiana*, and I. *spinosa.* Dominant trees include *Acacia mellifera*, *Acacia horrida*, *A. Senegal*, *A. reficiens*, *Cadaba farinosa* and *C. glandulosa.*. Common grasses are *Aristida adscenionis*, *Brachiaria leersioides Cenchrus ciliaris* and *Dactyloctenium aegyptium*. It is used mainly by cattle in all seasons and in the wet season by camels and small stock. The unit has a carrying capacity of 5.1 camels, 2.8 cattle, 5.7 sheep and 11.5 goats per km^2. The unit was lightly used except in areas around water points such as the Kargi−Kurkum road, and it was therefore in 'fair' condition.
WT2	N 02° 08 E 037° 29		
DR3	N 02° 36′ E 037° 30′		
WT5	N 02° 51′ E 037 2′	13	*Indigofera/Heliotropium* with *Acacia* dwarf Shrubland. The unit covers approximately 635.2 km. *Indigofera spinosa* and *Heliotropium albohispidum* are dominant dwarf shrubs. Most common tree species are *Acacia reficiens*, *Acacia mellifera*, and *A. nubica*. Major annuals include *Aerva persica*, *Aristida adscensionis*, *A. mutabilis* and *Blepharis linariifolia*. Grazing in this area depends to a great extent on the available rainfall. The unit has a carrying capacity of 1.3 camels, 2.8 cattle, 5.8 sheep and 2.9 goats. The unit is heavenly utilized and the condition was described as 'poor'.
WT6	N01° 48′ E037° 22		
WT7	N 01° 48′ E 037° 31′		
DR4	N 01° 50′ E 037° 32′		

surveyed landscapes and sampled plots were identified by herders and ecologists.[3] The different data sets for each of the three methods were then subjected to analysis.

Data Analysis

1. We used herder narratives which describe their perceptions of 'good' or 'bad' rangelands. We considered herder perceptions and their knowledge of livestock productivity, soil condition (i.e., in terms of describing degradation) and plant-based indicators. Additionally, we identified concepts herders use for describing land degradation and loss of plant species.

2. From the road transect surveys we evaluated herders' descriptions of landscape types, grazing seasons and the presence or absence of key fodder species. We used the frequency ('absence' or 'presence') of the key indicator species to describe the current state of land degradation at the landscape scale. We used plant species response to grazing (i.e., 'increasing,' 'decreasing' or 'stable') to evaluate the conditions of fodder, based on the preferences of different livestock species (cattle, sheep, goats and camels). The abundance of plant species relative to distances from the settlement were analyzed using the linear constrained ordination model (Redundancy Analysis (RDA) in CANOCO (Ter Braak and Šmilauer 1998), with distance as the environmental gradient.

To understand species richness and cover changes along the gradients of land use from the settlement of Korr, we

[3] Voucher samples of the plant species unidentifiable in the field were deposited at the Herbarium of the KARI station in Marsabit.

organized the data according to distance intervals along the road transects: 2–6, 8–14 and 16–20 km. The three distance gradients were coded as 1, 2 and 3 respectively. Each gradient corresponded with zones of relative grazing pressure. Gradient 1 corresponded with zones that had a history of overgrazing. During previous decades the vegetation in these zones had recovered from over-exploitation due to local conservation. Gradient 2 represented zones that corresponded to the area around the pastoral camps (*gop*), with high grazing pressure. Gradient 3 represented zones of communal grazing rangeland, also with high grazing pressure, but of less severity compared to gradient 2. Plant species richness was grouped into two categories: herbaceous and dwarf shrubs in one category and big shrubs (<1.5 m in height) and trees in another. The grouping of plants into broader categories was based on the types of forage categories for the different livestock species: small stock, cattle and camels. Plant species richness and cover in the three distance gradients were compared using the General Linear Model (SAS 2003).

3. For the herder assessment of the IPAL Range Unit transects, we described the past and current seasons of use and the vegetation trends. For the ecological assessment of species abundance: herbaceous, shrubs and trees, we compared the frequencies and cover between 1982 and 2006 (wet seasons), and 1983 and 2005 (dry seasons) using the paired *t*-test. Species composition (presence–absence) data for 1982 were compared with that of 2006, while the composition for 1983 was compared with that of 2005 using Principal Components Analysis (PCA) in the CANOCO program. Dissimilarities in species composition between different samples (1982 vs. 2006 and 1983 vs. 2005) were deduced based on the magnitude of the Euclidian distances in the ordination matrix (Lepš and Šmilauer 1999). For comparison purposes, species composition dissimilarity analysis was conducted only in Range Units 8, 10 and 13 that were represented by transects in both the wet and dry seasons. Range Unit 2 did not satisfy the sample size for the CANOCO program and was therefore excluded in the ordination analysis. The proximate spatial distances of the pairs of the wet versus wet and dry versus dry for the ordinations of ecological indicators from Range Units 8, 10 and 13 were used to deduce indicator changes associated with seasonality. A similar pattern between the wet and dry season for the data ordinations was assumed to reflect sustained land degradation, while different patterns between the wet and dry seasons disclosed seasonality effects.

Results

Herder Perceptions of Land Degradation

According to 70% of the herders interviewed, a 'good' rangeland provides favorable conditions for livestock production performance in terms of higher production of milk, rapid weight gains and regular mating and calving frequencies of the breeding stock. Herders' views of good rangelands were closely associated with spatial and temporal (seasonal) variation in important fodder species. A herder described a good rangeland as follows:

> A good rangeland is where livestock get fat and produce plenty of milk….Such areas usually have lots of nutritious plants such as Lemaruk (*Blepharis linariaefolia)* and Khoro (*Indigofera spinosa)*. A bad rangeland, [besides lacking good fodder]… are usually infested with ticks that are not good for livestock health…We Rendille think that there are some of our grazing areas [based on past experiences] which are not good for grazing [for different species of livestock]… Good land can [also] become bad...

According to the herders, the conditions described as 'good' and 'bad' rangelands varied not only from spatial and temporal perspectives, but also for different livestock species. They identified certain land areas as being not preferred for grazing by a given species of livestock, due to a combination of factors. Their descriptions refer to unfavorable changes in the range following heavy grazing pressure and there was consensus that 'bad' rangelands would not support increased livestock productivity. They gave an example of the areas around pastoralist camps, where important plant species were lost and the productivity of livestock had since declined. Sixty three percent of the herders reported that livestock managed around the pastoral camps produce less milk, while 55 percent observed reductions in mating and calving frequencies. A herder narrated changes in livestock production performance as follows:

> In the past we moved frequently with our livestock [over long distances]. Those times, livestock provided us with plenty of milk, and reproduced [very frequently]. These days the people have become fools [lazy], they stay in one place, and you can see for yourself this area does not have enough fodder for livestock grazing….We are surrounded by 'dead land'. [This is why] We have less milk and [our livestock have] shorter lactation duration…the animals change with changes in environment...[too].

The 'dead land' refers to extreme levels of land degradation currently observed in and around pastoral camps in the

Korr area. The areas the herders referred to suffer from wind erosion and problems of sand dune formation. Their view was that livestock productivity performance was adversely affected under such environmental conditions. Livestock productivity indicators such as loss of animal body condition, reduced milk yields and lack of rumen fill are monitored by the herders. Reduced vegetation cover and species composition were attributed to continuous livestock grazing pressure, according to 55% of the herders. When monitoring livestock productivity indicators, 80% of the herders considered seasonal effects. During the wet season all livestock productivity parameters improved. The indicators were optimal when the condition of the rangeland was 'good' and unsatisfactory when the range was in 'bad' condition. During the dry season, when forage conditions declined, livestock productivity indicators deteriorated.

