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PARTICIPATORY MONITORING OF BIODIVERSITY IN EAST AFRICAN GRAZING LANDS

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ABSTRACT

There are disagreements on the use of standard biodiversity monitoring methods to promote community participation. This study combined three methods to investigate questions why monitor biodiversity, what biodiversity to monitor and how participatory biodiversity monitoring can be promoted in central Uganda in East Africa. The question of why biodiversity should be monitored concerns the justification for monitoring, while the question of what to monitor concerns the choice of biodiversity variables, and the question of how to monitor biodiversity concerns the links between the data generated from monitoring and problems associated particularly with regard to community participation. The study selected landscape and sampling scales (i.e. plots) for participatory monitoring of biodiversity. Herders identified main landscape patches and plant species. Herder value-weighted indicators, such as invasive species and range condition scores (i.e. composite indicators representing species palatability, composition, cover, density and richness) were used for measuring biodiversity in their grazing lands. To understand what biodiversity to monitor, we interpreted the correlation between biodiversity indicators and herder value-weighted range conditions. Herders defined biodiversity from a utilitarian perspective, which is inconsistent with the conventional scientific goals of biodiversity conservation which focus on preservation of the total species pool. To address the question of how to monitor biodiversity, evidence from the folk taxonomy of sampled plant species and other proxy biodiversity indicators, including herder value-weighted range condition scores, were compared to understand scale dependence. We inferred that the landscape scale monitoring was more sensitive to measuring biodiversity than the conventional scales of plots. Copyright © 2008 John Wiley & Sons, Ltd.

KEY WORDS: Banyarwanda; herder knowledge; invasive species; landscape patches; Uganda

INTRODUCTION

The Global Environmental Convention for the conservation of biological diversity, which is of local, national and international concern, has generated discussions on and sharing of practical experiences on the monitoring of biodiversity. In eastern African grazing lands, which is the topic of this article, monitoring biodiversity must distinguish between community values that are influenced by utilitarian goals and conservationists' goals that make preservation a priority. The differences between these goals might influence the kinds of questions that need to be answered for promoting community participation in monitoring biodiversity of grazing lands.

The term 'monitoring' has become a buzzword in conservation science, despite the lack of established rules on how it should be conducted and by whom. Three monitoring methods appear to be employed. The first is monitoring in support of management systems, in which the information generated from the process will assist managers in making better decisions. The second is when the purpose of monitoring is to generate scientific data for testing conflicting hypotheses and informing policies and decisions. The third is an informal method, related to the knowledge of resource users. Ecologists in general do not agree on the best methods to be used for participatory

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biodiversity monitoring. Yoccoz *et al*. (2001) presented various propositions on scientific and community-used methods of resource monitoring. They acknowledge the need for monitoring to support resource managers in decision-making and generating data for testing hypotheses, but they do not appear to favour the combination of all three monitoring methods (Danielsen *et al*., 2003a). Doubts have also been raised about the suitability of integrated methods (i.e. combining the three monitoring methods) because the methods may not be equally suitable for quantitative monitoring (Rodriguez, 2003).

Our concern is that most of the discussions on monitoring methods (with the exception of Danielsen *et al*., 2003a) have not provided empirical evidence that can be used to test whether the integration of the three methods is effective for addressing the 'why', 'what' and 'how' questions for promoting monitoring of biodiversity (Yoccoz *et al*., 2001). The questions of why monitor biodiversity, what should be monitored and how monitoring of biodiversity should be carried out need to consider the social and ecological contexts (Danielsen *et al*., 2003b). The 'why' question of biodiversity monitoring concerns the justification for monitoring, while the 'what' question concerns the choice of variables. The 'how' question of biodiversity monitoring concerns the links between the data generated from monitoring and problems associated with management (Yoccoz *et al*., 2003). The issue is whether the combination of the empirical and informal monitoring methods (hereafter referred to as the 'integrated' methods) can realistically address these three questions.

The methods selected should be simpler and able to be used sustainably by local communities, compared to the standard technical methods, which are often expensive to carry out considering the financial difficulties and low technical capacity of developing countries (Danielsen *et al*., 2003a,b; Hutton and Leader-Williams, 2003). The application of standard ecological monitoring methods and their relevance to the societal systems of natural resource management have also been discussed by practitioners of different sub-disciplines of social science and conservation ecology (Andrade, 2005; Terborgh, 2005). The social science view is that the standard technical methods of monitoring on their own are ineffective for providing information on the roles played by community resource management (Pinedo-Vasquez *et al*., 2002; Critchley and Salomon, 2003; Danielsen *et al*., 2003a), particularly where baseline data are lacking (Rodriguez, 2003). The need for integrating the management methods used by traditional resource users with ecological methods used by ecologists has been suggested in order to promote conservation (Reed *et al*., 2007; Stringer and Reed, 2007; Verlinden and Kruger, 2007; Oba *et al*., 2008).

