LAND DEGRADATION & DEVELOPMENT

Land Degrad. Develop. **18**: 249–268 (2007)

Published online 21 January 2007 in Wiley InterScience (www.interscience.wiley.com) **DOI**: 10.1002/ldr.777

INTEGRATING LOCAL AND SCIENTIFIC KNOWLEDGE FOR ADAPTATION TO LAND DEGRADATION: KALAHARI RANGELAND MANAGEMENT OPTIONS

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Received 5 February 2006; Revised 15 August 2006; Accepted 2 September 2006

ABSTRACT

Despite numerous assessments of the sensitivity and resilience of drylands to degradation, there has been little research into the way affected communities innovate and adapt in response to land degradation. This paper shows how local and scientific knowledge can be combined to identify rangeland management strategies to reduce or adapt to land degradation. To achieve this, we have developed and applied a four-stage social learning approach based on stakeholder participation in three degradation 'hotspots' in communal rangelands of the Kalahari, Botswana. This approach aims to collate, evaluate and apply both scientific and local knowledge on rangeland degradation and management options. First, current practice and possible management options were identified from the literature. Second, a series of semi-structured interviews with rangeland users identified local knowledge of strategies to reduce and adapt to land degradation. Third, these options were discussed and evaluated with rangeland stakeholders in focus groups held across each study region. Finally, the outputs from these focus groups were used to produce rangeland assessment guides for each region that provided management options agreed to be locally relevant by both researchers and local stakeholders. The study found that the majority of strategies reported in the literature were not suitable for use by pastoralists in the Kalahari. However, many of the strategies suggested by stakeholders could only be applied effectively under common property regimes, giving impetus to the growing literature encouraging institutional reform to strengthen common property management regimes. The research stimulated a social learning process that combined knowledge from local stakeholders (both pastoralists and extension workers) with the scientific knowledge of researchers to provide a range of management options that could help land managers reduce or adapt to land degradation. By combining participatory research with insights from scientific literature in this way, more relevant results were provided than either approach could have achieved alone. Copyright © 2007 John Wiley & Sons, Ltd.

KEY WORDS: land degradation; social learning; Kalahari rangelands; participation; knowledge; Botswana

INTRODUCTION

It has been suggested that African semi-arid rangelands are trapped in a neo-Malthusian spiral of irreversible and uncontrollably worsening degradation (Barrow, 1991; Drechsel *et al*., 2001). Alternatively, others argue that human-induced land degradation can stimulate the innovation necessary to overcome resource scarcity and maintain sustainable livelihoods (Goldman, 1993; Zaal and Oostendorp, 2002). However, despite numerous assessments of the sensitivity and resilience of land to degradation, there has been little research into the ways in which people relying on the natural resources of semi-arid rangelands adapt in response to land degradation threats.

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Science has played a key role in providing large-scale responses to land degradation throughout the last 30 yr of global discussions on the desertification problem (Corell, 1999). However, scientific knowledge has limitations and cannot always provide an accurate diagnosis or solution (Fairhead and Leach, 1995; Thomas, 1997), as evidenced by the vastly different solutions to perceived degradation that national and inter-governmental agencies have attempted over the last three decades. Top-down applications of scientific knowledge rarely integrate different components of land degradation, focusing instead on single issues, which can lead to bias and prevent an appreciation of the multi-faceted nature of the problem. Local communities who are affected by land degradation rarely participate in science-led approaches, or derive results that can improve the sustainability of their land management.

Pastoralists have often been viewed by researchers and policy makers as agents of land degradation (e.g. Bollig and Schulte, 1999) through their profit-maximising and ultimately unsustainable behaviour (c.f. Hardin, 1968). However, during the 1970s and 1980s, with the rise of participatory research, a number of studies began to recognise the value of local pastoral knowledge (e.g. Swift, 1975; Dahl and Hjort, 1976; Western, 1982; Chambers, 1983). This culminated in Principle 10 of the Rio Declaration (UNCED, 1992) emphasising the need for stakeholder participation in environmental management and the UN Convention to Combat Desertification's emphasis on active local participation in desertification remediation (UNCCD, 1994).

However, the dangers of over-romanticising local knowledge are increasingly being recognised. Conceptual and political concerns have been added to methodological concerns about the tools used in participatory research (Cooke and Kothari, 2001). For example, the empowerment of previously marginalised groups may have unexpected and potentially negative interactions with existing power structures (Kothari, 2001). There are ways in which participatory research can re-inforce existing privileges and group dynamics can discourage minority perspectives from being expressed (Nelson and Wright, 1995), creating 'dysfunctional concensus' (Cooke, 2001: 19). It is clear that management decisions cannot be made on the basis of unverified local assumptions alone (e.g. Sullivan, 2000).

The need is neither for 'better' or 'more' science, nor to unquestioningly accept local knowledge. Instead, there is a need to integrate and harness knowledge from *within* and *between* scientific and local knowledge bases, so that communities are able to fully realise their capacity to adapt to the challenges of land degradation (Reed *et al*., 2006). The resultant 'hybrid knowledges' (Forsyth, 1996; Nygren, 1999) should allow scientists, local stakeholders and their different understandings to interact to produce useful policy and more effective land use management practice (Robbins *et al*., 2002; Fraser *et al*., 2006). Such co-operation has the potential to minimise the risk of conflicts, not only between ecological and economic values but also among multiple environmental management interests (Daniels and Walker, 1996). However, collaboration among stakeholders, and in particular between researchers and rural stakeholders, is often limited by a lack of effective communication (Lee, 1999). As yet, there is no consensus on how to integrate scientific and local knowledge and perceptions (Abelson *et al*., 2003), let alone how to incorporate diverse opinions into policy or land management advice (Folke *et al*., 2002; Dougill *et al*., 2006). Moreover, the meaningful interaction of local and Western scientific knowledge systems needs to overcome the different authority and values attached to the producers of these two disparate bodies of knowledge. There is, therefore, a need for research to test and refine participatory frameworks that can facilitate multi-stakeholder land use decision-making.

This paper examines how local and scientific knowledge can be combined to identify rangeland management strategies to reduce or adapt to land degradation in three degradation 'hotspots' in communal rangelands of the Kalahari in Botswana. To achieve this, we have developed and applied a four-stage social learning approach based on stakeholder participation (c.f. Reed *et al*., in press). This approach aims to collate, and then evaluate in multi-stakeholder fora, both scientific and local knowledge on rangeland degradation and management options. First, current practice and possible management options are identified from the literature. Second, a series of semi-structured interviews with rangeland users identify the local knowledge and adaptation being attempted to address land degradation in the Kalahari. Third, these options are discussed and evaluated with rangeland stakeholders in focus groups held at villages across each study region. Finally, the outputs from these focus groups are used to produce rangeland assessment and management guides for each region.