The Rendille herders' concepts of 'good' (*mirr qabdo*), and the less preferred condition (*mirr maqabdo*) symbolize 'the healthy and the sick land' respectively. Based on their historical knowledge, herders have mental maps of the *mirr qabdo* and *mirr maqabdo* landscapes. Livestock graze *mirr maqabdo* landscapes only briefly, and such areas are usually avoided by settlements, compared to *mirr qabdo* which are preferred for grazing and putting up pastoral camps. A herder described the choices as follows:

> When we get to a new grazing area we assess the amount of fodder for livestock. After herding in such areas and the livestock health [condition] remains poor, we move to new sites till we get to where livestock health and production is the best...some of our grazing lands may have good grass cover but they lack *mirr*...[such areas are avoided].

The herders' inferences were not from vegetation-based indicators alone. They also considered various inherent properties of the range (such as the presence or absence of pests, suitability of soils) that they inferred from livestock production performance. Thus, the rangelands that lacked *mirr* (i.e., *mirr maqabdo*) may have had abundant vegetation cover, but for reasons not clearly explicable, livestock productivity indicators were reduced. According to the herders, such influential factors might vary from one season to another, but for some landscapes they may represent a permanent phenomenon. Such rangelands are considered degraded from the utilitarian perspective.

The herders perceived that different plant species have different levels of tolerance to grazing pressure. Whereas annual grasses and forbs are least affected (because of their short-life cycles), the perennial species respond differently to grazing pressure. In their view, some important forage species were reduced around settlements due to grazing pressure (e.g., *Blepharis linariaefolia* (Lemaruk), *I. spinosa* (Khoro), *I. cliffordiana* and *Digeria muricata* (Geigithan)). The changes in composition of the key forage species, in addition to the livestock productivity indicators, were used to monitor land degradation. The concepts of *mirr* and *mirr maqabdo* might therefore have both a direct and an indirect relationship to land degradation. The herders also used the terms 'overgrazed' and 'degraded' synonymously. The degraded land is referred to as *barbadah,* which implies a lack of vegetation cover caused by heavy grazing, such as that observed around sedentary pastoral camps. According to the herders' perceptions, the grazing lands around pastoral camps are perpetually in a condition of *barbadah*. The concept of *barbadah* to the Rendille is, however, a temporal one, associated with dry season conditions. Recovery are possible if the livestock is removed temporarily during the wet season. The opposite of *barbadah* is *araan* (*Somali*) or *miiche* (Rendille), which implies plentiful forage that in turn supports increased livestock productivity such as that shown along land use grazing gradients from settlement.

Impacts of Land Use Gradients on Vegetation

Herders classified the landscapes into three major groups described on the basis of soil and vegetation characteristics (namely *tori*, *kuya* and *thobos*). The *tori* landscape patches are characterized by open vegetation and loam-sandy soil, and are grazed by all livestock species, throughout the year. These are the most dominant landscapes, accounting for 60% of the sampled areas. The *kuya* landscapes (12%) are characterized by poorly drained clay soils and sparse vegetation cover. Due to their poor drainage, these landscapes are traditionally less preferred for grazing or establishing pastoral camps. The *kuya* landscapes are grazed by small stock soon after the rainy season, when ephemeral plant species regenerate. At the time of the research, grazing of the *kuya* landscapes located close to the settlements was by sheep, goats, cattle and camels throughout the year. The *thobos* landscapes (38%) have relatively denser, woody vegetation cover, perhaps because of their location along seasonal watercourses. The soils are mixtures of sand and loam. These landscapes are traditionally preferred for livestock grazing due to the presence of salty plants (*Salsola* species), which the Rendille call *arabharis*. Livestock (i.e., cattle, goats and sheep) graze this landscape mainly during the dry season. At the time of the survey, the use of these landscapes had shifted from alternating between the wet and dry season to year-round grazing.

Each type of landscape has key forage species, which the herders use to monitor vegetation changes for the purposes of livestock grazing. The key forage species include *I. spinosa*, *Indigofera cliffordiana*, and *Aristida mutabilis* in *tori* landscapes; *Acacia tortilis* in the case of *kuya* landscapes; and *Acacia reficiens*, *Commiphora* sp. and *sporobolus* sp. in *thobos* landscapes. The loss ('absence') of key forage species was greater in the *kuya* landscapes (37.5%), than in the *tor* (31%) and *thobos* landscapes (30%). The herders identified 44 plant species in total (Table 2). Seventy five percent of the recorded species were described as 'stable' (no change in composition over the years), 20% as 'decreasing', and 5% as 'increasing' (compared to decades ago). In the stable species category, 59% of the species had good fodder values, while in the decreasing species category, 85% of the species were considered important for fodder for the livestock species (Table 2). The stable, decreasing and increasing species were well represented across the surveyed landscapes. The exception was *I. cliffordiana,* which was described as decreasing, but had a high relative frequency (Table 2). The species described by herders as increasing had greater frequencies, as was to be expected. These data imply that herder classification of species trends was supported by field observations, in most cases. The decreasing plant species affected the grazers (cattle and sheep) more adversely than the browsers (goats and camels) as they constitute greater proportion of the fodder requirements (Fig. 3). The species described as decreasing are mainly grasses and herbs, which are more vulnerable to grazing impacts, are likely to be more sensitive to changes in soil moisture, and are thus more vulnerable to land degradation than the stable species.

The species–distance ordination shows highly significant correlations (r), namely r=0.77 along the Korr−Kargi road, r=0.70 for the Korr−Ngurunit road, and r=0.60 for the Korr−Illaut road (all P<0.05, Fig. 4a–c). The coverage of important key fodder species, including *A. mutabilis*, *I. spinosa* and *Oropetium minimum* was negatively correlated with the distance from settlement, i.e., these species were more abundant close to the settlement than at distances further away. The species that were considered by the herders to be less useful for livestock grazing, including *Solanum dubium* and *Duosperma eremophilum*, were positively correlated with distances from settlement. Other preferred species, including *Barleria eranthemoides*, *I. cliffordiana* and *A. tortilis*, also increased with increasing distance (Fig. 4a–c). Across the distance classes, herbaceous species richness did not vary, while woody species richness, but not woody cover, increased with increasing distances from the settlement (Table 3). Herbaceous and shrub covers were significantly higher in the proximity of the settlement (Table 3). The herders related the responses of individual plant species to different livestock species grazing preferences (Table 2) and offered explanations for species-grazing response along the land use gradients. Except for the areas around pastoral camps considered degraded, herders were of the view that change in species cover around Korr town reflected conservation. Equally important to the herders is the difference in sensitivity (i.e., 'increasing,' 'decreasing' or 'stable') of fodder species to grazing. The evidence would show that in the absence of monitoring data, herder knowledge of forage species dynamics can be a valuable tool for understanding long-term responses to grazing pressure. The evidence can be corroborated by ecological monitoring.

Monitoring of the IPAL Transects

According to the herders, land use patterns in Range Units 2, 8, 10 and 13 by multi-species livestock have changed over the previous 23 years, from alternating between the wet and dry seasons to year-round exploitation. The altered patterns of land use were attributed to the permanent presence of livestock grazing at the pastoral *gop* around the Kargi and Korr settlements. Herders described the vegetation trends of Range Unit 8 as 'decreasing' compared to the previous status.[4] The fodder species adversely affected were *I. cliffordiana* and *I. spinosa*. Similarly, Range Units 10 and 13 were traditionally grazed during the wet season, but are currently being grazed year-round. The herders described the vegetation trends as stable for Range Units 10 and 13. Although the utilization patterns of these two range units changed from wet/dry season to year-round, the herders suggested that the areas remained stable due to their greater grazing potential (i.e., greater resilience). According to herders, the landscapes with greater grazing potential are able to resist grazing pressure. Traditionally, knowledge of landscape potential has been used to regulate seasonal grazing. In Range Units 8, 10 and 13 herders' descriptions of the previous land use seasons compared with current uses were important for understanding the causes of land degradation.