We believe that the discussions of different monitoring methods need to emphasize an additional aspect of monitoring, namely the level of resolution needed (Ludwig *et al*., 2000). We shall argue that sensitivity to changes in management may differ between the land use scale (i.e. landscape scale) and the sampling scale (i.e. plot levels). Resource users usually monitor grazing land biodiversity at landscape scales in contrast to technicians who assess biodiversity at plot levels and upscale findings to the larger scale for management purposes (Weiher, 1999; Ludwig *et al*., 2000). For monitoring at both the landscape and sampling scales, testing for scale dependence to avoid erroneous conclusions should precede the interpretation of biodiversity data.

The issue of scale is particularly relevant in communal grazing lands such as those in eastern Africa, where land use by livestock involves mobility at the landscape scale (Oba and Kaitira, 2006). Herder knowledge of management is dependent on knowledge of landscape patches (Fernandez-Gimenez, 2000; Oba *et al*., 2000a; Mapinduzi *et al*., 2003; Sheuyange *et al*., 2005) that may influence livestock grazing movements (Coppolillo, 2000; Oba and Kotile, 2001). On the landscape scale, monitoring biodiversity (MacFarlane, 2000; Bielders *et al*., 2001; Sheuyange *et al*., 2005) using community value-weighted indicators such as invasive species and range condition (i.e. composite indicators representing species palatability, composition, cover, density and richness), and indicators of biodiversity, such as plant species richness (Halffter, 1998), could be conducted using the three methods together (Gemedo-Dalle *et al*., 2005). Until now, this approach has not been used to investigate the three basic questions of why monitor biodiversity, what to monitor and how to monitor biodiversity in community participatory conservation programmes.

We addressed the three questions 'why monitor', 'what to monitor' and 'how to monitor' plant biodiversity in communal grazing lands in central Uganda. With regard to the 'why' question of biodiversity monitoring, our concern was that official range management policy has ignored traditional systems of biodiversity conservation (Kyagaba, 2004). Instead it has promoted conservation using the management of group or private ranches

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(Muhureheza and Otim, 2002), emphasized forest protection for wildlife habitats (Tweheyo, 2003) and used conventional methods for monitoring biodiversity (Muhureheza and Otim, 2002). For traditional grazing lands, on the other hand, conventional scientific methods alone are inappropriate. For example, in the central Ugandan rangelands, the communities are more concerned about shifts in vegetation structure due to invasive species that have reduced the grazing value of their land than habitat protection. We therefore wanted to understand how the herders monitored biodiversity and perceived the utilitarian values of biodiversity management in the grazing lands compared to the conventional methods monitoring.

The 'what' aspect of monitoring biodiversity led us to identify environmental indicators for classifying landscapes in order to understand the structure of natural vegetation in relation to management by herding communities. Herder range management as a long-term strategy assesses the effects of land use in terms of range condition scores. For the 'how' question of monitoring biodiversity, we investigated the relationship between biodiversity indicators, such as species richness and density, and herder value-weighted range condition scores related to invasive species, in order to test the integrated methods. We also considered the scale effects on the response variables at the levels of landscape and sampling units (i.e. plots). We hypothesized that if, on the one hand, the scale of herder assessments is effective, then differences in the spatial distribution of biodiversity indicators at the scale of management would be expected. If, on the other hand, the scales of sampling were more sensitive than the scales on which herders conducted assessments, then skepticism about herder knowledge would be justified.

METHODS

Study Area

We conducted the study in the Kiboga district in the Butemba and Kyankwanzi sub-counties in central Uganda (Figure 1). The topography consists of flat and hilly terrain at *c.* 1800 m a.s.l. alternating with valleys at *c.* 1400 m a.s.l. Soils are sandy loams, coarse sands, yellow clay-loam and red loam in the uplands, and dark clay in the valleys. The climate is tropical with rain falling in March–June and September–November, with a total annual rainfall of 560–1272 mm (Ssebagala, 2004). Vegetation types are open grassland, woodlands and bushy thickets (NEMA, 1998). The inhabitants are Banyarwanda agropastoralists, speaking Kinyarwanda, who are widely dispersed in Rwanda, Uganda and the Democratic Republic of Congo (DRC). Their livestock are the long-horned breed of Ankole cattle (Kyagaba, 2004). Herd sizes are 50–200, with an average stocking density estimated at 30 Tropical Livestock Units (1 TLU = 250 kg bovine). Land use by grazing cattle is free-ranging, involving movements between different landscapes during the wet and dry seasons. Herders ranging in age from 15 to over 40 years herded the cattle. Herder knowledge of landscapes and vegetation change influences herding practices on a daily basis.

Participatory Monitoring

In October 2004, we conducted field assessments of biodiversity jointly with herders. From 40 households we requested the community to select five active herders of 25–40 years of age. The older herders were selected because of their accumulated indigenous knowledge of the grazing landscapes and their understanding of changes in the environment in comparison with their youth. The herders were all familiar with the local grazing landscapes. In the absence of a map, the herders' knowledge of the geographical names of the local landscapes was relied upon. They described the landscapes as **Ekihita**, **Omugongo** and **Omukura** (Table I). The sizes of the landscapes were estimated to be 10 000 ha; 140 000 ha and 60 000 ha, respectively. The landscapes each comprised heterogeneous patches that varied in size from 5 to >10 ha. Field sampling was at landscape patch and plot scales (see below).

