Participatory Rangeland Monitoring and Management in the Kalahari, Botswana

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Abstract

The multi-dimensional and dynamic nature of rangeland degradation makes accurate assessment a difficult challenge. Existing assessment methods rarely integrate different components of land degradation and local communities rarely participate, or derive results that can improve the sustainability of their land management. Sustainability indicators offer one solution to this problem. They can be used by a range of stakeholders to derive multi-disciplinary information that can be used to both monitor and respond to environmental change. However, it is increasingly claimed that existing sustainability indicators provide few benefits to local users who, as a consequence, rarely apply them. The thesis therefore starts by reviewing land degradation causes and theoretical models in semi-arid rangelands, and critically evaluates a range of degradation assessment methods in the semi-arid rangelands of Botswana. This shows that multi-source, multi-scale land degradation assessment can provide more accurate and reliable results than the use of any single technique alone. This information is used to identify potential land degradation "hotspots", and a learning process for sustainability assessment is developed and tested in three of these problem areas. The process is designed to facilitate two-way and meaningful interaction between local communities, researchers and policy-makers to monitor environmental sustainability and respond appropriately. Application of the process identified a range of innovative management options that could prevent, reduce, reverse or help rangeland stakeholders adapt to land degradation. Communities identified a wide range of sustainability indicators, the majority of which were validated through field-based research. Local knowledge was more holistic than many published indicator lists for monitoring rangelands, encompassing vegetation, soil, livestock, wild animal and socio-economic indicators. By building on local knowledge, the indicators and management options were familiar to land users who could apply them without specialist training or equipment. Indicators and management options were integrated in a manual-style Decision Support System designed to help land managers easily monitor progress and adapt management to reach sustainability goals. These findings emphasise the value of local knowledge in rangeland monitoring and management. However, they also emphasise the need to integrate this with the knowledge of researchers, and open dialogue about environmental sustainability between communities, researchers and policy-makers. By combining qualitative insights from participatory research with more top-down empirical research it has been possible to produce more accurate and relevant results than either approach could have achieved alone. However, the future success of this work depends to a large extent on institutional reform in Botswana, as many of the management options are only likely to be effective under common property land tenure.

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I find it hard to believe that a few sheets of paper are capable of holding four and a half years of discover and loss, joy and dread, friendship and loneliness, inspiration and frustration, wonder and doubt, beauty and discomfort, and faith. Two years before starting this project, I had vowed never to return to Africa. Recognising that she had more to teach me was one of the hardest decisions I have ever made, knowing as I did how hard Africa's lessons could be. I have never experienced as much anguish as I did in the weeks leading up to each fieldtrip, knowing I would be entirely cut off from Joy, my wife, for months. After the first trip I decided I couldn't do it again, and started looking for a new project. But all along I knew that the lessons I had to learn could not be found at home. Like all good teachers, despite the difficulty of her material, Africa provided daily inspiration. I will never forget lying alone in the centre of the enormous pan at Mopipi, the Mopane forest on the horizon a thin wavering circle, and the sky bigger and bluer than I have ever seen. Or the simple joy of identifying and tagging plant specimens in the sunset at the end of a day's work in the savanna, or among the quiet cabinets of Botswana's National Herbarium. This thesis is a chance for me to share a small fraction of what I learned in the Kalahari.

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PhD Publications

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Contents

Abbreviations

BMC Botswana Meat Commission

CBNRM Community-Based Natural Resource Management

CCA Canonical Correspondence Analysis

DCA Detrended Correspondence Analysis

DSS Decision Support System

FAO United Nations Food and Agriculture Organisation

GIS Geographical Information System

GLASOD Global Assessment of Human-Induced Soil Degradation

IVP Indigenous Vegetation Project

LADA Land Degradation Assessment in drylands (FAO project)

MCE Multi-Criteria Evaluation

NDVI Normalized Difference Vegetation Index

NGO Non-Governmental Organisation

NMDS Non-Metric Multidimensional Scaling

PCA Principle Components Analysis

SOC Soil Organic Carbon

SSM Soft Systems Methodology

TGLP Tribal Grazing Land Policy

UNCCD United Nations Convention to Combat Desertification

UNEP United Nations Environment Programme

UNDP United Nations Development Programme

"This alphabet of natural objects - soil, rivers, birds and beasts - spells out a story which he who runs may read if he knows how. Once you learn to read the land, I have no fear what you will do with it. And I know the many pleasant things it will do to you."

(Aldo Leopold, 1948: 129)

1

Introduction

1.1 Introduction

Land degradation is one of the world's most pressing environmental problems, and has been described as "an assault on sustainability" (Warren, 2002: 454). It is widely perceived as particularly acute in the semi-arid rangelands of sub-Saharan Africa (Stiles, 1995; UNEP, 1997; Eswaran *et al*., 2001) that support the livelihoods of over 25 million pastoralists (Lane, 1998). However, major uncertainties remain. Are Africa's semi-arid rangelands trapped in a spiral of irreversible and uncontrollably worsening degradation? Or will human-induced land degradation stimulate the innovation necessary to overcome resource scarcity and maintain sustainable livelihoods? Despite the magnitude of these questions, few people can even agree on the extent or severity of dryland degradation. Partly, this is because existing monitoring methods rarely integrate different components of the problem, focusing instead on single issues or research disciplines, which can lead to bias and prevent an appreciation of the multi-faceted nature of the problem (LADA, 2001, 2004; Warren, 2002). It is often difficult to detect trends in degradation status over time, due to the use of unreplicable or incomparable methods. In addition, assessments tend to be carried out by researchers for use by policy-makers and academics. Local communities rarely participate, or derive results that can improve the sustainability of their land management. For this reason, monitoring rarely contributes to local sustainability.

In order to address these problems it is necessary to have a clear understanding of what is meant by local sustainability, however it is rarely defined. Most definitions of sustainable development emphasise a relationship between human social and economic systems and the natural environment that perpetuates the health and integrity of both human and natural systems (e.g. UNCED, 1992; Norton, 1992; Wimberly, 1993). In terms of systems properties, Constanza (1992) suggests that sustainability "implies the system's ability to maintain its structure (organization) and function (vigour) over time in the face of external stress (resilience)". In the absence of an accepted definition for local sustainability, this thesis draws from the results of a discussion between practitioners (Church & Elster, 2002) to define it as: the development of a local community, economy and environment that is led by empowered community members in the context of national and global issues and priorities, whilst maintaining the resources necessary to safeguard quality of life for present and future generations.

There is now a growing recognition that credible environmental sustainability assessment must integrate biophysical and socio-economic data from a range of sources and scales (UNCCD, 1994; LADA, 2001, 2004; Warren, 2002). Sustainability indicators offer one way to do this.

1.2 Sustainability indicators

Sustainability indicators have the capacity to engage a wide range of stakeholders, from policy-makers to land managers, to provide interdisciplinary information about the nature of environmental change. Adaptive rangeland management depends on effective monitoring to detect change as early as possible. However, it is increasingly claimed that existing sustainability indicators provide few benefits to users who as a consequence rarely apply them (Carruthers & Tinning, 2003; Innes & Booher, 1999). Partly, this is because indicators are usually developed by experts and applied without engaging local communities (Riley, 2001). Sustainable development literature and the United Nations Convention to Combat Desertification (UNCCD) stress the need for local communities to participate in all stages of project planning and implementation, including the selection, collection and monitoring of indicators (WCED, 1987; UNCCD, 1994; Corbiere-Nicollier *et al.*, 2003). To do this, the methods used to collect, apply and interpret indicators must be easily used by non-specialists. To achieve widespread uptake, sustainability indicators must also be clearly linked to community needs, priorities and goals.

This is an enormous methodological challenge, but one that could bring many rewards. In the hands of local communities, sustainability indicators have the potential to go beyond simply measuring progress. They could enhance the overall understanding of environmental and social problems and empower communities to respond appropriately to environmental change without having to rely on external experts. If the monitoring process can open a dialogue about sustainability with neighbours and policy-makers, sustainability indicators may be able to help relocalise and enrich sustainable development policy decisions, and enhance the sustainability of local livelihoods.

This thesis is an attempt to address this challenge through the development of a methodological process for local communities, researchers and policy-makers who wish to monitor environmental sustainability and respond adaptively. Through case studies at three study areas in the Kalahari rangelands of Botswana, this research asks about the role of local knowledge in sustainability monitoring and the value of local adaptive responses to rangeland degradation. Is it possible to fuse the strengths of local and scientific knowledge together? Will this fusion help us discover more effective monitoring approaches and innovative solutions to old problems? Or will it result in a clash of cultures that further entrenches scientific paternalism and public scepticism?

1.3 Thesis aims and objectives

In an attempt to answer such questions, this thesis develops and tests a learning process that aims to: facilitate use by non-specialists at local scales to monitor environmental sustainability; support sustainable land use decisions; integrate multidisciplinary scientific and local knowledge; combine a range of qualitative and quantitative research methods; involve active participation by end-users at every stage; and that is scientifically robust.

More specifically, the objectives of this research are to:

1. Compare and critically evaluate results from different land degradation assessment methods in Botswana, discuss the potential to integrate participatory and biophysical techniques at different scales and identify potential land degradation "hotspots" for more detailed environmental sustainability assessment;
2. Develop a learning process for environmental sustainability assessment that facilitates meaningful interaction and two-way communication between different stakeholders in local communities, between researchers from different disciplinary and epistemological backgrounds, and between stakeholders and researchers; and
3. Apply and evaluate this process in three land degradation hotspots in Botswana:
    - Investigating the potential for local knowledge and innovation to develop management options that could prevent, reduce, reverse or help people adapt to rangeland degradation;
    - Identifying potential environmental sustainability indicators from local stakeholders, evaluating them with stakeholder groups and testing their validity through field-based research;
    - Combining sustainability indicators and adaptive management options in a Decision Support System that can enable local land managers to easily monitor progress towards sustainability goals; and
    - Critically evaluating the proposed learning process and suggesting future improvements.

1.4 Study Area

Botswana (Figure 1.1) is a well studied country that is popularly believed to be experiencing dryland degradation[1], or "desertification" (Nellis & Bussing, 1989; Darkoh, 1999; Masilo *et al*., 1999). Indeed, Botswana has been described as "one of the most desertified countries in sub-Saharan Africa" (Barrow, 1991: 191).

Policy-makers and communities are keen to respond to these perceived problems. However, there is evidence that the Government's current policy of communal rangeland privatisation is further worsening land degradation and deepening already stark social and economic inequalities (e.g. Perkins, 1996; Thomas *et al*., 2000; Adams *et al.*, 2002). Despite Botswana's move from one of the poorest countries in the world to a middle-income country (driven largely by the diamond industry), 47% of the population still live below the national income poverty line[2] (Adams *et al.*, 2002; CIA, 2004).

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[1] Land degradation is defined by UNEP (1997) as "a reduction in the resource potential of the land…" and by Abel & Blaikie (1989) as "an effectively permanent decline in the rate at which land yields agricultural products under a given management system".

[2] Botswana Institute for Development Policy Analysis (1996 in CIA, 2004), considered income and capability measures of poverty in Botswana through a comparative analysis of the Household Income and Expenditure Surveys conducted in 1984/5 and 1993/4 by the Ministry of Finance and Development Planning.

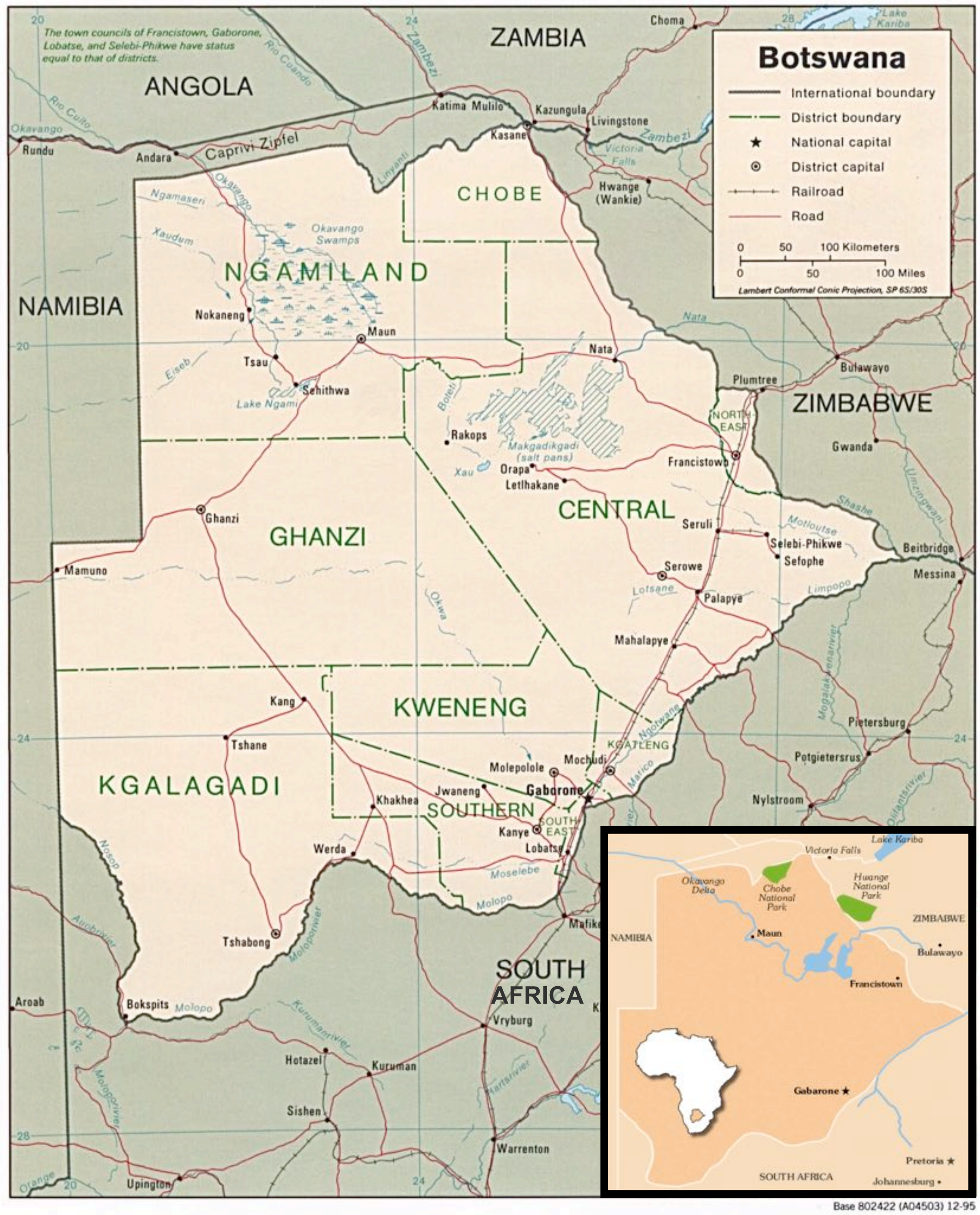

Figure 1.1 Map of Botswana showing location in Africa (inset) (IFC, 2005)

In an attempt to address some of these perceived concerns, the Global Environment Facility is funding 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" (abbreviated to Indigenous Vegetation Project or IVP). 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. Although Botswana has a community-based natural resource management (CBNRM) programme for wildlife, the idea of developing CBNRM for the full spectrum of rangeland resources, including livestock management, is a new concept in southern Africa (Taylor, 2003).

As a pilot project based in the Government of Botswana's Ministry of Agriculture, if successful, there are plans to extend common property management regimes more widely as an alternative to privatisation in Botswana's rangelands.

For this project to be successful there is an urgent need to document and build upon local knowledge of environmental monitoring and management. To this end, much of the research for this thesis was conducted in collaboration with the IVP, building on and contributing to the institutional capacity currently being developed with local communities in their study areas.

There have been a number of former attempts to assess environmental sustainability in Botswana. A range of indicator-based approaches have been employed, including remote sensing (e.g. Ringrose *et al*., 1996; Ringrose *et al*., 1999), soil hydrochemical analysis (e.g. Dougill *et al*., 1998; 1999); economic analyses (e.g. White, 1993); plant ecology (e.g. Perkins & Thomas, 1993; Thomas *et al*., 2002); participatory methods (e.g. Ringrose *et al*., 1996; Thomas *et al*., 2000) and expert opinion (Oldeman *et al*., 1990) (see chapter 2 for details). While many of these studies have provided valuable insights, results have often been conflicting, and have rarely been communicated to land managers. Each of these assessments was conducted by researchers for use by researchers and policy-makers, and has provided little guidance for land users to enhance the sustainability of land management. There is therefore a clear need to develop tools that can provide local communities with the capacity to monitor environmental sustainability and respond appropriately to land degradation without relying on the use of external experts or hi-tech equipment.

1.5 Thesis Overview

This thesis starts by reviewing land degradation causes and theoretical models in semi-arid rangelands, and critically evaluates a range of degradation assessment methods in the semi-arid rangelands of Botswana (chapter 2). This shows that multi-source, multi-scale land degradation assessment can provide more accurate and reliable results than the use of any single technique alone. This information is used to identify potential land degradation "hotspots" in Botswana. A learning process for sustainability assessment is developed in Chapter 3 through a review of literature on sustainability indicators. It proposes that there are four steps needed to use indicators as a tool for sustainability assessment at local scales (Figure 1.2). These four steps are applied and tested in the rest of the thesis. The process is designed to facilitate two-way and meaningful interaction between local communities, researchers and policy-makers to monitor environmental sustainability and respond appropriately. Chapter 4 describes the methods that were used to do this.

Following the four steps in Figure 1.2, chapter 5 identifies local stakeholders and the boundaries of the system that is to be assessed. In this chapter, a number of participatory research tools are used in a Sustainable Livelihoods Analysis to better understand the socio-economic, institutional and environmental context of each study area.

In chapter 6, local stakeholders identify sustainability goals and develop strategies that can help them reach these goals. This chapter identifies a wide range of innovative management options that could prevent, reduce, reverse or help rangeland stakeholders adapt to land degradation.

Then in chapter 7, sustainability indicators are identified, evaluated and selected through a combination of participatory and ecological research. Communities identified a range of sustainability indicators, the majority of which were validated through field-based research. Local knowledge was more holistic than many published indicator lists for monitoring rangelands, encompassing vegetation, soil, livestock, wild animal and socio-economic indicators. By building on local knowledge, the indicators and management options were familiar to land users who could apply them without specialist training or equipment.

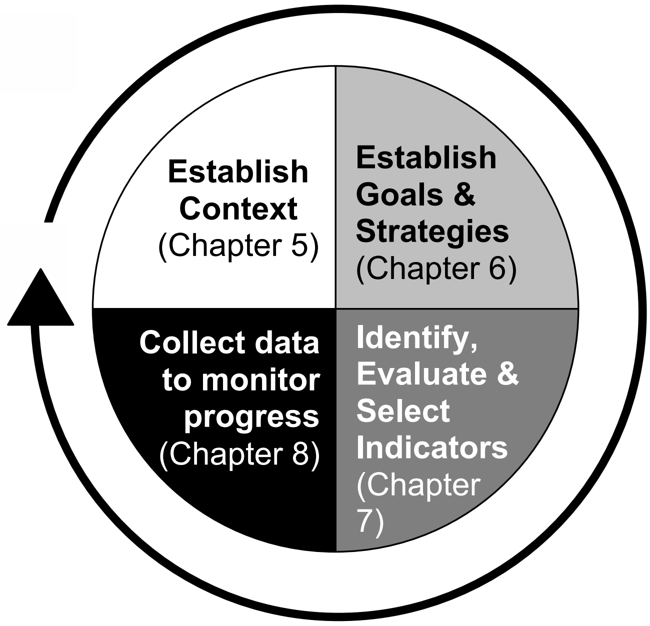

Figure 1.2 Summary of learning process for sustainability indicator development and application (for full version see chapter 3)

Then in chapter 8, indicators and management options were integrated in a manual-style Decision Support System designed to help land managers easily collect data to monitor progress and adapt management to reach sustainability goals.

Finally, chapter 9 uses lessons from the Kalahari case study to critically evaluate the proposed learning process. Suggestions for future improvements are made, and the extent to which the approach could be transferred to other environmental, social, economic and institutional settings is discussed.

2

Rangeland Degradation: problems & research priorities

Summary

This chapter reviews land degradation causes and theoretical models in semi-arid rangelands, and critically evaluates a range of degradation assessment methods in Botswana (field monitoring, remote sensing, agricultural productivity change, expert opinion and land user perspectives). This was done through a combination of literature review and the collection and analysis of primary (expert opinion) and secondary (agricultural) data. The assessment of land degradation provided by the expert opinion map developed here contrasts significantly with the map developed by the UN for their Global Assessment of Soil Degradation (GLASOD). The new map does however largely agree with degradation "hot-spots" identified through ecological and remote sensing research. Published land user perspectives and agricultural productivity changes did not always correspond with the outputs of other assessment methods. Expert opinion and remote sensing can provide degradation assessments at coarse spatial scales that are rapid and cost-effective. However, to interpret an assessment in an appropriate environmental and socio-economic context, it is essential to supplement this information with participatory, ecological and economic data at different spatial scales. At present, land user involvement in land degradation assessment, globally and in Botswana, is both rare and passive.

2.1 Introduction

The environmental, social and economic complexities of land degradation make accurate assessment a difficult challenge, especially in dynamic semi-arid rangeland environments. Existing methods rarely integrate different components of land degradation, focusing instead on single issues or academic disciplines. In particular, the majority of research to date has focussed on soil degradation, in particular erosion (Lynden & Kuhlmann, 2002). In addition to this, it is often difficult to detect trends in degradation status over time, due to the use of unreplicable or incomparable methods. Assessments tend to be carried out by researchers for use by the policy and academic community. Local communities rarely participate, or derive results that can improve the sustainability of their land management.

Acknowledging these limitations, researchers are increasingly recognising the value of multi-scale, multi-method studies that can assess degradation in the context of heterogeneous and dynamic local socio-economic, cultural and environmental conditions (LADA, 2001, 2004; Warren, 2002). However, to date there have been very few systematic comparisons of the outputs of different assessment methods, especially at a national scale. Using Botswana as a case study, this chapter therefore aims to:

- Review theoretical models of land degradation in semi-arid rangelands and the causes of land degradation in Botswana;
- Compare and critically evaluate results from five different land degradation assessment methods on a national scale for Botswana: field monitoring, remote sensing, agricultural productivity change, expert opinion and land user perspectives;
- Discuss the potential to integrate participatory and biophysical assessment methods at different scales; and
- Identify degradation "hotspots" where further investigations and remedial action could usefully be focussed. These areas will then be used to develop and test a learning process for environmental sustainability assessment in the rest of this thesis.

This chapter meets these objectives through a combination of literature review and the analysis of primary (expert opinion) and secondary (agricultural) data. Botswana is an ideal setting for this analysis, given the extensive amount of research already conducted there, its predominantly semi-arid rangeland setting, and extensive Government and UN support for improving rangeland assessment methods.

2.2 Land degradation: definitions

Before any comparison of assessment methods can be made, it is essential to be clear about what is meant by land degradation. UNEP (1992: 13) defined land degradation as "a lowering of the productive capacity of land as a result of human activities". It was recognised that such changes should be "effectively permanent" (Abel & Blaikie, 1989: 13), distinguishing it from short-term, reversible changes such as drought. It should be noted that while many forms of environmental change are theoretically reversible over short time-frames (e.g. thorny bush encroachment that out-competes more productive forage), socio-economic constraints may render the change *effectively* permanent (e.g. if land users do not have the capacity to remove bushes and exclude livestock to facilitate recovery). This definition also clearly describes land degradation as a human-induced phenomenon that cannot be caused by natural processes alone. As a direct result of political discussions of the land degradation definition at and following the Rio Summit in 1992 (UNCED, 1992), the United Nations Convention to Combat Desertification (1994) also included climatic variation as a primary cause of land degradation in drylands (or "desertification"), as well as human activities (UNCCD, 1994). Both climatic variation (particularly drought) and longer-term drying out or "desiccation" (due to climate change) can increase susceptibility to human-induced land degradation. To date, there is no evidence of long-term human-induced desiccation in southern Africa (Endfield & Nash, 2002), but there are suggestions that droughts may become more frequent and severe in the future, especially in relation to El Nino events (Mason, 2001).