The ecological data show that the majority of the plant species in the monitored range units showed declining frequencies over the sample periods in the wet (1982/2006) and dry (1983/2005) seasons (Tables 4 and 5). However, in Range Units 2, 8, 10 and 13 (wet season) and Range Units 8 and 10 (dry season) changes in species frequencies were not significant (t-tests, all P>0.05). The species frequencies were significantly higher in 1983 compared to 2005 for Range Unit 13 (t=3.41, P<0.05). The changes in vegetation cover between 1982 and 2006 (Fig. 5a), and between 1983 and 2005 (Fig. 5b) were not significant in any of the range units (t-test, all P>0.05). These observations on vegetation cover changes were in agreement with herders'

[4] The terms 'decreasing' (used by the herders) and 'declining' (used by ecologists) are interchangeable. In both cases, the reference was made to the past benchmark conditions referring to historical knowledge for the herders, and for the ecologists to the IPAL surveys of 1982 in the wet season and 1983 in the dry season.

Table 2 Herder assessments of trends and fodder values of plant species along 20 km road transects from Korr in northern Kenya

Species	Rendille name	Frequency (%)	Trends	Fodder value
Indigofera spinosa Forssk	Khoro	33.7	S	ALL
Duosperma eremophilum	Dyewalu	24.1	I	NONE
Indigofera cliffordiana J.B Gillett	Hanhanis	17.7	D	GO, SHE, CM
Solanum dubium		16.6	I	NONE
Acacia tortilis Hayne.	Dahar	13.3	S	GO,SHE,CM
Sericocomopsis hildebrandtii Schinz (ds)	Geidhabul	10.8	S	ALL
Acacia reficiens Wawra & Peyr.	Khasa	10	S	GO, CM
Aristida mutabilis Trin. & Rupr	Ririma	8.7	D	CT, GO,SHE
Cadaba farinosa Forssk	Geikuku	8.3	S	NONE
Maerua oblongifolia A. Rich.	Geigeri	7.5	S	GO, CM
Heliotropium steudneri Vatke	Dub-arar	7.9	S	NONE
Barleria eranthemoides R.Br.		7.9	S	GO, CM
Maerua crassifolia Forssk	Dume	5.4	S	GO, CM
Oropetium minimum (Hochst.) Pilg.	Hos	5.4	S	CT, GO, SHE
Commiphora flaviflora Engl.	Dowahadado	5	S	GO, CM
Dactyloctenium aegyptium (L.) Willd.	Maha	4.1	S	CT, SHE
Heliotropium albohispidum Baker	Okomi	4.1	S	GO,SHE,CM
Seddera hirsuta Damm. Ex Hallier	Dahar	4.1	S	GO. CM
Blepharis linariifolia Per.		3.75	S	CM
Cadaba mirabilis Gilg	Khathu	3.7	S	NONE
Justicia odora Vahl	Argi	3.7	S	GO, SHE, CM
Hermannia kirkii	Gei-Irban	3.3	S	NONE
Cadaba glandulosa Forssk	Guran-gur	3	S	CM
Salvadora persica L	Hayai	2.5	S	GO, CM
Cenchrus ciliaris Fig. & De Not.	Ballah	2.9	D	CT, SHE
Lycium europaeum L.	Adigorat	2.9	S	NONE
Acacia nubica Benth		2	S	None
Commiphora paoli		2.0	S	NONE
Acacia horrida Willd.	Gomor	1.6	D	NONE
Aerva persica Merr.	Gib	1.6	S	NONE
Boscia coriacea Paz	Ioror	1.6	S	NONE
Grewia tenax Forssk.	Mulehenyo	1.6	S	OG, CM
Euphorbia cuneata Vahl)	Andikha	1.25	D	GO,CM
Cordia sinensis Lam.		1.2	S	NONE
Terminalia brownii Fresen		1.2	D	GO, SHE. CM
Aristida adscensionis L.	Ririma	0.8	D	CT, SHE
Digeria muricata	Geigithan	0.8	D	CT
Leptothrium senegalense (Kunth) Clayton	Ballah	0.8	D	ALL
Acacia senegal Willd	Mirgi	0.8	S	GO
Acacia mellifera Benth	Bilahen	0.8	S	GO, SHE
Acacia seyal Delile.	Fulai	0.8	S	NONE
Balanites aegyptiaca (L.) Del	Kulum	0.8	S	NONE
Acacia paolii Chiov.	Gomor	0.4	S	NONE
Boswellia hildebrandtii Engl	Halale	0.4	D	ALL

D decreasing, *S* stable, *I* increasing, *CT* cattle, *GO* goats, *SHE* sheep, *CM* camels

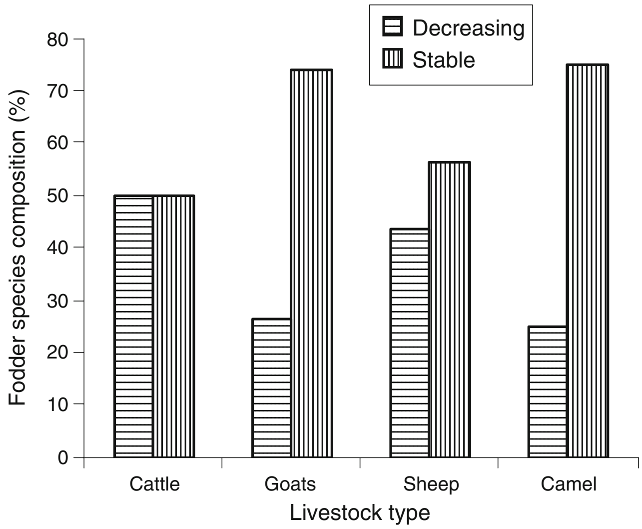

Fig. 3 Proportion of '*decreasing*' and '*stable*' species in livestock fodder around Korr settlement in northern Kenya

descriptions of stable trends, except for Range Unit 8 that had low cover levels during both the 1982/1983 and 2005/2006 periods, confirming the earlier description of the range conditions as 'fair' (Range Units 8 and 10) and 'poor' (Range Unit 13) respectively. However, herders' descriptions suggested that the range units remained in a stable condition, despite the changed seasons of land use. The herders' interpretation of changes in vegetation conditions did not amount to degradation, given that the changes over a period of two decades remained comparable with their historical experiences.

From ecological monitoring, the similarities in species composition during the dry seasons for the Range Units 10 and 13 were congruent with herders' descriptions of range trends as being stable. This evidence shows that the rangeland is resilient as far as changes in species composition are concerned. Herbaceous species richness was greater in 1982 compared to 2006 (wet seasons) in Range Units 2, 8 and 13 (Table 6), but there was no difference between 1983 and 2005 (dry seasons) for any of the range units. Shrub species richness was greater in 1982 compared to 2006 in Range Unit 13. In the dry seasons, shrub species richness was greater in 1983 compared to 2005 in Range Units 10 and 13. By comparison, tree species richness did not vary in any of the range units during the wet season sampling. For the dry seasons, tree species richness was greater in 1983 compared to 2005 in Range Unit 8, but did not differ in other range units (Table 6).