DOI: 10.1002/ldr

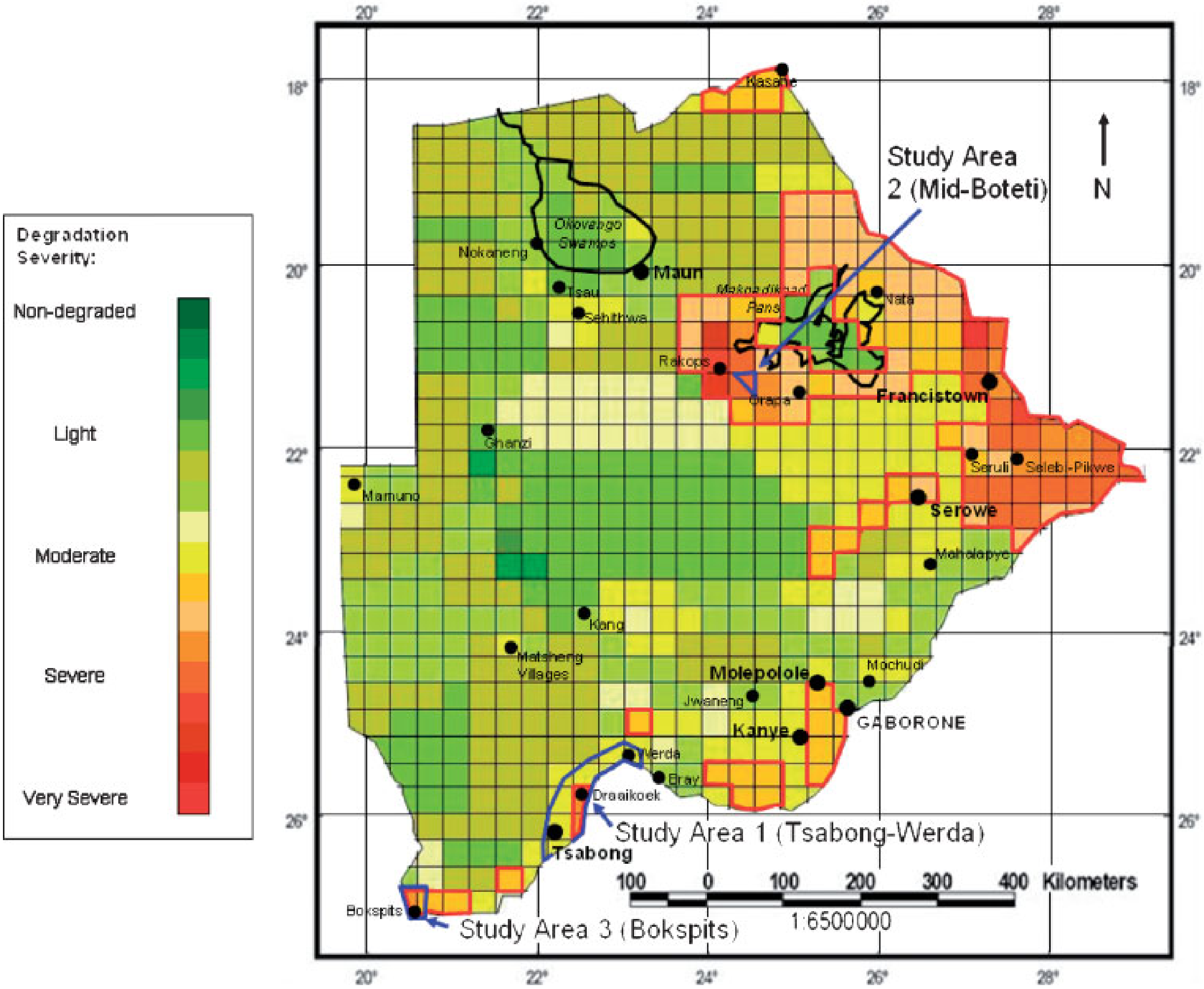

Figure 1. Land degradation map of Botswana, from the combined opinions of eight national and international advisors, with degradation 'hotspots' outlined in red (based on interviews and mapping exercise) and study areas outlined in blue where case study research was conducted.

SITE SELECTION AND DESCRIPTIONS

Three communally managed study areas were selected for this research, representing degradation 'hot spots'. Hot spots were selected using a participatory mapping exercise with eight national and international advisors on land degradation in Botswana from Universities, Government and NGOs. Five degradation severity classes were used to map degradation at a national scale. Panellists were asked to follow a definition of land degradation as 'a reduction in the resource potential of the land' (UNEP, 1997), considering human-induced, rather than climatic-induced change, as being effectively permanent over at least 50–100 yr under existing socio-economic constraints. They were asked to indicate degradation severity and extent on a base map of Botswana, leaving blank any areas they were unsure about. Maps were digitally scanned and colour-coded using graphics software. The information from individual maps was combined by assigning numerical values to degradation classes (0 for non-degraded, 1 for low, 2 for medium, 3 for high and 4 for very high), overlaying each map with a grid and calculating an average degradation score for each cell (Figure 1). Although it is not possible to show the variation between panellists in the resulting map, there was general agreement over the key degradation hotspots. However, given the level of

DOI: 10.1002/ldr

disagreement between panellists, this map should not be used to provide more than a broad-brush assessment of hotspots for further investigation.

Three study areas were selected from the range of potential degradation hotspots (outlined in red on Figure 1) to represent different biophysical (rainfall, soil and vegetation type) and cultural settings.

Study Area 1 was located between Tsabong and Werda in the southern Kalahari bush savanna zone of Kgalagadi District, with an annual rainfall of 250 mm (Figure 1). Livestock ownership in the area was high. Although ownership was concentrated particularly among a small number of commercial farmers, the majority of pastoralists used communal land. Since the expansion of the livestock sector in response to borehole provision in the 1970s, bush encroachment had become an increasing problem in this area (Reed and Dougill, 2002).

Study Area 2 was located in pan grasslands and *Colophospermum mopane* woodlands near the Makgadikgadi Pans, Mid-Boteti, Central District (Figure 1). Despite having a mean annual rainfall of 400 mm, this ecosystem has been under severe stress due to the desiccation of the previously perennial Boteti River. Livestock ownership was generally low, partly due to quarantine conditions imposed by the Botswana Meat Commission. In addition, the drying up of the river had reduced alternative livelihood options such as fishing and floodplain agriculture.

Study Area 3 was located in the arid bush savanna zone of south Kgalagadi District (Figure 1). The culture, values and practices of these communities were very different to the other study areas. The communities were founded through migrations of Nama-speakers from Namibia and South Africa at the turn of the 20th century and smallstock far exceeded cattle ownership. Livestock marketing was constrained by access to transport, condition of roads and distance to markets. There were also shortages of certain rangeland products, particularly firewood.

SCIENTIFIC LITERATURE DEBATES ON RANGELAND MANAGEMENT OPTIONS

This section reviews current rangeland management practice in the Kalahari and describes possible management options to reduce or adapt to land degradation identified in the scientific literature.

Traditional ‘opportunistic’ management systems are still practiced in many communal rangeland systems in Botswana, although they face decline in the changing social, economic and political context of contemporary Botswana (Sporton and Thomas, 2002). These approaches tend to conserve ecological productivity and biodiversity through the maintenance of a diverse economic base, the close control of grazing activities (such as by destocking in times of drought), a diversity of animal species and breeds and the movement of animals across a region in response to fodder availability (Behnke *et al*., 1993; Scoones, 1995).

In the past, it was common for livestock managers to burn rangeland to maintain grass dominance and to secure a supply of rangeland fruit, vegetables and hunting (Powell, 1994). However, this practice was banned in Botswana in the 1980s (Perkins, 1996). Lower fuel loads in heavily grazed and/or bush encroached land (due to reduced grass cover) have led to less frequent and less intense fires throughout most livestock-dominated rangelands, a factor that is viewed as a major cause of bush encroachment (Dougill *et al*., 1999).

Traditionally, livestock herds consisted of mixed species, including both browsers and grazers. This prevented the ecological changes that have resulted from selective grazing by cattle-dominated herds (such as a shift towards less palatable annual grasses and bush encroachment). Bayer and Waters-Bayer (1995) argue that mixed herds can be rebuilt faster after drought, as the feeding habits and physiology of goats make them more drought tolerant than sheep or cattle, and smallstock populations recover more quickly than cattle after drought. The last decade has seen an exponential increase in smallstock populations in Botswana (Figure 2).