To address the 'why' question of biodiversity monitoring, we discussed with the herders, in their local language and dialect, environmental problems related to land use and the way in which herders perceived and assessed these problems. Herder assessment is always linked to livestock management. For this reason, we informed the herders about the purposes of incorporating traditional techniques of assessment into conventional methods for surveying

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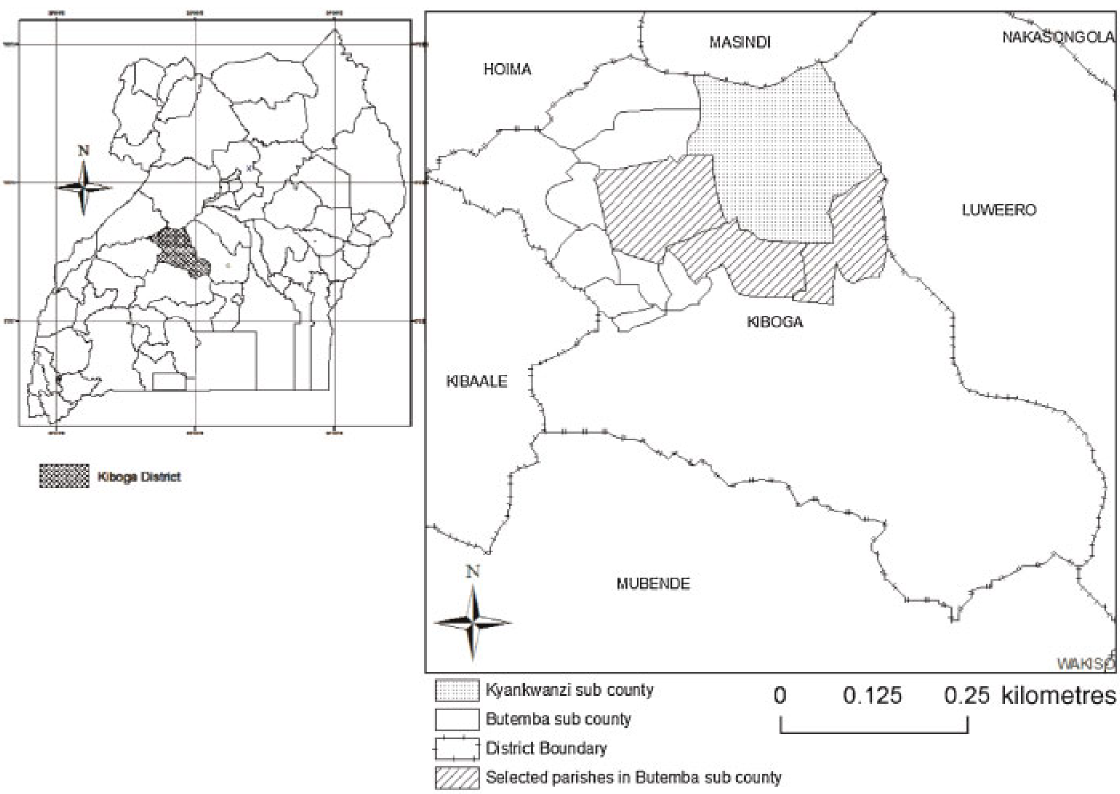

Figure 1. The geographical location of the study sites in the Kyankwanzi and Butemba sub-Counties in Kiboga district, Central Uganda. This figure is available in colour online at www.interscience.wiley.com/journal/ldr

biodiversity. Before starting the fieldwork important concepts used by herders, such as range condition rating, bush encroachment, invasive species and herders' preferences for plant species for livestock grazing, were discussed.

Herders addressed the 'how' question of monitoring biodiversity by making daily herding decisions. These involved the state of grazing lands in terms of forage, the type of species present or plant community structure and the overall condition of the range. The state of the grazing lands was interpreted in terms of accessibility of the vegetation where bush cover and invasive species posed a threat through a decline in forage plants needed for

Table I. The three landscape classifications used by the Banyarwanda agropastoralists with plant indicator species of the landscape and descriptions of land use during different seasons

Landscape	Description
Omugongo	Dominated by hilly uplands; woody cover generally high; herbaceous layer indicator species include *Loudetia arundinacea* (**omukabara**) and *Themeda triandra* (**emburara**); mostly grazed during the dry season
Ekihita	Plateaus with flat tops; soils generally well drained; bush cover is moderate; grassland patches that create bush–grass mosaics are dominated by the indicator species *Sporobolus pyramidalis* (**obuyanja**), *T. triandra* and *S. sangiuneus* (**omutsina**); used for wet season grazing
Omukura	Valleys with low bush cover; herbaceous layer is dominated by *S. pyramidalis*, *Scleria woodi* (**orubyamira**) and *Pycreus chlorostachys* (**engorogoro**); soils are poorly drained; mostly used as dry season or drought reserves

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livestock grazing. Thus herders made a reconnaissance of the grazing landscapes on a daily basis. In the present study, these traditional systems of resource surveys were used to address the 'how' question of biodiversity monitoring. The joint team of herders and researchers made a reconnaissance of the three landscapes and identified a total of 30 landscape patches, each identifiable in terms of the soils, the types of vegetation structure and composition and topographic locations (i.e. uplands vs. bottomlands). All the patches have the corresponding names of the three landscapes that comprise the Banyarwanda agropastoralists' grazing home range in the study area (Table I).