Dissimilarities in species composition represented by Euclidian distances separating the samples in the ordination matrix for Range Units 8, 10 and 13 were greater for the wet seasons (1982 vs. 2006) compared to the dry seasons (1983 vs. 2005; Fig. 6a–c). The ordination results may be

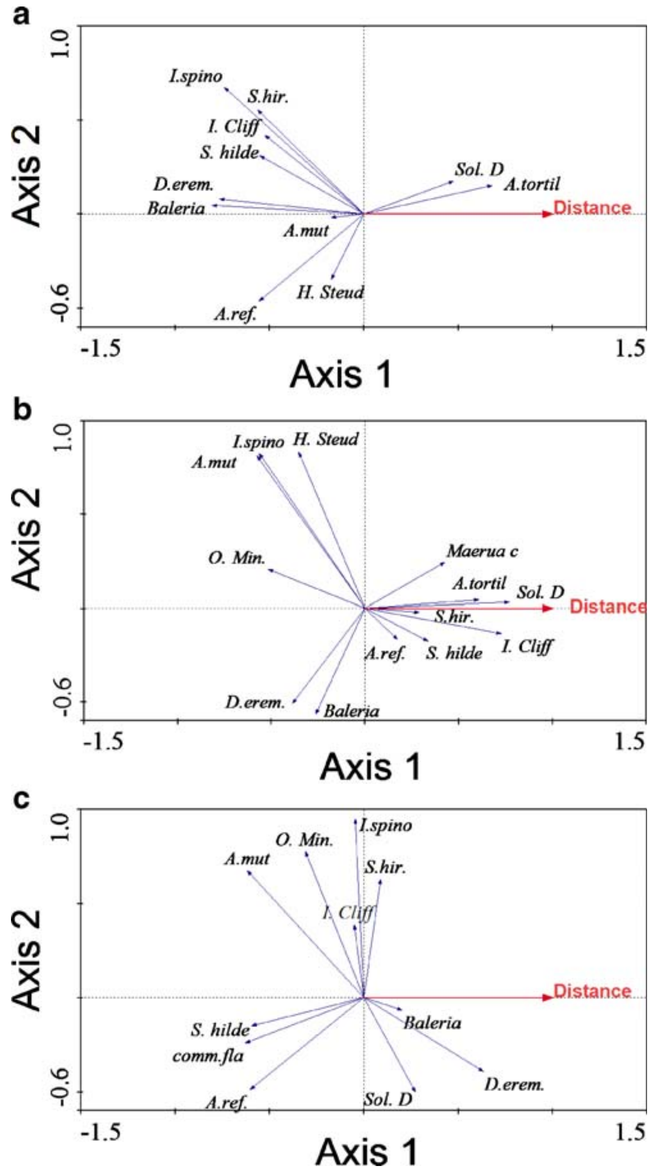

Fig. 4 **a** Ordination of species abundance along Korr–Kargi road transect. Key: *I.spino Indigofera spinosa*, *S.hir Sedera hirsuta*, *I.Cliff Indigofera cliffordiana, S.hilde Sericocomopsis hildebrandtii*, *D.erem. Duosperma eremophilum*, *Baleria Barleria eranthemoides*, *A.mut Aristida mutabilis*, *H. Steud Heliotropium steudneri*, *A.ref. Acacia reficiens*, *A. Tortil Acacia tortilis*, *Sol. D Solanum dubium*. **b** Ordination of species abundance along Korr–Ilaut road transect. *I. spino Indigofera spinosa*, *S.hir Sedera hirsuta*, *I.Cliff Indigofera cliffordiana*, *S.hilde Sericocomopsis hildebrandtii*, *D.erem. Duosperma eremophilum*, *Baleria Barleria eranthemoides*, *A.mut Aristida mutabilis*, *H. Steud Heliotropium steudneri*, *A.ref. Acacia reficiens*, *A. Tortil Acacia tortilis*, *Sol. D Solanum dubium*, *O.Min Oropetium minimum*, *M.cras. Maerua crasstiflia*. **c** Ordination of species abundance along Korr–Ngurunit road transect. *I.spino Indigofera spinosa*, *S.hir Sedera hirsuta*, *I.Cliff Indigofera cliffordiana*, *S.hilde Sericocomopsis hildebrandtii*, *D.erem. Duosperma eremopholiim*, *Baleria Barleria eranthemoides*, *A.mut Aristida mutabilis*, *H. Steud Heliotropium steudneri*, *A.ref. Acacia reficiens*, *Sol. D Solanum dubium*, *comm. fla. commiphora flaviflora*

Table 3 GLM analysis of changes in species richness and cover across distance classes from the Korr settlement in northern Kenya (see "Methods" and Fig. 2)

Distance classes	Herbaceous species richness	Woody species richness	Herb/shrubs cover	Woody cover
1	2.63±0.21	1.40±0.41	7.10±1.10	1.26±0.24
2	2.45±0.19	1.77±0.39	3.93±0.41	1.01±0.17
3	2.15±0.16	3.75±0.66	3.40±0.27	1.08±0.25
Sign.	*	**	**	*

*$P>0.05$, **$P<0.005$

interpreted using different vegetation change scenarios during the wet and the dry seasons. The difference in the wet season samples (1982 vs. 2006) might be due to the effects of rainfall on species regeneration. Another possibility is the replacement of the original species with new ones. Shorter Euclidian distances separating the samples in the dry seasons probably implied the lack of differences in species composition between the 1983 and 2005 samples. As opposed to the wet seasons with peaks of species regeneration, the dry seasons were characterized by reductions caused by the natural death of herbaceous species. We inferred from the spatial ordinations for the wet and dry seasons that the greatest variations were associated with seasonality—the dispersion of the ordination being more spread during the growing season than during the dormancy season (Fig. 6).

Table 4 Change in species frequency (%) at the range unit level for wet season sampling (1982/2006) in the rangeland of the Marsabit District, northern Kenya

Species	Range units											
	2			8			10			13		
	Frequency		Trend	Frequency		Trend	Frequency		Trend	Frequency		Trend
	1982	2006		1982	2006		1982	2006		1982	2006	
Aristida mutabilis Trin. & Rupr	60	0	Decline	60	0	Decline	15	10	Decline	66.6	23.3	Decline
Oropetium minimum (Hochst.) Pilg.	40	0	Decline	10	0	Decline				16.3	3.3	Decline
Dactyloctenium aegyptium (L.) Willd.	40	0	Decline	10	0	Decline	10	0	Decline			
Blepharis linariifolia Per.	20	10	Decline				40	40	No change			
Indigofera spinosa Forssk	30	60	Increase	20	10	Decline				0	16.3	Increase
Duosperma eremophilum	60	40	Decline	10	70	Increase				26.64	33.3	Increase
Seddera hirsuta Damm. Ex Hallier	30	20	Decline	10	0	Decline						
Euphorbia cuneata (Vahl)	50	0	Decline									
Cadaba farinosa Forssk	20	0	Decline									
Brachiaria leersioides Stapf	20	0	Decline									
Tetrapogon spathaceus Hack. ex T. Durand & Schinz	20	10	Decline				40	0	Decline	16.3	6.66	Decline
Cenchrus ciliaris Fig. & De Not	10	0	Decline				0	10	Increase			
Leptothrium senegalense (Kunth) Clayton	10	0	Decline									
Indigofera cliffordiana J.B Gillett	10	10	Stable	20	40	Increase	40	20	Decline	43.29	6.6	Decline
Heliotropium albohispidum Baker	2	10	Increase	50	30	Decline				33.3	9.9	Decline
Heliotropium steudneri Vatke	0	40	Increase							0	29.9	
Sericocomopsis pallida Schinz	0	10	Increase									
Amaranthus sp.	0	10	Increase	0	20	Decline	0	20	Increase	0	16.3	Increase
Acacia reficiens Wawra & Peyr.				0	40	Increase	0	10	Increase			
Acacia tortilis Hayne.							20	30	Increase	13.3	26.3	Increase
Aristida adscensionis L.				10	0	Decline	40	5		13.3	0	

Table 5 Change in species frequency (%) at the range units level for dry season sampling (1983/2005) in the rangeland of the Marsabit District, northern Kenya