Many academic definitions of land degradation refer to a loss of the biological and/or economic resilience[3] and adaptive capacity[4] of the land system (Holling, 1986; Dean *et al.*, 1995; Kasperson *et al*., 1995; Holling, 2001; IPCC, 2001). This approach emphasises the maintenance of basic system functions that may (or may not) include human uses. Building on this, it is argued that land degradation can only be determined in relation to the goals of the management system at the time of investigation (Abel & Blaikie, 1989; Turner & Benjamin, 1993), and in the context of a specific time frame, spatial scale, economy, environment and culture (Warren, 2002). In this context, Kasperson *et al*. (1995) define land degradation as "a decrease in the capacity of the environment as managed to meet its user demands". This resonates with UN definitions emphasising the "resource potential" and "productive capacity" of the land (UNEP, 1992; UNEP, 1997). As such, the extent and severity of land degradation may vary between land users with different management goals in different places at different times and in different socio-economic, environmental and technological contexts.

Land degradation and environmental sustainability are mirror images of the same process (Warren & Agnew, 1988; Warren, 2002). Environmental sustainability depends on the inherent stability[5] and resilience of the resources being used, their sensitivity[6] to change and the system's capacity to adapt to change. For example, a *sustainable* land use system can either regain its productive potential after a perturbation (e.g. rapid and full recovery after drought) or provide alternative ways to support the livelihoods of those who depend on it (e.g. exploitation of bush encroachment by smallstock). By its definition, land degradation occurs when the resilience and adaptive capacity of the land is compromised.

Despite ongoing political and academic debate over the definition of land degradation, it is possible to distil a number of key components from this discussion. Land degradation: 1. is a human-induced phenomenon that cannot be caused by natural processes alone; 2. decreases the capacity of the land system as managed to meet its user demands; and 3. threatens the long-term biological and/or economic resilience and adaptive capacity of the ecosystem.

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[3] The ability of a system to maintain the structure essential to support basic system functions during stress or perturbation (Holling, 1986; 2001)

[4] The ability (often measured in the time it takes) for a system to regain the structure essential to support basic system functions after stress or perturbation (Kasperson *et al*., 1995; IPCC, 2001)

[5] "The propensity of a system to attain an equilibrium condition of steady state or stable oscillation" (Holling, 1986: 296)

[6] The degree of system (or system component) change associated with a given degree of stress or perturbation

In the context of this definition, it is now possible to begin discussing the processes that lead to land degradation. This discussion focuses on semi-arid rangelands, which are widely considered to be at high risk from land degradation (Stiles, 1995; UNEP, 1997; Stocking, 2000; Eswaran *et al*., 2001). A theoretical understanding of land degradation processes is necessary to disentangle human and natural causation, and determine the how long-term or reversible environmental changes are likely to be.

2.3 Rangeland degradation: theoretical models

A variety of theoretical models have been proposed to explain ecological processes in semi-arid environments (e.g. Walker & Noy-Meir, 1982; Westoby *et al*., 1989; Schlesinger *et al*., 1990; Illius & O'Connor, 1999; Dougill *et al*., 1999; Walker & Abel, 2002). Each offer different interpretations of the spatial and temporal relationships between grazers, browsers, vegetation, climate, fire and soil.

For example, successional theory states that ecological systems proceed through a definable sequence of stages in which different types of species occupy a habitat through time after a disturbance. Historically, there are two contrasting views of succession. Clements (1916) believed in a unidirectional, deterministic process culminating in a stable "climax" ecological community in equilibrium with climatic conditions. This gave rise to the notion of "carrying capacity". The ecological carrying capacity is the point at which production of plant biomass equals its consumption by animals, and animal populations stop growing due to limited forage, i.e. the point at which animals are in equilibrium with their fodder resources. Clementsian views dominated mainstream ecology until the 1950s and 1960s, and still influence policy in Botswana and throughout much of sub-Saharan Africa.

In contrast, Gleason (1926) conceived succession as a more complex process, with species composition and distribution determined by interactions between the physical environment, population-level interactions between species, and disturbance regimes. He argued that this could lead to multiple steady states within ecosystems, rather than a single climatic climax towards which all communities proceed. Gleason's view of ecosystems under continual change in response to disturbance led to the contemporary view that ecosystems are composed of numerous patches, of various sizes and at different successional stages (Townsend *et al*., 2002).

Under natural conditions, disturbances are so frequent that there is rarely enough time between them for plant and animal communities to reach stable equilibria (Wiens, 1984). It has been argued that ecosystems characterised by frequent disturbance, such as drought-prone semi-arid systems, therefore never reach equilibrium (e.g. Behnke *et al*., 1993; Scoones, 1995). Various authors have argued that for this reason, conceptions of equilibrium ecological dynamics based on Clementsian succession are not relevant for semi-arid systems (e.g. de Angelis and Waterhouse, 1987; Ellis & Swift, 1988; Westoby *et al*., 1989). Such authors argue that these systems display "non-equilibrium" behaviour, with animal and plant dynamics largely independent from one another, and system structure and dynamics dominated instead by unpredictable rainfall events (Behnke & Scoones, 1993). Frequent droughts prevent livestock populations ever growing large enough to reach or exceed equilibrium with their fodder resources due to drought-induced mortality in cattle herds (Mace, 1991). Hence, it is argued that "the risk of environmental degradation in non-equilibrial environments is limited, as livestock populations rarely reach levels likely to cause irreversible damage" (Scoones, 1995: ix).

Gleason (1926) recognised that triggers such as disturbance (e.g. fire, flood) or management (e.g. grazing, fertilising) could cause ecosystems to move unpredictably between multiple states. When a system approaches a threshold, these transitions can occur very rapidly (May, 1977; Wissel, 1984) and may not always be reversible (Friedel, 1991). Westoby *et al*. (1989) drew these concepts together into their "state-and-transition" model of ecological dynamics. This has been used to describe semi-arid ecosystems as a set of discrete states, with a diverse series of transitions between states (e.g. Dougill *et al*. (1999) for Kalahari rangeland state-and-transition model).

Alternatively, Gunderson & Holling's (2002) "Panarchy" framework captures equilibrium ecosystem dynamics within a broader framework of episodic ecosystem collapse and re-organisation (Figure 2.1). Panarchy conceptualises rangelands as complex systems capable of reaching stable equilibria, or ecological climax (K phase) and yet vulnerable to collapse in response to perturbations (fire or a combination of grazing and drought in semi-arid rangelands) (omega phase), and able to re-organise to form potentially new species assemblages (alpha phase) that become increasingly rich, connected and rigid as they build (r phase) towards new equilibria (back to K phase) (Gunderson & Holling, 2002; Walker & Abel, 2002).

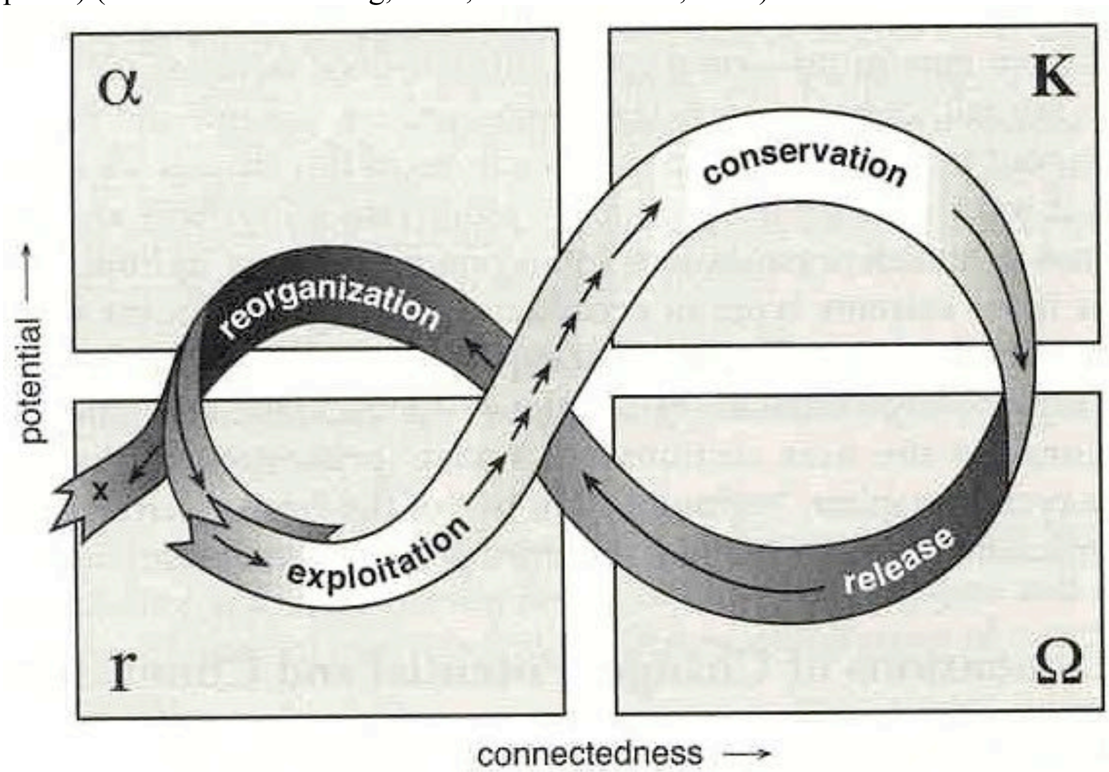

Figure 2.1 A stylized representation of the four ecosystem states (r, K, omega and alpha) and the flow of events among them. The arrows show the speed of that flow in the cycle, where short, closely spaced arrows indicate a slowly changing situation and long arrows indicate a rapidly changing situation. The cycle reflects changes in two properties: (1) Y axis – the potential that is inherent in the accumulated resources of biomass and nutrients; (2) X axis – the degree of connectedness among controlling variables. Low connectedness is associated with diffuse elements loosely connected to each other whose behaviour is dominated by outward relations and affected by outside variability. High connectedness is associated with aggregated elements whose behaviour is dominated by inward relations among elements of the aggregates, relations that control of mediate the influence of external variability. The exit from the cycle indicated at the left of the figure suggests, in a stylised way, the stage where the potential can lead away and where a flip into a less productive and organised system is most likely (Gunderson & Holling, 2002)

Although the Clementsian view of ecological equilibria has been out of favour for much of the last two decades, evidence has recently emerged that has caused a swing back towards this position. In particular, a number of authors have questioned the assumption of non-equilibrium ecologists that competition is weak within and between species in semi-arid ecosystems (e.g. Illius & O'Connor, 1999; Walker & Wilson, 2002). One of the strongest proponents of the non-equilibrium paradigm, Scoones (1995), noted that equilibrium dynamics do indeed occur in semi-arid environments at certain times and in certain places, and are critical for sustaining livestock populations through the dry season:

> "In some sites more stable, predictable equilibrium dynamics may occur in a run of wetter years, with non-equilibrium, uncertain, event-driven patterns emerging when a dry period strikes. Equally in any one area there may be certain areas which commonly show a more equilibrial pattern (e.g. relatively wetter bottomland sites where primary production varies little between years) within a wider landscape of dry rangeland which shows non-equilibrium dynamic patterns with high levels of interannual variability."

Building on this, Illius & O'Connor (1999) argued that animal populations are in fact regulated in a density-dependant (i.e. equilbrial) manner by the availability of forage in these key dry season resource areas.

The debate between equilibrium and non-equilibrium protagonists has been converging in recent years, with the acceptance that a combination of equilibrium and non-equilibrium dynamics occurs to varying degrees at different temporal and spatial scales (Vetter, 2005). In this context it is relevant to revisit the work of Wiens (1984), to whom rangeland ecologists attribute the term "non-equilibrium". In his work with birds, he suggested that ecological communities actually exist along a continuum from equilibrium to non-equilibrium functioning. In this context, Briske *et al*. (2003: 601) suggest that "therefore, the rangeland debate should be redirected from the dichotomy between paradigms to one of paradigm integration". Nevertheless, the debate has highlighted the role of climatic variability in semi-arid livestock management, and rightly questioned the inflexibility of recommended stocking rates based on carrying capacity. It has spawned a variety of alternative, more flexible management approaches that can better respond to climatic variability.

Whatever the mechanisms, it is apparent that rangeland degradation has occurred and is continuing to occur in the semi-arid rangelands of sub-Saharan Africa. Numerous local scale studies have identified changes in species composition (shifting towards unpalatable (often thorn-bush) species), vegetation cover and erosion features. However, as the next section will show, many of these assessments have been contested; finding an accurate and reliable way to assess land degradation is still a major research challenge.

2.4 Dryland degradation assessment

The first global attempt to quantify dryland degradation extent took place for the United Nations Conference on Desertification (UNCOD, 1977) in response to the Sahelian drought of the 1970s and (now discredited) research suggesting the Sahara was expanding by 5.5 km per year (Lamprey, 1975). The conference concluded that 3970 million hectares were desertified, an area four times the size of Europe (UNCOD, 1977). Despite the development of a provisional methodology for assessing and monitoring desertification by the FAO and UNEP in the 1980s, reliable data was still lacking at national and global scales and global assessments were still not based on systematic measurements. In 1984, with little new empirical evidence, UNEP revised their estimate to 3475 million hectares and in 1987 made the wild claim that because 27 million hectares were becoming desert each year, "in less than 200 years, at the current rate of desertification, there will not be a single hectare of fully productive land on earth" (UNEP, 1987: 63). Figures of two-thirds to three-quarters of all drylands are still cited as being degraded (Diouf & Lambin, 2001; Eswaran *et al*., 2001). These assessments were challenged by a series of detailed remote sensing studies that showed the extent to which the location of desert margins can change in response to rainfall variability (Hellden, 1991; Tucker *et al*., 1991). This led some researchers to question the existence of dryland degradation (Warren & Agnew, 1988), suggesting it was an "institutional myth" (Thomas, 1993). Figure 2.2 illustrates the huge scale of revisions that led to this collapse of confidence.

In response to this wide range of estimates, UNEP commissioned a Global Assessment of Human-Induced Soil Degradation (GLASOD) from the International Soil Reference Centre (Oldeman *et al*., 1990). This indicated that 1016 to 1035 million hectares of drylands were degraded; less than a third of the area suggested by previous estimates. It was based on expert opinion, eliciting information about the type, extent, degree, rate and cause of soil degradation over the last 50 years from 200 soil scientists and environmental experts in 21 regions of the world (Oldeman *et al.*, 1990; UNEP, 1997). Despite being "the first scientifically systematic" assessment of land degradation, it has been criticised (e.g. Thomas *et al*., 1997). By its nature, it is a qualitative and potentially subjective assessment (ISRIC, 2003). It is difficult to

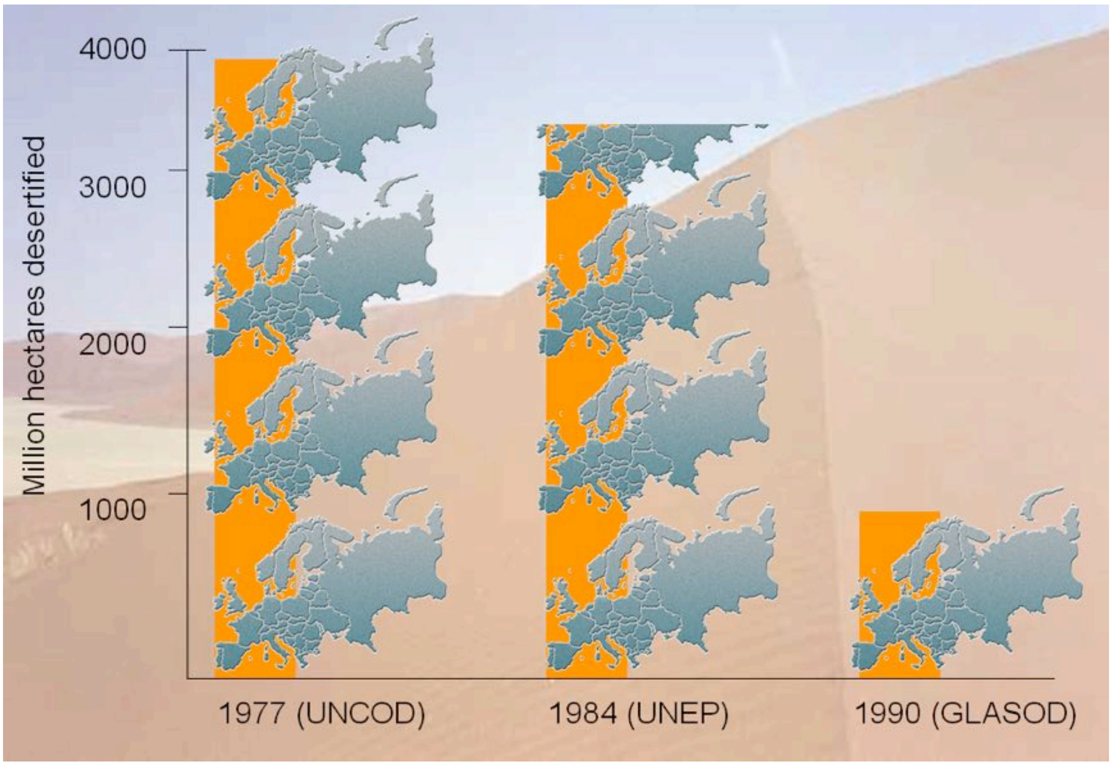

Figure 2.2 The shrinking desert: from four-times the size of Europe to a quarter of that size in 13 years (based on figures from UNCOD, 1977; UNEP, 1984; Oldeman *et al*., 1990) (graphic: M. Reed)

replicate; even if the same experts can be used, their perceptions of degradation may have changed unpredictably (van Lynden & Kuhlmann, 2002). Despite claiming to assess trends over the last 50 years, few experts had personal experience of soil conditions in the 1940s, and there was little data available at this time for much of the world. It does not take management goals or other contextual information into account. It does not involve local stakeholders who may have very different perspectives of land degradation. Related to this, it only provides information about one biophysical component of land degradation (the soil), ignoring other system components, notably ecological changes that are vital for semi-arid rangelands. Despite these problems and the fact that it is now fifteen years old, GLASOD is still cited in peer-reviewed literature (e.g. Conant & Paustian, 2002; Polyakov & Lal, 2004) and is still widely used by national and international policy-makers (ISRIC, 2003). It also forms the basis for the widely cited World Atlas of Desertification (UNEP, 1997).

Acknowledging these limitations, the recent United Nations Food and Agriculture Organisation's Land Degradation in Drylands (LADA) project aims to combine traditional and scientific knowledge to assess degradation severity and extent using a variety of techniques to measure environmental indicators, from local to national and international scales (van Lynden & Kuhlmann, 2002). They propose a combination of the following degradation assessment methods:

- Field monitoring;
- Remote sensing;
- Agricultural productivity change;
- Expert opinion; and
- Land user perspectives.

As yet (despite the rhetoric of the LADA project) there has been no national (or international) systematic comparison of data from these sources, and few attempts to integrate them. This chapter attempts to do this for Botswana, in order to identify key research priorities for land degradation assessment. To introduce this national case study, the next section reviews the complex socio-economic, historical and political causes of land use and institutional change that have been blamed for land degradation in Botswana.

2.5 Causes of land degradation in the semi-arid rangelands of Botswana

Botswana has one of the highest ratios of livestock to people in Africa, with 2.9 million cattle, 1.7 million goats and 267 000 sheep providing the largest single source of income for around 700 000 pastoralists out of a total population of 1.8 million (Ministry of Agriculture Statistics, 2002; Cullis & Watson, 2004; FAO, 2005). A nationwide survey conducted as part of the review of the Rural Development Survey (BIDPA, 2002) indicated that 67.9% of households own livestock. As its third largest export product, beef production is also a major source of foreign exchange (OECD/AfDB, 2002). In addition, the semi-arid rangelands of Botswana are globally significant for biodiversity (Stuart *et al.*, 1990).

The majority of pastoralists graze their livestock on communal rangelands. This is often referred to as the "cattle post" system. Cattle posts consist of fenced or thorn bush livestock enclosures ("kraals"), a water supply and in some cases huts for herders (Figure 2.3). Water is pumped from deep boreholes into storage troughs and livestock graze the surrounding rangeland, returning to troughs for water on a daily basis. However, these systems have been progressively weakened by the replacement of traditional institutions with government agencies responsible for overseeing the management of land and common rangeland resources.

The enormous forage potential of the Kalahari was recognised by the Bechuanaland Protectorate Government in the 1930s (Parsons & Crowder, 1988). Since this time, the Government has expanded the livestock industry into the Kalahari through the provision of deep boreholes to access groundwater (Darkoh & Mbaiwa, 2002). Some boreholes were drilled for communal use, but many have been privatised and are now owned by individuals or (more commonly) syndicates (Peters, 1994).

Until colonial times, all cattle had been the property of local chiefs, who allocated cattle for herding and milk production. Each household had access to certain areas of communal rangeland according to the location of their village and was entitled to enough arable land to meet its needs. A land overseer (or "Modisa") allocated access to surface water, ensured grazing areas were used by those with rights, and regulated livestock numbers and the spacing of cattle posts (Lawry, 1983; White, 1998). This included informal monitoring of rangeland condition and stocking density and manipulating grazing though a variety of methods, such as the allocation of grazing rights to different areas (Niamir, 1991).

In 1970, Land Boards took over customary land administration and allocation from chiefs and land overseers. By replacing traditional common property institutions with government agencies, the Government encouraged a shift towards a more open access rangeland system. Agricultural development policies since this time have attempted to solve the problems that this generated through a shift to private property ownership.

The privatisation of communal grazing land was first promoted under the Tribal Grazing Lands Policy (1975) and then the National Policy for Agricultural Development (1991). The main objectives of these policies were to increase livestock production and reduce rangeland degradation through improved management. Large tracts of land were privatised and fenced for use by wealthy cattle owners in an attempt to relieve pressure on communal grazing land. Most of these ranches were managed as cattle posts (very few were subdivided into camps), with overstocking leading in many cases to worse land degradation (Perkins, 1996; Adams *et al.*, 2002). This was a particular problem during drought, as grazing reserves that were traditionally used during times of need became fenced off from communal pastoralists. Despite the availability of loans under the TGLP, the large down-payments they required limited their uptake to the richest cattle owners (Cullis & Watson, 2004). These pastoralists often retained dual grazing rights, grazing communal land during the wet season, and using ranches as dry season and drought fodder reserves (Perkins, 1996). This practice is blamed for exacerbating degradation in communal areas, increasing the polarisation between rich and poor, and fuelling rural-urban migration (Perkins, 1996; Thomas *et al.*, 2000).

Figure 2.3 Boreholes with diesel (top) and wind (bottom) pumps, showing fenced kraals in distance (top) and walled water storage tank (bottom) (photos: M. Reed)

The 2002 National Agricultural Master Plan for Agriculture and Dairy Development attempts to address these problems by allocating larger agricultural holdings so as to benefit from economies of scale (with farmers forming collectives or syndicates where necessary) and providing relevant agricultural infrastructure throughout the country. According to the Minister of Agriculture, it is people-driven and open to poor farmers (Botswana Daily News, 12 June, 2003).

Although it is too early to evaluate the impact of this new policy, opponents have attacked land privatisation policy on two theoretical grounds (e.g. White, 1993; Thomas *et al*., 2000). First, they argue that privatisation is not ecologically or culturally compatible with Kalahari rangelands. There is no history of private rangeland ownership among Kalahari livestock owners, and the carrying capacity concept on which ranch sizes are based is difficult to apply under such variable rainfall (see section 2.3). Second, they argue that the benefits of privatisation are concentrated in the hands of a few, while poor rural households permanently lose access to land and the resources on it that often function as a safety net from absolute poverty (Selolwane, 1995; Cullis & Watson, 2004). Those whose livelihoods are most affected are households that rely on hunting and gathering and small-scale livestock production (Taylor, 2002).