Seasonal livestock movement has been a key component of livestock management in the Kalahari for many decades. During drought, cattle were often taken to less affected, higher value grazing areas, sometimes over a 100 kilometres away. Cattle were left with relatives in the short-term, or looked after for longer periods by clients in exchange for the use of livestock products (milk, dung, draught power and sometimes some of the calves). By distributing livestock among a number of people in different places, pastoralists have been able to reduce the risks of livestock mortality during drought. This livestock loan system, called **mafisa**, is unique in southern Africa (Hitchcock, 2002). Although the system is still widely used (an estimated 11·2 per cent of households in 2002 were

DOI: 10.1002/ldr

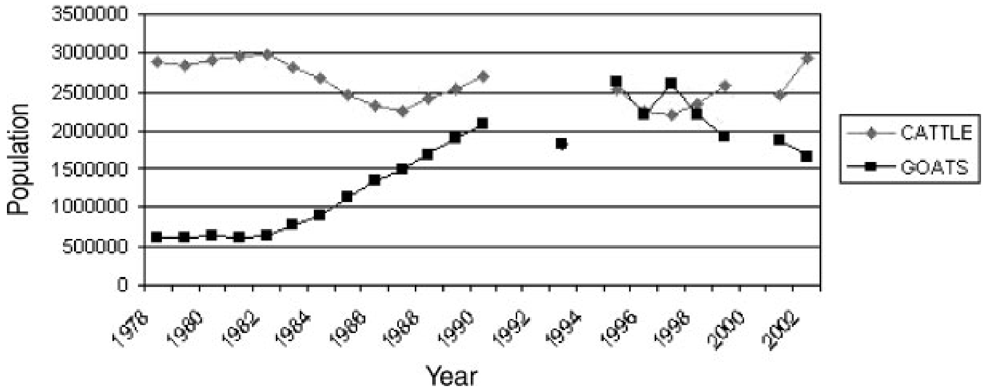

Figure 2. Cattle and goat populations in Botswana 1978–2003 (Ministry of Agriculture statistics).

recipients of mafisa cattle according to the Botswana Institute for Development Policy Analysis (BIDPA), 2002), there are an increasing number of barriers to its effective use. For example, the increasing numbers of absentee livestock owners are less in touch with environmental change and hired managers have less incentive to look after the herd (Perkins, 1996). In addition, privatisation of previously common grazing areas may prevent pastoralists from using traditional grazing reserves during drought (Twyman *et al*., 2001; Taylor, in press).

In addition to destocking and movement, there are a range of other techniques that can help livestock better match changes in fodder availability. For example, animal fodder intake can be reduced during drought by switching to cattle breeds with lower metabolic rates or increasing the number of dry versus lactating females, and adult versus young animals (Bayer and Waters-Bayer, 1995). Pastoralists can start keeping a lower proportion of breeding stock, as non-breeding stock can be more quickly disposed of at the onset of drought (Rothauge, 1998). Local fodder availability can also be increased by buying in feeds, growing drought-resistant fodder crops such as saltbush (*Atriplex* sp.), fencing fodder banks or by making tree foliage and pods available to animals (Bayer and Waters-Bayer, 1995; Rothauge, 1998). Grass can be cut and transported from places where there is little grazing pressure such as Wildlife Management Areas (van Rooyen, 1998; Twyman *et al*., 2001). Having said this, Horn *et al*. (2002) argue that supplementary feeding should be avoided if this delays destocking, as grazing-induced land degradation is more likely, the longer high stocking rates persist into drought conditions.

The ecological benefits of opportunistic strategies during drought appear to be relatively clear-cut. Weber *et al*. (2000) modelled the effect of fixed and opportunistic strategies at various stocking densities on Kalahari vegetation. They found that fixed stocking strategies at all stocking densities were more likely to induce bush encroachment than opportunistic strategies. Fynn and O'Connor (2000: 494) examined the effect of different stocking strategies during drought on vegetation composition and livestock condition, and noted detrimental effects on vegetation and livestock under higher stocking rates, concluding that, 'opportunistic management is a prerequisite for sustained utilisation of semi-arid African savanna'.

However, opportunistic strategies are not currently promoted by extension services in Botswana, who recommend fixed carrying capacities based on equilibrium-based ecological theory (e.g. Field, 1978; Hendzel, 1981). Opportunistic strategies are unlikely to achieve widespread recognition in Government agencies unless it can be demonstrated that they are more productive than fixed stocking strategies. Illius *et al*. (1998) found that opportunistic strategies reduced mortality losses but did not increase average annual sales compared with fixed stocking strategies. They suggested that this was because droughts lasting 2 or more years leave pastoralists with insufficient resources to restock effectively. They concluded that 'for subsistence pastoralists, the traditional policies of maintaining the maximum number of breeding stock, and of hoping that most of them will survive drought, may be as close as ''opportunistic'' management can get to dealing with drought' (p. 381). Campbell *et al*.'s (2000) economic model included price data collected from communal areas of semi-arid Zimbabwe. They

DOI: 10.1002/ldr

concluded that opportunistic strategies were less profitable (in terms of lower Net Present Value) than fixed, conservative stocking strategies. They suggested that one of the reasons for this was that previous analyses failed to account for economic losses due to drought-induced mortality and the costs of capital tied up in livestock and they pointed to the large amounts of public funds used to rebuild herds after drought in southern Africa as evidence for the cost of opportunistic strategies. As a consequence, they argued that government marketing systems designed to facilitate rapid destocking would amount to a heavy subsidisation of the livestock sector.

Market-based mass destocking would require co-operation and organisation on a scale not currently seen in Botswana (Dougill, 2002). The Botswana Meat Commission would have to play a significant role if this capability was to be developed. It is the largest buyer of livestock in the country, holding a monopoly over meat export. To meet the demands of the export market, the amount of livestock it buys changes little from month to month, even during drought events. Prices are fixed and paid by weight. Although this prevents the kinds of price crashes seen elsewhere in the region during drought, it does not facilitate rapid or large-scale destocking. Instead, the Botswana Government subsidises supplementary feed and provides drought relief for the poorest members of society through paid work and rations.

Behnke and Kerven (1994) propose a top-down solution to this problem. Governments could assist subsistence livestock owners by buying their cattle during droughts when fodder is scarce, and help households restock when rains return and fodder becomes more abundant. Neither Illius *et al*. (1998) nor Campbell *et al*. (2000) considered livestock movements, focussing instead on market-based destocking strategies. In contrast, Morton and Barton (2002) argue that a combination of partial destocking and livestock movement may be more appropriate. They suggest reserving externally assisted destocking through the sale of animals for more extreme, geographically widespread droughts. But they suggest that destocking should only be partial, with revenues from the sale of livestock facilitating the purchase of grain, veterinary drugs and diesel for boreholes to maintain remnant herds through drought. During less extreme, more localised droughts, livestock movement should be sufficient to maintain herds.

It is clear from the above discussion that there are no clear-cut solutions to livestock and rangeland management under the extremes of rainfall variability that semi-arid regions experience. Although there is a well-developed scientific literature on this subject, much of it focuses on large-scale private and commercial production and offers little guidance for communal systems. In order to develop options for pastoralists to prevent, reduce or adapt to rangeland degradation in communal systems, the rest of this paper compares and (where possible) integrates knowledge from scientific literature with local knowledge. To uncover this local knowledge, a range of participatory methods were employed, and these are described in the next section.