Species	RANGE UNITS								
	8			10			13		
	Frequency		Trend	Frequency		Trend	Frequency		Trend
	1983	2005		1983	2005		1983	2005	
Dactyloctenium aegyptium (L.) Willd.	45	0	Decline						
Leptothrium senegalense (Kunth) Clayton	45	10	Decline				20	10	Decline
Sporobolus fimbriatus Nees	25	0	Decline						
Heliotropium albohispidum Baker	60	10	Decline				90	20	Decline
Indigofera cliffordiana J.B Gillett	50	5	Decline	20	0	Decline			
Seddera hirsuta Damm. Ex Hallier	25	0	Decline						
Acacia reficiens Wawra & Peyr.	30	5	Decline				50	10	Decline
Cadaba farinosa Forssk	40	10	Decline	30	0	Decline	20	0	Decline
Acacia tortilis Hayne.	15	5	Decline	0	30	Increase			
Duosperma eremophilum	15	0	Decline						
Barleria eranthemoides C.B.CL	15	0	Decline	10	0	Decline			
Indigofera spinosa Forsk	0	70	Increase	0	40	Increase	80	60	Decline
Aristida mutabilis Trin. & Rupr	0	35	Increase						
Oropetium minimum (Hochst.)							40	10	Decline
Sericocompsis hildebrandtii Schinz (ds)							30	30	Stable

Discussion

Herder Perceptions of Land Degradation

Herders used livestock productivity performance and trends of vegetation status as indicators to monitor land degradation. Their use of livestock productivity performance as a proxy for land degradation can be understood from the perspective that livestock play an intermediary role in terms of vegetation productivity and human food requirements. Herders' observations about the decline in livestock productivity indicators (such as milk yield, weight gains and mating frequency) were made at herding unit levels and views were shared at the elders' meetings for appropriate decision making (Oba 1985a). Since the observations were based on long-term experience, the decisions formed a basis for monitoring livestock–vegetation relationships. Herders responded to the apparent reduction in livestock productivity indicators by transferring excess herds to the *fora* system (O'Leary 1985). In the study area, 98% of cattle, 91% of goats, 92% of sheep and 74% of camels were managed at *fora* (Roba 2008).

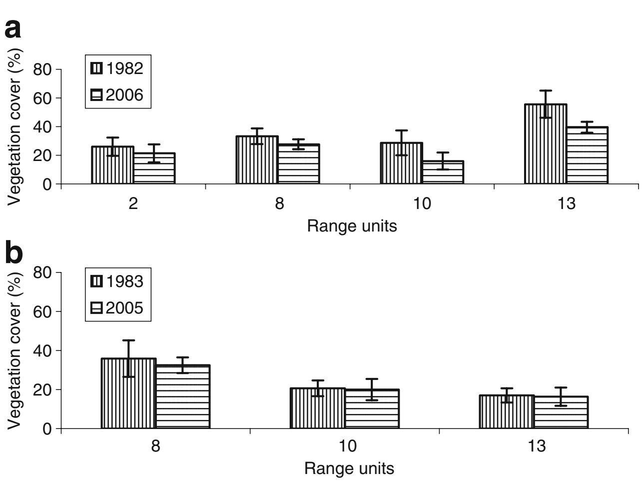

Fig. 5 Changes in vegetation cover at the Range Unit level in **a** wet season (1982/2006); and **b** dry season (1983/2005) sampling in northern Kenya

According to the herders, livestock serve as an important environmental barometer to determine the utilitarian value of rangelands, including those that cannot be related to the biological state of vegetation, but rather to physical factors such as landscape potential, suitability for grazing, and herders' decisions for management of different livestock species across diverse landscapes (Roba and Oba 2008, 2009). Changes in livestock body condition and reproduction performance are important early warning indicators of the changing environment. Such changes are what prompt herders' rangeland assessments for aiding decisions on herd mobility.

The evidence that some landscapes may appear 'bare' and hence degraded from the point of view of plant cover value, but are described as '*mirr qabdo*'—showing greater

Table 6 A *t*-test comparison of species richness in 1982 vs. 2006 (wet season) and in 1983 vs. 2005 (dry season) in four range units in northern Kenya

Range Units	Plant life form	1982/2006 (wet season)			1983/2005 (dry season)		
		df	*t*	*P* value	*df*	*t*	*P* value
2	H	9	−2.59	*			
	S	9	−0.32	*			
	T	9	−0.29	*			
8	H	9	0.77	*	19	−0.42	*
	S	9	−1.11	*	19	−1.79	*
	T	9	1.34	*	19	−2.82	*
10	H	19	−5.90	***	9	0	*
	S	19	−0.78	*	9	−2.24	*
	T	19	1.31	*	9	1.96	*
13	H	29	−3.10	**	9	1.41	*
	S	29	−3.90	***	9	−2.35	*
	T	29	−1. 92	*	9	−0.89	*

Data for Range Unit 2 were not available for the dry season in 1983 and 2005

H herbaceous, *S* shrubs, *T* trees

*$p<0.05$, **$p<0.01$, ***$p<0.001$

potential (i.e., good) for supporting livestock production—might appear to be contradictory from the perspective of ecologists. For the pastoral herders, the preferences of various livestock species influence perceptions about the utility values of grazing lands. We argue that such utilitarian perspectives of the herders imply that the level of range degradation differs from what may be gleaned from plant-based ecological data alone. The inference we draw is that land degradation cannot be described only from plant indicators that are measurable, but may also be affected by changes that can only be inferred from livestock reproduction performance. Such knowledge is influenced by cultural factors and sustained as cultural memories of all the landscapes used for livestock grazing.

The Rendille, as with other herders in East Africa, have clear ideas about the relative suitability and potential of every landscape. An interesting experience was that landscapes that were referred to as *mirr maqabdo* (i.e., bad) for cattle might be in *mirr qabdo* (i.e., good) condition for camels and so on. This means that changes in plant species composition that might be used to describe land degradation from the perspectives of cattle and sheep grazing may not be the same for browsing species such as camels and goats (Oba and Kaitira 2006). Ecologists might consider changes in plant species composition, where an increase in certain species might be desirable for purposes of biodiversity conservation; whereas herders are more concerned with the presence or absence of key forage species in grazing landscapes that might indicate land degradation, even when the total species present (including invasive species) might not have changed significantly (Roba and Oba 2008). Such perceptions differ from ecologists' views that failed to identify the utilitarian value of rangelands and relied on plant indicators alone to determine ecological status. The dynamics of land degradation from utilitarian perspectives linked to livestock productivity indicators can be better understood by drawing on herder experiences. The difficulty in the past was that ecologists were less inclined to support such perceptions, arguing that the data from such sources could not meet statistical rigor. However, increased understanding of herder perceptions in terms of relevance for management might in the future change such resistance by ecologists (see also Oba 1985b; Oba and Kotile 2001; Oba and Kaitira 2006).

We deduced that through the management of multiple livestock species, the herders used all the grazing landscapes. Herder associations of land degradation with the loss of key fodder species are common knowledge among pastoral herders in general (Bollig and Schulte 1999; Mapinduzi *et al*. 2003; Gemedo *et al*. 2006; Roba and Oba 2008; Oba *et al*. 2008a, b). By considering livestock production performance relative to the seasonal fluctuation of fodder availability, herders were able to closely monitor range productivity. Thus in terms of plant indicators, there is a convergence between herder knowledge and ecological knowledge. If degradation is defined in terms of a reduction in the potential of land to support sustainable livestock production for the intended utility of the rangelands (Abel and Blaikie 1989; Biot 1993), then herder knowledge of the status of key forage species could be put to important use by ecologists. Herder knowledge implied that some fodder plant species with greater utilitarian value were used as more sensitive indicators of land degradation than less preferred plant species.