An alternative, more appropriate solution to the tragedy of the commons (Hardin, 1968) may be to revert to common property regimes. Ostrom (1999) notes that there are few incentives for people to innovate under open access regimes. Hardin (1968) advocated a transition to private or public ownership to prevent the degradation of open access resources. However, Ostrom (1999) shows how (well designed and implemented) common property regimes are more likely to foster innovative solutions to environmental problems and promote sustainable use. In addition, within the current context of communal rangeland privatisation, securing formal common property rights by communities may be a means of preventing further alienation of commonly-held rangeland resources by wealthy individuals (Taylor, 2004).

Most academics agree that pastoral development policies and changes to land tenure systems have been one of the prime driving forces behind land degradation in Botswana (e.g. White, 1993; Perkins, 1996; Dougill *et al*., 1999; Thomas *et al*., 2000; Adams *et al*., 2002; Thomas & Twyman, 2004). However, given the conflicting results of research using different methods at different scales, it is difficult for policy-makers to build up a reliable picture of land degradation at a national scale. The rest of this chapter therefore draws on a combination of existing literature and primary and secondary data to critically evaluate outputs from different land degradation assessment methods, and the following discussion (section 2.6) identifies degradation "hotspots" for more detailed future research and discusses the potential to integrate participatory and biophysical assessment methods at different scales.

2.6 Land degradation assessment in Botswana

A variety of methods are available to assess land degradation, including field monitoring, remote sensing, agricultural productivity change, expert opinion and land user perspectives (van Lynden & Kuhlmann, 2002; section 2.4). Land degradation assessment in Botswana has been predominantly carried out by ecologists and soil scientists. As technology has developed, an increasing number of studies have used satellite remote sensing. However, very few studies have involved local communities in degradation assessment or sought to capture their perceptions of the problem. There has been no national assessment of expert opinion since Oldeman *et al*.'s (1990) Global Assessment of Human-Induced Soil Degradation (GLASOD), and agricultural productivity trends in Botswana have never been systematically assessed for evidence of land degradation. For this reason, in addition to literature review, the following primary and secondary data were gathered specifically for this chapter:

- an international panel of experts were interviewed and asked to map their opinions of land degradation extent; and
- time-series data were analysed from Botswana's agricultural census.

Results from these two assessment methods will be outlined first before reviewing published information available from field monitoring, remote sensing and land user perspectives.

2.6.1 Expert opinion

A land degradation map for Botswana was created by experts under the Global Assessment of Human-Induced Soil Degradation (GLASOD) (Figure 2.4) (see section 2.3 for the methods used) (Oldeman *et al*., 1990). According to this assessment, the most severely degraded areas were shown in red around the Makgadikgadi Pans in mid-Boteti sub-district. In addition to this, the map indicated "severe" and "moderate" degradation throughout most of the Eastern Hardveld. The area adjacent to the Molopo River on Botswana's southern border (with South Africa) and the country's National Parks were deemed to have no land degradation.

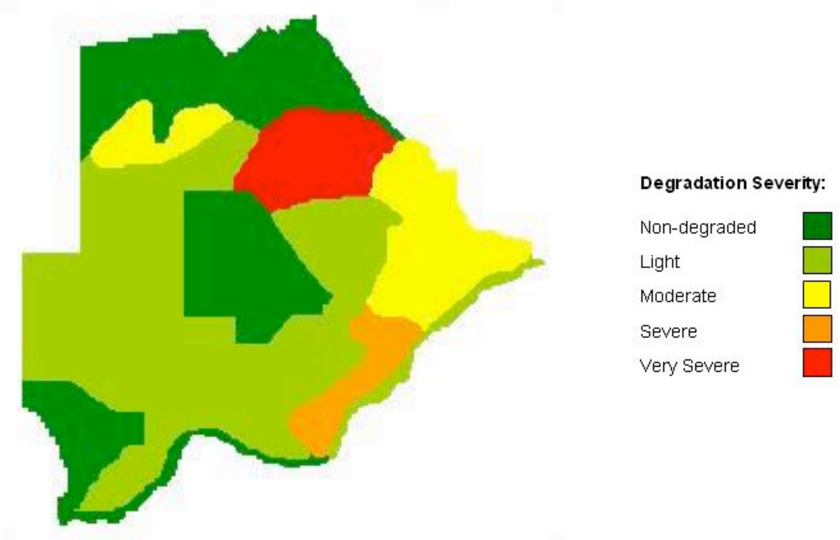

Figure 2.4 Human-induced soil degradation map of Botswana from GLASOD (recoloured from FAO/AGL, 2004)

For this chapter, individual interviews were conducted with a panel of eight international experts on land degradation in Botswana (3 members of staff from the Ministry of Agriculture; 3 academics and 2 environmental consultants based in Botswana). Panelists were selected using a snowball sampling strategy, where panelists suggested additional suitable qualified members themselves (stating the basis of their recommendation). Five degradation severity classes were used to map degradation at a national scale. Instead of solely focussing on the coverage of physical and chemical soil degradation indicators as GLASOD did, panellists were asked to follow a broader definition of land degradation as "a reduction in the resource potential of the land" (UNEP, 1997), considering human-induced rather than climatic-induced change that is "effectively permanent" (Abel & Blaikie, 1989) over at least 50-100 years 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. They were asked to provide reasons for their classifications before marking areas on the map. These discussions were recorded, and used to clarify unclear boundaries during digitisation. Maps were digitally scanned and colour-coded using graphics software.

By far the most notable finding was the extent of differences between the assessments this exercise produced (Figure 2.5). Although it is difficult to generalise, Ministry of Agriculture respondents tended to provide information about a higher proportion of the country than other respondents, and often drew degradation along roads they were familiar with.

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

The resulting map differs considerably from that produced by GLASOD. In particular, the strip of degraded land along Botswana's southern border that was considered to be non-degraded by GLASOD, was highlighted as an area of particular concern by five out of the eight panellists. Although they considered the country's National Parks to be largely non-degraded, the northern part of Chobe National Park (at Botswana's most northern point) was considered to be severely degraded by elephants due to poor management. The two maps do agree that most of the densely populated Eastern Hardveld is moderately or severely degraded. The GLASOD map highlights the mid-Boteti region that borders the Makadikgadi Pans as very severely degraded. Although the panellists broadly agreed with this assessment, they distinguished between the salt pans themselves (a natural feature that provides few resources and are not degraded) and the surrounding rangeland which is deemed to be degraded to the southwest of the pan system.

Land degradation "hotspots" were identified as areas in the upper half of the degradation severity scale (between moderate and very severe) (Figure 2.6). More detailed case study research was conducted for this thesis in three of these hotspots shown in Figure 2.6.

Expert opinion can be used rapidly and cost effectively to assess degradation status across wide areas. Changes in agricultural productivity also have the potential to detect land degradation at similar spatial scales, and with similar ease and cost.

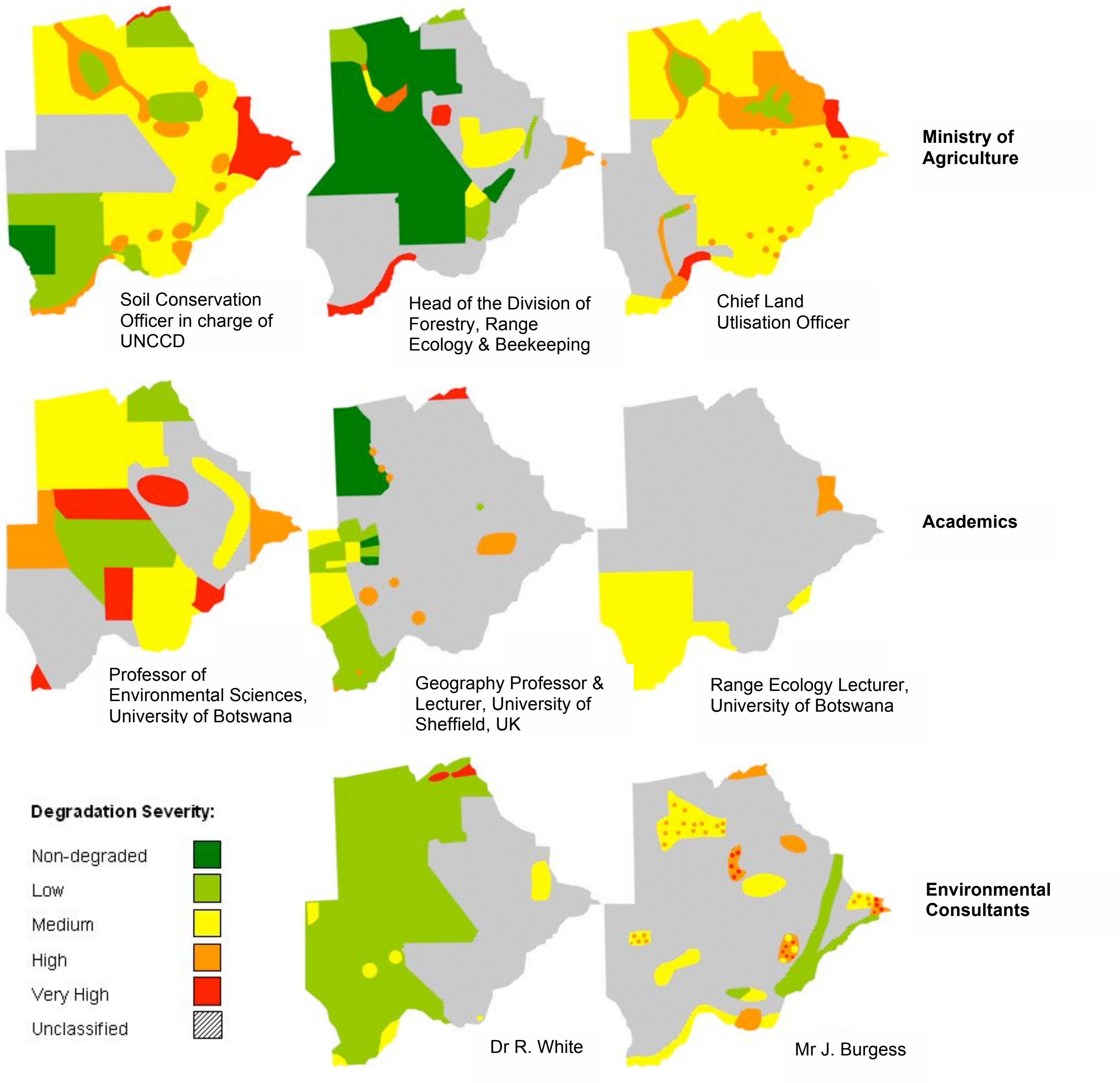

Figure 2.5 Land degradation map of Botswana according to the opinions of eight national experts (based on interviews and mapping exercise)

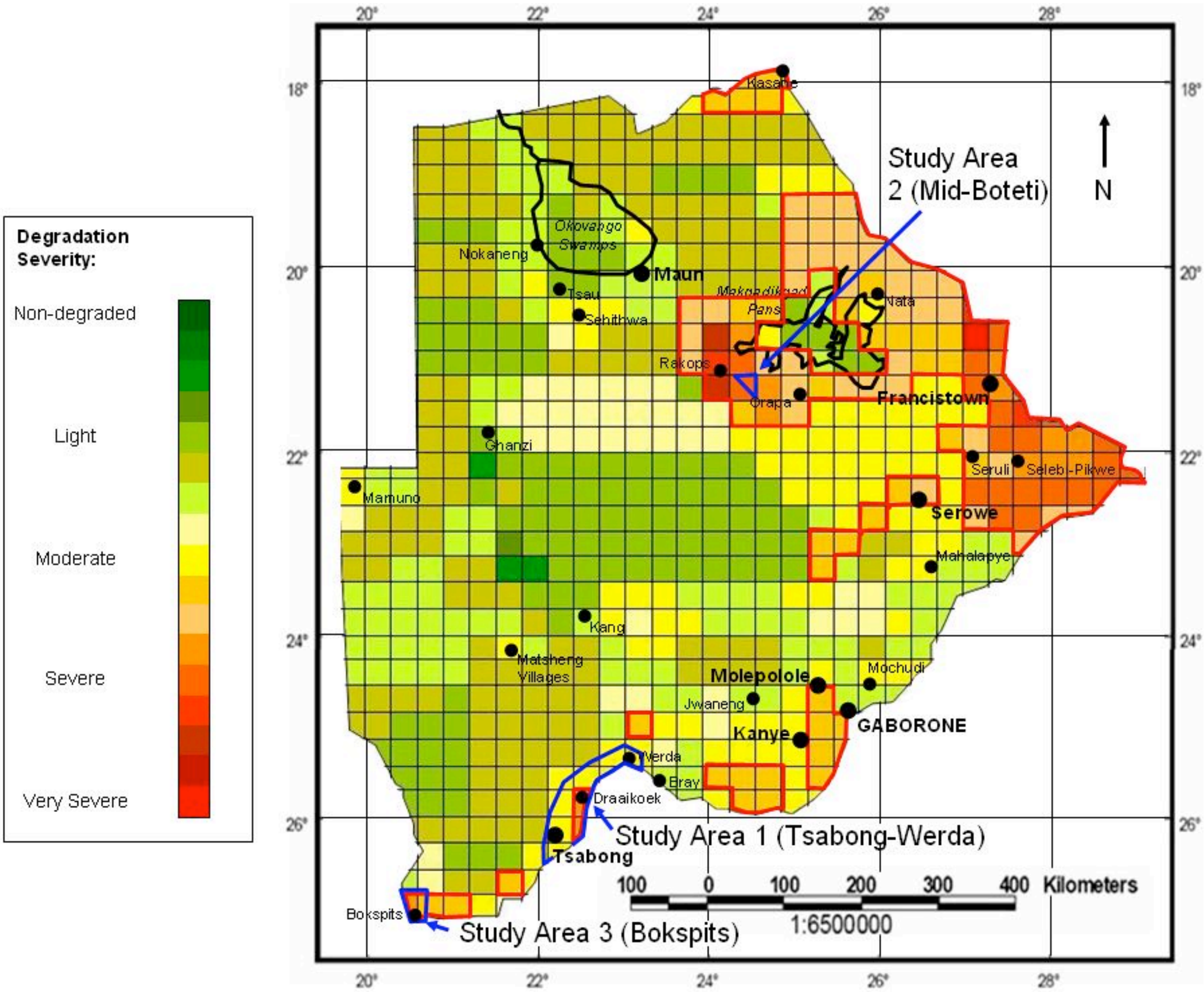

Figure 2.6 Land degradation map of Botswana, from the combined opinions of eight national experts, with degradation "hotspots" outlined in red (based on interviews and mapping exercise) and study areas outlined in blue where case study research (reported in future chapters) was conducted

2.6.2 Agricultural productivity change

The land's "productive capacity" and "resource potential" feature in many definitions of land degradation (section 2.2). As such, it is perhaps surprising that agricultural productivity[7] is rarely considered in land degradation assessment (Lynden & Kuhlmann, 2002). Although it can be difficult to prove whether productivity changes are human-induced and the extent to which adaptive capacity has been impaired, it may be possible to use time-series agricultural productivity data to examine the long-term capacity agricultural of land systems to meet user demands (Lynden & Kuhlmann, 2002). Using this kind of data to determine the resilience of agricultural systems is more difficult in semi-arid environments due to high rainfall variability. For example, following the definition of resilience as "the speed of return to equilibrium or the capacity of the system in some state to absorb stresses and shocks", Perrings & Stern (2000) looked at the speed with which national cattle populations returned to equilibrium carrying capacity after a drought in the 1980s, and found a small loss of resilience. However, this loss was not statistically significant, and their approach assumed that livestock in semi-arid ecosystems have an equilibrium carrying capacity; an idea that is widely contested in ecological literature (section 2.3).

It is necessary to use agricultural productivity data with great care, as different land degradation processes have different effects on productivity. In addition, productivity can be influenced by a number of other factors, such as pests and diseases, extreme climatic events and inappropriate management. For example, Dean & MacDonald (1994) used livestock population trends between 1911-1981 in Cape Province, South Africa to infer rangeland degradation, but the decline in numbers has since been attributed largely to changes in livestock policy over this period (Hudak, 1999). Having said this, if such influences are taken into account over a sufficient time-series, changes in productivity can be a useful indication of land degradation. Following this approach, changes in livestock populations from 1980-1998[8] were analysed for Botswana. Livestock were used, as the semi-arid climate precludes significant arable production. Data was obtained from the Department of Animal Health and Production (Ministry of Agriculture, Government of Botswana) at the highest spatial resolution possible (veterinary districts). Although this is still coarse, it is sufficient to look for sub-district differences in productivity trends. A re-organisation of district boundaries in 1993 led to the amalgamation of some districts into larger districts. Where this occurred, the most recent boundaries were used and pre-1993 data for old districts was combined where necessary. Trends were determined using regression and their direction and significance was colour-coded for each district, for example, orange for a significant decrease in productivity ($p < 0.05$) and red for a highly significant decrease ($p < 0.01$). These colours were then entered into a veterinary map of Botswana (Figures 2.7 and 2.8). There were significant differences between cattle and smallstock trends: most districts showed significant increases in smallstock (sheep and goat) productivity, while cattle production was more variable. Figure 2.8 shows cattle, goat and sheep productivity combined as Tropical Livestock Units.

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[7] Productivity can be defined as "the inherent potential of a land system to produce crop yields", wheras production is defined as "the actual yield levels achieved by farmers" (Stocking & Murnaghan, 2001: 112).

[8] The only years for which data was available.

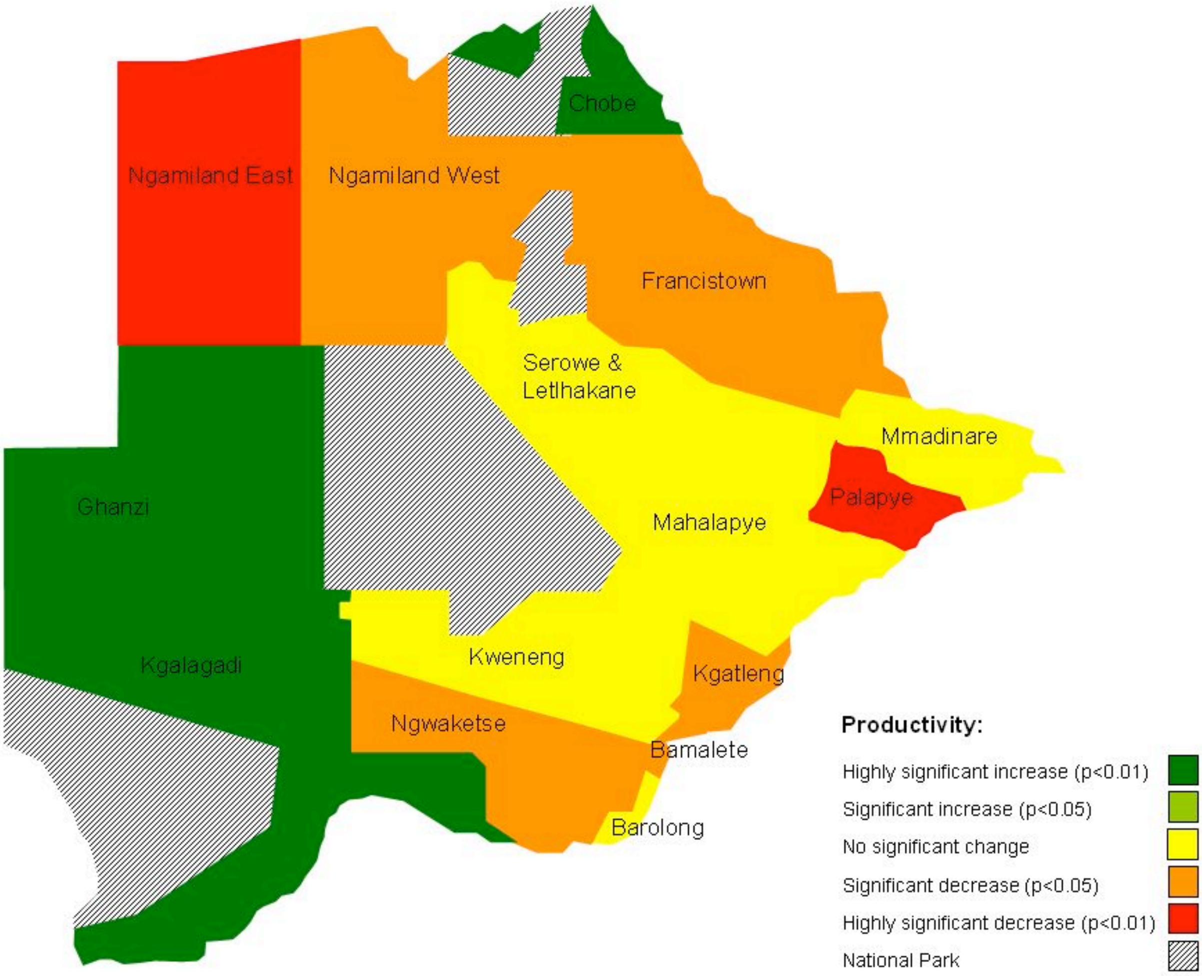

Figure 2.7 Cattle productivity trends in Botswana by veterinary district

In semi-arid rangelands, rainfall is widely believed to be the most significant factor influencing livestock production (e.g. de Angelis and Waterhouse, 1987; Ellis & Swift, 1988). For this reason, productivity and rainfall data for each sub-district were analysed for correlation using linear regression. No significant correlations were found. Although the period under study experienced drought in the early 1980s and mid 1990s, there was no overall trend in rainfall during this time (Figure 2.9; $r^2 = 0.003$).

