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Participatory selection process for indicators of rangeland condition in the Kalahari

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To develop indicator-based management tools that can facilitate sustainable natural resource management by non-specialists, meaningful participation of stakeholders is essential. A participatory framework is proposed for the identification, evaluation and selection of rangeland condition indicators. This framework is applied to the assessment of rangeland degradation processes and sustainable natural resource management with pastoralists in the southern Kalahari, Botswana. Farmer knowledge focused on vegetation and livestock, with soil, wild animal and socio-economic indicators playing a lesser role. Most were indicators of current rangeland condition; however 'early warning' indicators were also identified by some key informants. This demonstrates that some local knowledge is process-based. Such knowledge could be used to improve indicator-based management tools and extension advice on the livelihood adaptations necessary to prevent or reduce ecological change, capable of threatening livelihood sustainability. There is evidence that social background influences indicator use. Communal farmers rely most heavily on vegetation and livestock indicators, whilst syndicate and land-owning pastoralists cite wild animal and soil-based indicators most frequently. These factors must be considered if indicator-based management tools are to meet the requirements of a diverse community.

KEY WORDS: Kalahari, participation, indicators, rangeland condition, degradation, livestock management

Introduction

Although a number of frameworks have been used to generate indicators for sustainable natural resource management, indicators have too frequently been identified, evaluated and selected by researchers (e.g. Breckenridge *et al.* 1995; NRC 2000). For this reason, they often carry little meaning for local communities who require specialist training and equipment to use them. In order to develop indicator-based management tools that can facilitate use by non-specialists, meaningful participation of stakeholders is essential in indicator identification, evaluation and selection. This paper therefore proposes a framework for participatory indicator identification, evaluation and selection. This framework is used to identify relevant indicators of rangeland condition and degradation through participatory research with Kalahari pastoralists and extension workers. Consistent with farmer knowledge, application of the framework leads to the integration of a wide range of indicators that can monitor both current rangeland condition and the processes that mediate it. Links to process-based indicators are vital to develop indicator-based management tools and improve extension advice, as they can facilitate management adaptations required to prevent changes in rangeland condition that threaten pastoral livelihood sustainability.

A number of participatory land degradation assessments have been developed for other regions (e.g. Tongway 1994; Milton *et al.* 1998; NRC 2000; Stocking and Murnaghan 2001). However, none of these focuses on the complexity of issues that represent environmental change in the highly dynamic semi-arid rangelands that support the livelihoods of over 25 million African pastoralists (Lane 1998). Throughout dryland Africa, the use

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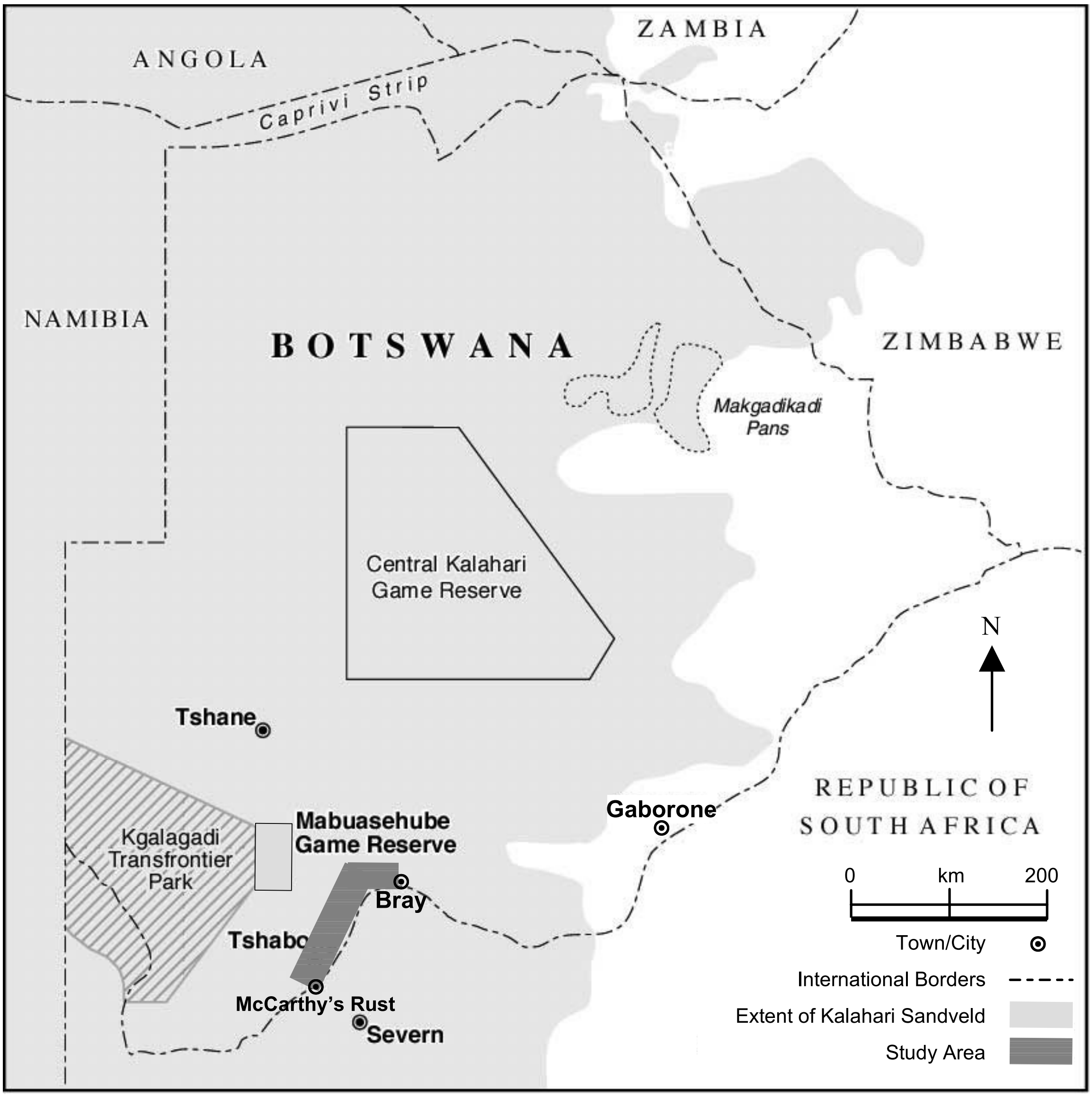