PARTICIPATORY METHODS

There is a growing recognition that participatory, stakeholder-led approaches have an important role to play in facilitating learning to identify more sustainable land management practices (Bell and Morse, 2005). Following a social learning approach (Pahl-Wostl and Hare, 2004), the methodological process employed in this research was designed to be an ongoing process of learning and negotiation.

We based this process primarily on experiential learning (Kolb, 1984). Experiential learning theory suggests that it is necessary to reflect on and learn from past experiences to ensure that planning captures the complexity of a multi-stakeholder world. Kolb (1984) proposes that learning takes place in four generic phases: concrete experience, reflective observation, abstract conceptualisation and active experimentation. Our four-stage methodological framework draws on each of Kolb's (1984) learning phases.

Building on this, the process was designed to bring different stakeholders together with researchers and policy people to take part in a wider social learning process. Social learning views learning as a process that is based on social interaction around areas of mutual concern. It is accompanied by individual and group reflection on what is being learned as well as iterative attempts to apply what is being learned to the issues under discussion (Bandura, 1977; Pahl-Wostl and Hare, 2004). Within the context of environmental management, social learning has

DOI: 10.1002/ldr

increasingly gained recognition as a participatory, adaptive approach to managing environmental problems (Chambers *et al*., 1989; Leeuwis and Pyburn, 2002; Pahl-Wostl and Hare, 2004).

Social learning can be viewed as an emergent property of social interactions within a social context (Cole and Engestrom, 1993). It can also lead to the transformation of relationships within that social context: developing new relationships; building upon existing collaborations and transforming adversarial relationships (Schusler and Decker, 2003). Such changes occur as individuals within a group learn about the character and trustworthiness of other group members through their interactions with each other, and learn to appreciate the legitimacy of each others' views (Forester, 1999). This can have significant implications for group dynamics, enabling diverse groups of potentially conflicting stakeholders to see new ways of working together. This does not preclude conflict, but when conflict is appropriately bounded (e.g. agreeing on rules for engagement and building bridges across socially constructed boundaries between interest groups) it can stimulate learning (Keen and Mahanty, 2006).

Building on these theoretical foundations, the following research phases were conducted:

1. Identify current practice and possible management options from the literature through a combination of semi-structured interviews with rangeland stakeholders and literature review (concrete experience);
2. Identify local knowledge of strategies to reduce or adapt to land degradation (reflective observation);
3. Evaluate options from interviews and literature in multi-stakeholder focus groups (abstract conceptualisation) and
4. Use outputs from these focus groups to produce rangeland assessment and management guides for each region, that provide stakeholders with a series of management options they can experiment with (active experimentation).

This approach was trialled in Study Area 1, and a number of minor methodological refinements were made to streamline the process in Study Areas 2 and 3. Rangeland stakeholders were identified through discussions with key informants (Study Area 1) and focus groups (three each in Study Areas 2 and 3). Potentially marginalised groups (e.g. women and 'destitutes') were identified explicitly during these discussions. Following a snowball sampling approach (Bryman, 2001), a combination of respondents and key informants identified successive respondents for interviews. This facilitated the selection of some individuals who were perceived as innovators by the rest of the community. Stakeholders were also grouped according to wealth in Study Areas 2 and 3 to ensure that respondents represented a sufficiently wide range of wealth categories (c.f. Rennie and Singh, 1996).

Potential management adaptations to land degradation were explored through semi-structured interviews with 67, 40 and 53 livestock owners in Study Areas 1, 2 and 3 respectively. The resulting strategies were then discussed and evaluated by local communities in village level focus groups (three in different villages in each study area—note that these were not the same focus groups as those used to identify stakeholders). In addition to strategies suggested in interviews, strategies from the literature were also discussed. Although many strategies were rejected during these focus groups, some new strategies were proposed and many were further developed or combined to produce more effective and/or viable strategies.

Pains were taken to ensure that the adaptations elicited were for coping with land degradation rather than drought, given that definitions of land degradation agree that it is a long-term, effectively permanent process, as distinct from the short-term, reversible nature of drought (UNCCD, 1994). Some kinds of environmental change may be reversible in theory, but are 'effectively' permanent due to socio-economic constraints (e.g. bush encroachment). *In combination with human activities*, drought can lead to land degradation. But as a rapidly reversible, natural event, drought cannot itself be classified as degradation. Having said this, a limited amount of work was conducted to try and better understand drought-coping strategies as distinct from land degradation adaptations. This was done through semi-structured interviews with 49 of the land users in Study Area 1. Three oral histories were also taken at this site to assess historical changes in rangeland condition.

Given the lack of detailed maps available for the study areas, it was difficult to effectively discuss spatial aspects of proposed management strategies. For this reason, participatory mapping exercises (c.f. Booltink *et al*., 2001) of ecological assemblages and resource use patterns were conducted with each community. Maps were drawn by community groups in the sand before being transcribed to paper and amended during rangeland drives with land users. Using a combination of aerial photography, remote sensing, existing maps and Global Positioning System

DOI: 10.1002/ldr

readings, each study area was mapped (c.f. Suyanto *et al*., 2004). Preliminary maps were further checked and amended by land users before being finalised.

RESULTS: MANAGEMENT ALTERNATIVES FROM STAKEHOLDERS

'It is not possible to be a cattle farmer in a place like this: you have to be a grass farmer'.
Male farmer, age 74, Hereford Farm.

Participatory research was conducted with pastoralists to evaluate management options from the literature and identify local knowledge of alternative strategies that have the capacity to prevent, reduce, reverse or help people adapt to land degradation in communal rangelands. Table I shows some examples of the breadth of innovation that was elicited from Kalahari pastoralists in response to rangeland degradation.

Many of the suggested strategies were species-specific. For example, in Study Area 3 a number of new uses were suggested for the encroacher bush species *Rhigozum trichotomum*. This species has been cleared and used successfully to stabilise sand dunes in South Africa (van Rooyen, 1998) and the palatability of its flowers and pods is well known (van der Walt and le Riche, 1999). However, there are no reports in the literature of *R. trichotomum* being used in the innovative ways involving cutting, grinding for fodder and harvesting of flowers as suggested by stakeholders in this study. Other strategies were based on adapting or combining old traditions, for example the use of wild watermelons (*Citrullus lanatus*) and watered smallstock kraals to facilitate shifting grazing patterns that can rest different rangeland at different times of the year (Table I). Planting indigenous fodder species in fenced exclosures with corridors for livestock to reach boreholes was an adaptation of a Ministry of Agriculture pilot project in Study Area 3 that had planted mainly *Eucalyptus* trees (not indigenous to the area) (Table I).