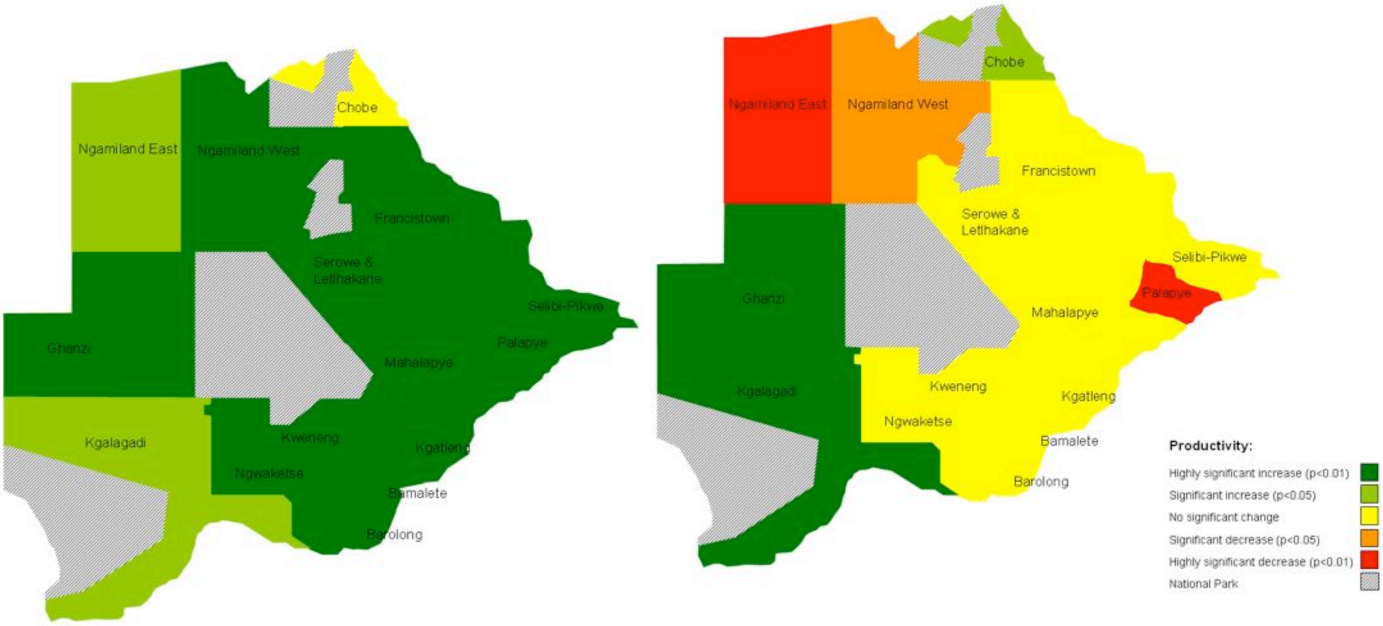

Figure 2.8 Productivity trends of smallstock (left) and Tropical Livestock Unit (right) in Botswana by veterinary district

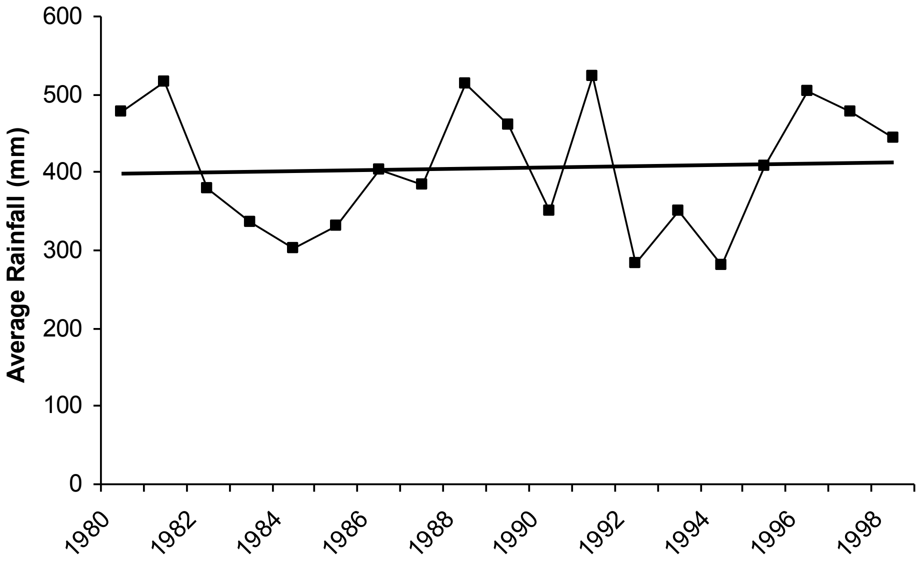

Figure 2.9 Average annual rainfall for Botswana (1980-1998) showing trendline ($r^2 = 0.003$) (Government of Botswana Meteorological Services)

Literature review and interviews with Ministry of Agriculture officials were therefore used to identify other factors that may have influenced trends. The only policy driver identified was the Financial Assistance Plan (1982-2002) which was designed to promote smallstock production (among other objectives). This probably accounts for the significant increase in smallstock production at both a national (Figure 2.10) and sub-national scale (Figure 2.8). For this reason, changes in smallstock populations cannot be used to infer land degradation status in the period for which data was collected. There were two disease outbreaks during the studied period: cattle lung disease (Contagious Bovine Pleuropneumonia) led to the slaughter of over 400,000 cattle in West Ngamiland in 1995, followed by the slaughter of around 320,000 cattle in East and West Ngamiland in 1997 due to Foot and Mouth Disease (FAO, 1997). This probably accounts for the decline in cattle populations found in this district (Figure 2.7). Increased borehole provision in the west of Botswana (de Queiroz, 1993) may account for rising population trends in the drier southwestern parts of the country (Ghanzi, south Kgalagadi and north Kgalagadi). However, it was not possible to isolate factors that could be responsible for declining productivity in parts of the Eastern Hardveld (Palapye, Ngwaketse, Bamalete and Kgatleng veterinary districts). The decline in cattle productivity in these areas may therefore indicate land degradation. Historically, the Eastern Hardveld has been the most densely populated part of the country, and remains so. Elsewhere, there was no significant increase or decline in cattle productivity. This was notable around the Makgadikgadi Pans, which had been identified as a degradation hotspot according to other assessment methods.

By incorporating agricultural productivity changes into degradation assessment, it is possible to examine the “resource potential of the land”, which is integral to the concept of land degradation (UNEP, 1997: iv). However, interpretation of results (in particular in relation to possible causal factors) is a challenge, and can introduce subjectivity into the analysis. The above interpretation was informed partly by interviews with national experts. Alternatively, field monitoring may provide more objective results.

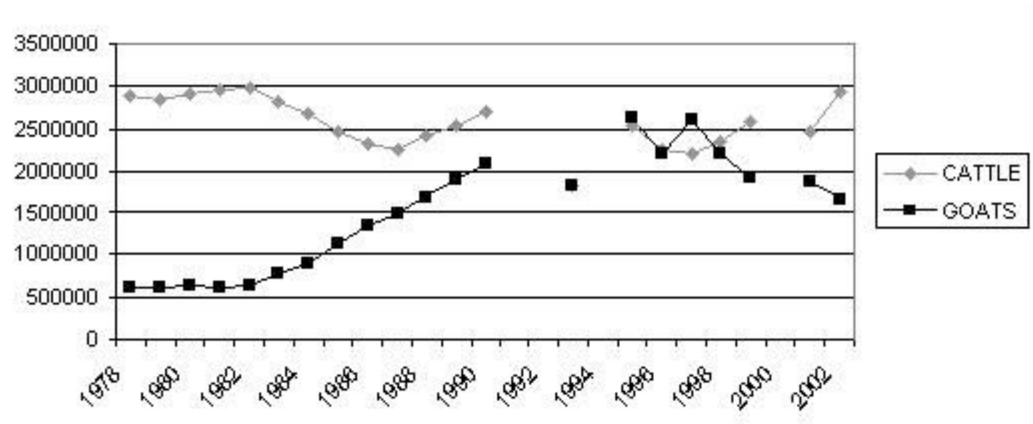

Figure 2.10 Cattle and goat populations in Botswana 1978-2003 (Ministry of Agriculture statistics)

2.6.3 Field monitoring

Ecological studies

Field monitoring has provided evidence for ecological change in Kalahari rangelands, most notably in the form of unpalatable bush encroachment around water points. On a global scale, thorny bush encroachment has been described as "the most widespread problem on dryland pastures" (Warren & Agnew, 1988: 6). It reduces the availability and heterogeneity of fodder (Scoones, 1995) and is associated with a reduction in grass production and an increase in other invasive species that are unpalatable to cattle (Perkins & Thomas, 1993). It can therefore lead to a reduction in economic outputs in cattle-based systems (de Ridder & Breman, 1993; Quan *et al*. 1994; Dean & MacDonald, 1994). For the predominantly cattle-based systems of the Kalahari, bush encroachment is viewed as the major form of land degradation in terms of its impact on livelihood sustainability (Sporton & Thomas, 2002).

There remain important debates on the extent and reversibility of such ecological changes, especially in relation to non-equilibrium ecological dynamics (Behnke & Scoones, 1993; Illius & O'Connor, 1999; Thomas *et al*., 2001). For example, *limited* bush encroachment may enhance the resilience of Kalahari rangelands, providing drought fodder for cattle from fallen pods and leaves, and protecting palatable grass seed sources which can facilitate rapid recovery of rangeland after drought (Perkins & Thomas, 1993; Dougill *et al*., 1999). Initial soil hydrochemical research suggested that bush encroachment could be reversible (Dougill *et al*., 1998), though the more recent analysis of hydrochemical spatial heterogeneity counters this supposition (Dougill & Thomas, 2004; Berkeley *et al*., 2005) by suggesting that enhanced nitrogen availability under *A. mellifera* canopies (Hagos & Smit, 2005) can lead to rapid rates of bush encroachment. Ecological modelling simulations suggest excluding cattle grazing alone is unlikely to significantly reduce bush cover in less than 100 years (Jeltsch *et al*., 1996). As such, bush encroachment is only reversible over relatively short periods with mechanical or chemical removal, grass re-seeding and sufficient rain. However, it is "effectively permanent" for the majority of land users in Botswana who lack sufficient resources to remove bushes and exclude grazing to allow recovery.

Bush encroachment around water points has been observed in numerous ecological studies throughout the Kalahari (e.g. Cole & Brown, 1976; van Vegten, 1983; Cooke, 1985; Archer *et al*., 1988; Skarpe, 1991; Tietema *et al*., 1991; Perkins & Thomas, 1993; Bester, 1996; Moleele & Perkins, 1998; Dougill *et al*., 1999; Thomas *et al*., 2000; Buss & Nuppenau, 2003; Chanda *et al*., 2003; Dube *et al*., 2003; Sekhwela, 2003; Moleele & Mainah, 2003; Moleele & Chanda, 2003; Thomas & Twyman, 2004). The extent of these zones is generally between 1-4 km, but they can extend much further. Boreholes were initially drilled on average 8 km apart throughout most of the Kalahari under the 1975 Tribal Grazing Land Policy, but this has now been relaxed in many areas (Tsimako, 1991). As a consequence, there is the potential for bush encroached zones around boreholes to coalesce. Thirty-five years ago, Donaldson (1969) estimated that over a million hectares of land in the Molopo area of Kgalagadi District were encroached by *Acacia mellifera*, reducing grazing capacity by 50% or more. More recently, the retreat of grass cover has been documented up to 18 km from elsewhere in this district (around the Matsheng villages) combined with bush encroachment nearer villages (Moleele & Mainah, 2003; Moleele & Chanda, 2003; Chanda *et al*., 2003). The reversibility of these changes is uncertain. Ministry of Agriculture research showed little change in biomass or species composition in exclosure plots around these villages after 10 years (Mphinyane, 1990). However, poor consultation with local pastoralists had led to exclosure fences being cut on a regular basis (WN Mphinyane, pers. comm.). In research elsewhere in this district, Thomas & Twyman (2004) found a significant decrease in perennial grasses and increased bare ground and unpalatable species up to 10 km from Struizendam in Botswana's southwest tip.

In summary, ecological research has highlighted degradation problems in parts of: north Kgalagadi District (e.g. Mphinyane, 1990; Skarpe, 1991; Chanda *et al.*, 2003; Moleele & Mainah, 2003; Moleele & Chanda, 2003); southwest Kgalagadi District (e.g. Thomas *et al.*, 2000; Thomas & Twyman, 2004); southeast Kgalagadi District (e.g. Thomas *et al.*, 2000); Central District (e.g. Perkins & Thomas, 1993; Dougill *et al.*, 1999) including Makgadikgadi Pans (e.g. Ringrose *et al.*, 1996); Eastern Hardveld, Kgatleng District (e.g. Moleele & Perkins, 1998); and Ghanzi District (e.g. Thomas *et al.*, 2000) (see Figure 1.1 for location of districts). However, the localised scale of these studies (rarely sampling more than 3 km from individual boreholes) makes it difficult to use them to assess land degradation at a national scale. This limitation also applies to research conducted into soil degradation in Botswana.

<u>Soil-based studies</u>
Soil studies have shown limited erosion losses throughout the Kalahari, and no significant link between bush encroachment and changes in soil processes. Dougill *et al.* (1999) found no difference in soil hydrochemical properties along grazing gradients that demonstrated clear vegetation trends. Indeed, Moore & Attwell (1999) suggest that soil nutrient content has little influence on Kalahari vegetation communities, given the extremely low nutrient and organic matter content of Kalahari sand soils (Skarpe & Bergstrom, 1986; Perkins & Thomas, 1993). The surface soil layer under the canopies of the encroacher *A. mellifera* tends to be enriched due to the presence of N-fixing biological soil crusts and sediment accumulation around bush stems (Dougill & Thomas, 2002; 2004; Hagos & Smit, 2005). This N-enriched sub-canopy zone potentially provides *A. mellifera* bushes with a competitive advantage over other species that can help explain its rapid and widespread encroachment over vast tracts of the Kalahari.

Most soil loss models (e.g. Biot, 1993; Abel, 1993) are of limited relevance to Kalahari soils, given their extremely limited topography. Wind erosion only becomes significant at very low vegetation cover (Wiggs *et al.* (1995) calculated a 14% vegetation cover threshold in south Kgalagadi District), and there is evidence that the majority of eroded soils are only redistributed locally (Dougill & Thomas, 2002).

However, the full extent of land degradation is impossible to accurately assess using localised soil or ecological monitoring. This is one reason for the research interest in assessing the extent of the problem using remote sensing methods.

2.6.4 Remote sensing

Remotely sensed data, especially using analysis of satellite imagery, has the potential to assess the degradation status of large areas. Although it has been used successfully to map certain kinds of land degradation, e.g. salinity, water-logging and deforestation (Lynden & Kuhlmann, 2002), its application in semi-arid rangelands is usually restricted to detecting vegetation cover and it is often difficult to determine the nature of ecological change, such as shifts from grass to bush dominance (Dougill & Trodd, 1999). There are a number of problems associated with the application of remote sensing techniques to degradation assessment in semi-arid environments. Background variability of soil colour and moisture can significantly distort results, limiting repeatability (Tanser & Palmer, 1999). As such, it is not possible to distinguish between bushes (that are often associated with land degradation in semi-arid rangelands) and trees (Trodd & Dougill, 1998). In addition, it is not possible to distinguish between palatable and unpalatable bushes, grasses or forbs (Pickup, 1996; Thomas, 1997). Given the shift towards unpalatable plants in degraded rangeland, information about vegetation cover is meaningless unless its palatability is also known.

Nevertheless, remote sensing research in the Kalahari has shown that vegetation has not recovered after drought in some of the most intensely grazed parts of Botswana (Ringrose *et al*., 1996). Also using remotely sensed data, Ringrose *et al*. (1999) showed "small reductions in high-quality rangeland, larger reductions in moderate-quality rangeland and increases in low-quality rangeland". Tanser & Palmer (1999) observed significantly lower standing biomass, lower basal cover, and more bare soil in intensively grazed communal rangeland in comparison to conservation land in the Kalahari.

The recent UK Government and UN funded "Botswana Rangeland Inventory and Management Project" developed a grazing capacity map based on Normalised Difference Vegetation Index readings[9], which is routinely used by policy-makers in the Ministry of Agriculture (Figure 2.11). However, it is not possible to infer degradation status from this map: with the exception of areas around the Makgadikgadi Pans, green biomass in this map broadly corresponds to a rainfall gradient (Figure 2.12), notably in the year before the images that were used to produce this map.

Remotely sensed data have been used to corroborate the bush encroachment claims of field ecologists. According to Moleele *et al*. (2002) 37 000 km^2 (6.4% of Botswana) was affected by bush encroachment in 1994 (Figure 2.13). They drew particular attention to the area around the Makgadikgadi Pans and the densely populated Eastern Hardveld. However, it is not possible to determine vegetation height using remote sensing, and so it is therefore difficult to distinguish between bush encroachment and natural tree cover. The high level of supposed bush encroachment in many National Parks (outlined in red on Figure 2.13) suggests that this map is in fact a map of woody vegetation cover, not specifically bush encroachment, and as such cannot be used to infer degradation status. Comparing a vegetation map of 1971 with remotely sensed images, Moleele *et al*. (2002) blamed "widespread bush encroachment" in the Eastern Hardveld on livestock grazing. Earlier work in this area had also shown heavy bush encroachment (Ringrose *et al*., 1999). However, the accuracy of bush cover change assessment in this work was

[9] NDVI is calculated from the visible and near-infrared light that is reflected by vegetation. Healthy vegetation absorbs most of the visible light, and reflects a large proportion of the near-infrared light that hits it. Sparse vegetation reflects more visible light and less near-infrared light. To quantify vegetation density NDVI subtracts visible radiation from near-infrared radiation and divides this by near-infrared radiation plus visible radiation.

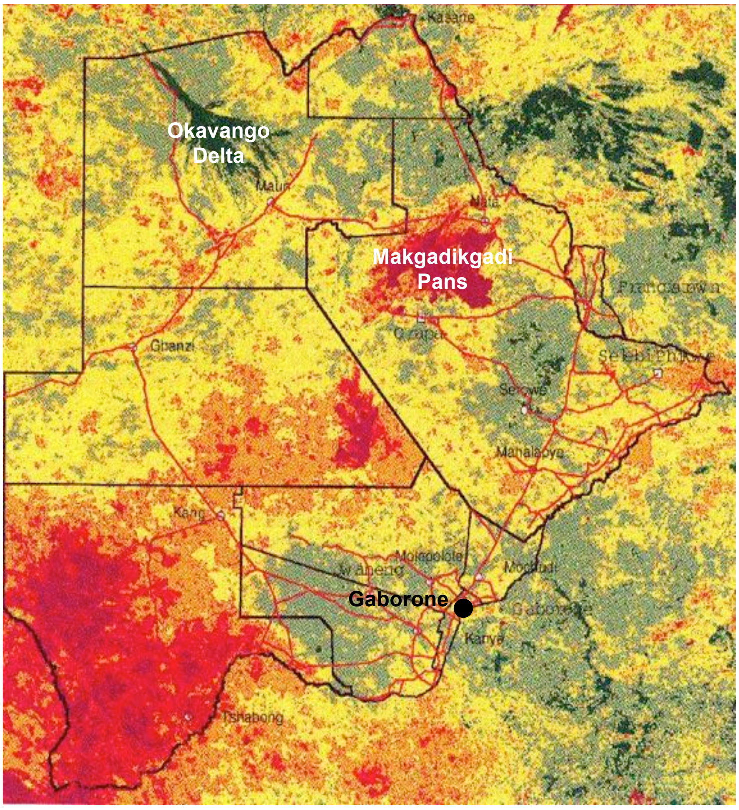

Figure 2.11 Grazing capacity map based on NDVI readings showing biomass in green (Botswana Rangeland Inventory and Monitoring Project, unpublished data)

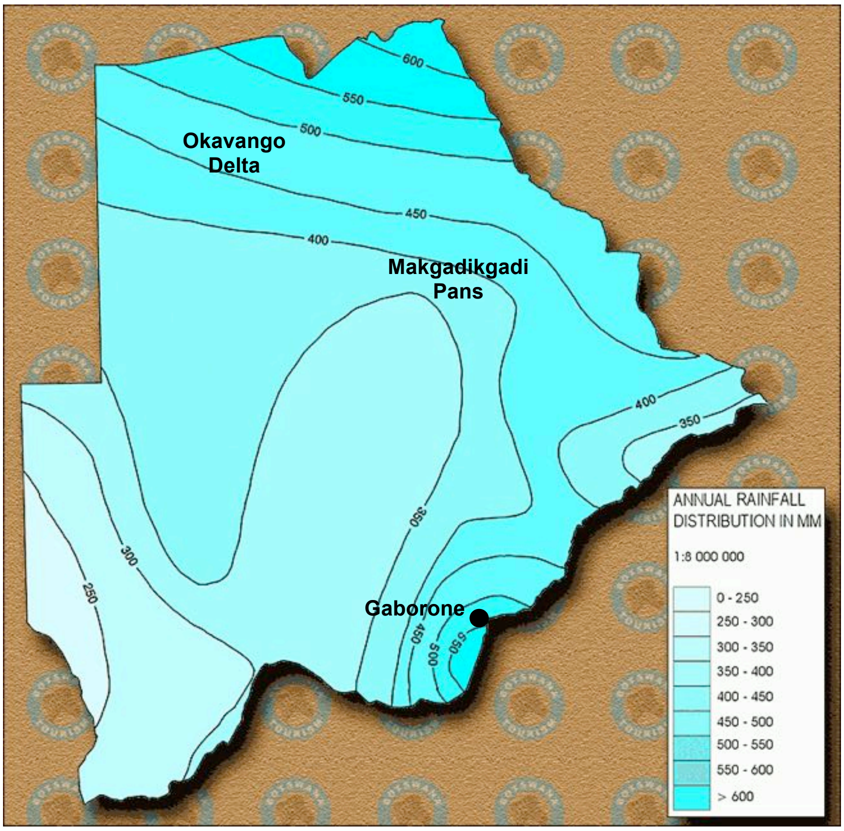

Figure 2.12 Mean annual rainfall and interannual variability in Botswana (Department of Tourism, 2001)

limited by the spatial resolution of the original vegetation map which divided Botswana into just 13 broad vegetation zones. These were described by dominant species assemblages, and did not indicate bush cover.

Despite being able to cover large areas quickly and cost-effectively, the technical difficulties of inferring land degradation from remotely sensed data have prevented this sort of approach being applied more widely for degradation assessment in semi-arid regions. Remote sensing is a hi-tech method that tends to be applied only by experts. However, it is possible to involve people more actively in degradation assessment.

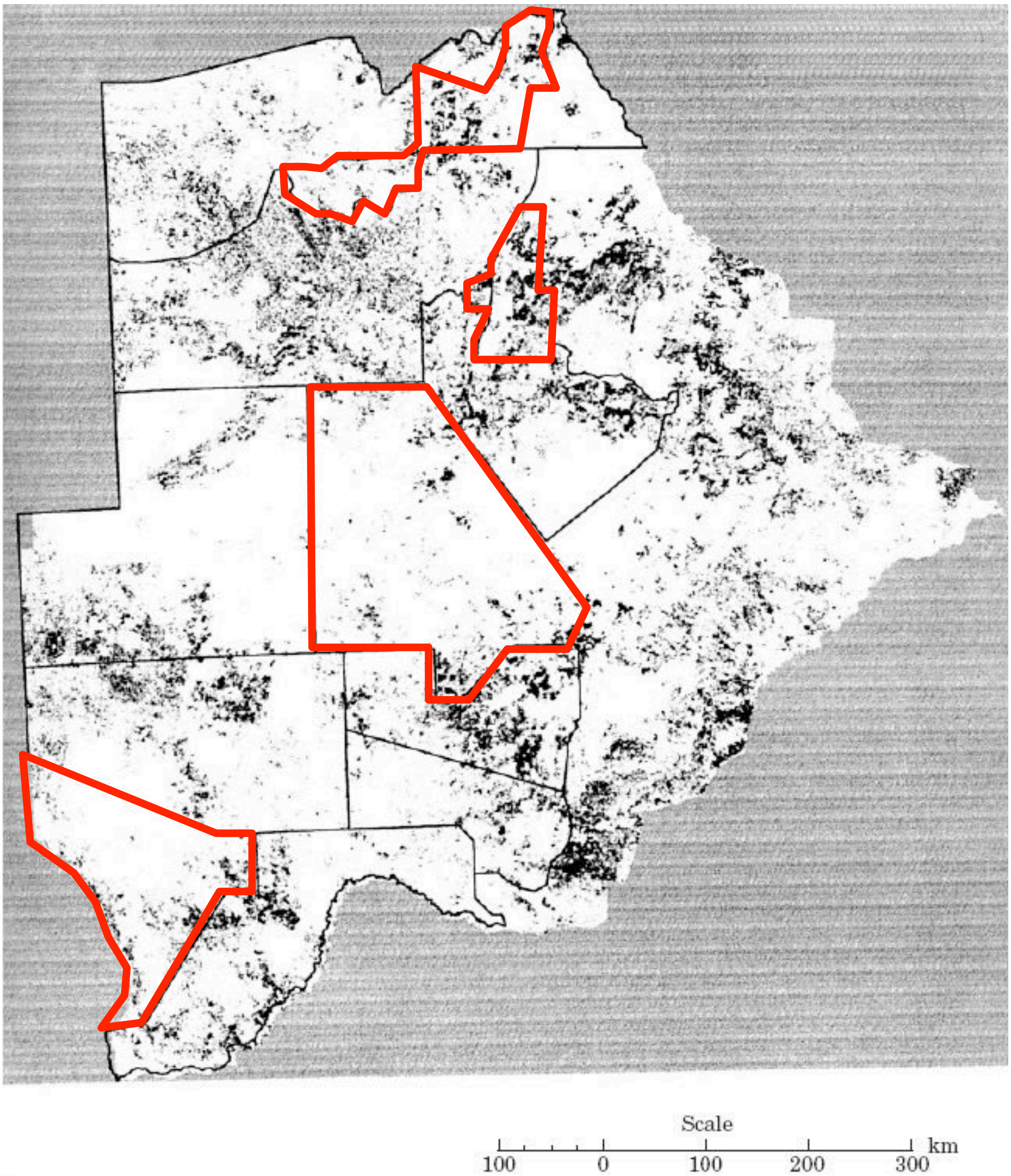

Figure 2.13 A map showing the extent of bush encroached areas in Botswana. Dark black represents the heavily affected areas; white represents those areas that have not yet experienced bush encroachment (Moleele *et al*., 2002). National Parks are outlined in red.