Figure 1 Location of study area

of rangeland condition assessment techniques by pastoralists has been limited, as they tend to be time-consuming and complicated. These pastoralists face multi-faceted problems resulting from an increased incidence of droughts (IPCC 2001) and changes to land tenure systems (Toulmin and Quan 2000). Together these processes threaten to increase degradation problems, and exacerbate pastoralist livelihood vulnerability to rangeland environmental change.

Kalahari rangelands

The research reported here was conducted with pastoralists along a 200 km transect between McCarthy's Rust and Bray, Kgalagadi District, Southwest Botswana (Figure 1). Although there has been considerable debate over the extent and nature of degradation affecting Kalahari rangelands (e.g. Perkins and Thomas 1993; Dougill and Cox 1995; Thomas *et al.* 2000), there has been no attempt to develop farmer-led rangeland condition assessments.

Since independence in 1966, the Government of Botswana has progressively privatized communal grazing lands in the Kalahari by opening large tracts to increasingly commercialized livestock production by the provision of water from deep boreholes (Thomas and Shaw 1991; Sporton and Thomas 2002). Resultant environmental changes have occurred most notably in the form of bush-encroached zones that have become the dominant vegetation assemblage within a 2 km radius of boreholes (Perkins and Thomas 1993). Both ecological surveys (Perkins and Thomas 1993) and satellite observations (Dougill and Trodd 1999) suggest that these zones do not expand linearly over time. This suggests that frequent disturbance from agents such as fire, drought, frost, lightening, wind and wood harvesting provide Kalahari rangelands with a degree of ecological resilience (Dougill *et al.* 1999). However, as the spacing between boreholes has decreased in recent years, there are real fears that bush-encroached areas may coalesce, reducing the ecological fodder diversity and availability, and thus pastoral productivity. Such concerns have been further emphasized by recent shifts in dryland ecological theory. These imply that a density-dependant relationship exists between livestock and dry-season fodder resources. This may lead to a long-term, grazing-induced decline in primary and hence secondary production in outlying areas (i.e. land degradation) (Illius and O'Connor 1999 2000).

In Kalahari rangelands, dry-season fodder typically comprises perennial grass, in addition to bush leaves, pods and litter (Skarpe and Bergström 1986). This implies that maintaining ecological heterogeneity is vital for pastoralist drought-coping strategies and is important in retaining ecological resilience (Dougill *et al.* 1999). As such, the association between bush encroachment and rangeland degradation must be questioned. This could be achieved through an improved understanding of pastoralist use of different ecological resource areas through time. In particular, studies need to focus on drought events when both dryland environments and pastoral livelihoods are at their most vulnerable.