We introduced systematic sampling of the landscape patches to obtain representative information on the status of floral biodiversity. The herders were instructed to make stops along their landscape walks. The number of stops varied with the size of the landscape patches and the extent of heterogeneity. Herders were asked to avoid border areas of patch mosaics with transitional names because these were found to be inconsistent. Thus, in order to address the 'how' question of monitoring biodiversity, the herders were asked to scale downwards from the landscape patch levels to the plot levels. This meant that herders made assessments at two scales: the coarse landscape patch scale and the fine plot level scales. We did all the sampling at the plot scale but used the information to scale up to the landscape patch levels. This did not in any way contradict the way herders conducted the surveys, but was done for practical reasons in conducting field surveys in inaccessible landscapes (see also Oba and Kotile, 2001).

Data Collection

The first level of assessment to address the 'how' question of biodiversity monitoring, used nested plots; distributed within the landscape patches at each stop. We made several assumptions when determining the number of plots. The first assumption was that the location of plots within landscape patches was not pre-determined. Secondly, sampling intensity was related to the amount of time spent in the field, which varied with the heterogeneity of the landscape patches. In the more heterogeneous landscape patches, more plots were sampled and therefore more time was spent in sampling the given landscape. Four levels of plot sizes were used: $1 \times 1\,m^2$ for sampling grasses/sedges, $2 \times 2\,m^2$ for herbs, $10 \times 10\,m^2$ for shrubs and $15 \times 15\,m^2$ for trees. On average 30 plots of each size per landscape were sampled for a total average of 120 plots over a 3-week period. The plots were used to record the number of species for determining species richness and estimate percentage cover, and the same plots were assessed by the herders for plant identification.

In the second level of assessment, to address the 'what' question of biodiversity monitoring, herders evaluated range condition scores, species richness and the invasiveness of species in the same landscape patches and plots where the joint herder–researcher vegetation sampling had been conducted. Here, it was made clear to the herders in their local language that their assessments, albeit scaled downwards, should be done in the same way they had conducted the assessments at the landscape scales. Working in groups of two or three and then in a group consensus they used the following procedures. The herders in their groups scored the invasiveness of different plant species in different landscape patches. Discussions focussed on the status of species related to historical knowledge of land use. The herders considered three factors when determining invasiveness scores. Firstly, whether the species concerned was native to the particular landscape. Secondly, whether the species had increased in cover compared to that of the past. Thirdly, herders considered whether the species reduced or increased the quality of livestock grazing in the given landscape over the historical period.

To determine the scores for addressing the 'what' question of monitoring biodiversity, we marked three squares on the ground, and leaves of a plant representative, respectively, of highly invasive, moderately invasive and non-invasive species according to the consensus group assessments were placed in each square. Then the herders categorized each plant species sampled in the plots and the surrounding landscape patches in terms of invasiveness and, after discussion and reaching consensus, placed each species in one of the three score classes using pebbles. The species that posed the greatest threat was allocated a score of five pebbles, while the species with a score of four indicated moderate invasion threats and those that received three or less showed no threats. The herders then used the information on species invasiveness and the species richness and level of invasiveness to develop a value-weighted range condition rating (termed as highly desirable, moderately desirable and undesirable) for each

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patch. The range condition was negative if the scale of invasiveness was high and was positive when the scale of invasiveness was low. The herders and ecologists then used the nested plots for individual landscape patches and assessed bush cover, woody density, key forage species and presence/absence of invasive species. The landscape patches that had lower bush cover with the presence of representative key forage species and low frequencies of invasive species received the highest condition scores. The lowest range condition scores were for the landscape patches that had high bush cover and greater occurrence of invasive species, that is the landscape patches with high invasiveness scores.

As stated earlier, one purpose of monitoring biodiversity is to generate scientific data for testing scientific hypothesis. Thus, in the first methodological approach, we were interested in knowing if the variability of biodiversity (in terms of species richness, plant cover, etc.) actually varied according to the landscapes that were identified by the herders. Evidence of difference would confirm that one landscape could be distinguished from others using the criteria selected. In our case, we wanted to understand the variability in terms of variations by species richness by different plant life forms. We were also interested, based on the herders' knowledge, in the degree of invasiveness threats posed by different plant species in different landscapes. Our second interest related to the empirical data were to understand if the various biodiversity indicators were ecologically linked and if we could explain those links to understand their relevance for the herder management decisions. The third interest concerned the researchers in general, who usually use plots in landscapes and make some opinion at a larger scale. We wanted to understand what risks researchers face in making opinions based on the plot data. What are the risks involved for using one scale for making decisions on the status of biodiversity at another scale?