2.6.5 Land user perspectives

Critchley (2000) describes a lack of local participation as "one of the gravest omissions to date in land degradation and conservation research" (p5). According to Stocking (2000), local participation in land degradation assessment can provide: i) more realistic measurements of actual field level processes; ii) a more integrated view of land degradation than is typically presented by single disciplinary expert approaches; and iii) more practical suggestions for preventing or ameliorating land degradation that are more likely to be accepted by local land users.

However, very few assessments have involved local communities or investigated their perceptions of land degradation in Botswana, particularly prior to the start of this research in 2000. Although there has been an increase in multi-disciplinary research into land degradation in Botswana, a lack of integration between participatory and biophysical research has sometimes limited the role and value of local community perspectives in degradation assessment. For example, Chanda *et al.* (2003) inferred rangeland degradation around the Matsheng villages in north Kgalagadi from aerial photography and ecological sampling. Although information about historic and alternative livelihood options was gathered through interviews with local communities, their views did not inform the degradation assessment.

Thomas & Twyman (2004) found that land managers in southwest Botswana (a degradation hotspot according to expert opinion) regarded the bush encroacher, *Rhigozum trichotomum*, as an important forage resource and windbreak. This is contrary to views in South African literature that bush encroachment is a major problem in this area (van Rooyen, 1998). Thomas & Twyman's (2004) results emphasised the range of opportunistic adaptations available to land users experiencing environmental change. They argued that by combining land user interpretations with ecological sampling, it may be possible to develop a more holistic and meaningful interpretation of environmental change.

Similarly, Dalhlberg's (2000) participatory and ecological research in North East District around Francistown (another degradation hotspot) suggested that bush encroachment was not caused by overgrazing and was considered easily reversible by local people (see Figure 1.1 for location of Districts). She also found that contrary to evidence from the literature, firewood was not usually scarce in the area. She blamed the degraded perception of the area on observations and studies carried out during drought years.

Linked to this, Thomas *et al.* (2000) investigated land degradation with local communities on a number of TGLP ranches in Botswana. They found that communities tended to attribute fluctuations in hunting and gathering opportunities on ranches to drought. This contrasted with evidence from ecological sampling, ranch owners and local government officials that these opportunities were affected by differences in livestock management between ranches. Confusion between land degradation and drought, described by Thomas *et al.* (2000: 336) as "the product of historically grounded enviro-social relationships conditioned by climatic variability", has been found elsewhere in Botswana. Ringrose *et al.* (1996) provided evidence of land degradation indicators in the mid-Boteti area of Botswana, which local communities blamed on drought. However, both of these studies were conducted in drought years, which may have biased responses. In addition to this, each of Ringrose *et al.*'s (1996) land degradation indicators (increased wind erosion, loss of vegetation cover and lowered water table) may simply have been indicators of drought.

Given the lack of participatory research on land degradation assessment, and the apparent contradictions between community and biophysical perspectives, there is a clear need for greater involvement of local communities in land degradation assessment in Botswana. Indeed, Warren (2002: 457) concludes that:

> "The only valid assessment [of land degradation] is by those who may suffer the consequences."

This is one of the most significant research gaps in land degradation assessment in Botswana, and is addressed in the chapters that follow.

2.7 Discussion

Traditionally, environmental monitoring has been a top-down activity, conducted predominantly by researchers and government agencies, with little or no involvement from local communities. Such work has focussed on objective measurement by independent experts to meet the needs of funding-agencies and policy-makers, rather than local communities (Estrella & Gaventa, 2000). It has predominantly been conducted by external experts from predominantly natural science disciplines who often try to maintain distance from local communities in order to retain objectivity (Estrella & Gaventa, 2000). However, the dynamic, context-specific and value-laden nature of land degradation as a concept makes it hard to assess mechanistically. There can be no simple, universal system for assessing land degradation. Instead, land degradation assessment must recognise a multiplicity of perspectives, and cannot be judged in isolation from those who face its consequences (Warren, 2002).

GLASOD (Oldeman *et al.*, 1990; UNEP, 1997) is a classic example of a non-participatory, single-disciplinary approach to land degradation assessment that fails to capture the many complex and dynamic components of the problem. GLASOD's focus on soil degradation may explain why it only considered degradation to have occurred in the wetter, northern and eastern parts of Botswana (Figure 2.5). In contrast to GLASOD's assessment (that there was no degradation), the expert panel identified a strip along Botswana's semi-arid southwestern border with South Africa as experiencing moderate to severe degradation. The panel also reduced the extent of degradation around the Makgadikgadi Pans and Okavango Delta. Again, this is a consequence of GLASOD's narrow focus on soils: the GLASOD map shows the whole pan system as very severely degraded, when it is actually a natural feature which has never been productive. In contrast to the GLASOD map, the expert panel pointed to severe problems with livestock-induced degradation in the most easterly parts of the country (around Selibe-Pikwe) and elephant degradation in the north of Chobe National Park (Botswana's northern most tip). Both GLASOD and expert panel maps agreed that National Parks were largely non-degraded, a view supported by floristic surveys of the Kgalagadi Transfrontier National Park (van Rooyen, 1998). With this exception, the expert panel map that was developed in this research contrasts starkly with the GLASOD map. Although this could be used as evidence of the limited replicability of expert option-based degradation assessment, the results may also reflect the shift from soil-based expert assessment to an assessment based on a more comprehensive definition of land degradation.

The majority of degradation "hotspots" according to expert opinion in Figure 2.6 could be supported by evidence from ecology and remote sensing research (e.g.

Thomas *et al*., 2000; Thomas & Twyman, 2004; Thomas *et al*., 2000; Moleele & Perkins, 1998). However, the results of ecological and remote sensing research are not always clear-cut. In research funded by the UN Convention to Combat Desertification, Ringrose *et al*. (1996) found evidence of severe land degradation around the Makgadikgadi Pan system (Central District). However local communities countered that the researchers had simply measured the effects of drought around a natural pan system. Similarly, based on ecological and participatory research around Francistown, Dahlberg (2000: 560) claimed that "the area has been described as severely degraded, but the present results contradict previous descriptions and instead describe a temporally fluctuating, and spatially heterogeneous environment with few signs of deterioration."

Despite the recognised need to better integrate participatory methods into land degradation assessment (e.g. UNCCD, 1994; Thomas & Twyman, 2004), there has been very little local involvement in degradation assessment in Botswana, and little participatory research into land user perspectives of land degradation. Such research is complicated by the popular belief that degradation is caused by drought. Although it is a challenge to elicit land user perspectives about degradation, local knowledge should not be undervalued on the basis of popular misconception. Ringrose (personal communication, 2003) admits that local people in the Makgadikgadi Pans area might have been right when they told her she was measuring the effects of drought (Ringrose *et al*., 1996), since the degradation indicators they used were also drought indicators. Dalhlberg's (2000) research emphasises the need to interpret environmental change in the context of land user perspectives. She was able to ascertain that bush encroachment was not caused by overgrazing and was considered easily reversible, and that firewood not scarce. She blamed the degraded perception of the area on observations and studies carried out during drought years.

Many people in Botswana depend primarily on livestock for their livelihood, and cattle are a mainstay of Botswana's economy. As such, the primary concern of the Government and public in relation to land degradation is the possibility that livestock production will decline. There is evidence that this is happening in some areas (Figure 2.7), most notably in parts of the Eastern Hardveld. This area was identified as a degradation hotspot in both maps of expert opinion, and in ecological and remote sensing research by Moleele & Perkins (1998) and Moleele *et al*. (2002).

However, there was no evidence of declining livestock production throughout most of the country, including the area around the Makgadikgadi Pans that was considered to be degraded by both expert maps and research by Ringrose *et al*. (1996). Similarly, there had been a significant increase in livestock production in the southwest of Botswana (Kgalagadi District). Although this was consistent with the GLASOD map, much of this area was classified as moderately to severely degraded by the expert panel. Although Donaldson (1969) identified this as an area of severe bush encroachment, Thomas *et al*. (2000) found no direct evidence of degradation in this area, but made their ecological measurements in a ranch so it is unclear if this work represents conditions more geneally in this area. Although the area around the Matsheng villages (Figure 2.6) was not classified as a degradation hotspot, it was considered to be significantly more degraded than surrounding areas. This is supported by ecological and remote sensing research carried out around the Matsheng villages (Mphinyane, 1990; Skarpe, 1991; Chanda *et al*., 2003; Moleele & Mainah, 2003; Moleele & Chanda, 2003).

There may be explanations for the apparent contradiction between agricultural productivity data and other assessment methods in Kgalagadi District. de Queiroz

(1993) suggests that an increase in borehole provision in the District has facilitated an expansion of cattle herds whilst not significantly increasing stocking densities. In addition, Dougill *et al*. (1999) argue that there may still be sufficient forage diversity in terms of a bush and grass mosaic to continue supporting cattle production in bush encroached systems. Both Dougill *et al*. (1999) and de Queiroz (1993) agree, however, that continued expansion of the livestock sector through borehole provision in these areas is likely to lead to a level of land degradation that could threaten livestock production in the future.

These examples show how a combination of expert opinion, agricultural productivity, ecology and remote sensing can build up a picture of the degradation status of the land, and the current impact it is having on local people. Expert opinion and remote sensing can provide degradation assessments at coarse spatial scales and are replicable, rapid and cost-effective. However, to interpret an assessment in an appropriate environmental and socio-economic context, it is essential to supplement this information with participatory, ecological and economic data at different spatial scales. Given the reliance of most people on agriculture, land user perspectives in Botswana are closely linked to the productivity of the land. Experts from local communities may have very different perspectives to researchers and policy-makers, and, where possible, these opinions should be taken into account. Although agricultural productivity can be influenced by a host of factors (e.g. pests, disease and subsidy changes), consistency between productivity trends and land user perspectives in many parts of Botswana suggest that it can provide valuable additional information in the context of other data sources.

Ecological research can provide triangulation that can help determine degradation status. In addition to this, research into ecological processes has the capacity to determine if ecological changes are "effectively permanent" rather than short-term consequences of fire or rainfall variability. Given the cost and time associated with conducting such work, it may be possible to use broad-brush expert opinion and remote sensing work to prioritise potential degradation hotspots for more detailed participatory and ecological work. The results can then be easily compared with available agricultural productivity data.

But can these different sources of data collected at different spatial scales be integrated? Although expert opinion and remote sensing data could be easily integrated into a single map using a simple scoring system, the results would be biased towards the form of degradation measured by remote sensing (in the case of Botswana, bush encroached land). Ecological work is often integrated with remote sensing through the "ground truthing" process, where the interpretation of remotely sensed images is validated through ground-based ecology. This process can provide information about species assemblages across wide areas.

However, agricultural productivity data are rarely recorded at fine enough spatial scales to be meaningfully integrated with expert opinion or remotely sensed data. In addition, the qualitative nature of participatory data make it impossible to quantitatively integrate in such a map. Such data can however provide valuable triangulation with other data sources and provide a socio-economic context in which results from these sources can be interpreted. For this reason, a more qualitative process of combining information from different data sources through triangulation may be more appropriate (it may be possible to use a Geographical Information System to do this). Such an approach should provide a more accurate and reliable assessment of land degradation than the use of any single approach alone. In addition to this, by involving land users in degradation assessment, such a process has the potential to deliver results that are relevant to land management.

2.8 Conclusion

This chapter has reviewed land degradation processes in semi-arid rangelands and introduced the causes of land degradation in Botswana. This country was used as a case study to compare and critically evaluate outputs from five land degradation assessment methods. There were significant differences between the two maps based on expert opinion, with the exception of the degraded Eastern Hardveld. Ecological and remotely sensed data also supported the suggestion that this area is degraded. In particular, the expert map developed for this chapter identified degradation hotspots in the southwest of the country (Kgalagadi District), that were absent from GLASOD's expert map. These hotspots were supported by evidence from previous ecological and remote sensing research in the area, but contradicted by agricultural productivity data (probably explained by the increase in borehole provision in the District). Rising livestock populations may also account for the mixed land user perspectives in this area that have been documented in the literature.

Although both maps agreed that the Makgadikgadi Pans area was severely degraded, the new expert map reduced this area significantly. Although ecological and remote sensing research appears to support this designation, there are doubts over the relevance of the methods used: local land users blame environmental changes on drought rather than long-term degradation and there has been no long-term decline in livestock productivity observed in the area.

Given the interesting mix of outputs from degradation assessment methods in Kgalagadi District and the area around the Makgadikgadi Pans, and their very different biophysical and cultural settings, these "potential degradation hotspots" were selected for more detailed participatory and ecological research.

At present, land user involvement in land degradation assessment, globally and in Botswana, is both rare and passive. When it happens, there is usually a one-way transfer of information from land users to researchers, who rarely return to the community to communicate their findings in a way that is meaningful or useful. Communities are not granted insights into the findings of ecological or remote sensing work on their land. It may however be possible to facilitate active degradation monitoring and assessment by local communities through indicators that can be used easily, rapidly and cost-effectively by non-specialists to capture complex information about environmental change. By linking the results of indicator-based degradation monitoring to adaptive management options, it may also be possible to facilitate grass-roots action that can improve the environmental sustainability of local land management.

To achieve these goals, chapter 3 proposes a learning process that is then applied and tested with local communities in three of the degradation hotspots identified in this chapter. Drought bias accounts for discrepancies between land user and research perspectives on land degradation in many studies. Given the dynamic and drought-prone nature of semi-arid environments, reliable outputs can only be inferred from long-term land degradation assessment. For this reason, rather than attempting to infer the degradation status of the selected study areas, the learning process proposed in the next chapter is designed to provide local communities with the tools they need to do this.

3

A learning process for developing and applying sustainability indicators with local communities

Summary

Sustainability indicators based on local data provide a practical way to monitor local progress towards sustainable development. However, since there are many conflicting frameworks proposed to develop indicators, it is unclear how best to collect these data. The purpose of this chapter is to analyse the literature on developing and applying sustainability indicators at local scales to develop a learning process that will highlight best practice. First, two ideological paradigms are identified: one that is expert led and based largely in applied natural science and economics. The other is participatory and draws on applied social sciences. Second, this chapter assesses the methodological steps proposed in each paradigm to identify, select and measure indicators. Finally, the chapter concludes by proposing a learning process that integrates best practice for stakeholder-led sustainability assessments. By integrating approaches from different methodologies, the proposed process offers a holistic approach for measuring progress towards sustainable development. It emphasises the importance of participatory approaches for sustainability assessment at local scales, but then stresses the role of expert knowledge in indicator evaluation and dissemination. In this way it should be possible to develop quantitative and qualitative sustainability indicators that are both objective and easy for local communities to use.

3.1 Introduction

To help move towards a more sustainable society, we need tools that can both measure and facilitate progress towards a broad range of social, environmental and economic goals. As such, the selection and interpretation of "sustainability indicators"[10] has become an integral part of international and national policy since the publication of the United Nation's Commission on Environment and Development's (1992) Agenda 21. The academic and policy literature on sustainability indicators is now so prolific that King *et al*. (2000: 631) refer to it as "an industry on its own". However, it is increasingly claimed that indicators may provide few benefits to users (e.g. Carruthers & Tinning, 2003), and that, "…millions of dollars and much time…has been wasted on preparing national, state and local indicator reports that remain on the shelf gathering dust" (Innes & Booher, 1999: 2).

Communities are unlikely to invest in collecting data on sustainability indicators unless monitoring is linked to action that provides immediate and clear local benefits (Freebairn & King, 2003). Partly problems emerge because indicators are chosen by external experts who collect data without engaging local communities. This is contrary to a major theme in sustainable development literature that stresses the need to re-localize policy and development interventions. This requires local communities to participate in all stages of project planning and implementation, including the selection, collection and monitoring of indicators (e.g. Corbiere-Nicollier *et al.*, 2003). In this sense, indicators must not only be relevant to local people, but the methods used to collect, interpret and display data must be easily used by non-specialists. Although it is clear that indicators must have the capacity to accurately monitor local sustainability, indicators may also need to evolve over time as communities become engaged and circumstances change (Carruthers & Tinning, 2003). In this way sustainability indicators can go beyond simply measuring progress. They can enhance the overall understanding of environmental and social problems, facilitate community empowerment and help guide policy decisions and community development.

When it comes to accomplishing these goals, and developing a process that uses sustainability indicators to engage and empower local stakeholders, the user is presented with a bewildering array of methodological frameworks. While there is considerable overlap between many of the published frameworks there are also many contradictions. Although there are clear benefits to both bottom-up, community-led approaches and more top-down, expert-led approaches, this chapter argues that integrating these approaches will produce more accurate and relevant results than either on its own.

In light of this complexity, the goal of this chapter is to critically analyse existing frameworks for sustainability indicator development and application at the local level. After systematically evaluating the strengths and weaknesses of published methodological approaches, a learning process is proposed that tries to capitalise on their various strengths. To do this, the chapter will:

1. Identify different *methodological paradigms* proposed in the literature for developing and applying sustainability indicators at a local scale;

[10] Sustainability indicators are defined in this thesis as the collection of specific measurable characteristics of society that address social, economic and environmental quality.

2. Identify the generic *tasks* that each framework implicitly or explicitly proposes and qualitatively assess different *tools* that have been used to carry out each *task;* and
3. Synthesize the results into a *learning process* that integrates best practices.

The next chapter will describe the combination of methods that were used to apply this process in the land degradation "hotspots" identified in the previous chapter.

3.2 Methodological paradigms

The literature on sustainability indicators falls into two broad methodological paradigms (Bell & Morse, 2001): one that is expert-led and top-down and another that is community-based and bottom-up. The first finds its epistemological roots in scientific reductionism and uses explicitly quantitative indicators. This top-down approach is common in many fields, including landscape ecology, conservation biology, soil science, as well as economics. Expert-led approaches acknowledge the need for indicators to quantify the complexities of system dynamics, but do not necessarily emphasise the complex variety of resource user perspectives. The second paradigm is based on a bottom-up, participatory philosophy (Bell & Morse, 2001 refer to this as the "conversational" approach). It draws on the post-modern tradition within the social sciences, including cultural anthropology, social activism, adult education, development studies and social psychology. Research in this tradition emphasises the importance of understanding local context to set goals and establish priorities and that sustainability monitoring should be an on-going learning process for both communities and researchers (Freebairn & King, 2003). Exponents of this approach argue that to gain relevant and meaningful perspectives on local problems, it is necessary to actively involve social actors in the research process to stimulate social action or change (Pretty, 1995). Table 3.1 provides a representative summary of sustainability indicator literature and shows how proposed frameworks can be divided into top-down and bottom-up paradigms.

There are strengths and weaknesses in both approaches. Indicators that emerge from top-down approaches are generally collected rigorously, scrutinized by experts, and assessed for relevance using statistical tools. This process exposes trends (both between regions and over time) that might be missed by a more casual observation. However, this sort of approach may fail to engage (or at worst alienate) local communities. Indicators from the bottom-up school tend to be rooted in an understanding of local context, and are derived by systematically understanding local perceptions of the environment and society. This not only provides a good source of indicators, but also offers the opportunity to enhance community learning and understanding. However, there is a danger that indicators developed through participatory techniques alone may not have the capacity to accurately or reliably monitor sustainability. Whilst it is simple to view these two approaches as fundamentally different, there is increasing awareness and academic debate on the need to develop innovative hybrid methodologies to capture both knowledge repertoires (Batterbury *et al*., 1997; Nygren, 1999; Thomas & Twyman, 2004). As yet, there remains no consensus on how this integration of methods can be best achieved and the analysis in this chapter is designed to better inform these ongoing debates.

Table 3.1 Description of methodological frameworks for developing and applying sustainability indicators at a local scale

Selected Examples	Brief Description
Bottom-Up	
Soft Systems Analysis (Checkland, 1981)	Builds on systems thinking and experiential learning to develop indicators as part of a participatory learning process to enhance sustainability with stakeholders.
Sustainable Livelihoods Analysis (Scoones, 1998)	Develops indicators of livelihood sustainability that can monitor changes in natural, physical, human, social and financial capital based on entitlements theory.
Classification Hierarchy Framework (Bellows, 1995)	Identifies indicators by incrementally increasing the resolution of the system component being assessed, e.g. element = soil; property = productivity; descriptor = soil fertility; indicator = % organic matter.
The Natural Step (TNS, 2004)	Develops indicators to represent four conditions for a sustainable society to identify sustainability problems, visions and strategies.
Top-Down	
Panarchy Theory and Adaptive Management (Gunderson & Holling, 2002)	Based on a model that assesses how ecosystems respond to disturbance, the Panarchy framework suggests that key indicators fall into one of three categories: wealth, connectivity, diversity. Wealthy, connected and simple systems are most vulnerable to disturbances.
Orientation Theory (Bossel, 2001)	Develops indicators to represent system "orientators" (existence, effectiveness, freedom of action, security, adaptability, coexistence and psychological needs) to assess system viability and performance .
Pressure-State-Response (OECD, 1993)	Identifies environmental indicators based on human *pressures* on the environment, the environmental *states* this leads to and societal *responses* to change for a series of environmental themes. Later versions replaced pressure with *driving forces* (which can be both positive and negative, unlike pressures which are negative) (DSR) and included environmental *impacts* (DPSIR).
Framework for Evaluating Sustainable Land Management (Dumanski *et al*., 1991)	A systematic procedure for developing indicators and thresholds of sustainability to maintain environmental, economic, and social opportunities with present and future generations while maintaining and enhancing the quality of the land.
Wellbeing Assessment (Prescott-Allen, 2001)	Uses four indexes to measure human and ecosystem well-being: a human well-being index, an ecosystem well-being index, a combined ecosystem and human well-being index, and a fourth index quantifying the impact of improvements in human well-being on ecosystem health.
Thematic Indicator Development (e.g.	Identifies indicators in each of the following sectors or themes: environmental, economic, social and institutional, often subdividing these into policy issues.

3.3 Steps and tools

Notwithstanding epistemological differences, indicator frameworks from both set out to accomplish many of the same basic steps (Table 3.2). First, sustaina indicator frameworks must help those developing indicators to establish the h and environmental context that they are working in. Second, sustainability in frameworks provide guidance on how to set goals for sustainable developmen all sustainability indicator frameworks provide methods to choose the indicato will measure progress. Finally, in all frameworks data is collected and analys following discussion analyses key methodological issues for use of both top-d and/or bottom-up approaches in each of these steps and suggest best practice i relation to evidence from the literature.

3.3.1 Step 1: Establishing Context

There are two primary components to establishing context. The first is to ider stakeholders in order to understand the socio-economic, institutional and environmental context of the sustainability assessment. The second is to iden area or system that is relevant to the problem. Stakeholders are often identifie somewhat informal fashion. For example, researchers and policy-makers usin OECD's (1993) Pressure-State-Response (PSR) framework typically only ide stakeholders to understand the source of human pressures on the environment farmers using irrigation in dryland Australia (Hamblin, 1998) or people living watersheds (Bricker *et al*., 2003)). However, a growing body of participatory research emphasises the need to start any project by formally identifying stak and assessing connections between groups (e.g. Bell & Morse's (1999) "Syste Sustainability Analysis" applied recently by Bell & Morse (2004) in Malta).