Since maintaining high livestock numbers during drought can lead to land degradation in the Kalahari (Dougill *et al*., 1999), a key preventative strategy that was suggested by pastoralists was to move livestock at the onset of drought. Although destocking is widely recommended in the rangeland management literature (e.g. Behnke *et al.*, 1993; Scoones, 1995), most literature focuses on the sale of livestock, rather than movement. Effective movement relies on good social networks. Interviews with pastoralists in Study Area 1 suggested that herds belonging to those with small, weak and/or geographically restricted social networks may be more likely to suffer from high levels of livestock mortality during drought. Figure 3 shows the different drought coping strategies that respondents used in Study Area 1, suggesting that strategies based on movement were least likely to result in heavy livestock mortality. Most pastoralists who moved their livestock, did so to family members within a 100 km radius. Those pastoralists who did not move livestock stated that they did not know anyone in less affected areas who could care for their livestock, that is their social network was insufficiently, strong or geographically extensive. Although it is argued that open access to communal rangeland is necessary for the mafisa system to work (Behnke *et al*., 1993), only 12 per cent of respondents set up cattle-posts in open-access rangeland (the 'grazing reserve' that is beyond the reach of livestock). The majority used common property rangeland managed by family members (Figure 3). Only three of the respondents interviewed had completely destocked by selling animals before the onset of drought. These results are consistent with research elsewhere in southern Africa. For example, Scoones (1993), studying the effects of a drought in Zimbabwe, found that 40 per cent of cattle survived if they were moved during early onset of drought, compared to 23 per cent survival for those who moved later and 3·3 per cent survival for those who remained where they were. Similarly, Twyman *et al*. (2001) emphasised the importance of strong family ties for successful livestock movement in the Namibian Kalahari.

The challenges of bush encroachment and possible solutions were often emphasised by respondents during interviews and focus groups. For example, one respondent described the rangeland condition when she arrived in south Kgalagadi District in 1951. Although there was insufficient water to rear many livestock, there were many grasses, most of which were highly palatable for livestock. There were many palatable *Grewia flava* bushes in the

DOI: 10.1002/ldr

Table I. Examples of management options to prevent rangeland degradation or rehabilitate degraded rangeland in Botswana, suggested by land users during semi-structured interviews and evaluated in community focus groups

Option	Methods
Soil management	• Avoid felling trees near boreholes (where vegetation cover is usually lowest) to reduce wind erosion • If no other trees are available, pollard trees near boreholes • Move kraals regularly so that they do not make soils toxic • Make piles of manure beyond the borehole vicinity (where soils are already enriched), allowing it to be dried and spread by wind. If browse is limited, smallstock manure may be used to promote browse species, but this should be avoided if managing for cattle • During bush clearance, leave strips of bush lined against prevailing wind to reduce erosion • During bush clearance, breaking up thorn bushes and laying them on the ground can: protect against wind erosion; allow recycling of nutrients from bush biomass and enable grass to re-establish under protection from thorny branches
Better use of *Rhigozum trichotomum*	• Cutting and grinding: Since young bushes (1–2 yr) make most nutritious fodder, old bushes must be cut first and left to re-sprout from their base. The waste can be used to stabilise and revegetate encroaching dunes. The following year, new material can be harvested and fed into a hammer mill to produce fodder • Harvesting flowers and pods: Many more flowers and pods are produced than can be consumed by livestock each year, but surplus flowers and pods can be harvested by hand. If there is a danger that all surplus flowers will be harvested, it is better to wait and collect the pods as these are more nutritious. The pods and flowers need to be dried and store in a dry and dark place for use during the dry season or drought *Note*: Because *R. trichotomum* only flowers and fruits after 3 yr, it is only possible to *either* grind whole bushes *or* harvest flowers and pods in any one area.
Borehole rotation	• Create a large syndicate with farmers from at least two other non-neighbouring boreholes. Rest the rangeland that is in worst condition first by moving all livestock to the other boreholes in the syndicate. This will reduce pressure, giving the rangeland a chance to recover. Then pile manure from kraals in rangeland around the resting borehole (see option 1). In the first year, supplementary feeding may be necessary to maintain the herd around fewer boreholes (the more boreholes in the syndicate, the less feed will be needed). If rangeland around all boreholes in the syndicate is very poor, supplementary feeding may be necessary until rangeland around each borehole in the syndicate has been rested. In future years, it should be sustainable to maintain the herd around fewer boreholes. It is not possible to use this approach in rangeland where boreholes are spaced closely, or if water yields are low or salty. If drought persists, it may still be necessary to destock
Shifting grazing	• In the dry season, set up cattle posts for smallstock in healthy rangeland away from the village and transport water there. If enough people do this, it may be possible to allocate farmers to valleys between parallel dunes along which herd boys or trained dogs can keep herds separate and prevent over-use of less healthy rangeland. This strategy is less labour-intensive than the traditional methods of herding livestock in different directions every day, which is not considered possible with current labour availability • Identify areas where *Citrullus lanatus (Tsama melons)* grow and herd cattle to these areas in the relevant season (usually March–June). Cattle can survive for 4–5 months without water in these areas

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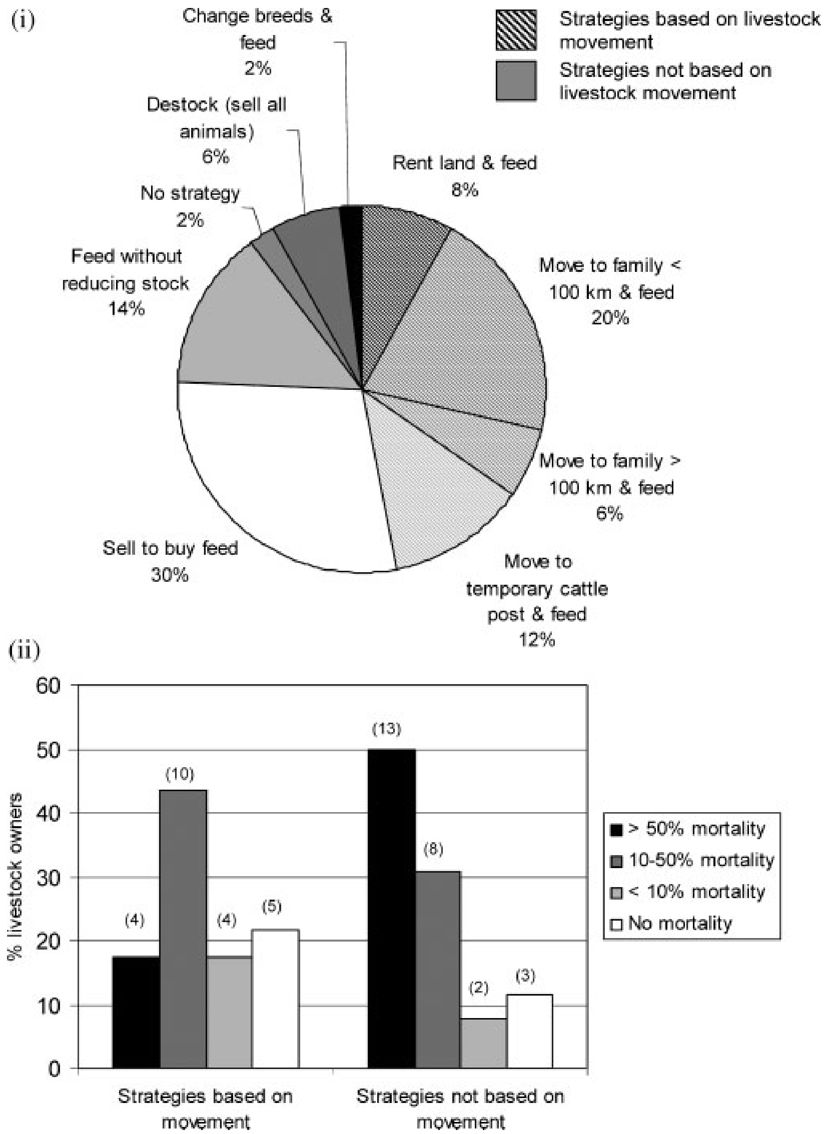

Figure 3. (i) Proportion of livestock owners using different drought coping strategies in South Kgalagadi District, Botswana, showing strategies based on livestock movement (hatched) or not (solid) (n = 49). (ii) Percentage of livestock owners (numbers in brackets) reporting different levels of mortality during droughts in the 1980s and 1990s, divided into those who used strategies based on movement (left) or not (right) (n = 49).

rangeland at this time. However, abundance of *G. flava* steadily declined as *A. mellifera* thorn-bushes became more widespread. She first started noticing an increased abundance of *A. mellifera* in the 1970s around the village boreholes, and watched the bush encroached area steadily expand:

> 'First they were just on the other side of the road. Then they came this side and went beyond this house. Now you can walk for 10 km, and see nothing but thorn bushes. The cattle can not even get through them—they have to use the tracks like you or me'.
>
> Female farmer, age 70, Makopong.