The need for user-friendly rangeland condition assessment methods has been expressed by the Ministry of Agriculture at a District level (Leehro personal communication), and repeatedly by the pastoralists interviewed. This is consistent with a wider recognition that degradation appraisal tools must meet farmer specifications if they are to achieve widespread uptake and enhance livelihood sustainability (Stocking and Murnaghan 2001). There is no accepted framework for farmer-led identification, evaluation and selection of indicators that can feed into rangeland management decisions. It is to this end that the methodological framework described below was devised and applied to Kalahari rangelands.

Methodological framework for indicator identification, evaluation and selection

A number of frameworks have been developed to classify indicators. The most widely used of these are the Framework for the Evaluation of Sustainable Land Management (FESLM) (Smyth and Dumanski 1995), Pressure–State–Response (PSR) (OECD 1993) and Driving Force–State–Response (DSR) (UNCSD 1996) frameworks. Although none are explicitly participatory, classification frameworks like these go further than the numerous former attempts to define indicator evaluation criteria that have led to the non-participatory development of many indicator sets (e.g. Rennie and Singh 1996; NRC 2000).

The development of pre-defined, externally generated evaluation criteria for indicators does not acknowledge the diversity of stakeholders with wide-ranging perceptions of relevant criteria. Participation of stakeholders in the development of evaluation criteria is therefore essential to select appropriate indicators. Evaluation criteria directly influence indicator selection, and are themselves influenced by the objectives for which users wish to develop indicators (Krugmann 1996). Determining user objectives and evaluation criteria prior to the identification and selection of indicators is therefore a key step, but one that has been rarely addressed in indicator development frameworks.

In one of the few previous frameworks to fully involve local communities in the development and testing of indicators, Bellows (1995) advocated indicator identification by local communities, followed by research-based review and subsequent revision through negotiations with stakeholders. Similar approaches based on individual semi-structured interviews (Kipuri 1996; Stockdale and Ambrose 1996) and a combination of group and individual approaches (Lightfoot *et al.* 1993; Smyth and Dumanski 1995; Woodhouse *et al.* 2000; Morse *et al.* 2001) have also been developed. A number of studies have taken this a step further, by incorporating indicators into participatory degradation assessment manuals (e.g. Savory 1988; Tongway 1994; Milton *et al.* 1998; Stocking and Murnaghan 2001). However, community involvement in their development has been limited. They tend to have been developed with little reference