The quantitative changes in vegetation cover due to heavy livestock grazing pressure which the Rendille described as '*barbadah*,' is a familiar concept among pastoralists. Conditions of *barbadah'* might vary from moderate to what they call *hara hababaweite*—which suggests the degradation is so severe that even the afterbirth

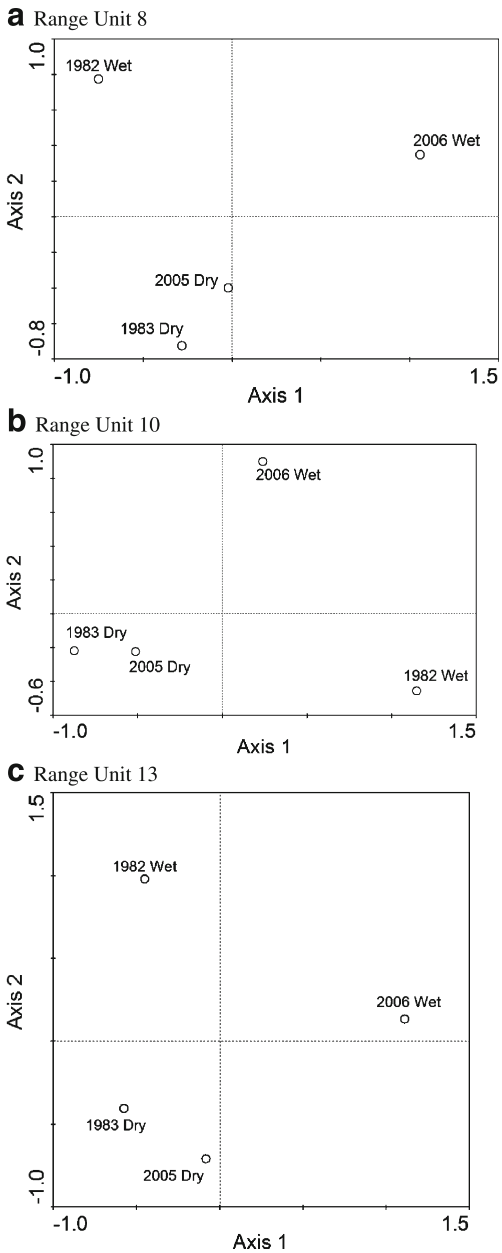

Fig. 6 Principal Components Analysis (PCA) of the dissimilarities of species composition (presence–absence) in wet season sample (1982 vs 2006) and dry season sample (1983 vs. 2005) in **a** Range Unit 8; **b** Range Unit 10; and **c** Range Unit 13

of cattle will not pick up any plant litter (see Oba 1985b). This is common terminology among pastoralists in East Africa. The Oromo speakers in northern Kenya consider overgrazed rangelands as *barbadha diluuni uuba hinfuune*—"even the afterbirth will not pick up a speck of grass litter."[5] Such rangelands are associated with reduced livestock productivity. Other herders in East Africa have terms that explain that the livestock tend to 'like'[6] the condition of particular landscapes, which is inferred from livestock productivity performance. Ecologists for their part tend to dismiss this type of assessment, although it has been shown that pastoral perceptions do influence the way the rangelands are used (see also Oba and Kotile 2001; Okoti *et al*. 2006). From this observation we can deduce that in addition to the fodder abundance, herders considered other variables as indicators of degradation, such as soil physical conditions, which to a certain extent correspond with the assessments used by ecologists.[7] The difference is that the herders used a combination of indicators for making assessments, while ecologists relied only on a few measurable environmental indicators (Roba and Oba 2008), very rarely considering livestock productivity performance as an indicator of land degradation, as pastoralists do.

In terms of monitoring changes in the quality of the vegetation, herders observed variations in the composition of key fodder species on a continuous basis. According to the herders, degradation occurred if the "roots of key forage species disappeared." Heavy grazing, with varying outcomes from one landscape to another, may cause the disappearance of key forage species. Landscapes with greater grazing potential are more resistant to land degradation than those with less potential (see Oba *et al.* 2008a). As opposed to herder perceptions, ecological assessments of vegetation indicators are not closely related to livestock production performance. Herders, because of their daily attachment to livestock, considered livestock productivity indicators as being more sensitive to changes in the environment than vegetation indicators. Ecologists may monitor forage species alone to reach decisions on land degradation, while herders used multiple indicators—including livestock performances and historical knowledge (e.g., Fernandez-Gimenez 2000; Oba and Kotile 2001). Thus, in terms of herder perceptions, links between livestock and environmental change in general cannot be separated from history of land use.

Impacts of Gradients of Land Use on Vegetation

Landscape classification for herding different livestock species in different seasons is important for assessing and monitoring land degradation. By taking into consideration the heterogeneity of the landscapes in terms of vegetation

[5] The after-birth organ is sticky and could collect litter when dropped by livestock at birth. The symbolism for land degradation is that even plant litter cannot be found.

[6] Herders usually use the concept of an animal's comfort in lying down, as they become restless where the conditions are not suitable. The inference is always made in terms of the conditions of the soils (see Roba and Oba 2008).

[7] Ecologists describe land degradation in terms of soil movements and loss of soil nutients (see Oba *et al*. 2008c).

and soil characteristics, and variations of seasonal use, herder assessments were appropriate for capturing the vegetation production dynamics. Traditionally, the assessment and monitoring of key indicator plant species at landscape level was done in conjunction with the evaluation of livestock performance indicators. It was expected that the loss of key fodder species at a given landscape was not a spontaneous occurrence, but a process that included reduction in species frequency, resulting in the final disappearance of the species. In traditional land use practices, herder management avoided the loss of forage plants through mobile land use. Herding decisions were influenced by both vegetation and livestock production performances (Roba and Oba 2009). By moving the herds from one landscape patch to another, the pastoralists avoided over-exploitation of the vegetation. Herders attributed the recent loss of important plant species to inflexible livestock grazing as a result of sedentarization and year-round grazing (see below).

According to the Rendille herders, therefore, rangeland plants respond differently to historical grazing pressures at two levels. Firstly, landscapes that are more vulnerable to sustained grazing pressure lose the key forage species more easily than landscapes that have greater grazing potential. The latter landscapes are expected to recover from previous heavy grazing more rapidly, whereas the more degradation-vulnerable landscapes are less likely to recover from over-exploitation (Oba and Kaitira 2006; Roba and Oba 2008). This knowledge is important for regulating livestock movements. The more degradation-vulnerable landscapes are grazed for shorter periods (mostly during the wet season) than those with greater potential that are often grazed for longer periods (Oba *et al*. 2008a; Roba and Oba 2009).

Secondly, the herders considered key forage species as being important indicators of degradation. The plant species they categorized as ‘decreasing’ are most vulnerable. These species are susceptible to heavy grazing pressure and rainfall fluctuations. The ‘increasing’ species are least desirable from the perspective of livestock grazing. They comprise weedy species that proliferate around settlements during the wet season. Although this observation on the species trends around the settlements may not reflect the conditions for the distant rangelands, it appears that the settlement areas according to herders are becoming less suitable for livestock management.

The analysis of the plant species–distance ordination provides a varied picture from the herder perspective (see also Lamprey and Yussuf 1981; Walther and Herlocker 1980). From the plant-based indicators in the species–distance ordinations, we made two deductions. Firstly, the gradient distributions of plant species might reflect species responses to historical grazing pressure. Secondly, the changes in plant-based indicators along land use gradients might also reflect effects of recent improved management. Responding to degradation around the settlement, a greater proportion of livestock was kept at the pastoral camps, as part of official and community motivated conservation practices. This decision was made in the early 1990s. Satellite data covering the Korr settlement show an increase of about 36% shrub cover from 1986 to 2000 within 4 km of the settlement, which is associated with reduced livestock grazing and improved land management through community conservation efforts (Roba 2008). Thus, the greater abundance of the key fodder species close to the Korr settlement was a result of reduced livestock grazing pressures compared to the conditions around pastoral camps, which due to high grazing pressure had a greater abundance of non-fodder species. The lower woody species richness around Korr could be due to past over-exploitation (Lusigi 1981).