DOI: 10.1002/ldr

The low biodiversity of bush encroached systems and their low fodder value for cattle has raised concerns from pastoralists, policy-makers and researchers alike (Sporton and Thomas, 2002). There is a real concern that a positive feedback cycle exists whereby privatisation leads to more boreholes, which leads to bush encroachment, leading to a loss of productive rangeland for cattle, motivating landowners to drill additional boreholes in remaining grass dominant areas that then become bush encroached (Perkins and Thomas, 1993). This is especially of particular concern given that a dryland region's ability to support livestock depends on maintaining diverse and heterogeneous fodder resources (Scoones, 1995).

In areas where woody plants have already gained dominance, two broad management strategies were suggested by stakeholders: control and adaptation.

Cutting is a cheap and fast method of bush control, but rarely effective, as most bushes re-sprout vigorously (Tainton, 1999; Smit *et al*., 1999). However, respondents suggested three methods to make this strategy more effective:

a. Follow-up above-ground stem-cutting with intense smallstock browsing;
b. Paint above-ground cut stems with herbicide. Although local alternatives such as diesel, turpentine-based paint or paraffin are cheaper than commercial herbicides, most respondents considered this option still to be too expensive and without the guaranteed results of herbicide. Despite claims from a number of stakeholders that these substitutes are effective, there is no evidence to support their claims and some focus group participants remained sceptical and
c. Hollow out the ground around the base of the bush and cut stems 10–60 cm beneath the ground, and re-fill earth over the cut stem. Respondents noted that for best results, this should be done in the wet season.

Below-ground stem-cutting is an innovative technique that has not been discussed in the rangeland management literature. Pioneered by a range ecologist from the Ministry of Agriculture, plots have been established to test the technique. This technique is labour-intensive, but the results are visually impressive (Figure 4). It should be noted that the high vegetation cover in Figure 4 is due to stock exclusion. Without fencing, and the implications of this and other bush eradication strategies for soil erosion would need to be considered carefully—something that was addressed explicitly by respondents who suggested a number of rehabilitation strategies that could be coupled with bush eradication (see below).

Uprooting was suggested as an alternative to cutting bushes. Although uprooting can be difficult and time-consuming without machinery, respondents suggested that it may be possible to pay herd boys a bonus for every bush they uproot or to work with members of a syndicate or village. There is little information about non-mechanical uprooting operations in the literature. However, Smit *et al*. (1999) suggested that soil disturbance from mechanical uprooting operations may severely affect the grass layer, and its re-establishment may favour less palatable annual species in the first instance. They thought it may also favour mass germination of encroacher species such as *Dichrostachys cinerea*. Using data from mechanical uprooting experiments conducted by Botswana's Ministry of Agriculture in the 1970s, Burgess (2003) showed that cleared and partially cleared land had consistently higher dry matter yield than uncleared areas, in addition to increased cover and yield of palatable grasses.

i) ii)

Figure 4. (i) Ministry of Agriculture exclosure between Makopong and Werda where bush have been cleared using below-ground cutting, showing control plot (left), cleared (centre) and partially cleared (right) and (ii) individual stem burning of bushes on Hereford Farm, near Bray, Kgalagadi District, Botswana.

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In contrast to rangeland management literature suggesting that prescribed fires are cheaper than chemical or mechanical bush control (Trollope, 1992; Buss and Nuppenau, 2003), respondents downplayed the importance of prescribed fire as a control option. They pointed out that in heavily encroached sites (e.g. Study Area 1), there was an insufficient fuel load from grass to maintain fires at sufficient intensity to kill bushes. Managing prescribed fires also requires extensive skills and experience that are not available to all farmers.

Stem-burning of individual bushes may be labour-intensive but was suggested by respondents as a cheap and effective alternative to prescribed fires in heavily encroached systems. Following this approach, low intensity fires are set to smoulder under selected bushes. Although this strategy was suggested by Smit *et al*. (1999), they did not recommend it due to the significant labour resources that are required. They also suggested that it could only be used on the largest thorn bushes as it may be difficult to access the stems of young bushes. However, respondents in this study suggested that it can be used on a range of bush age classes and that sufficient labour is available to use this method in communal systems. Respondents suggested that to be most effective, stem-burning should be carried out during the wet season when bushes are in leaf. They explained that dry season stem-burning results in top-kill but bushes usually re-sprout. Wood, dry dung or a combination of the two can be used to light the fire. It may be necessary to do this more than once for some bushes, but it was suggested that two burns would kill most bushes.

There is evidence from the literature that repeated browsing by goats can effectively prevent the establishment of bush seedlings and bush re-growth after fire or cutting (Kelly and Walker, 1976) and prevent further spreading of bush cover (Tainton, 1999; Scogings, 2003). Goats have also been used to reduce bush cover in conjunction with prescribed burning in South Africa and Namibia (e.g. Trollope, 1974; Zimmermann *et al*., 2003). Similarly, Trollope and Dondofema (2003) compared a combination of continuous goat browsing and rotational grazing during winter after annual burning between 1973 and 2001 with (i) grazing only and (ii) burning only. They found that the combination of browsing and grazing after burning resulted in the lowest density of bushes with the lowest biomass and the highest cover of palatable grasses. However, during focus group discussions, respondents in this research noted that it would be difficult to achieve sufficient browsing intensity without fences or careful shepherding (for which there was insufficient skilled labour).

Some commercial ranchers were using commercial herbicides to control bushes on their land. They warned that the use of herbicides requires caution due to the potential negative environmental and human health effects if they get into groundwater or the food chain. However, one respondent noted that urea-based herbicides are capable of enhancing soil fertility in the long-term as they breakdown (supported by Ghosh *et al*., 2002). It was suggested that herbicides (such as those with the active ingredients Tebuthiuron, Ethidimuron or Bromacil) which can be applied to the soil (rather than to the plant itself) were usually the least capital and labour-intensive method, and could suppress bush seedling growth for up to 4 or 5 yr. However, Smit *et al*. (1999) point out that this sort of herbicide does not work for all bush species. Both mechanical and chemical control methods are expensive (Burgess, 2003) and rarely provide a return on investment within an adequate timeframe for most farmers (Buss and Nuppenau, 2003), and may give negative returns on investment (Quan *et al*., 1994). They also require considerable expertise and equipment. For this reason, Trollope (1989) suggested only resorting to these methods when: (i) there is insufficient fuel for a prescribed burn or (ii) the majority of bushes have grown above the browse line or bushes are too dense for animals to penetrate or are unpalatable.