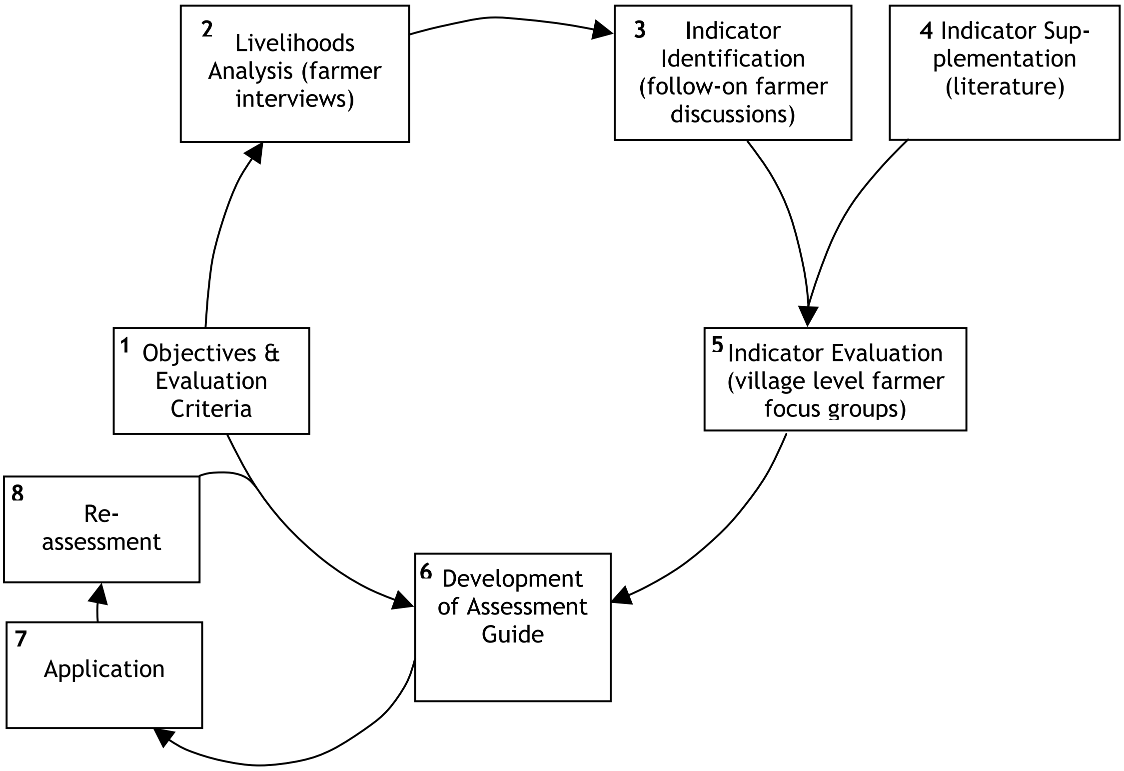

Figure 2 Conceptual framework for farmer-led indicator development (stages 1–5 reported in research here)

to land-user objectives, strengths or constraints, and they tend to encompass a limited range of indicators.

Building on these models, the framework proposed here (Figure 2) stresses the need for farmer involvement at every level, including the definition of indicator objectives and evaluation criteria. It also integrates individual interviews with subsequent discussion of key findings in farmer group meetings at a village level. The framework was applied using a modified sustainable livelihoods analysis, which has gained acceptance as an approach for understanding the multiple dimensions of rural livelihoods (Carney 1998; Scoones 1998). This modified approach enables a more explicit analysis of individual access to key natural resources (notably land tenure and water availability) and their effect on pastoralist decisionmaking. Given the impacts of drought on pastoral livelihood strategies in such dynamic, 'risk-prone' dryland environments (Davies 1996; Twyman *et al.* in press), particular attention was paid to management practices during drought. Using this approach enables each individual's livelihood objectives to be identified prior to the selection of rangeland condition indicators. Semi-structured interviews and time-line discussions were then used to examine dynamism in natural resources (e.g. rainfall variability and ecological changes), social systems (e.g. land tenure arrangements), physical infrastructure (principally access to markets), labour availability and access to financial capital. This matches the holistic, people-centred nature of the sustainable livelihoods approach (Carney 1998). The inclusion of time-lines in discussion addresses the perception that such approaches have previously failed to capture the temporal dynamism of key assets (Ashley 2000). In total, 67 semi-structured interviews were conducted in this manner. In addition, five selected key informant interviews and three oral histories were undertaken to assess changes at the village/community scale. These were then used to test the consistency of information collected in individual interviews.

Pastoralists were asked to identify objectives they would like indicators of rangeland condition to meet. Where this was not possible, they were asked to identify their main objectives for farm management, followed by an assessment of the extent indicators could help meet these objectives.

Evaluation criteria for assessing the value of different potential indicators were also elicited, initially through interviews and then in more formal discussion at farmer focus groups. Farmers were then asked to identify parameters they associated with rangeland degradation. Consistent with accepted definitions (Abel and Blakie 1989; Middleton and Thomas 1997), this was defined as formerly productive rangeland that has declined to low productivity (independent of rainfall). They were also asked to identify which of these indicators they would expect to change first before this degraded state was reached: these were termed 'early warning' indicators.

The accuracy and utility of indicators obtained from semi-structured interviews was assessed in three focus groups, attended by 17, 10 and 26 pastoralists in the villages of Makopong, Draaihoek and Omawoneno, respectively. Approximately half those attending had been interviewed previously. Groups were asked to evaluate each indicator in turn with reference to their accuracy, ease of use and applicability to their surrounding rangeland. Where there was disagreement or uncertainty, the nature and length of discussion was recorded. Focus groups provided both a rapid evaluation of indicator utility and a mechanism for rapid dissemination of results, to ensure some immediate value to farmers involved in the research process.

The research findings reported here focus on stages 1–5 of the proposed methodological framework (Figure 2). Building on this, future research will lead to the production and iterative evaluation of rangeland degradation assessment manuals for pastoralists and extension workers (stages 6–8).

Results and analysis

Objectives and evaluation criteria

Indicator objectives were elicited in two ways. Pastoralists who were able to identify objectives for indicators to meet most frequently cited improved rangeland and livestock management, in addition to income generation. However, objectives were more frequently elicited through an assessment of management objectives, which led to greater emphasis on increasing herd size and quality, and improved income generation. Other more frequently cited objectives using this approach were improved rangeland condition and management, and provision for children.