Data Analyses

In order to understand why the herders monitored biodiversity, we have shown that they used environmental variables to make distinctions between different landscapes for grazing resources. We have considered some indicators—species richness, woody density—as proxy measures for biodiversity that could be used to classify the different landscapes and understand biodiversity indicator changes. According to the hypothesis, when comparing landscape level differences, the indicators should be able to display spatial variability. We considered the range condition based on herder-invasive scores and researchers' estimations of bush cover. Herders rated individual species' invasive scores and the species frequencies in the landscape patches (as well as plots) in order to have a measure of spatial variability between landscapes. For the herder value-weighted range condition scores, biodiversity indicators represented by species richness and woody plant densities, we used the General Linear model (SAS, 2001) to assess the landscape differences. Means of different landscapes for each response variable were then compared using a turkey test. We used Pearson's correlation to assess the relationship between the proxy biodiversity indicators and herder value-weighted range condition scores. To address the scale effects we used linear models to assess the grass/sedge and herb species richness and woody density and herder value-weighted condition at a coarse scale (controlling for landscapes) and sampling scale (without including landscape in the model).

RESULTS

Why Monitor Biodiversity

The herders distinguished the different landscapes based on physical and biological differences (Table I). For the physical attributes the herders considered topographical positions of landscapes and the drainage of the soils and for purposes of management they considered seasons of the year when the particular landscapes could be optimally utilized. For example, **Omukura** is marshy and its use during the wet season for grazing is undesirable because of the sticky soils and the 'watery' vegetation. According to the herders, this particular landscape was used as a drought reserve because it had better forage during critical years than the other landscapes. The greater moisture available during the dry years makes these landscapes refuge resources. By comparison, the **Omugongo** landscapes, which are hilly, are also unsuitable for grazing during the rains, due to the thickness of the vegetation

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Table II. Species of herbs, grasses and shrubs and trees assessed by herders across three major landscapes in the Kiboga district, central Uganda, with the invasiveness score of each species and per cent frequency (per cent) in each of the three landscape types (see text for details)

Family	Species	Local name	Invasiveness scores*	Species occurrence by landscape (%)		
				Omugongo	**Omukura**	**Ekihita**
Herbs species						
Zingiberaceae	*Aframomum angustifolium K. Schum.*	**Amatunguru**	4	10		
Labiatae	*Platostoma africanum P. Beauv.*	Unknown	3	1		
Compositae	*Microglossa angolensis Oliver & Hiern.*	**Kyakuyambaki**	4	10		
Rubiaceae	*Spermacoce princeae (K.Schum.) Verdc.*	Unknown	3	1		
Labiatae	*Ocimum lamiifolium Hochst*	**Emwenyi**	3	1		
Euphorbiaceae	*Tragia brevipes Pax*	**Isusa**	3	1		
Compositae	*Aspilia africana (Pers.) C.D.Adams*	**Omusununu**	3	2	2	
Labiatae	*Leucas calostachys Oliver*	**Akasiburampiki**	3	2		
Commelinaceae	*Commelina africana L.*	**Enanda**	3	1		
Compositae	*Conyza floribunda H.B. & K.*	**Kafumbamusaja**	3	1		
Commelinaceae	*Commelina benghalensis L.*	**Eteeiza**	3	1		20
Cyperaceae	*Scleria globonux C.B.Clarke*	Unknown	3			20
Melastomataceae	*Dissotis senegambiensis Triana*	Unknown	4		58	30
Acanthaceae	*Hygrophila auriculata (Schumach.) Heine*	**Oruhaya**	3		7	5
Oxalidaceae	*Biophytum petersianum Klotzsch*	**Kahurira**	3			5
Compositae	*Vernonia vialacea Oliver & Hiern*	Unknown	3			5
Compositae	*Crassocephalum sarcobasis S. Moore*	Unknown	3			10
Commelinaceae	*Commelina albescens Hassk.*	Unknown	3			5
Melastomataceae	*Dissotis perkinsiae Gilg*	Unknown	3		4	
Compositae	*Melananthera scandens (Schu, nach. & Thonn.) Brenan*	Unknown	3		4	
Menispermaceae	*Cissampelos mucronata A.Rich.*	**Orusikasikye**	3		2	
Papilionaceae	*Desmodium salicifolium DC.*	**Akafunyampekye**	3		2	
Papilionaceae	*Abrus canescens Welw.*	Unknown	3		2	
Compositae	*Sphaeranthus suaveolens DC.*	**Emitwe y'abagurusi**	3		13	
Labiatae	*Pycnostachys stuhlmannii Güerke*	Unknown	3		6	
Gramineae	*Sporobolus pyramidalis Beauv.*	**Obuyanja**	5	70		87
Cyperaceae	*Scleria woodii C.B. Clarke*	**Orubyamira**	4			80
Cyperaceae	*Scleria melanomphala Kunth*	**Oruchemba**	3	10		23
Gramineae	*Sporobolus piliferus Kunth*	Unknown	3	3		7
Cyperaceae	*Kyllinga crassipes Boeck.*	Unknown	3			3
Gramineae	*Hyparrhenia mutica Clayton*	**Omuchenyi**	3			3
Commelinaceae	*Commelina latifolia C.B. Clarke*	**Etaija**	3			3
Gramineae	*Brachiaria decumbens Stapf*	**Ezubwe**	4		9	
Gramineae	*Sporobolus sanguineus Rendle*	**Omutsina**	3	27	27	
Gramineae	*Loudetia arundinacea Steud.*	**Omukabara**	5	30	70	
Gramineae	*Digitaria abyssinica Stapf*	**Ekatsi**	3		17	
Gramineae	*Imperata cylindrical P.Beauv.*	**Umushojwa**	3	3		
Cyperaceae	*Pycreus polystachyos (Rottb.) P. Beauv.*	**Orugorogoro**	3			17
Gramineae	*Themeda triandra Forssk.*	**Emburara**	4	66	30	
Gramineae	*Setaria sphacelata Chipp*	Unknown	3	3	3	3