There is considerable literature on how to identify stakeholders. For ex key informants can suggest other relevant stakeholders, using snowball-sampl techniques (Bryman, 2001). Stakeholders can also be identified using a strati sample (see: Rennie & Singh, 1996 for a wealth based sampling technique). H there are considerable limitations to both procedures, and research has shown social stratification may alienate some stakeholders (Rennie & Singh, 1996). Alternatively, a "Stakeholder Analysis" (Matikainen, 1994) can be used wher stakeholders are identified and described by researchers, assisted by local info This method is based on the notion of social networks, defined as a set of indi or groups who are connected to one another through socially meaningful relat (Prell, 2003). The purpose of this exercise is two-fold: first to understand the that different groups play in a community, and second to understand how diff groups interact with each other. Social networks can be mapped to explore relationships between stakeholder groups (Brass, 1992), and how these relatio affect the flow of information and resources (Wellman & Gulia, 1999). By do it is possible to target community opinion leaders at the start of a project, and strategies to engage community input, identify conflicts and common interests between stakeholders, and thus to ensure a representative sample of stakehold involved in all parts of the research.

Table 3.2 Two methodological paradigms for developing and applying sustainability indicators at local scales and how each approach approaches four basic steps

Methodo-logical Paradigm	Step 1: Establish context	Step 2: Establish sustainability goals & strategies	Step 3: Identify, evaluate & select indicators	Step 4: Collect data to monitor progress
Top-Down	Typically land use or environmental system boundaries define the context in which indicators are developed, such as a watershed or agricultural system	Natural scientists identify key ecological conditions that they feel must be maintained to ensure system integrity	Based on expert knowledge, researchers identify indicators that are widely accepted in the scientific community and select the most appropriate indicators using a list of pre-set evaluation criteria	Indicators are used by experts to collect quantitative data which they analyse to monitor environmental change
Bottom-Up	Context is established through local community consultation that identifies strengths, weaknesses, opportunities and threats for specific systems	Multi-stakeholder processes to identify sometimes competing visions, end-state goals and scenarios for sustainability	Communities identify potential indicators, evaluate them against their own (potentially weighted) criteria and select indicators they can use	Indicators are used by communities to collect quantitative or qualitative data that they can analyse to monitor progress towards their sustainability goals

The second part of establishing context is to identify the specific area or system that is relevant to a problem. Researchers and/or policy-makers often define the system in a top-down manner according to land use or ecological system boundaries. For example, "Orientation Theory" helps researchers develop a conceptual understanding of relevant systems by identifying a hierarchy of systems, sub-systems and supra-systems and describing the relationships between "affected" and "affecting" systems (Bossel, 1977, 1998). This approach views the studied system in the context of its wider "system environment", including links between different environmental systems (e.g. soil, hydrological and ecosystems) and between human (social, economic and political) and environmental systems. The system environment in a sustainability assessment therefore contains multiple sub-systems that affect and/or are affected by the system being studied. Since human systems can only survive and develop in an environment to which they are adapted, it is essential to understand the challenges of a particular system environment (i.e. the links between human and environmental systems affecting a given community) in order to determine the sustainability of the system being studied. Orientation Theory echoes Gunderson & Holling's (2002) hierarchy (or "Panarchy") of adaptive cycles nested one within the other, across space and time scales. Panarchy has been applied in a variety of contexts to account for the socio-economic impacts of ecological disturbances. For example, Fraser (2003) used this approach to understand why the 1845 outbreak of *Phythopthera infestans* caused a social collapse in Ireland. More generally, Panarchy uses ecological pathways (Fraser *et al*., 2003), or the connectivity of landscape units (Holling, 2001) to define relevant spatial boundaries. As yet there has been limited application of this approach to social systems (Fraser *et al*., in press).

The bottom-up paradigm is more explicit in the need to understand the historical and social context, and draws on the opinions of stakeholders themselves to define system boundaries. There are a variety of participatory tools to define and describe the system that is being assessed, and its context. One of the best known is Soft Systems Analysis that starts by expressing the "problem situation" with stakeholders (Checkland, 1981). Using informal and unstructured discussions on people's daily routines, as well as quantitative tools (structured questionnaires, daily logs and participant observation) this approach attempts to understand the scale, scope and nature of problems in the context of the community's organisational structure and the processes and transformations that occur within it. Tools that can be used in Soft Systems Analysis have considerable overlap with participatory tools that describe livelihood systems, such as transect walks, participatory mapping, activity calendars, oral histories, daily time use analysis and participatory video making (Chambers, 2002). Such approaches can be used to provide a longer-term view of how environmental or socio-economic changes affect the vulnerability of the system to external shocks; information that is particularly useful for developing sustainability indicators.

To summarise these two different ways of establishing context, the top-down approach tends to favour external experts who use pre-determined boundaries to determine the relevant system, and how that system interacts with other landscape units. The bottom-up approach makes fewer such assumptions, and stresses the need to begin the sustainability assessment process with a dialogue that defines stakeholders and system boundaries. The top-down approach is useful in that it provides expert guidance that will provide more comparable assessments of problems. This may be increasingly important in light of climate change models that suggest the poorest, remote communities may become more vulnerable to external threats that lie outside community understanding (IPCC, 2001). In contrast, the bottom-up approach provides a more contextualised understanding of local problems. Although this approach is better suited to participatory, community-based projects, a combination of both approaches is necessary to place the community in its relevant national, regional or global context and effectively identify external threats and shocks. The application of this and the next step with Kalahari pastoralists is described in chapter 5.

3.3.2 Step 2: Setting goals and strategies

Sustainability indicators are not only useful for measuring progress but also for identifying problems and setting sustainable development goals and strategies. The second step in many sustainability indicator frameworks is therefore to establish the goals that a project or community is working towards. Top-down approaches rarely include this step, as project goals are generally pre-determined by the agendas of researchers or government offices. In contrast, bottom-up frameworks such as Sustainable Livelihoods Analysis and Soft Systems Analysis provide considerable guidance on how to work with stakeholders to set locally relevant goals and targets.

Sustainable Livelihoods Analysis is a conceptual tool that can help researchers to interact with community members to identify problems, strengths and opportunities around which goals and strategies can be developed. Carney (1998) provides examples of the goals communities can identify through a livelihoods-based approach, such as more income, reduced vulnerability and improved food security. Using this approach, community members identify and describe the financial, natural, human, institutional and social capital assets they have access to, and methods have been extended to initiate discussions on how these assets have been used to overcome past problems (Hussein, 2002). Although not explicit in the framework, Sustainable

Livelihoods Analysis has been conducted in a historical context, using oral histories to track temporal changes in system assets (e.g. Barnett, 2001). Analogous to Orientation Theory's "system environment", Sustainable Livelihoods Analysis identifies external shocks, trends and seasonality that affect a livelihood system (its "vulnerability context") (Scoones, 1998; Carney, 1998). Despite being largely outside the control of actors within the livelihood system, Scoones (1998) and Carney (1998) argue that by understanding their system context, people can become more resilient and better able to capitalise on its positive aspects (see Figure 3.2). Having said this, it can be argued that so-called "empowerment" can be a mirage created to justify and support an established power dichotomy (Cooke & Kothari, 2001).

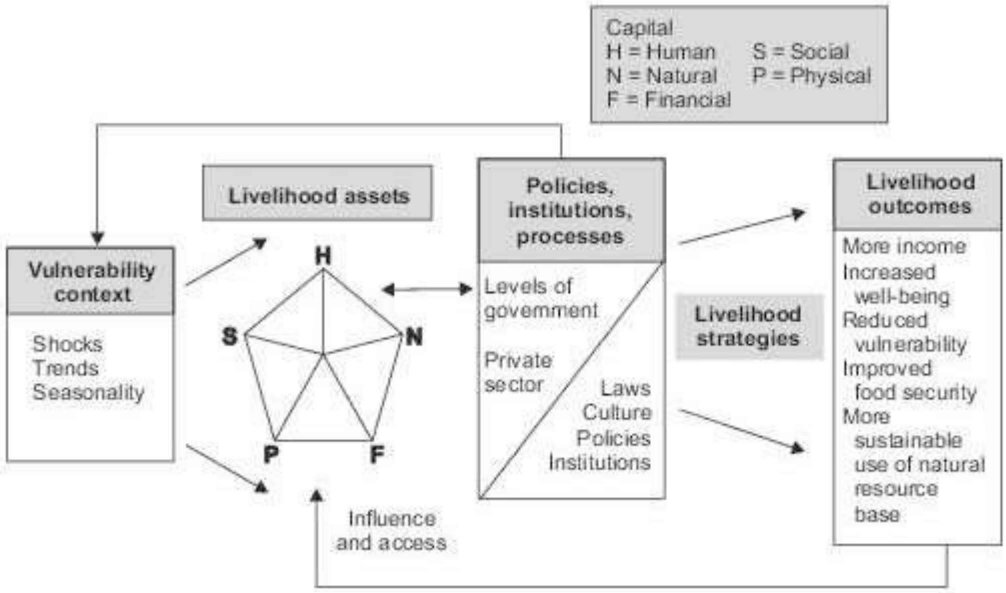

Figure 3.1 Sustainable Livelihoods Framework (source: Carney, 1998)

Soft Systems Analysis also provides a wide variety of participatory tools to support and structure thinking about complex organisational problems with stakeholders. This information is then used to identify goals and strategies, which are refined from the "desirable" to the "feasible" in focus group discussions. It recognises that shared understandings (which are essential for action) must be established, negotiated, argued and tested as part of a complex social process (Checkland, 2000). SSM uses the insight gained through this process to introduce changes and monitor the impacts of those actions, before starting the cycle again (Magnezewski *et al.*, in press).

A community's goal may not always be to reach a defined target; it may be simply to move in a particular direction. An alternative (or addition) to setting targets is, therefore, to establish baselines. In this way, it is possible to use sustainability indicators to determine the direction of change in relation to a particular reference condition. Targets may take longer to reach than anticipated. This kind of approach values progress rather than simply assessing whether a target has been reached or missed.

The establishment of goals, targets and baselines can also provide a way of identifying and resolving conflicts between stakeholders. For example, scenario analysis can bring stakeholders together to explore alternative future scenarios as a means of identifying synergies and resolving conflicts (Swarta *et al*., 2004). Scenario analysis is a flexible methodology that involves researchers developing a series of future scenarios based on community consultation, and then feeding these scenarios back to a range of stakeholder focus groups. This discussion can be enhanced by eliciting expert opinion about the likelihood of various scenarios occurring and by using statistical methods to assess past trends (NAS, 1999). Alternative scenarios may also be visualised using tools such as Geographic Information Systems or Virtual Reality Modelling (Lovett *et al*., 1999).

Decision Support Systems (DSS) can also be used to identify sustainability goals and strategies. DSSs can range from book-style manuals that provide practical, largely scientific-based advice on how to develop management plans (e.g. Milton *et al*., 1998) to complex software applications incorporating GIS technology (e.g. Giupponi *et al*., 2004). A sophisticated form of DSS whose use is increasingly being advocated is a Multi-Criteria Evaluation (MCE). MCE is a research tool designed to facilitate complex evaluation, prioritisation and decision-making by groups (Stagl, 2003). In an MCE exercise, goals and criteria are established and weighted using an empirical preference ranking. Some of these techniques have recently been used to evaluate sustainability indicators (e.g. Phillis & Andriantiatsaholiniaina, 2001; Ferrarini *et al*., 2001). Whatever tool is used, it remains important to establish pre-set criteria that stakeholders evaluate each scenario against (Sheppard & Meitner, 2003).

Although goals and strategies are often set by external agencies, practical research experience suggests it is possible to use bottom-up approaches to foster community support and involvement and to improve project goals and strategies. For example, NGOs in Thailand worked with communities to apply government policies to improve the urban environment (Fraser, 2002). By beginning with a series of public meetings, an educational workshop, and a planning process to create visions for the future, communities became increasingly supportive of the policy's goals, took ownership of the project and provided creative new ideas that resulted in a broadening of the project's scope. Decision Support Systems have also been seen to help resolve conflicts between competing stakeholders and help groups to evaluate and prioritise goals and strategies. They can link the results of sustainability indicator measurements to relevant strategies that will ensure goals are met (something that is attempted in this thesis and discussed in chapter 8). In this thesis, goals and strategies are established for Kalahari rangelands in Chapter 6.

3.3.3 Step 3: Identifying, evaluating and selecting indicators

The third step in developing and applying sustainability indicators at local scales is to select the specific indicators that can measure progress towards the goals that have been articulated. Broadly speaking, indicators need to meet at least two criteria. First, they must accurately and objectively measure progress towards sustainable development goals. Second, it must be easy for local users to apply them. These two broad categories can then be broken into a series of sub-criteria summarised in Table 3.3.

Table 3.3 Criteria to evaluate sustainability indicators

Objectivity Criteria	**Ease of Use Criteria**
Indicators should:	
Be accurate and bias free [1, 2]	Be easily measured [1, 2, 5, 6, 10]
Be reliable and consistent over space and time [2, 5, 6]	Make use of available data [2, 6]
Assess trends over time [1, 2, 6, 7]	Have social appeal and resonance [5, 6]
Provide early warning of detrimental change [2, 6-8]	Be cost effective to measure [2, 4-7]
Be representative of system variability [2, 4, 7]	Be rapid to measure [4, 5]
Provide timely information [1, 2, 5]	Be clear and unambiguous, easy to understand and interpret [5-7, 9]
Be scientifically robust and credible [6, 7]	Simplify complex phenomena and facilitate communication of information [3]
Be verifiable and replicable [1, 5]	Be limited in number [9]
Be relevant to the local system/environment [11]	Use existing data [7-9]
Sensitive to system stresses or the changes it is meant to indicate [7, 8]	Measure what is important to stakeholders [5]
Have a target level, baseline or threshold against which to measure them [7, 8]	Easily accessible to decision-makers [5]
	Be diverse to meet the requirements of different users [10]
	Be linked to practical action [1]
	Be developed by the end-users [5, 10]

(1) UNCCD, 1994; (2) Breckenridge *et al*., 1995; (3) Pieri *et al*., 1995; (4) Krugmann, 1996; (5) Abbot & Guijt, 1997; (6) Rubio & Bochet, 1998; (7) UK Government, 1999; (8) Zhen & Routray 2003; (9) UNCSD 2001; (10) Freebairn & King, 2003; (11) Mitchell *et al*., 1995

There is often a tension because although the scientifically rigorous indicators used in the top-down paradigm may be quite objective, they may also be difficult for local people to use. Therefore, objectivity may come at the expense of usability (Breckenridge *et al*., 1995; Deutsch *et al*., 2003). Similarly, while bottom-up indicators tend to be easy to use, they have been criticised for not being objective enough (Lingayah & Sommer, 2001; Freebairn & King, 2003). For example in Santiago, Chile, a pollution indicator that is a widely used by local people is the number of days that the peaks of the Andes are obscured by smog (Lingayah & Sommer, 2001). However, certain weather conditions also obscure the Andes and affect the amount of smog, and because this information is not recorded systematically, it is difficult to say anything objective about pollution trends. Another example of the trade-off between indicator objectivity and usability comes from the USA. The measurement of most water quality indicators requires specialist equipment and analysis that few non-specialists can use, and the results (e.g. dissolved organic carbon expressed in mg/l) have little meaning for local residents. Although much less accurate and potentially less objective, Senator Bernie Fowler's "Sneaker Index" mobilised widespread public involvement in water quality monitoring, and led to a significant reduction in the pollution of Chesapeake Bay, Maryland. Every year, local residents wade into the river with white shoes on and measure how deep they are when they lose sight of their feet. Their goal is to reach 57 inches (they reached 44 inches in 1997 and 42 inches in 2002). Despite its lack of precision, it is possible to detect a clear improving trend over the 17 years of monitoring (Chesapeake Bay, 2005). Although it was difficult to draw objective conclusions from this data at first, it is becoming easier as the time-series increases. A range of hydrological measurements are also made at the site, but much of the success of the monitoring programme has been attributed to the public awareness and support for water quality issues that was generated by the "sneaker index".

There are many quantitative tools for identifying indicators. These include analytical methods such as cluster analysis, de-trended correspondence analysis, canonical correspondence analysis and principal components analysis. These methods determine which indicators account for most of the observed change, and which are therefore likely to be the most powerful predictors of future change. However, while these tools help create objective indicators, a study by Andrews & Carroll (2001) illustrates how the technical challenges posed makes them inaccessible to those without advanced academic training. They used multivariate statistics to evaluate the performance of forty soil quality indicators and used the results to select a much smaller list of indicators that accounted for over 85% of the variability in soil quality. By correlating each indicator with sustainable management goals (e.g. net revenues, nutrient retention, reduced metal contamination) using multiple regression, they determined which were the most effective indicators of sustainable farm management. This lengthy research process produced excellent results, but is well beyond the means of most local communities. Indicators can alternatively be chosen more qualitatively, by reviewing expert knowledge and the peer-reviewed literature (e.g. Beckley *et al*., 2002), however, synthesising findings from scientific articles also requires significant training. Additionally, while it might be assumed that indicators selected from the scientific literature need little in the way of testing, Riley (2001) argues that too little research has been conducted into the statistical robustness of many widely accepted indicators.

Bottom-up frameworks depart from traditional scientific methods and suggest that local stakeholders should be the chief actors in choosing relevant indicators. However, this can create a number of challenges. For example, if local residents in two different areas choose different indicators it is difficult to compare sustainability between regions. To get around this problem, local sustainability assessment programmes often run alongside regional and/or national initiatives. For example, the "sneaker index" in Chesapeake Bay runs alongside a more comprehensive and technical assessment at the Watershed scale, which is in turn feeds into national Environmental Protection Agency monitoring. This is one way in which top-down and bottom-up approaches can work hand-in-hand to empower and inform local communities at the same time as delivering quantitative data to policy-makers and researchers.

Another challenge of stakeholder involvement is that if their goals, strategies or practice are not consistent with the principles of sustainable development (as defined in chapter 1), then participation may not enhance sustainability. Where stakeholder goals and practices are not sustainable, top-down approaches to sustainability assessment are likely to antagonise stakeholders. By involving such stakeholders in dialogue about sustainability goals, it may be possible to find ways to overcome differences and work together. For example, ongoing research in UK uplands (Reed *et al*., 2005) has shown that many stakeholder groups accused of unsustainable practices (e.g. farmers and game keepers) share the same general goal of sustaining the environment in as good condition as possible for future generations, but differ over their definition of "good condition" and the extent to which managed burning should be used to achieve this goal. Despite considerable common ground, the debate has been polarised by the top-down implementation of sustainability monitoring by Government agencies who have classified the majority of uplands in the study area as being in "unfavourable condition".

The generation of novel indicators through bottom-up approaches therefore necessitates objective validation. This is rarely done, partly due to the fact that stakeholder involvement can lead to a large number of potential indicators, and partly because indicator validation requires technical scientific skills and long periods of time. So, we are faced with a conflict. There is the need to collect indicators that allow data to be systematically and objectively collected across time and in different regions. However, there is also the need to ground indicators in local problems and to empower local communities to choose indicators that are locally meaningful and useable. Although this may seem like an insurmountable divide, preliminary evidence suggests that this can be bridged. In regions where expert and community selected indicators have been compared, it seems that there is a great deal of overlap between expert led and community approaches (e.g. Stocking & Murnaghan, 2001).

In addition to being objective and usable, indicators need to be holistic, covering environmental, social, economic and institutional aspects of sustainability. A number of indicator categories (or themes) have been devised to ensure that those who select indicators fully represent each of these dimensions. Although environmental, economic and social themes are commonly used (e.g. Herrera-Ulloa *et al*., 2003; Ng & Hills, 2003), the capital assets from Sustainable Livelihoods Analysis provide one of most comprehensive theoretical frameworks for classifying indicators. Bossel (1998) further sub-divides these capital assets into nine "orientors", suggesting that indicators should represent each of the factors essential for sustainable development in human systems (reproduction, psychological needs and responsibility) and natural systems (existence, effectiveness, freedom of action, security, adaptability, coexistence). This approach is one of the most holistic and rationalised frameworks for developing sustainability indicators. However, while Bossel's orientors are a useful guide for selecting appropriate indicators, it may not adequately reflect perceived local needs and objectives. Also, an apparently rigid framework such as this, even if well-intended to aid progress to a goal, can be taken as a 'given' and not questioned by those involved. Their 'task' then becomes how to fit indicators into the categories rather than consider the categories themselves as mutable and open to question. "Learning" is not just about the imbibing of valued knowledge from an expert – it is also about being able to question and reason for oneself (Reed *et al*., in press). In contrast, the widely used Pressure-State-Response (OECD, 1993) framework is only able to monitor *environmental* change effectively and is unable to capture information about complex causal relationships and system behaviour (Kelly, 1998). In addition, the terminology can be confusing for non-technical users (UK Government, 1999), and it has tended to be applied in a rigid fashion (Morse, 2004).

Although bottom-up approaches are capable of generating long and comprehensive lists of sustainability indicators, the process can be time-consuming and complicated, and can produce more indicators than can be practically applied. For example, participatory research to develop sustainability indicators with forest stakeholder groups in British Columbia led to a list of 141 indicators. Sustainability assessment using these indicators took significantly longer than had originally been expected. The final report was submitted almost a year late, leading to a project overspend. This, combined with unwieldy data tables and skewed results meant that by the time work on the assessment was complete, reduced the utility of the assessment (Fraser *et al*., in press).

Eliciting active involvement and representation of stakeholders in indicator development can also sometimes be problematic. For example, the development of sustainability indicators for Guernsey was envisaged to involve local community members, in an open and transparent process designed to monitor and help steer the Island's policy planning process (Fraser *et al*., in press). Initially, a lack of enthusiasm frustrated this process and the government decided to move ahead by tasking experts, including members of its own civil service, to generate the preliminary sustainability indicators. From this preliminary iteration, this list has evolved incrementally, slowly involving an increasing number of stakeholders. In this way, although the process was instigated in a top-down fashion, developing and collecting these indicators created a platform through which a wide range of people could express their concerns. It might have been possible to avoid the initial participation difficulties in Guernsey by objectively identifying relevant stakeholders at the outset, and involving them in setting goals and strategies for sustainability monitoring (Steps 1 and 2 described above).

In summary, top-down frameworks have relied on experts to identify indicators while bottom-up approaches emphasise local knowledge and dialogue to generate indicators. Each approach has its merits but clear frameworks are required to enable better integration. The divide between these two ideological approaches can be bridged, and evidence from the literature suggests that by working together, community members and scientists can develop locally relevant, objective and easy-to-collect indicators at a range of scales. This is attempted with Kalahari pastoralists in chapter 7.

3.3.4 Step 4: Indicator application by communities

The final step is to collect data that can be used by communities to monitor any changes in sustainability that emerge over time. In the top-down paradigm, indicators tend to be monitored by researchers. Local communities are sometimes involved, but often only as data gatherers (Holt-Giménez, 2002). In contrast, bottom-up frameworks as well as international environmental agreements such as the UNCCD (1994) emphasise the active involvement of local communities in monitoring. This can be valuable and evidence suggests that community involvement can raise awareness of local values, issues and concerns, improve community response and enhance the local capacity to monitor progress, voice opinions and engage in debate (Legowski, 2000; Fraser, 2002). By developing indicators with stakeholders, monitoring activities can make use of people's existing capabilities. However, monitoring capacity may often have to be built in the community through identification of livelihood experts who can share their knowledge and practice more widely.

One often-contentious way of helping community members to monitor changes over time is to use pre-determined thresholds for certain indicators. If the indicator goes above or below one of these thresholds (e.g. Palmer Drought Index falls below -3.0), then a remedial action is triggered (e.g. sell or move cattle). However, there are significant challenges in determining these sorts of thresholds as it is difficult to generalize from one region to another (Riley, 2001). As a result, in bottom-up frameworks, targets and baselines are commonly used instead of thresholds (Bell & Morse, 2004).