All farmers suggested that useful indicators should be easy and rapid to use, relevant to the target area, and use existing skills and knowledge. Owners also suggested that indicators should be reliable over space and time, should encompass a diverse range of parameters and should be possible to monitor visually on a daily basis. This information is essential to optimize the value of indicator-based management tools for pastoralists and ensure widespread uptake.

Livelihoods analysis

As part of the initial livelihoods survey, pastoralists were asked to identify what they perceived as their main constraints to maintaining a secure livelihood. Changes and access to natural resources (both ecological and water) were the most widely cited constraint (72% of those interviewed). Bush encroachment (almost entirely attributed to *Acacia mellifera*) was the most commonly cited problem, matching widespread concern over this phenomenon raised in the regional scientific literature (e.g. Perkins and Thomas 1993; Dougill *et al*. 1999). Perceived constraints in the other capital assets were lower, with 42%, 34%, 32% and 15% of farmers stating that they experienced constraints in financial, human, physical and social capital, respectively. This information was used to assess factors influencing farmer objectives, evaluation criteria and the quality and nature of indicators they use.

Participatory selection of rangeland condition indicators

In total, 83 indicators were elicited from farmers and ranked in order of citation frequency (Table 1). A classification of indicators by type showed that vegetation indicators were most commonly cited (54% indicators elicited), followed by livestock (21%), soil (16%), wild animal (5%), socio-economic (2%) and other (2%) indicators. The quantity and nature of indicators elicited was analyzed according to a number of factors: use of fencing; herd size trends; information from other farmers and the radio; formal education status; constraints and trend lines for each capital asset; usage and attitude towards agricultural extension; health constraints; use of savings and credit; and occupation status. There were notable differences in the type of indicators used by the different land tenure groups (Figure 3). Land owners cited proportionately less vegetation (48% compared to 54%) and more wild animal indicators (9% compared to 5%) than communal farmers who relied more on vegetation (58% compared to 54%) and livestock (35% compared to 21%) indicators. Indicators that were most frequently cited by communal farmers were declining livestock condition, and decreases in both total grass cover and the abundance of key palatable forbs, shrubs and grasses. Commercial land owners

Table 1 Indicators ranked by frequency cited (excluding indicators cited by less than three farmers)

Rank	Indicator	Times cited
1	Poor livestock condition/weight	46
2	Decreased grass cover	45
3	Increased abundance of unpalatable forbs and shrubs	34
4	Increased soil looseness	20
5	Increased abundance of unpalatable grasses	17
6	Decreased abundance of palatable grasses	16
7	Increased proportion of trees and shrubs dropping branches and leaves or dead	12
8	Decreased abundance of palatable forbs and shrubs	11
9	Increased incidence of non-vegetated dunes	10
	Increased incidence of livestock disease	
10	Decreased abundance of trees	9
11	Livestock graze at increased distance from borehole	7
12	Decreased abundance of medicinal/edible plants	5
	Decreased calving rate	
	Increased grass greyness/brittleness (less nutritious)	
	Increased abundance of Harvester termites (Makaka)	
13	Increased abundance of grasses with hollow tillers	4
	Increased incidence of nebkha dunes	
	Increased infiltration rate in soils	
	Decreased rain-use efficiency in vegetation (poor growth despite rain)	
14	Increased difficulty using two-wheel-drive vehicles and bicycles	3
	Declining herd size	
	Decreased abundance of veld fruit and flowers	
	Increased prevalence of bankruptcy	
	Increased bare ground	
	Increased abundance of *Boscia albitrunca* (Motlopi)	
	Increased incidence of cattle tracks	
	Increased abundance of creeping plants	
	Increased frequency and severity of dust storms	
	Increased gullying	
	Decreased rainfall in degraded areas	
	Increasing input requirements, e.g. supplementary feeds and de-bushing	
	Soil salinization	
	Tree growth increasingly stunted (new trees do not reach the height of existing ones)	
	Increased abundance of refuse and bones in the veld	

cited significantly more indicators, with a Kruskal-Wallis H test showing a significant difference between the number of indicators cited by owner (n=20; mean=7.7; σ=4.0), syndicate (n=33; mean=4.8; σ=2.1) and communal (n=10; mean=4.3; σ=2.1) farmers ($p<0.01$).