For all bush control techniques, two strategies were suggested that could aid rangeland rehabilitation after bush clearance. First, respondents suggested that any sort of bush removal should leave wind-breaks arranged against the prevailing wind to reduce wind erosion. Second, in order for cleared rangeland to recover, it must be rested. This can be problematic in unfenced communal rangeland, however, two options were suggested by respondents:

a. It may be possible to rest the land sufficiently by breaking up bushes that have been cut or uprooted and laying them on the ground. This serves a number of functions: (1) it further protects the soil from wind erosion; (2) it allows nutrients from the bushes to be returned to the soil and (3) the thorny branches protect young grasses from grazers until they are tall enough to reach above the height of the bush branches—by the time they have decomposed enough to allow free grazing, the grass should be well established;

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b. Alternatively, respondents suggested using whole uprooted bushes as fencing to keep livestock out of resting areas. However, respondents pointed out that it may be difficult to prevent other rangeland users opening the fence to allow their livestock to graze in the protected area.

Given the widespread use of fencing to protect and rest cleared rangeland elsewhere in southern Africa, strategies to facilitate protection and rest in communal land are of particular interest. The need to leave remnant bushes echoes assertions from non-equilibrium range ecologists that fodder diversity and landscape heterogeneity are essential to maintain the resilience of rangeland systems (e.g. Behnke *et al*., 1993). The use of thorn bush branches to cover the soil is another example of an innovative approach to protect recovering rangeland from livestock in the absence of fencing. This was trialled in communal farms in the Northern Cape Province of South Africa to stabilise sand dunes, yielding promising results (van Rooyen, 1998).

In addition to the wide range of bush control strategies discussed above, a number of adaptation options were suggested by land managers for bush encroached systems. Such suggestions were aimed at maintaining livelihoods in degraded land, while preventing further degradation where possible. For example, it may be possible to shift from cattle to smallstock production, particularly goats, in order to utilise bushes as a browse resource. Bushes invade around boreholes first and gradually spread out into the surrounding rangeland (Perkins and Thomas, 1993). Pastoralists in heavily encroached sites were, therefore, making smallstock **kraals** further from the borehole, near the edge of the bushy zone where bushes were younger, more dense and more easily within reach for smallstock.

Game farming/conservation was also suggested as an alternative adaptation to bush encroachment. The primary reason given for this was: their greater resistance to drought than livestock; the ability to stock browsers to feed off encroaching bush species and the extra revenue option they could offer. For these reasons, it has been seen by some Botswana Government sources (DHV, 1980 in Perkins *et al*., 2002) as one of the best way to enhance the livelihoods of the poorest people in the Kalahari. There are examples of nature conservancies and game ranches managed by community groups (under CBNRM programmes) that have been highly profitable elsewhere in the Kalahari (Van Rooyen, 1998; Jones, 2003; Taylor, 2003). However, there have also been many instances where such programmes delivered conservation benefits but failed to deliver the socio-economic gains that the promised to local communities (Twyman *et al*., 2001; Taylor, 2003). In particular, such schemes may not be economically viable in remote areas with poor infrastructure that are rarely visited by tourists (Jones, 2003). Consequently, such programmes are not widespread in Botswana (Taylor, 2003).

As an alternative adaptive strategy, charcoal production was suggested by some respondents. Encroacher species such as *C. mopane* and *A. mellifera* have been shown to be appropriate for charcoal production in Namibia (Cunningham, 1998). However, Quan *et al*. (1994) warn that income generation from charcoal production may be constrained by lack of markets. Although the sand soils of the Kalahari are not well suited to traditional charcoal production techniques used elsewhere in Africa (which involve covering charcoal pits with earth and providing air holes), it is possible to make an effective kiln easily from an old oil drum or some other such container (Tabor, 1994).

The above bush control and adaptation options were discussed and ranked by local pastoralists and extension workers in two focus groups in Study Area 1, which had the greatest problems with bush encroachment (Tables II and III). Both pastoralists and extension workers ranked stem-burning and below-ground stem-cutting as the most appropriate control techniques. Their reasons were similar: both were considered to be cheap and effective. Although capital was limited for bush control, few considered labour to be a limiting factor. Extension workers viewed shifting towards smallstock production as the best adaptation option, although most pastoralists said their primary reason for increasing their smallstock herds was the availability of grants for this purpose through the Government's Financial Assistance Plan. Nevertheless, the rapid expansion of local smallstock herds would have been difficult to support without extensive bush cover. Similarly, water was transported to the edge of the bush encroached zone for a number of reasons, and the increased availability of browse in this area was not always the primary motive.

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Table II. Bush control, adaptation and prevention strategies ranked and evaluated by communal pastoralists in Study Area 1

Rank	Strategy	Comments
Bush control		
1	Individual stem burning using piled firewood	Labour intensive but not capital intensive; it has worked effectively elsewhere; there may not always be sufficient firewood
2	Cut main stem 10–60 cm below ground (use branches as mulch)	Labour intensive but not capital intensive; do not need firewood
3	Commercial herbicide	Fast and effective; expensive; concerns over goat poisoning; better suited to fenced ranches
4	Ring-bark	Only easy for large bushes due to low growth habit and thorns
5	Prescribed burning	Insufficient fuel to set fire
6	Uproot whole bushes (use branches as mulch)	Takes too long without machinery, but could be done by herd boys or as a community
7	Cut and paint stem with diesel or turpentine paint (use branches as mulch)	Although cheaper than commercial herbicides, most consider this option to be too expensive and without the guaranteed results of herbicide
Bush prevention		
1	Water reticulation	Land board take a long time to grant permission; expensive to put in infrastructure but cheapest option in the long-term; little time and effort required to install
2	Purchase supplementary feeds	Too expensive without drought subsidies
Bush adaptation		
1	Change breeds	Drought tolerant bulls can be expensive, and it is difficult to selectively breed in communal land
2-	Diversify into non-livestock livelihood activities	There are few activities that can replace the kind of income generated by cattle
2-	Grind bushes into cattle feed	The necessary machinery is expensive
3	Transport water to edge of bush encroached zone	Done to separate herds from each other and prevent road-kills, in addition to a response to bush encroachment; very expensive by truck, but more profitable by donkey cart
4	Increase smallstock production, particularly goats	Although they browse the bush, primary reason for increase is funding from Financial Assistance Plan rather than an alternative to cattle production

DISCUSSION: PROMOTING FARMER INNOVATION TO TACKLE LAND DEGRADATION

This research combined local and scientific knowledge through a social learning process where management options were identified through literature review and interviews with local pastoralists and then evaluated in focus groups with communities and agricultural extension workers. This process identified numerous relevant and often innovative strategies that could be used by local communities to reduce or adapt to land degradation in common property rangeland systems. An innovation does not need to be universally new—ideas that an individual has not formerly encountered may also be considered ‘innovations’ (Rogers, 1995). Each of the innovations described here were based on local knowledge, but combined different ideas from individuals and/or literature in ways that were new to the local and scientific community.