Another contentious issue in monitoring indicators is how to report the final results. There is considerable debate about whether or not to aggregate data into easy-to-communicate indices or to simply present data in tabular form, drawing attention to key indicators. For South African rangelands Milton *et al.* (1998) developed sustainability scorecards for a range of indicators (such as biological soil crust cover and erosion features) that were totalled to give a single rangeland health score of sustainability. By comparing scores to reference ranges, farmers were then guided to a range of generalised management recommendations. Single indices like this remain popular, given their capacity to communicate information rapidly and powerfully to a wide public. However, they are difficult to defend philosophically, practically and statistically (Riley, 2001). They hide potentially valuable information that could provide guidance on action to enhance sustainability or solve problems. For example, field-testing Milton *et al.'s* (1998) score card of dryland degradation, showed that scoring was highly variable between farmers (S. Milton, personal communication, 2003) with the latest edition of the field guide acknowledging this subjectivity and providing an alternative more objective but less user-friendly assessment method (Esler *et al.*, in press).

Various methods have been used to aggregate data. Indicator scores can be simply added together but it is unlikely that all indicators are of equal importance. One way of addressing this is to give indicators different weights. However this is often difficult to justify, and changing weights can significantly alter overall scores (Morse & Fraser, in press). Multi-Criteria Evaluation can be used to assign weights to indicators (Ferrarini *et al.*, 2001). Although this provides a theoretical justification for weightings, the results may not always be replicable. An alternative to aggregating indicators is to select a core set of indicators from a larger list of supplementary indicators (often referred to as "headline" indicators). It is also possible to report results visually rather than numerically. This avoids the problem of aggregating data into single indices, and is often easier to communicate than headline tables:

> "Diagrams and images are able to show relationships and linkages, which written words often fail to convey, and they highlight the very soul of sustainability—its vibrant embracing of multi-disciplinarity, richness and diversity in perspective."
>
> (Bell & Morse, 2005: 37)

One approach is to plot sustainability indicators along standardised axes, representing different categories or dimensions of sustainability. Polygons can be created by joining the points on each axis. Examples include sustainability polygons (Herweg *et al.*, 1998), sustainability AMEOBAs (Ten Brink *et al.*, 1991), sustainability webs (Bockstaller *et al.*, 1997), kite diagrams (Garcia, 1997), sustainable livelihood asset pentagons (Scoones, 1998) and the sustainability barometer (Prescott-Allen, 2001). Although it is not possible to use such approaches in a highly quantitative manner, they can articulate the complexities and multiple dimensions of sustainability assessment.

In summary, the application of sustainability indicators in top-down frameworks tends to use more quantitative tools that may require expert training and/or equipment. The results tend to be quantitative, often evaluating results against pre-determined thresholds, sometimes in addition to baselines and targets. This approach suits the desire of policy-makers for quantifiable data to measure progress towards specified goals. Although bottom-up frameworks can provide quantitative data, they usually provide more qualitative information. The focus of indicator application may be as much about community learning, dialogue, co-operation and the diffusion of knowledge as it is about quantifiable sustainability monitoring. Indeed, Innes & Booher (1999) argue that indicators often have more influence while they are being developed than they do once they are implemented. Bell & Morse (2001) confirm this from their experience and argue that more qualitative indicators developed through local participation are more likely to achieve widespread uptake than the more quantitative, expert-driven indicators.

3.4 Why combine methods?

There are two main sources of knowledge that local communities can draw upon if they are to monitor sustainability and respond appropriately to the results they obtain. First, there is the knowledge of researchers from a wide range of social and natural science disciplines and epistemological backgrounds. Second, there is a wealth of knowledge that has been accumulated by local communities through informal experimentation, innovation and (often generations of) experience. However, the value of this knowledge is often limited by a lack of learning and meaningful interaction from people within and between these two spheres. Learning and interaction between communities may be limited by the geographical extent and exclusivity of their social networks (in groups that have diverse and often conflicting interests or that have traditionally been relatively isolated). Learning and interaction between researchers has frequently been limited by the inability to cross disciplinary boundaries. Although the value of local knowledge has been increasingly recognised by the research community, there are few examples of meaningful interaction leading to *two-way* learning between stakeholders and researchers. Only by integrating and harnessing knowledge from *within* and *between* these spheres can communities fully realise their capacity to monitor and respond to sustainability challenges.

Significant steps are being made towards this goal by many in the research community. The burgeoning of sustainability research after the Rio Conference (UNCED, 1992) has increasingly required researchers to cross disciplinary boundaries. These interdisciplinary demands have led many researchers to combine qualitative and quantitative methods (Holland & Campbell, 2005). Although this has implied a movement between epistemologies to some commentators (e.g. Halfpenny, 1979), methods need not necessarily correspond to epistemology (Brannan, 1992; Holland & Campbell, 2005). Choice of method is rarely made on the basis of epistemology alone; method must also be chosen to suit the hypotheses and theories being tested and is often influenced by pragmatic considerations such as availability of time and resources. Theoretically, the interface between qualitative and quantitative methods can be viewed either as a *combination* of different approaches tailored to distinct components of the research cycle, or as an *integration* of different approaches to the same component of the research cycle (triangulation) (Brannen, 1992). Following the combined methods approach, research cycles typically start by defining problems and research questions, and formulating hypotheses and theories through qualitative research. Relevant qualitative and quantitative methods are then chosen to test hypotheses and refine theories (Huysamen, 1997). Following the integrated methods approach, each component of the research cycle is triangulated, using data from different sources and disciplines, and using a range of different methods, investigators and theories (Denzin, 1970). Results may not always be complementary, but the differences between the outputs of different methods, investigators and theories may lead to the formulation of new and better theories. Integrationists claim that triangulation offers an opportunity to enhance the validity of conclusions drawn from their data (e.g. Halfpenny, 1979). However, post-modernists claim that the data are products of the methods that created them, and is hence incommensurable. Instead, different methods may be usefully applied to explore different aspects of a research question, adding breadth and depth to the analysis (Fielding & Fielding, 1986).

Whether qualitative and quantitative approaches are integrated or combined, the benefits of eliciting multiple perspectives are evident. In order to gain relevant and meaningful perspectives it is necessary to actively involve relevant social actors in the research process. This is particularly important if the objectives of the research are to stimulate social action or change, as:

> "No change can be affected without the full involvement of all stakeholders and the adequate representation of their views and perspectives."
>
> (Pretty, 1995: 1251)

Local knowledge of sustainability indicators is frequently overlooked by researchers who consider it to be insufficiently robust or quantitative. However, the validity of many high-profile sustainability assessments conducted by researchers using "scientifically proven" indicators has also been called into question. For example, Lamprey (1975) monitored a single indicator (desert margins) in a wet and a dry year and concluded that the Sahara was expanding by 5.5 km per year (extrapolated by UNEP (1987) to suggest that "in less than 200 years, at the current rate of desertification, there will not be a single hectare of fully productive land on earth"). Remote sensing studies later showed that desert margins shift dramatically in response to rainfall variability (Hellden, 1984; 1988): a fact that local communities would have known at the time of Lamprey's study.

The value of local knowledge is increasingly being recognised by researchers, but there remain important ways in which it can be augmented by the skills of the external experts. Although qualitative indicators developed through bottom-up research can promote community learning and action (e.g. the "sneaker" index), it is not always possible to guarantee the accuracy, reliability or sensitivity of indicators. For this reason, monitoring results may not be as useful as they could be, or they could even be misleading. By empirically testing indicators developed through participatory research, it is possible to retain community ownership of indicators, whilst improving accuracy, reliability and sensitivity. It may also be possible to develop quantitative thresholds that can improve the usefulness of sustainability indicators. By combining quantitative and qualitative approaches in this way, it is possible to enhance learning by both community members and researchers. If presented in a manner that is accessible to community members, empirical results can help people better understand the indicators they have proposed, and the multiple dimensions of sustainability. By listening to community reactions to these results, researchers can learn more about the indicators they have tested.

Research dissemination at wider spatial scales can facilitate knowledge sharing between communities and researchers in comparable social, economic and environmental contexts. This is particularly relevant under conditions of rapid environmental change, where local knowledge may not be able to guide community adaptability. For example, within the Kalahari although the Basarwa (or "bushmen") are ideally placed to observe the environmental changes wrought by climate change, it is unclear how their knowledge of the ecosystem (e.g. on wildlife migrations, seasonal plant locations and traditional hunting routes) will be helpful if these conditions change rapidly. In this situation, local knowledge will need to be augmented by perspectives from researchers who can apply insights on how to anticipate and best manage new environmental conditions. Therefore, although there are clear benefits to both bottom-up and top-down approaches to sustainability monitoring, integration of these approaches will produce more accurate and relevant results.

This chapter has highlighted the need to embed sustainability indicators in a comprehensive learning process to ensure monitoring contributes meaningfully to local sustainable development. To do this effectively requires active participation by stakeholders to identify relevant sustainability problems, goals and strategies in the context of a defined local system. This suggests a shift from a narrow focus on environmental sustainability indicators towards a more holistic sustainability assessment across environmental, social and economic systems. Only with meaningful participation and discussion around these themes, can measurement be translated into empowerment and action. While bottom-up methodological frameworks have much to offer, it is also necessary to draw on conceptual and methodological insights from top-down approaches.

As such, initial attempts have been made to integrate methods in other published frameworks reviewed in this chapter. For example, in their mutual vulnerability framework, Fraser *et al*. (2003) tried to fuse social and ecological data into a single framework to assess vulnerability to environmental change. This was done by combining environmental resilience indicators, drawn from Panarchy theory (Gunderson & Holling, 2002), with social resilience indicators that were generated through the use of livelihood entitlements. Similarly, Orientation Theory comes from applied ecological roots, but uses capital assets from Sustainable Livelihoods Analysis in an explicitly participatory framework (Bossel, 2001). The next section attempts to go beyond these analyses to develop a learning process integrates best practice from a wide range of bottom-up and top-down approaches.

3.5 Learning process for sustainability indicator development & application

There is a growing recognition that individual and organisational learning have an important role to play in sustainability research and development projects (Bell & Morse, 2005), and learning is increasingly being emphasised as an essential step beyond public participation in environmental assessment (e.g. Bosch *et al*., 2003; Fitzpatrick & Sinclair, 2003; McDaniels & Gregory, 2004). Following the review of approaches presented in this chapter, this section combines the strengths of existing frameworks into a learning process applicable to a range of local situations by a range of actors (Figure 3.2). Following a social learning[11] approach (Bandura, 1977; Pahl-Wostl & Hare, 2004), the proposed process is designed to stimulate change of individuals, organisations and/or systems through an ongoing process of learning and negotiation that emphasises communication and perspective sharing to develop

[11] It should be noted "social learning" is used in two quite different ways in the literature: i) learning by individuals that takes place in social settings and/or is socially conditioned; and ii) learning by social groups or systems (Stagl, 2003). The learning process described in this chapter can be used to facilitate learning by individuals and/or groups.

adaptive strategies in response to changing social and environmental conditions. Based on Immanuel Kant's (1724-1804) constructivist conception of learning as a process of individual transformation, social learning includes approaches such as critical pedagogy (Freire & Ramos, 1970), experiential learning (Kolb, 1984), transformational learning (Alexander, 1999; Diduck, 1999), action research (Lewin, 1946; Reason & Bradbury, 2001), and collaborative learning (Daniels & Walker, 1996).

The learning process proposed in this section describes the order in which different tasks fit into an iterative sustainability assessment cycle. It does not prescribe methods or tools for the tasks that it proposes. Instead, it emphasises the need for methodological flexibility and triangulation, adapting a diverse sustainability toolkit to dynamic and heterogeneous local conditions. The process should be useful for anyone engaged in local-scale sustainability assessment, from citizens groups, community projects and local planning authorities to NGOs, businesses, researchers and statutory bodies (referred to as "practitioners" from here on).

Following the proposed learning process (1)[12], practitioners must first identify system boundaries and invite relevant stakeholders to take part in the sustainability assessment. There are a variety of techniques that can be used to achieve this, which vary in their degree of stakeholder involvement, but that need to be based on a rigorous stakeholder analysis to provide the relevant context and system boundaries. Each of the following steps should then be carried out with active involvement from local stakeholders. The conceptual model of the system can be expanded to describe its wider context, historically and in relation to other linked systems (2). Although it may not be necessary to deal with this in detail, it can be important to identify opportunities, causes of existing system problems and the likelihood of future shocks, and thus to predict constraints and effects of proposed strategies.

Based on this context, goals can be established to help stakeholders move towards a more sustainable future (3). Next, practitioners need to work with local users to develop strategies that can be used to reach these goals (4). Tools like Multi-Criteria Evaluation can be used to evaluate and prioritise these goals and establish specific strategies for sustainable management. Decision support systems can also link the results of sustainability indicator measurements to relevant strategies to ensure goals are met. In this way, the sustainability assessment process can foster the collaboration that is necessary to achieve local empowerment.

Based on this foundation, it is then possible to develop sustainability indicators that can lead to meaningful action to stimulate sustainable development. Therefore, the fifth step is for the practitioner to identify potential indicators that can monitor progress towards sustainability goals (5). A variety of top-down classification schemes can be used to ensure indicators cover the breadth of relevant system components (for example, Pressure-State-Response). Although this step is often the domain of researchers and policy-makers, all relevant stakeholders must be included if locally relevant indicator lists are to be provided. Potential indicators must then be evaluated to select those that are most appropriate (indicated by the feedback loop between steps 5-8). There are a number of participatory tools, including focus group meetings and MCE that can facilitate the evaluation of indicators by local communities (6). The practitioner may also evaluate indicators using empirical or modelling techniques to ensure their accuracy, reliability and sensitivity (7). Depending on the results of this work, it may be necessary to refine potential

[12] The numbers in parentheses refer to tasks in Figure 3.2.

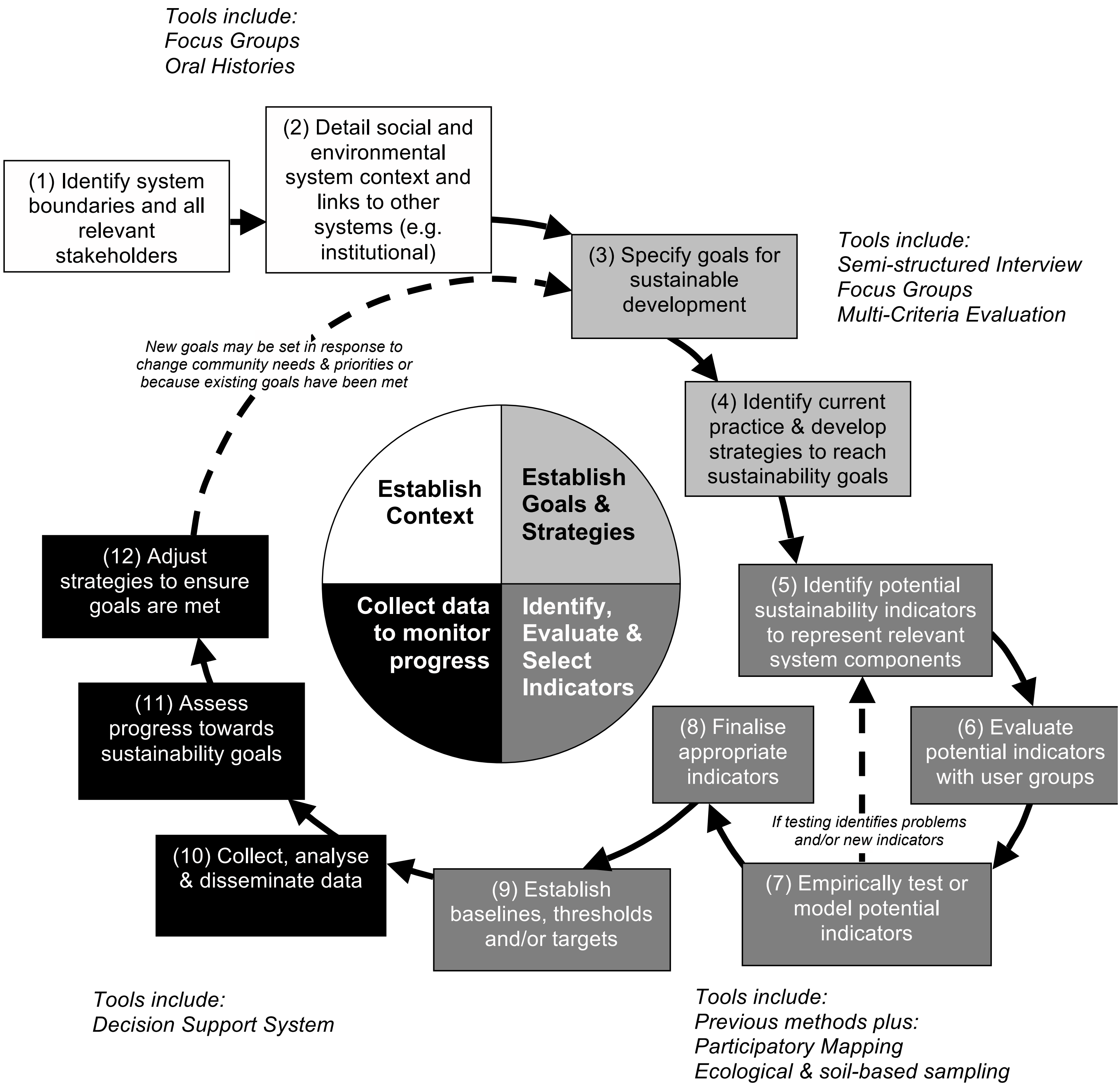

Figure 3.2 Learning process for sustainability indicator development and application (the methods used in this thesis are shown in italics around the outside of the figure)

indicators in light of this assessment (therefore, leading back to step five) to ensure that communities are fully involved in the final selection of indicators (8). At this point, it is also useful to establish baselines from which progress can be monitored (9). If it is also possible to collect information about thresholds over which problems may become critical or irreversible to further improve the value of monitoring data. Such thresholds are often difficult to identify due to the dynamic, interactive nature of transitions in managed ecosystems.

Data on these indicators must then be collected, analysed and disseminated (10) to assess progress towards sustainability goals (11). Although this data analysis is usually the domain of external experts, decision support systems can facilitate easy and rapid analysis and interpretation by local communities. If necessary, information collected from monitoring indicators can then be used to adjust strategies in order to ensure sustainability goals are met (12). As a result of this, new goals may be set. Alternatively goals may change in response to changing needs and priorities of the stakeholders that initially set them. For this reason, the sustainability process must be iterative. This is represented by the feedback loop between tasks (12) and (3).

By integrating approaches from so many different methodological frameworks, Figure 3.2 is able to build on the strengths of each and provide a more holistic approach for sustainability indicator development and application. Although this chapter emphasises the importance of bottom-up approaches for sustainability assessment at local scales, the learning process incorporates insights from top-down approaches. It shows that, despite little cross-fertilisation, there is a high degree of overlap between many of the published frameworks. By making these links, the chapter reveals the large choice of methodological and conceptual tools available for practitioners to develop and apply sustainability indicators in the context of local sustainability issues, goals and strategies. As a result, it is possible to choose a combination of qualitative and quantitative techniques that are relevant to diverse and changing local circumstances, and triangulate information using different methods in one integrated learning process. The process can be used in a variety of ways to help develop quantitative and qualitative sustainability indicators that are both objective and easy for a wide range of stakeholders to use as part of a wider sustainability assessment cycle.

3.6 Conclusion

This chapter has critically evaluated frameworks from two methodological paradigms for sustainability indicator development and application at local scales. Reflecting the emphasis on complex systems throughout the sustainable development literature, both paradigms have evolved towards an increasingly interdisciplinary and systems-based approach in recent years. This convergence provides a basis for integrating frameworks from different epistemological backgrounds. Seen in this light, the learning process proposed in this chapter is a modest next step towards a convergence between social and natural sciences in our pursuit of better human-environmental relations.

Application of such a learning process will not necessarily result in smooth environmental decision-making. Results from different stages may not always be complementary. Conflicts will emerge. But, by following such a process, it may be possible to identify more appropriate stakeholders, systems of interest, problems, goals and strategies, and thus formulate more relevant sustainability indicators. The proposed learning process suggests a flexible combination of qualitative and quantitative methods for different sustainability assessment tasks. In addition, given the wide range of tools available (and sufficient time and resources), each task can be triangulated using both quantitative and qualitative techniques.

There is obviously no single “optimal” way to follow the proposed learning process. Methods should be chosen to suit the research context, and may need to be adapted to suit different or changing local settings. The following chapter describes the combination of methods that were used to apply the process with pastoralist communities in the Kalahari, Botswana.

4

Applying the Learning Process: Research Design & Methods

Summary

This chapter describes the combination of methods that were used to apply and test the learning process described in the previous chapter with pastoralist communities in three study areas in the Kalahari, Botswana. It describes how context, goals and management strategies were established, how indicators were identified and evaluated, and how they will be used to collect data and monitor progress towards sustainability goals. The methods that were applied with communities in the first study area over a number of months were streamlined and applied over three weeks in each of two very different study areas to streamline and test the transferability of the learning process. This application emphasised the iterative nature of the learning process, testing and refining information from local communities through a combination of qualitative and quantitative techniques, and the interactive interpretation of results by both stakeholders and researchers.

4.1 Introduction

This chapter describes the combination of methods that were used to apply the learning process described in the previous chapter with pastoralist communities in three parts of the Kalahari, Botswana. The first section shows how study areas were selected. In the following sections, the methods that were used for each of the four steps from Figure 3.2 are described in turn.

4.2 Study Area Selection

Study areas for this research were selected to represent perceived land degradation "hotspots" identified qualitatively through interviews with a panel of international experts. The methods that were used to do this are described in chapter 2 (section 2.6.1). This provided a wide choice of potential study areas (Figure 2.6). In order to test the transferability of the approach, study areas were selected to represent very different biophysical (rainfall, soil and vegetation type) and cultural settings. However, given the wide choice of significantly different areas, the eventual selection was also based on the availability of logistical support from the Ministry of Agriculture and IVP, and interest from local communities. Study area characteristics were determined through a combination of discussions with researchers and policy-makers in the Ministry of Agriculture, and site reconnaissance visits.

Full site descriptions are provided in the next chapter, but key differences that were used during the study area selection process are provided in Table 4.1. The location of these sites is shown in Figure 2.6.

Table 4.1 Key differences between study areas, used during selection process

Site Characteristics	Study Area 1 (Tsabong-Werda)	Study Area 2 (Mid-Boteti)	Study Area 3 (Bokspits)
Average annual rainfall (mm) (Bhalotra, 1987)	315	372	150-200
Interannual rainfall variability (%) (Bhalotra, 1987)	45	35	>50
Soil type (FAO classification)	Arenosols	Calcisols and luvisols	Arenosols
Vegetation type (Weare & Yalala, 1971)	Southern Kalahari bush savanna	*Colophospermum mopane* woodland and pan grassland	Arid bush savanna
Ethnic composition	Batswana, Herero and Eurasian	Bakalanga, Bahurutshe, Bangwato, Bananjwa, Barotsi, Bayei, Nyadzwbye	Mixed race
Community interest	Community leaders and local extension workers expressed a strong desire to collaborate during reconnaissance visit	Communities actively involved in Indigenous Vegetation Project (IVP)	Communities actively involved in IVP
Logistical support provided by	South Kgalagadi Veterinary Services	IVP	IVP

For the first 10 months of fieldwork, research focussed on Study Area 1. The transferability of the approach was then tested through intensive 3 week assessments in two very different study areas. The UNDP/UNEP-funded Indigenous Vegetation Project (see chapter 1 for details) was already working in the second two study areas, so it was possible to build on existing relationships they had developed with local communities.