(*Continues*)

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Table II. (Continued)

Family	Species	Local name	Invasiveness scores*	Species occurrence by landscape (%)		
				Omugongo	**Omukura**	**Ekihita**
Woody species						
Malvaceae	*Urena lobata L.*	**Oruhigura**	5	67		
Solanaceae	*Solanum incanum L.*	**Umucucu**	3	2		
Papiloanaceae	*Milletia dura Dunn.*	**Omurongo**	3	1		33
Combretaceae	*Combretum collinum Fresen.*	**Omukora**	5	57		
Tiliaceae	*Grewia mollis Juss.*	**Omukoma**	4	10		
Anacardiaceae	*Rhus natalensis Krauss*	**Omusheshe**	3	1		
Annonaceae	*Annona senegalensis Pers.*	**Ekibengeya**	3	1		
Caesalpiniaceae	*Piliostigma thonningii (Schumach.) Milne-Redh.*	**Omugari**	3	2	16	28
Bignoniaceae	*Stereospermum kunthianum Cham.*	**Omuremera**	3	1		
Rubiaceae	*Oxyanthus specious DC.*	**Omubare**	3	1		
Pittosporaceae	*Pittosporum spathicalyx De Wild.*	**Kabaruka**	3	1		
Mimosaceae	*Acacia sieberiana DC.*	**Omutyaza**	4	6	50	33
Combretaceae	*Combretum molle G. Don*	**Omurama**	3	1		
Leguminosae	*Albizia zygia Macbride*	**Omurongo**	4	12		
Mimosaceae	*Acacia tortilis Hayne*	**Omunyinya**	3	1		
Mimosaceae	*Acacia hockii De Wild.*	**Orugando**	3	2	30	
Combretaceae	*Terminalia glaucescens Benth.*	**Omutama**	3	1		
Verbenaceae	*Lantana camara L.*	**Kapanga**	3	2		
Leguminosae	*Albizia coriaria Welw.*	**Omusisa**	3		4	
Sapindaceae	*Allophylus africanus P.Beauv.*	**Omutete**	3			3
Celastraceae	*Maytenus undata (Thunb.) Blakelock*	**Omweza**	3			3

*3, least invasive; 4, moderately invasive; 5, highly invasive.

and the steep slopes. They serve as the dry season reserve, while **Ekihita**, which are patch mosaics of the savanna landscapes, are ideally the most desired landscapes for grazing, particularly during the wet season. The Banyarwanda herders have regulated the impacts on rangeland biodiversity by allocating different seasons of grazing to the different landscapes. However, according to the herders, the changes in landscape conditions associated with bush cover and invasiveness were attributable to the withdrawal of fire as a management tool through official forest policy. Fire plays an important role in savanna dynamics. Every landscape reflects the past history of fire (Sheuyange *et al*., 2005; Nefabas and Gambiza, 2007). Fire and grazing as natural ecosystem drivers often influence the changes in vegetation structure and composition (Roques *et al*., 2001). In the case of central Uganda, fire frequency according to the local communities has been reduced due to landscape fragmentations for cropping, grazing and settlements. Consequently, the invasive species have expanded across different landscape patches.