Monitoring of Ipal Transects

Monitoring of the IPAL transects was intended to investigate trends of plant-based ecological indicators. However, since the sampling periods occurred over a 23-year period at different points in time, analyzing trends was problematic from that perspective alone for three reasons. Firstly, the communal land use practices of the Rendille pastoralists had changed in intensity although the spatial movements of the mobile herds have not changed in any significant manner since the 1970s. At local levels, the grazing patterns changed from seasonal to year-round. This change is expected to have impacted the vegetation of the rangeland units. The second problem was that the different data sets represented different sampling points in time. It is therefore not clear as to whether any differences observed are those particular to the different periods of sampling or are due to changes that had occurred over time. For this reason, we used herder knowledge to gauge what the changes represented. Thirdly, the season of sampling may have had confounding effects over long-term trends. Thus, in our interpretation of the data, we remain cautious about making hasty conclusions about the trends of vegetation indicators. We suspect that the changes observed are complex, reflecting seasonal variations and changing management practices.

Having considered the various confounding factors, we interpreted the changes based on the baseline data and herder knowledge. The IPAL findings described some of the range units as being in ‘fair’ condition, based on soil stability and a greater proportion of annual species, and others as being in ‘poor’ condition for the opposite reasons. The current decline according to herder assessments, might suggest that the rangelands have been subjected to heavy continuous use that has induced the decline of key forage species. Again, the main problem mentioned by the herders was changing land use patterns. The ability of the range units to withstand high grazing pressure is important evidence that herders differentiate between degradation sensitive and less degradation sensitive rangelands (e.g., Oba and Kotile 2001; Oba and Kaitira 2006; Oba *et al*. 2008a).

The IPAL ecologists described the range units as being vulnerable to grazing pressure because of a rapid decline in the primary productivity (in Range Unit 10) and low standing crop biomass (in Range Unit 13) (Lusigi *et al*. 1986). In determining vegetation 'trends,' herders made deductions using their knowledge of the key fodder species in different range units. For the herders, therefore, changes in species frequencies were seasonal or long term. For the majority of annual species, the dynamics were associated with seasonal rainfall variability. Degradation on the other hand, did not refer to seasonal variability, but rather to long-term changes, where some species had become noticeably rare compared to the past. Over the sampling periods, the region had experienced periodic droughts and overgrazing, alternating with unusually heavy rainfall. Droughts combined with overgrazing contributed to the decline of species, while unusually heavy rainfall seemed to stimulate "even the lost plant species to return" after the suspected permanent loss. Herder assessments were therefore not definitive on any single driver of change. Rather, herders monitored long-term changes in species composition and livestock performance, while taking into consideration seasonal variability before concluding that a given landscape is or not degraded.

From the ecological data analysis, however, the trends of species in Range Unit 13 implied degradation. The herders' descriptions of range trends as 'stable' contradict this conclusion. The difference is that their interpretation was based on key fodder species, which did not show significant declines, whereas the total species counts did show a variation between the wet and dry seasons and between sampling dates over 23 years. Greater herbaceous species richness in 1982 compared to 2006 and the lack of differences between 1983 and 2005 probably imply that the differences could be attributed to rainfall variability. The total rainfall recorded at the Kargi station was approximately 124 and 41 mm in 1982 and 2006 respectively. In arid ecosystems, the amount and distribution of rainfall greatly influences herbaceous species dynamics (Fynn and O'Connor 2000). Because of the great temporal variability in the herbaceous species cover (and therefore high spatial rainfall variability), it is difficult to directly link the dynamics of vegetation to the exploitation by livestock grazing alone. Ideally, controlled experiments would shed more light on the main factors driving changes in herbaceous cover (e.g., Oba *et al*. 2000a). In grazed systems, isolating the causative factors of land degradation demands careful analysis of data in terms of plant life forms (e.g., shrubs, grasses and trees) due to their different adaptations to moisture variations and management impacts.

The changes in shrub species richness between 1983 and 2005 in Range Units 10 and 13 are probably related to anthropogenic pressures. Changes in land use patterns from traditional wet season use to the current practice of year-round grazing may have contributed to over-exploitation of shrubs and hence the decline in shrub species richness. The observed reduction in shrub species richness in the dry season also contradicts herder monitoring, according to which the range was considered to be stable (i.e., Range Units 10 and 13). The shrub species that showed a decline according to ecological monitoring were probably over-exploited. Similarly, the reduced tree species richness between 1983 and 2005 in Range Unit 8 might suggest increased anthropogenic pressures related to overharvesting of woody plants by the sedentary pastoral camps (Lusigi *et al*. 1986).[8] The inference we make is that in the range units that showed evidence of degradation, the changes were more explicit in terms of shrubs and trees than for herbaceous vegetation. From this finding, we deduced that in the Rendille rangelands of southwestern Marsabit in northern Kenya, current land use threats to vegetation are mostly in terms of over-harvesting woody species as opposed to overgrazing herbaceous vegetation. The latter is influenced more by the combined effects of grazing and rainfall variability which was corroborated by the species composition and ordination data.

The Efficacy of Integrating Herder Knowledge and Ecological Methods

In this paper we endeavored to integrate herder knowledge and ecological methods for assessment and monitoring of rangeland degradation in the Rendille grazing region. We considered the different indicators used by both herders and ecologists. We then applied three different methods in the field jointly with herders, by assessing vegetation communities from the perspectives of local knowledge, land use gradients and repeated sampling of fixed transects that were

[8] The Rendille were blamed for over-exploitation of woody plants. For this reason, the herders did not offer opinions, perhaps reasoning that 'outsiders' do not appreciate their use of trees for building fences for protecting their livestock from predation by 'hyenas.' The herders used 'hyenas' as a generic term for all large predators that kill their livestock. When questioned about their use of trees around pastoral camps, an elder responded "...then would you pay for our goats, [which are eaten by hyenas] if we stopped cutting trees...We have no solution ourselves..."

sampled earlier in 1982 and 1983. We presented the results and attempted to highlight the possible interpretations from the perspectives of both herder indigenous knowledge and scientific methods. The problem remains as to how to evaluate the efficacy of the different methods to achieve improved assessment and monitoring of land degradation and additionally, their use for promoting community participation for the implementation of the Conventions on Combating Desertification and Convention on Biological Diversity at local levels (Roba and Oba 2008). We considered the efficacy of the methods from three perspectives. Firstly, relating the indicators and concepts used by herders to ecological theories. By associating different landscapes with different key forage species, the herders described niche dynamics and site potential, while the responses of different plant species to grazing echo the equilibrium principle which associates land degradation with loss of vegetation indicators when grazing thresholds are exceeded. In the equilibrium ecological system, total vegetation cover is usually described in relation to livestock grazing densities. Their association of vegetation variability with variable rainfall also corresponds to the non-equilibrium description of vegetation dynamics. The interpretation of herder knowledge however requires careful definitions of all the parameters before being amenable to verifying theories (Oba *et al*. 2000b, 2008a, b). For example, the non-equilibrium ecological theory attributes vegetation change to environmental variability and proposes that arid rangelands are resilient, as demonstrated by the recovery of vegetation in response to rainfall fluctuations. Herders are aware of this fact as they suggested that grazing pressure becomes critically damaging only when rainfall is deficient and/or heavy grazing is perpetuated. This awareness implies that levels of land use and rainfall variability may influence herder perceptions of land degradation (Oba *et al*. 2003, 2008a, b).