Despite the variety of rangeland management options available in the literature, few are suitable for use by pastoralists in the Kalahari. Many are not compatible with communal land tenure, for example requiring stock exclusion which is not possible without fencing. Similarly, many are too expensive or labour-intensive for most

DOI: 10.1002/ldr

Table III. Bush control, adaptation and prevention strategies ranked and evaluated by Government of Botswana Range Ecologists and Extension Workers in Study Area 1

Rank	Strategy	Comments
Bush control		
1	Cut main stem 10–60 cm below ground	Cut deeper for larger bushes
2-	Individual stem burning using piled firewood/manure	No additional comments
2-	Uproot whole bushes (use branches as mulch)	Difficult for large bushes
3	Commercial herbicide	Need to investigate the environmental impacts of different brands
4	Prescribed burning	Fuel-load usually insufficient in bush encroached areas, fire breaks are costly to install
5	Cut and paint stem with diesel or turpentine paint (use branches as mulch) or drill holes around bush and pour in diesel or paraffin	May be polluting—do not recommend
Bush prevention		
1	Improve rangeland management	No additional comments
2	Increase proportion of smallstock (particularly goats) in herd	No additional comments
Bush adaptation		
1	Increase smallstock production (particularly goats)	No additional comments
2-	Transport water to edge of bush encroached zone	No additional comments
2-	Change breeds	No additional comments
2-	Diversify into non-livestock livelihood activities	No additional comments
3	Grind bushes into cattle feed	No additional comments

pastoralists to use (e.g. mechanical and chemical methods of bush removal), and raise issues over who pays in communal systems. Nevertheless, by evaluating options from the literature with local stakeholders, and identifying innovative alternatives from communities, it has been possible to identify a number of relevant options.

It should be noted that many of the strategies that were suggested could only be applied effectively under common property regimes. This was particularly true for a number of traditional approaches that respondents suggested could be adapted to contemporary contexts, for example shifting grazing (Table I). Institutional support and reform will, therefore, be necessary to successfully apply the strategies identified to reduce or adapt to land degradation in the Kalahari. In Botswana, the 2002 National Agricultural Master Plan for Agriculture and Dairy Development aims to allocate larger agricultural holdings and improve agricultural infrastructure to benefit from economies of scale. However, contrary to these aims, this research suggests that socio-organisational and institutional constraints may be more significant than technological constraints on the sustainability of livestock production in the Kalahari. Indeed, Waters-Bayer *et al*. (2003) suggest that socio-organisational and institutional innovation is often more important than technological innovation in pastoral systems.

By replacing traditional common property institutions with government agencies in the 1970s, the Government of Botswana encouraged a shift towards a more open access rangeland system (Rohde *et al*., 2006). Agricultural development policies since this time (e.g. the 1975 Tribal Grazing Lands Policy and the 1991 New Agricultural Development Policy) attempted to solve the problems that this has generated through a shift to private property ownership. Opponents have attacked these policies on two theoretical grounds (e.g. White, 1993; Thomas *et al*., 2000; Rohde *et al*., 2006). First, privatisation is not ecologically or culturally compatible with Kalahari rangelands. There is no history of private rangeland ownership among Kalahari pastoralists and the carrying capacity concept on which ranch sizes are based is inapplicable under such variable rainfall. Second, the benefits of privatisation are concentrated in the hands of a few, while poor rural households lose access to land and the resources on it that had functioned as a safety net from poverty and the impacts of drought and land degradation (Cullis and Watson, 2004).

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Alternatively, more formalised systems of common property natural resource management are more likely to foster innovative solutions to environmental problems and promote sustainable use (Ostrom *et al.*, 1999). In addition, securing formal common property rights by communities may be a means of preventing further alienation of commonly-held rangeland resources by wealthy individuals (Taylor, in press).

In an attempt to address this issue, the Global Environment Facility is funding a pilot project between UNEP, UNDP and the Government of Botswana to develop sustainable management systems based on indigenous knowledge for the 'Management of Indigenous Vegetation for the Rehabilitation of Degraded Rangelands in the Arid Zone of Africa'. The project aims to empower local pastoral communities to monitor and manage their rangeland and to develop, adapt and apply traditional and innovative rangeland management systems. Although Botswana has been implementing a community-based natural resource management programme for wildlife since the early-1990s, the idea of developing formal community-based management systems for the full spectrum of rangeland resources, including grazing and browsing, has not been established southern Africa (Taylor, 2003). As a pilot project based in the Government of Botswana's Ministry of Environment, Wildlife and Tourism, the potential exists that formalised common property management regimes will be extended beyond the pilot phase as an alternative to privatisation in Botswana's rangelands.

For this institutional experiment to work, it is vital to start re-building the local capacity for sustainable land management that has been lost over the last 30 yr of effectively open access regimes. Although local knowledge of common property management regimes still exists, it is held by a small number of older community members. Given the environmental, social and economic changes that have occurred over this period, many of these practices are no longer relevant. Despite the disempowerment of local institutions, traditional knowledge has not stagnated. There were numerous examples of local adaptations and innovations, many of which sprang from focus group discussions between stakeholders during this research. The research process was designed to stimulate this social learning process, bringing stakeholders and researchers together to share innovative ideas from other communities and the literature. For example, rotational grazing is an example of textbook grazing management that pastoralists in Study Area 2 adapted to develop borehole rotation as a management option that may reduce land degradation (Table I). Operational details were discussed jointly by focus group participants, who integrated soil management ideas from Study Area 1 (about distributing livestock manure from kraals around the rangeland) into the strategy. By stimulating learning between stakeholders from different communities and researchers, the four-stage approach reported in this paper delivered management strategies that no individual community or researcher would have developed in isolation.

Translating these management ideas into effective policy requires meaningful engagement with policy-makers. Since common property management regimes are a prerequisite for the successful implementation of many of the suggestions that arose from this research, this dialogue needs to start by challenging the assumptions behind current rangeland policy. Such dialogue is currently taking place through the active involvement of the Government of Botswana's Ministry of Agriculture in the Indigenous Vegetation Project's institutional support of communal rangeland management committees.

CONCLUSION

This paper describes a four-stage social learning process that has integrated scientific and local knowledge bases to develop new rangeland management options for Kalahari pastoralists. The findings of this research emphasise the value of local knowledge in responding appropriately to land degradation. They also emphasise the need to integrate this with the scientific knowledge of researchers, and to facilitate an open dialogue about environmental sustainability between local stakeholders, researchers and policy-makers. By combining the findings of participatory research with insights from scientific literature it was possible to produce more relevant results than either approach could have achieved alone. While this research emphasises the value of local knowledge, there remain important ways in which researchers can augment this. For example, research dissemination across broad spatial scales can facilitate knowledge sharing between communities and researchers in comparable social, economic and environmental contexts. This is particularly relevant where adaptations based on local knowledge are unable to keep pace with rapid rates of environmental change. By forming fruitful partnerships between

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communities, researchers and extentionists, it was possible to foster local innovation that could better guide attempts to enhance the capacity for communities to reduce degradation or adapt their livelihoods to land degradation threats. This is particularly pertinent in relation to Botswana's UNCCD National Action Plan (Government of Botswana, 2002: 4) that aims to 'facilitate capacity building initiatives for stakeholders involved in efforts to combat desertification . . . and control land and rangeland degradation'.

To achieve this goal, management options identified through this research are now being integrated with land degradation indicators in a manual-style decision support system for local pastoralists in each study area. They are designed to share the integrated knowledge of pastoralists and researchers in a flexible form that encourages active experimentation by users, rather than providing prescriptive solutions. Draft manuals have been peer-reviewed and revised versions are about to be trialled and optimised with users prior to publication. However, the future success of this work depends to a large extent on the ability of the Indigenous Vegetation Project (described above) to influence Government policy on land tenure, as many of the management options are only likely to be effective under common property tenure.

ACKNOWLEDGEMENTS

This research was conducted under Government of Botswana Permit OP46/1XCVI(87). Funding for this research was provided by the Global Environment Facility/United Nations Development Programme through the Indigenous Vegetation Project, Explorer's Club, Royal Scottish Geographical Society, Royal Society and University of Leeds. The Ministry of Agriculture in Botswana have provided invaluable co-operation and support for this research. Thanks to Evan Fraser and Lindsay Stringer for feedback on earlier drafts of this manuscript.

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