What Biodiversity to Monitor

This question was an inventory tool. A total of 61 plant species that belonged to 27 families were recorded in the three landscapes (Table II). Herders were able to identify 79 per cent of the species given to them as samples by ecologists. In the surveyed landscapes, **Omugongo**, for example contained 38 per cent of the total herbaceous species, more than **Omukura** (35 per cent) and **Ekihita** (27 per cent). For the grass and sedges the frequency was greater in **Ekihita** (39 per cent) compared to **Omugongo** (35 per cent) and **Omukura** (26 per cent). Generally, **Omugongo** had a higher frequency (i.e. composition by life form) of shrubs and trees combined (66 per cent) relative to **Ekihita** (19 per cent) and **Omukura** (15 per cent). The **Omugongo** landscape had more herbs, shrubs

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Table III. Means (±SE) of plant species richness and woody plant density and herder value-weighted range condition scores in ekihita, omugongo and omukura landscapes (Table I) in Uganda

Parameter	Landscape*		
	Ekihita	Omugongo	Omukura
Richness			
Grass species	$8 \pm 0{\cdot}14^{a}$	$9 \pm 0{\cdot}14^{a}$	$9 \pm 0{\cdot}14^{a}$
Herb species	$3 \pm 0{\cdot}5^{b}$	$4 \pm 0{\cdot}5^{a}$	$1 \pm 0{\cdot}5^{b}$
Shrub species	$5 \pm 1{\cdot}0^{b}$	$7 \pm 1{\cdot}0^{a}$	$2 \pm 1{\cdot}0^{c}$
Tree species	$2 \pm 1{\cdot}5^{b}$	$5 \pm 1{\cdot}5^{a}$	$3 \pm 1{\cdot}5^{b}$
Density			
Shrub	118 ± 50^{b}	218 ± 50^{a}	78 ± 50^{c}
Tree	18 ± 20^{b}	98 ± 20^{a}	9 ± 20^{b}
Herder value-weighted			
Condition score	$4 \pm 0{\cdot}14^{ab}$	$3{\cdot}7 \pm 0{\cdot}14^{b}$	$4{\cdot}7 \pm 0{\cdot}14^{a}$

*Means with different letters were significantly different at $p < 0{\cdot}05$.

and tree species and also a greater shrub and tree density than other landscapes, whereas richness of grass species was similar across the three landscapes (Table III).

How to Monitor Biodiversity

According to the herder value-weighted assessments of range condition, **Omukura** had the highest condition score and **Omugongo** the lowest condition (Table III). In the latter landscape, the herders attributed the declining range condition to invasions by *Urena lobata* (**oruhigura**) and *Lantana camara* (**kapanga**) (Table II), and increased shrub and tree density (Table III). The herder assessed range condition was negatively correlated with the herb species richness, shrub species richness and tree species richness, as well as woody density, but positively correlated with grass species richness (Table IV). The answer to how to monitor biodiversity might be inferred from the scale effects of the spatial variability of the plant species and range condition indicators. The data showed that the biodiversity indicators and the herder value-weighted range condition scores had high variability at the landscape scale but not at the sampling scale. The implication was that if the information from researchers alone was to be relied on, a critical aspect of the information necessary for decision-making would be missed (Table V).

DISCUSSIONS

We established that the traditional system of biodiversity monitoring by the Banyarwanda agropastoralists was based on knowledge of landscapes. The herders showed their in-depth knowledge of taxonomy (With, 2002;

Table IV. Matrix of Pearson's correlation coefficients between proxy indicators of biodiversity and herder value-weighted range condition scores

	Herbs	Grasses	Shrubs	Trees	Woody density
Herbs					
Grasses	0·41				
Shrubs	$0{\cdot}40^{***}$	0·04			
Trees	$0{\cdot}46^{***}$	−0·02	$0{\cdot}57^{***}$		
Density	$0{\cdot}49^{**}$	0·01	$0{\cdot}85^{**}$	$0{\cdot}91^{***}$	
Condition	−0·2	$0{\cdot}73^{*}$	$-0{\cdot}31^{**}$	$-0{\cdot}25^{*}$	$-0{\cdot}31^{**}$

*$p < 0{\cdot}05$.
**$p < 0{\cdot}01$.
***$p < 0{\cdot}001$.

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Table V. Results of linear models showing spatial variations of plant species richness and density at landscape scale (controlling for landscape) and at sampling scale (without including landscape) in central Uganda

Response variable	Landscape scale			Sampling scale		
	df	*F*	*p*	df	*F*	*p*
Range condition score	2	6·13	0·003			
Herb species richness	2	18·73	<0·001	29	0·68	0·869
Shrub species richness	2	32·95	<0·001	29	0·42	0·994
Tree species richness	2	3·38	0·039	29	0·28	0·999
Shrub density	2	32·95	<0·001	29	0·81	0·727
Tree density	2	76·65	<0·001	29	0·69	0·858

Gemedo-Dalle *et al*., 2005), which is of huge value to ecologists who are unfamiliar with the studied environment. Herders would therefore be helpful in initial identification of plants during field sampling. In similar studies conducted using herders in eastern and southern Africa, it has been established that herders in general possess a knowledge of the biodiversity inventory that has the potential for developing local herbaria (Oba *et al*., 2000a; Oba and Kotile, 2001; Mapinduzi *et al*., 2003; Sheuyange *et al*., 2005; Stave *et al*., 2007; Verlinden and Kruger, 2007; Oba *et al*., 2008). The rich folk taxonomic knowledge of local herders would be of great benefit to non-taxonomist technicians for the purposes of recording the samples (in the local names given by the participants) before making scientific identifications of the specimens using herbarium references. The alternative for researchers unfamiliar with the taxonomy would be to have many unidentified species, which would make sampling and data collection more difficult.