Inferring that herder interpretations are directly linked to ecological theories may however appear simplistic as there are no single causative factors (i.e., independent variables) that can be tested against a dependent variable (i.e., the response to management). Analyzing herder interpretations would have demanded consideration of more complex data sets including perceptional data, with which most ecologists lack familiarity. Ecologists could, however, overcome this limitation by identifying all observable and perceptional variables using ordinal grouping of the response variables. For example, ecologists, similar to herders, can assess the level of grazing as low, moderate and high which can be expressed on numerical scales. This can then be analyzed by applying appropriate statistical protocols against dependent variables such as biomass, species richness and cover, while grazing is used as environmental gradient (see Oba *et al*. 2008b, c).

Secondly, we considered if the methods increased the comprehension of land degradation problems than if we used indigenous knowledge alone or ecological methods alone. Herder knowledge is interdisciplinary, combining both the livestock and plant-based indicators for the assessment and monitoring of land degradation. For the herders who used livestock productivity and plant-based indicators as proxies for understanding land degradation, the focus was on key forage species that are landscape specific. Crucially, the herders' view that land degraded for one species of livestock may not be so for others, would suggest that the problem of land degradation is a relative one. According to the herders, the key fodder species were better indicators of livestock productivity, rather than monitoring the total diversity of species available. Through continuous observation of the performance of individual plant species in the field, in relation to livestock production performance, herders provided reliable methods for monitoring vegetation dynamics across grazing landscapes. By incorporating all the different indicators used by the herders, ecologists could improve the application of theories for monitoring rangelands in arid zones in East Africa. A cautionary note is, however, necessary in view of the claims by ecologists that arid lands cannot be degraded (e.g., Behnke and Scoones 1993). Our interpretations of the field data with the help of herders suggest that land degradation is relative to landscape potential and livestock types managed. The evidence is unequivocal that the misuse of arid lands causes land degradation around settlements, but such environments would recover rapidly with introduction of proper management (see "Method 2").

Thirdly, the criteria for achieving the integration of herder knowledge and ecological methods for monitoring rangeland degradation must be based on comparable objectives. For example, most ecological monitoring is for the purpose of conservation, as compared to herder monitoring which aims at making livestock grazing management decisions. But the same information could be applied to local environmental problems and for developing national action plans to implement the Convention on Combating Desertification and the Convention on Biological Diversity. The herders, for their part, are more concerned with local land use problems, but the basis of their land use monitoring practices has relevance for the conservation goals. More importantly, for the herders, rangeland monitoring is for the purpose of safeguarding their livelihood in terms of maintaining livestock productivity. They are able to make rapid management decisions by combining plant and livestock productivity indicators. What is the likelihood of integrating herder knowledge into the implementations of the conventions?

We can respond to the question by retrospectively reflecting on our own experiences from the joint assessments and monitoring with herders. Firstly, our understanding of herder perceptions and knowledge for assessments was immensely increased. Indeed, despite our understanding of the problem of land degradation in Northern Kenya, we achieved better clarity on various issues related to herder knowledge of plant responses to seasons of grazing. Secondly, from the ease with which our team worked with herders and exchanging opinions on changes in vegetation, we shall suggest that we demonstrated a microcosm of community participation in implementing the activities of the conventions, which involved planning, assessment, monitoring and decision making. Secondly, we subjected the data from herder assessments to rigorous statistical analysis showing that the system is scientifically robust. Thirdly, as ecologists, we played multiple roles by analyzing herder interpretations from ecological perspectives and found corresponding conclusions that we had independently reached. Where there was divergence in the views, the reasons were that the herders unlike ecologists considered multiple indicators which they combined in their assessments and monitoring. As some of the herder perceptions used could not be directly measured, we could only make inferences by looking at the overall picture of herder interpretations within the context of land degradation. These deductions in our view were not only reasonable but showed novelty in bridging gaps in collaborations between local communities and scientists. Perhaps we may add that these are the new ideas that ecologists could learn from herders. Finally, based on these deductions, herders can be part of the research and management team for addressing the conventions.

Conclusion

Previous monitoring of land degradation in Northern Kenya lacked integration of local community knowledge and ecological methods for promoting community participation in the implementations of the United Nations Convention on Combating Desertification (CCD) and the Convention on Biological Diversity (CBD). In this study we made an attempt to show how this might be achieved by evaluating three methods for integrating herder knowledge and ecological methods for assessing and monitoring rangeland degradation. We considered herder and ecological indicators for measuring land degradation. Herder perceptions of land degradation are influenced by changes in livestock production indicators to determine which landscapes are degraded and which are not degraded. According to herders, landscapes that may be considered degraded for one type of livestock species (e.g., grazers) may not be degraded for others (e.g., browsers). Using livestock production indicators as barometers of environmental change, the herders were able to follow closely changes in range condition from good to bad, and to make adjustments in their management strategies.

Herder reliance on livestock production performance to corroborate evidence of declining fodder resources hastens the process of environmental assessment, compared to relying on plant-based indicators alone. The utilitarian definition of land degradation used by the herders differs from that of ecologists who rely mostly on plant-based ecological indicators. Compared to the herders, ecologists do not often link livestock and vegetation indicators, although the purpose of monitoring assumes such a link. The evidence shows that herder indicators for the purpose of monitoring are relevant for pastoral production, as they are closely linked to the livelihood of the people. Furthermore, in monitoring vegetation changes, herders were particularly concerned with key fodder species. Ecologists, for their part, monitored all the plant species by giving them equal weights. An interesting aspect of the herder plant-based indicators is that they conducted assessments and monitoring in terms of the livestock species most suited for grazing in the area. Their use of the terms ‘decreasing’, ‘increasing’ and ‘stable’ fodder species were specific to livestock species affected most by the changes. From the information gleaned from joint field surveys, herders easily selected landscapes suitable not for the grazing of all livestock species, but only for those whose desired forage species was available.

The complexity of herder monitoring is due to their consideration of other factors inherent in the environment that cannot be measured directly, but can only be inferred from livestock production performance. This knowledge, which is common amongst most pastoralists, does not necessarily make sense to ecologists. Thus, conducting ecological monitoring alone might miss subtle changes in the environment that would be crucial for herder management decisions. Joint monitoring increases the understanding of the complex dynamics of rangeland vegetation in relation to human perceptions, land use gradients and management, as well as effects of seasonal variations. Herders’ perceptions that rangeland degradation is associated with changing patterns of land use from wet/dry seasons to year-round grazing were corroborated by long-term ecological monitoring. The herders considered changes during the dry season as being temporary. The impact of the dry season did not translate into land degradation if conditions could be reversed during the growth season. Land degradation was more explicitly described in terms of the presence or absence of different plant life forms (e.g., grasses vs. shrubs) in relation to different livestock species directly affected by changes in the forage as well as changes in seasons of land use. The current study has therefore shown that the recent land degradation debate in northern Kenya is associated with multiple factors. In order to improve monitoring of grazing lands, we recommend a combination of livestock productivity performance indicators and plant-based indicators that would support the integration of herder knowledge and ecological methods. Such integration is necessary for promoting participation of local communities in the implementation of the United Nations Convention on Combating Desertification and the Convention on Biological Diversity.

Acknowledgements This work was part of a PhD project completed by Hassan Guyo Roba on the integration of indigenous knowledge and ecological methods. The work was supervised by Professor Gufu Oba of the Department of International Environment and Development Studies, at the Norwegian University of Life Sciences, Noragric. The Norwegian Research Council funded the research work under project no: 161359/S30. Hassan acknowledges the assistance of Hussein Walaga, Peter Geykuku and Diba Guyo of the Kenya Agriculture Research Institute (KARI) in Marsabit for their assistance with the fieldwork. Lesuper Joseph is acknowledged for language translation and conducting interviews. The authors acknowledge with appreciation the constructive comments by two referees on the earlier version of the paper.

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