Participatory recognition of 'early warning' indicators

In addition to the systematic analysis of rangeland condition indicators cited by type (Figure 3), a functional classification was undertaken. A differentiation was made between indicators that solely described current rangeland condition and more process-based indicators that could be used as an 'early warning' of likely changes in rangeland condition (Table 2). Many interviewees found this distinction difficult to make and cited only indicators of current condition. This is consistent with Kipuri's (1996) findings from work with pastoralists in Kenya, and may be related to the apparency of current condition indicators. However, the extra

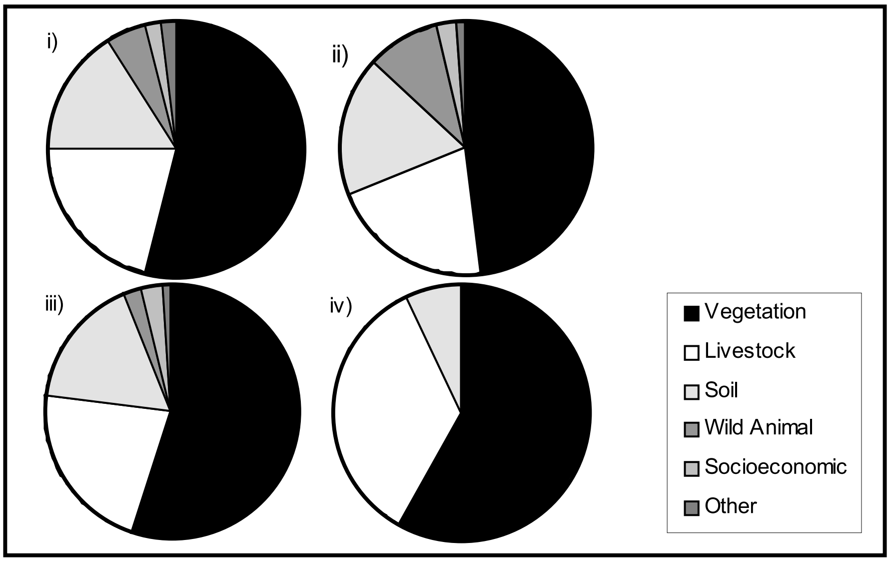

Figure 3 Indicator type profiles for (i) sample population (n=67); (ii) land owners (n=20); (iii) syndicate members (n=33) and (iv) communal farmers (n=10)

Table 2 Early warning indicators ranked by number of times cited (excluding those cited less than three times)

Rank	Early warning indicator	Times cited
1	Decreased grass cover	20
2	Increased proportion of trees and shrubs dropping branches and leaves or dead	7
3	Poor livestock condition/weight	6
4	Decreased abundance of trees	4
	Increased abundance of unpalatable grasses	
	Increased soil looseness	
5	Declining herd size	3
	Decreased abundance of palatable grasses	
	Increased abundance of unpalatable forbs and shrubs	

information available in process-based indicators makes them vital to develop effective indicator-based management tools and enhance extension advice. Early warning indicators elicited from the few indicator 'experts' interviewed should be disseminated as widely as possible. This may facilitate timely adaptation to ecological change by pastoralists, and feed into regional agricultural development initiatives.

A good example of a process-based indicator is the increased incidence of cattle tracks in a landscape. In turn, this can lead to increased soil looseness, which farmers expressed by the difficulty in using two-wheel-drive vehicles or bicycles. Subsequently this leads to increased wind erosion, more rapid losses of water to depth in soils, and the more widely cited problem of 'Long Claw' in cattle (a condition where hooves become deformed due to walking on soft sand). Ecologically, some indicators were also regarded differently as early warning indicators. Tree-based parameters tended to rank higher as early warning indicators; notably an increased proportion of trees and shrubs dropping branches and leaves or dead and decreased abundance of large trees. A decline in total grass cover was widely cited as the best early warning indicator of changes in rangeland condition. This is indicative of the increased stresses imposed on rangelands by

Table 3 Indicators all focus groups agreed were both accurate, easy to use and applicable to their surrounding rangeland

Indicator
Vegetation:
Decreased grass cover
Decreased abundance of palatable grasses
Decreased abundance of palatable forbs and shrubs
Increased abundance of unpalatable grasses
Increased abundance of unpalatable forbs and shrubs
Decreased plant species richness
Decreased rain-use efficiency in vegetation (poor growth despite rain)
Decreased abundance of trees
Stunted tree growth (new trees do not reach the height of existing ones)
Decreased incidence of veld fruit and flowers
Livestock:
Poor livestock condition/weight
Livestock graze at increased distance from borehole
Increased incidence of 'Long Claw' due to walking on soft sand
Decreased milk production
Soil:
Increased soil looseness
Increased deposition of sand on roads and productive land
Increased incidence of cattle tracks

intense grazing, especially during drought events (Illius and O'Connor 1999 2000). It is at such times that effectively permanent changes in ecological communities of the Kalahari have been predicted (Dougill *et al*. 1999) and therefore early warning indicators need to be tied to advice on drought-coping strategies that aim to retain some grass cover.