The assessments of biodiversity indicators confirmed that there was variability between landscapes, with the exception of the grass species richness. The greater species pools, as well as woody plant density in the **Omugongo** compared to the other landscapes, had influenced the grazing management preferences of the herders. This was shown by the herder value-weighted range condition scores, which were lower in the **Omugongo** than in the **Ekihita** and **Omukura** landscapes. We inferred from the evidence that the **Omugongo** landscape with the highest species pool was not necessarily the most preferred for livestock grazing. The particular landscape had a greater cover of invasive species as well as greater densities of woody plants.

The inference we draw was that livestock grazing requirements influenced herder perceptions of biodiversity. In the current study, we did not include human uses of plants and plant products to broaden the value for biodiversity. We acknowledge, as others have shown (e.g. Salafsky *et al*., 2001), that community-based biodiversity is valued in diverse ways. In our case, the negative correlation between herbs and woody species and density and herder value-weighted range condition scores reflected the undesirable state of biodiversity for grazing management. This is contrasted with the positive relationships between grass species and range condition scores, which reflected the herder-desired state of biodiversity. In the system dominated by grazers, pastoralists would prefer grasses to woody species. Herders therefore evaluated the conditions of biodiversity in terms of key forage species, while considering that the undesirable species posed grazing management problems. The inference we draw is that biodiversity consisting of herbs, shrubs and trees was not preferred for grazing mainly by cattle. The herder preference might differ if they managed browsers (Oba *et al*., 2000b). We would also need to qualify our statement because the assessment did not include important economic plant species uses, such as for medicine, fuel and other domestic uses (Gemedo-Dalle *et al*., 2005). Nonetheless, the definitions of biodiversity from a utilitarian perspective would show inconsistencies with the conventional scientific goals of biodiversity conservation that concerns the preservation of total native biota. Our results showed that in order for biodiversity monitoring to succeed in the eastern African grazing lands, the values given by the herding communities should be understood and taken into consideration when designing conservation programmes. According to the herders, the useful plant species represented favourable range condition indicators, while the undesirable species reflected deteriorating trends.

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A reflection on the how to monitor biodiversity might be necessary. We hypothesized that if the scale of herder assessments was effective, we would expect differences in spatial distributions of biodiversity indicators at the scale of management rather than at the scale of sampling. This was confirmed by the findings from the joint research. Using the scale effects, we inferred that spatial distribution of biodiversity indicators reflecting effects of landscape heterogeneity would be detected at landscape scales but not at plot levels. The evidence would suggest that the scale of herder assessment is more appropriate for monitoring changes in grazing land biodiversity, as it is capable of accounting for spatial variations associated with landscape heterogeneity and the effects of past management. The weakness of the plot scale for representing the scale at which management decisions are made is that it would require up scaling, thereby introducing further uncertainty to management and conservation of biodiversity. However, ecologists' selection of plot scale sampling is influenced more by practical decisions in the field than by their representations of natural ecosystems. It is usual that the information collected at the sampling scales is used for recommending conservation at larger scales. The risk of doing so should be appreciated by conservation agencies. Scaling effects remain important for assessments by herders as well as ecologists (Oba *et al*., 2003). Scaling allows the linking of effects of management on biodiversity conservation at an appropriate scale.

CONCLUSIONS

In conclusion, the why question of monitoring biodiversity, what should be monitored and how monitoring biodiversity should take place could be appropriately addressed through integration of technical and participatory methods. The why monitor biodiversity addressed the problem associated with range management, the what biodiversity to monitor considered the biodiversity proxy indicators used by the herders. The how to monitor biodiversity has always considered the scales involved. The issue of scale was addressed to understand the implications for making decisions based on data made at the landscape and sampling scales. To avoid bias, all the major ecological conditions need to be considered and herders should reach consensus in their assessments. The indicators of biodiversity could easily be related to the herder value-weighted range condition scores. Assessments by herders and ecologists were more effective at the landscape scales than at the sampling scales, suggesting that monitoring of biodiversity should be conducted at the coarser scales. The study also showed some limitations of the participatory monitoring methods of which researchers should be cognizant. One such problem was matching the assessments of herders and ecologists. The second problem was making conservation recommendations based on the interpretation of biodiversity trends based on herder knowledge alone. Herder value-weighted ratings were more concerned with utilitarian values than with preserving the total species pool. In the grazing lands, monitoring of biodiversity would therefore be more effective if managers assessed biodiversity and established monitoring regimes based on improved knowledge of different local uses of biodiversity. Scales are crucial for understanding how monitoring of biodiversity needs to be conducted. In this regard, the integrated monitoring method could be used at the appropriate scales of monitoring biodiversity. In the grazing lands, monitoring of biodiversity at landscape scales and popularizing local knowledge for assessing biodiversity will increase the effectiveness of conservation programmes as well as promoting community participation in the implementation of the Global Convention on Biological Diversity.

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