Indicator evaluation in village-level farmer focus groups

Although many farmers found it difficult to conceptualize their evaluation criteria of what makes an effective indicator in individual interviews, most felt able to evaluate indicators in focus groups when they were introduced to the key criteria of accuracy, ease of use and applicability to their surrounding rangeland. Table 3 shows indicators that all three village focus groups agreed were accurate, easy to use and applicable to their surrounding rangeland. The proportion of indicators from each category is similar to their overall proportions (59% plant, 24% livestock and 18% soil) and again stresses the need to focus primarily on indicators of vegetation and livestock change, together with the simplest soil-based assessments.

Discussion

> Staying in an area too long is like wearing the same dress for years; it gets worn out.

> The veld [rangeland] is like a person: there are fat and thin people and no matter how much you feed some people, they remain thin. If the soil is poor, no matter how much it rains, nothing will grow.

The magnitude of natural capital constraints faced by Kalahari pastoralists shown in the livelihoods analysis emphasizes the need for farm-level participatory rangeland condition assessment tools. The participatory framework developed in this research (Figure 2) can guide the identification, evaluation and selection of indicators. These can then be used by farmers to understand range degradation pressures affecting their grazing lands and enhance rangeland management. This is important for Kalahari farmers, as rangeland degradation, especially in the forms of bush encroachment and declining grass cover, was perceived by the majority of farmers to constrain their ability to manage their livestock and livelihoods.

Perceptions of bush encroachment varied between the farmers interviewed. Although most considered it a significant constraint, some of the farmers with most encroachment had a positive perception of bush in their rangeland. Given the fodder value of bushes for smallstock, one explanation for this is the fact that most of these farmers owned a signficantly higher ratio of smallstock to cattle. This matches views expressed by smallstock farmers in more arid parts of the Kalahari around Bokspits in Botswana (Thomas *et al*. submitted). In addition to this, a number of farmers asserted the value of bushes as a drought fodder resource, a view found elsewhere in the Kalahari (Perkins and Thomas 1993). Indeed, Perkins and Thomas (1993) presented evidence that bush cover could protect grass seed sources under their canopies, enabling rapid grass regrowth following rainfall and thus facilitating rapid restocking of cattle herds after drought. Scoones (1995) argues that such opportunistic management strategies can maximize the economic productivity of the pastoral production system, although more recent analyses have questioned this view (Campbell *et al*. 2000). Nevertheless, the majority of farmers held the view that *A. mellifera*, the main encroaching species, was the primary cause of reduced grass cover, due to its ability to 'take water' from grass, and thus was viewed as a major constraint to livestock production.

The suitability of the proposed approach is confirmed by the wealth of indicator knowledge expressed by those interviewed. This included many indicators not found in an extensive review of rangeland condition indicators from comparable environments (Reed and Dougill 2001). Pastoralists' preference for vegetation-based indicators matches that of Milton *et al*.'s (1998) farm-level assessment manual for the South African Karroo, and other less user-friendly manuals that preceded it in southern Africa (e.g. Foran *et al.* 1978; Vorster 1982). However these assessments have been species-based, an emphasis brought into question by this research. Farmers tended to group vegetation by morphology and palatability, rarely mentioning individual species.

Kalahari pastoralists generally downplayed soil-based indicators, something which is at variance with the focus of manuals produced for other regions (e.g. Tongway 1994; NRC 2001). This is consistent with scientific evidence that physical and hydrochemical soil degradation processes are not widely evident in the Kalahari (Dougill *et al.* 1999). This is particularly interesting in relation to contemporary theoretical debates (e.g. Cowling 2000). Pastoralists' focus on vegetation and livestock indicators can be viewed either as a recognition that grazing may induce a transition to a less productive ecological state (as predicted by non-equilibrium state-and-transition models (Behnke *et al*. 1993; Dougill *et al*. 1999)), or evidence of equilibrial relations between dry season fodder and livestock numbers (Illius and O'Connor 1999 2000). This demonstrates how the use of participatory assessments can transcend theoretical disagreements that typify much of the rangeland ecological change literature. Instead, participatory assessment can provide information that can facilitate livelihood adaptations capable of reducing or preventing rangeland degradation.

The absence of livestock indicators from previous rangeland condition assessment manuals is also at variance with information provided by Kalahari pastoralists. Previous attempts to identify livestock indicators tended to be highly specialized, and cannot be assessed by pastoralists. For example, there are a number of references to declining livestock production (e.g. Abel 1993; White 1993), the most frequently used index of which is the energy contained in the output of calves (Abel 1993), whereas Grant *et al*. (1996) refer to reduced mineral status in cattle, determined from laboratory analysis of faecal grab and milk samples. The only exception is work showing that Maasai in dryland Kenya monitor livestock condition to inform rangeland management (Kipuri 1996).

The support given to this work by the Ministry of Agriculture in Botswana is indicative of a broader trend towards the recognition of local knowledge in degradation appraisal, even for such complex pastoral farming systems. This matches the findings of studies from a range of African arable farming systems, showing indicators developed by farmers are most likely to achieve widespread uptake (Reij and Waters-Bayer 2001). However, it should be noted that the diffusion of local knowledge is likely to be shaped by the social differentiation of communities.

One reason for the different range of indicators cited by different social groups appears to be the objectives for which they use indicators. This is due to a combination of their different management aims and variations in rangeland condition between commercial, syndicate and communally owned rangeland. In particular, communal pastoralists were more likely to cite the need for improvements in herd size and quality, and income generation. Indicators cited by this group tended to focus more on livestock and vegetation (Figure 3). Land owners cited a more diverse range of objectives, including identification of optimal rotational grazing regimes, livestock breeds and the grasses most suitable for the different breeds. This group tended to cite a more diverse range of indicators (Figure 3).

In addition to this, differences in indicator knowledge can be explained to an extent by broad socio-economic differences in social networks, the time available for rangeland assessments and access to formal education and extension services. Educational background may influence indicator knowledge, with the farmer citing the most indicators (18 compared to a mean of 5.5) having a University education and others stating links to information gained in school education. However, when questioned on the source of indicator knowledge, the majority of farmers first cited training from parents, with additional inputs from other farmers (i.e. their close social network), extension services and from white commercial farmers in South Africa (whom many had worked for in the past). In addition, land owners' access to paid labour resources may give them more time to develop and apply indicators. For example, one such farmer emphasized the importance of his regular rangeland walks.

A number of adaptive responses to drought were noted in this study, including livestock movements to remaining perennial grass resources, notably close the ephemeral Molopo River, as well as some regional-scale cattle movements. Work in other

Kalahari pastoralist societies in eastern Namibia (Twyman *et al.* in press) and in the more arid south-west of Kgalagadi District (Thomas *et al.* 2001) suggest that livelihood adaptations remain capable of mitigating the impacts of ecological change on agricultural productivity. Livelihood adaptations include a shift to smallstock farming, utilizing the bush fodder resource; bush clearance for fuelwood; increased use of livestock feeds in areas dominated by annual grasses such as *Schmidtia kalahariensis*. Such changes in pastoral management practices broadly follow opportunistic strategies as outlined by Scoones (1995).

These suppositions are to be analyzed in further studies examining agricultural production trends and pastoralist adaptations to ecological change and drought. This will involve the collation of agreed key indicators of rangeland condition (Table 3) into a rangeland assessment manual designed for use by both pastoralists and extension workers.

Conclusions

This research demonstrates the value of local knowledge in indicator identification, evaluation and selection. Indicators developed using the proposed framework can facilitate effective assessment of rangeland condition by non-specialists, empowering communities to conduct tasks they formerly relied on experts to carry out. It is possible for indicator-based management tools to be developed using the framework to enhance extension advice. However, it may also be relevant to train extension agents in participatory techniques in order to elicit and disseminate local expertise, and build monitoring capacity in farming communities.

Research demonstrated that indicator use by Kalahari pastoralists differs significantly from rangeland assessment manuals developed for other regions. A number of key informants were able to identify process-based, 'early warning' indicators. These are particularly well suited for the development of rangeland condition assessment manuals, as they can indicate management adaptations to prevent or reduce long-term productivity declines. Indicator knowledge was differentiated by social background. The results suggest that extension services and indicator-based management tools should be targeted towards the least asset rich, who have least indicator knowledge. It should be possible for farmers with differing capital asset status to benefit from the kind of indicators developed using this approach, diffusing knowledge more widely throughout the community, building capacity and enhancing the sustainability of pastoral production and livelihoods.

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