4.3 Step 1: Establishing Context

The system of interest was initially defined broadly as "degraded land systems" through discussion with policy-makers and researchers. The focus was then refined through discussions with local key informants in selected land degradation "hotspots" as "degraded rangeland systems". Rangeland stakeholders were then identified through discussions with key informants (Study Area 1) and focus groups[13] (three each in Study Area 2 (attended by 8, 5 and 10 people) and Study Area 3 (attended by 15, 12 and 17 people)) (see Figure 2.6 for Study Area locations). The recommended number of people per group is usually six to ten (MacIntosh, 1981), but some researchers have used up to fifteen people (e.g. Goss & Leinbach, 1996) or as few as four (e.g. Kitzinger, 1995). Focus groups are particularly useful to facilitate the expression and discussion of different perspectives on the use of management strategies, and facilitated learning between different stakeholders and between stakeholders and researchers (Morgan & Kreuger, 1993). Discussions were facilitated by the lead researcher (through interpretation), and efforts were made to encourage interaction and discussion between all participants. This was to avoid dominance by certain individuals and keep discussions focussed and was accomplished through a combination of open questions to stimulate discussion and probing questions to explore differences of opinions and obtain necessary detail. Neutral venues were selected for focus group meetings. Women felt uncomfortable speaking in "Kgotlas" (equivalent to a Town Hall), so this venue was quickly abandoned and two women-only focus groups were held to compensate for this (for more reflections on this, see section 9.3).

Potentially marginalised groups (e.g. women and "destitutes"[14]) 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. Wealth ranking (or "wellbeing grouping") is commonly used in participatory research to stratify and differentiate between stakeholders (Rennie & Singh, 1996).

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[13] "A group of individuals selected and assembled by researchers to discuss and comment on, from personal experience, the topic that is the subject of the research" (Powell *et al.*, 1996: 499).

[14] The Government of Botswana's National Policy on Destitutes provides food, toiletries, medical care and shelter to "an individual without assets; a person who is physically or mentally incapable of working due to old age or a handicap; a minor child or children whose parent(s) have died or deserted the family or are not supporting his family; or an individual who is rendered helpless due to a natural disaster or temporary hardship." (UNHCR, 2004: 55)

Following this approach, local indicators of poverty and wealth were identified by community members (e.g. number of livestock, tin roof, motor vehicle) from which wealth categories were agreed (e.g. rich, poor and intermediate). For example, 8 wealth indicators were identified in Struizendam: a rich family would be expected to have at least six of these indicators, and a poor family would be expected to have no more than two (intermediate families would have 3-5 indicators). A family in Struizendam would be considered rich if they owned over 200 smallstock and/or 30 cattle, and would be considered poor if they owned less than 25 smallstock and/or 3 cattle. In addition, a rich family might own a vehicle, own their own borehole, own a business and have a house with more than six rooms (Appendix 3).

There are some problems with wealth ranking. For example it is difficult to carry out in large communities containing many households (Davies, 1997) and it is often seen as intrusive by stakeholders (Rennie & Singh, 1996). To overcome these problems, instead of evaluating individual households in focus groups (which was considered both intrusive and impractical given the number of households), wealth categories and criteria were developed in focus groups and evaluated for each household at the time of interview. A running total was calculated for the number interviewed from each wealth category. Towards the end of interviewing, key informants helped identify households from wealth categories that were under-represented to supplement the sample.

Sustainable Livelihoods Analysis (Scoones, 1998) was used to establish natural, human, social, physical, financial and institutional context in each study area. This was achieved through semi-structured interviews[15] with 67, 40 and 53 people in Study Areas 1, 2 and 3 respectively (see Appendix 3 for interview check-list). Interviews continued until theoretical saturation was reached for indicators (i.e. no or very few new indicators were being elicited from successive interviews). Interviews were accompanied by a drive through rangeland to further discuss points of interest, when respondents had time to illustrate with examples from the field (Figure 4.1). This is an adaptation of the transect walk approach that has been widely applied in participatory research (e.g. Chambers, 2002), but is not practical at the kind of scales pastoralists work at in the Kalahari.

In addition, time-line discussions (Rennie & Singh, 1996) were used to examine dynamism in capital assets including: natural resources (e.g. rainfall variability and ecological changes), social systems (e.g. land tenure and access to information through social networks), physical infrastructure (e.g. transport and access to markets), human capital (e.g. labour availability and education) and access to financial capital (e.g. savings and credit). This involves drawing a line graph with time along the X-axis and the capital asset along the Y-axis. Time-lines were drawn by respondents in the sand or on paper immediately after answering questions about each type of capital asset. As trend lines were drawn, explanations were sought, focussing particularly on the effects of drought and factors determining the direction of the trend drawn. Where respondents struggled to conceptualise capital assets in an integrated form, they were asked to identify the most important components of each capital asset (e.g. rangeland condition for natural capital), and asked to draw time-lines for these components alone. Where respondents were unable to draw time-lines, questions were asked about the nature of change in each capital asset. The inclusion of time-lines addresses the perception that Sustainable Livelihoods Analyses have

[15] May (1991 cited in Thompson, 2000: 157) defines semi-structured interviews "as those organized around areas of particular interest, while still allowing considerable flexibility in scope and depth."

previously failed to capture the temporal dynamism and context of key assets (Ashley, 2000). This information was used to identify key livelihood constraints in Study Area 1, but given the amount of time that it took, was dropped in Study Areas 2 and 3 in an attempt to streamline the process.

Figure 4.1 Where relevant, semi-structured interviews were supplemented with visits to points of interest

Where possible, oral histories (Pretty, 1995; Rennie & Singh, 1996) were conducted with older members of the community to determine longer-term trends in capital assets at a community or landscape scale. The main difference between this and time-line discussions was the broader scope (e.g. including institutional change) and wider spatial scale of information collected during oral histories.

English and Setswana are the two official languages in Botswana, and interpretation was used where necessary from English to Setswana, Afrikaans and occasionally Herero. Interpretation was provided by staff from the Government of Botswana's Ministry of Agriculture who were seconded to this research. They were occasionally assisted with vocabulary by members of the local community. Extensive notes were taken during interviews.

In Study Areas 2 and 3, training materials (Reed & Dougill, 2003) were developed for local extension workers and interested members of the community, who accompanied and sometimes led interviews with the lead researcher (M. Reed). Community involvement in interviews had a number of key benefits and drawbacks. For example, by working with local people who understand and are committed to the objectives of the research, it is possible to build rapport and trust far more quickly and effectively with respondents. Their knowledge of the community can help verify the accuracy of information collected in interviews. They can assist in translation during interviews, which can be particularly useful for local plant names. However, the familiarity that helps build trust and rapport may compromise confidentiality. Although there was little evidence for this, it may be harder to gain the trust of some respondents who may fear that neighbours are prying. Community members and extension workers needed considerable help when leading interviews, which increased the length of a few interviews. Members of the community who contributed to the research in this way are referred to as "key informants" in this research. The results of this work are presented in Chapter 5.

4.4 Step 2: Establishing goals and strategies

The goals and management objectives of local land users were explored in semi-structured interviews after the Sustainable Livelihoods Analysis. Management strategies that could enable land users to attain their goals whilst protecting the land for use by future generations were elicited during the same interviews. Prompts were used to elicit strategies that could either prevent or ameliorate land degradation (see check-list in Appendix 3).

These strategies were then discussed and evaluated in a second round of focus groups. Two were conducted in Study Area 1 (attended by 5 and 15 people), and three each in Study Area 2 (attended by 3, 7 and 9 people) and Study Area 3 (attended by 14, 9 and 12 people) (a total of 8 meetings) (see Figure 2.6 for Study Area locations). In addition to strategies suggested in interviews, some strategies from the literature were also discussed. Although many strategies were rejected at these fora, some new strategies were proposed and many were further developed or combined to produce more effective and/or viable strategies. Due to the number and complexity of bush management strategies an additional focus group was held to discuss these with a community in the most bush encroached area (Draaihoek, Study Area 1, attended by 13 people). An additional focus group to discuss bush management strategies was also held with extension workers (attended by 5 people) from Study Areas 1 and 3. The results of this work are presented in chapter 6.

4.5 Step 3: Identifying, evaluating and selecting indicators

4.5.1 Participatory identification and evaluation of indicators

An essential first step in participatory indicator development is to find terms for both "indicator" and "sustainability" that people recognise (Abbot & Guijt, 1997). There are many academic definitions of indicators, but few of these are helpful for non-academics (Abbot & Guijt, 1997). For example, Bellows (1995) suggests the word "predictor". In a research project in Uganda, the word "signpost" was chosen since a signpost provides information that point to some reality but is not the reality itself (Rennie & Singh, 1996). These words were discussed with key informants, and the word "sign" (and its equivalent in local languages) was chosen in each study area.

In the absence of consensus over a precise operational definition and meaning of "sustainability" (e.g. Jacobs, 1995; Pezzey, 1997; Weersink *et al*., 2002), eliciting sustainability indicators from local communities is problematic. This may explain the lack of participation in the development of many published farm-level sustainability indicators (e.g. Taylor *et al.*, 1993; Gomez *et al.*, 1996; Rigby *et al*., 2001). Woodhouse *et al*. (2000) tackled this problem by asking farmers to identify indicators of "successful" or "failing" farming systems. Definitions of success and failure may however differ over space and time. In addition to this, success may or may not equate to sustainability, depending on a variety of factors, such as the time-span over which it is measured. Woodhouse *et al*. (2000) used wealth as a key criterion of success, which may or may not be related to farming practices or environmental sustainability.

In contrast to ongoing debates of operational definitions of sustainability, definitions of land degradation are relatively well established (section 2.2), and eliciting degradation indicators from communities is relatively straightforward (Stocking & Murnaghan, 2001). As the antithesis of sustainability (Warren, 2002), degradation indicators elicited from communities may be reversed to derive sustainability indicators. In this way, it may be possible to better elicit sustainability indicators from land users.

Indicators were identified during the semi-structured interviews that followed the Sustainable Livelihoods Analysis. Consistent with accepted definitions of land degradation (section 2.2), respondents were asked to identify signs they would expect to see in rangeland that had lost its productivity long-term, due to over-use (as opposed to drought). Where necessary, prompts were used to elicit indicators representing different ecosystem components (e.g. soils, plants and animals). Respondents were then asked to identify which of these signs they would expect to appear first, that might provide an early warning that detrimental change was likely in the future.

During these interviews, respondents were asked to identify characteristics of useful indicators that could be used as selection criteria. Although a number of criteria for evaluating indicators were elicited from rangeland stakeholders, "accuracy" and "ease of use" summarise the majority of them well (see section 7.3). This is consistent with literature on this subject (Table 3.3). Local participation in the development of evaluation criteria is essential to select appropriate indicators: these criteria directly influence indicator selection, and are themselves influenced by the objectives for which users wish to develop indicators (Krugmann, 1996).

Indicators identified in interviews were compared and combined with indicators from other areas (where deemed relevant) and the literature (developed in comparable environments). They were then evaluated against community-derived criteria in focus groups. In Study Areas 2 & 3, indicators were evaluated in the same focus groups as management options were discussed (section 4.4). In Study Area 1, three additional focus groups were held (attended by 12, 14 and 10 people). During a trial focus group, people were asked to evaluate indicator accuracy and easy of use by raising their hands for each criteria in turn (no hands = not accurate or easy to use; one hand = somewhat accurate or easy to use; two hands = very accurate or easy to use) followed by a discussion of the response. However, respondents were heavily influenced by their peers leading to an unrealistically positive evaluation of indicators and lack of critical discussion.

This data was therefore discarded, and a simple form of Multi-Criteria Evaluation (MCE) (see chapter 3) was adopted instead (called "Matrix Ranking" by Rennie & Singh, 1996). MCE has been used successfully elsewhere to evaluate sustainability indicators (e.g. Phillis & Andriantiatsaholiniaina, 2001; Miranda 2001; Ferrarini *et al*., 2001). Although there are many highly quantitative approaches to MCE (e.g. De Montis *et al*., 2003), a more qualitative approach was taken in this research, aimed at structuring group discussions about the relevance of different indicators. Following this approach, all indicators were printed on cards in local languages and supported with images (Figure 4.2). Where necessary, illiterate participants were given one-to-one support by participating extension workers. Indicators were ranked against criteria (accuracy and ease of use) by assigning counters (in this case stones) to cards (Figure 4.2). Participants were given the same number of stones as there were indicator cards. Stones were then placed on cards to rank the accuracy of each indicator, placing more stones next to more accurate indicators. Stones were returned to the participants, who were asked to repeat this exercise to evaluate the ease with which each indicator could be used. Information from interviews suggested that each of the criteria were equally essential, and so they were weighted equally. Information about early warning indicators (see above) was also triangulated in these focus groups by asking participants to select and rank (using stones) early warning indicators from the available indicators. Although stones were counted to rank indicators, this was essentially a qualitative exercise, using ranks to initiate group discussions about the accuracy and ease of use of different indicators.

Figure 4.2 Evaluation of proposed indicators using Multi-Criteria Evaluation in Study Area 1, showing allocation of counters (left) to indicator cards (right)

4.5.2 Empirical evaluation and final selection of indicators

Degradation indicators, perceived to be accurate and easy to use by at least two out of three focus groups in each site, were tested empirically in the field using ecological and soil-based sampling techniques.

Members of the community were involved in the collection of ecological data in each study area, and provided expert assistance with species identification, local plant names and uses (Appendix 2) (c.f. Oba & Kotile, 2001; Mapinduzi *et al*., 2003). Although there is a danger that local participants become enumerators rather than being used in their capacity as experts (e.g. Holt-Giménez, 2002), there are many benefits to community involvement in ecological fieldwork. Their detailed knowledge of land use, management, vegetation zones and local history was invaluable in selecting sample sites (see participatory maps in chapter 5). In addition, it was possible to collect valuable additional botanical data with their assistance, including local names and uses. It was also possible to discuss the palatability of different species; information which is critical to rangeland management decisions.

Within each of the three study areas, ecological sampling sites were selected on the basis of local knowledge. Participatory mapping (Rocheleau, 1995; Booltink *et* *al*., 2001) of ecological assemblages and resource use patterns was conducted with each community (Figure 4.3). Maps were drawn by groups of land users in the sand before being transcribed to paper and amended during farm drives with as many land users from the group as possible. Using a combination of aerial photography, remote sensing, existing maps and Global Positioning System readings taken on rangeland drives, each study area was mapped (c.f. Suyanto *et al*., 2004). Preliminary maps were further checked and amended by land users before being finalised. Due to a malfunctioning Global Positioning System, it was not possible to complete a participatory map for Study Area 2.

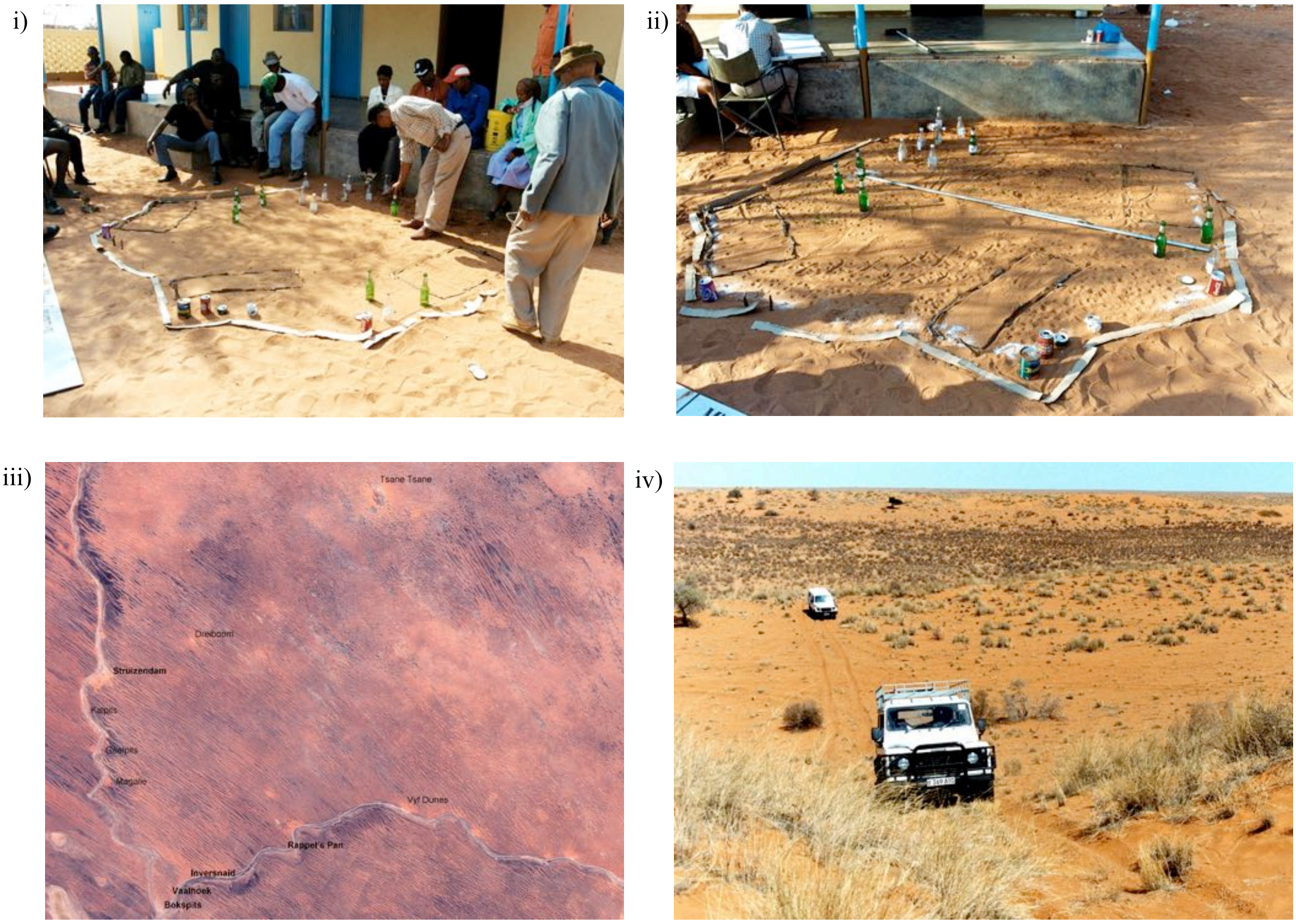


Figure 4.3 Participatory mapping: i) members of the community draw ecological and land use zones in the sand; ii) the resulting map is transferred to paper; iii) cross-reference with remotely sensed imagery and/or aerial photographs; and iv) check the location of key points and boundaries with a Global Positioning System. The resulting maps are shown in chapter 5 (photos: M. Reed)

Following widely accepted definitions of land degradation by UNEP (1997) and Abel & Blaikie (1989), the link between rangeland condition and secondary production was examined to identify degraded and non-degraded study areas. This was done using trend lines developed during semi-structured interviews to determine changes in livestock herd size at boreholes (and their causes). This showed that production was variable, stable or increasing at the majority of boreholes in all study areas, except where drought or disease had reduced the livestock population. It was not possible to identify boreholes where livestock production was consistently declining. In the absence of such sites, grazing gradients were used as surrogates for degradation, based on the assumption (corroborated through interviews) that rangeland degradation is primarily grazing-induced in this environment (c.f. Perkins & Thomas, 1993; Dougill *et al*., 1999).

This assumption is justified as there is no evidence for a long-term reduction in rainfall at either study area (Figure 4.4), and it is important to avoid confusing long-term, human-induced land degradation with short-term climatic fluctuations. This is a common difficulty for communities in Botswana with many people stating drought as the main cause of degradation, despite the lack of evidence in climatic records (e.g. Ringrose *et al*., 1996; Chanda *et al*., 2003).

Indicators were measured along grazing gradients. The grazing gradient or "piosphere" approach (Andrew, 1988) assumes that rangeland degradation is driven by grazing intensity and that this declines uniformly with distance from a water source. Although the decline is rarely spatially uniform, it is possible to use dung and cattle track frequency to corroborate assumed changes in grazing intensity (Dougill & Cox, 1995). The approach is widely used in semi-arid rangelands with point water sources (e.g. Hardy & Hurt, 1989; Perkins & Thomas, 1993; Jeltsch *et al*., 1996; Pickup *et al*., 1998; Dougill *et al*., 1999; Thomas *et al*., 2000; van der Westhuizen *et al*., 2005). It follows the principle that space (along degradation gradients) can be substituted for time to look at degradation processes.

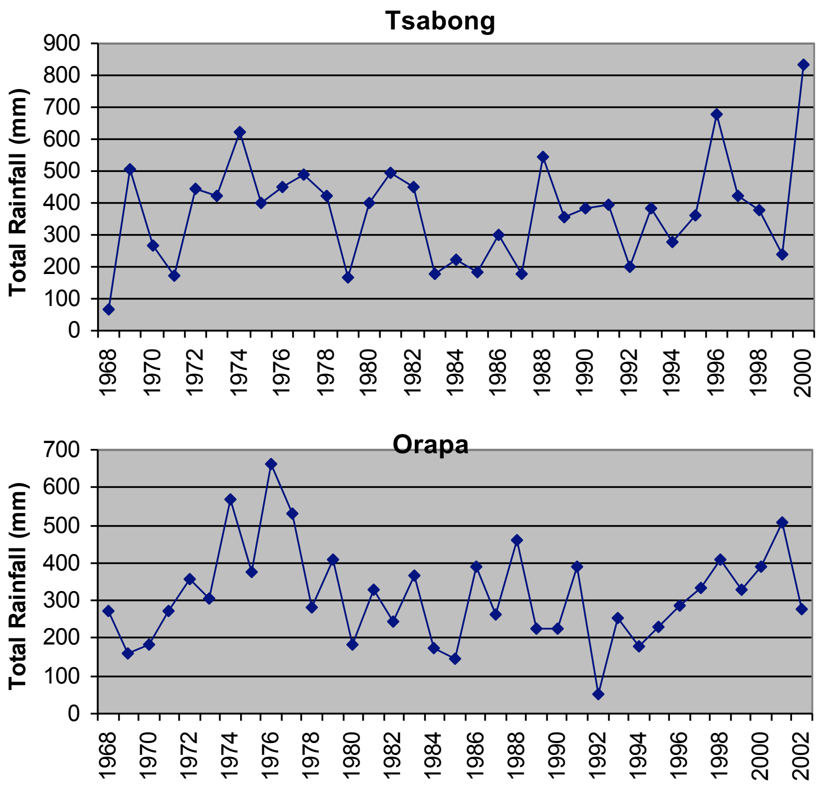


Figure 4.4 Total annual rainfall for Tsabong (nearest station to both Study Areas 1 & 3) (above) and Orapa (Study Area 2) (below) (source: Government of Botswana Meteorological Services)

Indicators were measured along line intercepts at exponentially increasing distances from each borehole (water source), to reflect the assumed exponential decrease in grazing intensity. Grazing gradients started 200 m from boreholes, in an area widely referred to as the "sacrifice zone" which is typically devoid of vegetation due to trampling and soil toxicity from livestock excrement (Perkins & Thomas, 1993). The distance of each gradient was determined by the extent of ecological zones on participatory maps: ranging from 3.2 km in Study Area 2 to 12.8 km in Study Area 1. Boreholes with clear grazing gradients were selected for sampling, avoiding areas where gradients were interrupted by fences or overlapped with gradients from other boreholes. In Study Area 2 this was problematic, as numerous (unauthorised) wells had been dug between (deeper, drilled and authorised) boreholes, creating an overlapping mosaic of grazing gradients. However there were clear grazing gradients radiating from villages in this study area and these were used in place of water sources. The length of grazing gradients (up to 18 km) and logistical difficulties of following gradients across fields of parallel dunes meant that this approach had to be modified in Study Area 3. It also limited the number of sites that could be sampled (14 in Study Area 3 compared to 44 in Study Area 1 and 32 in Study Area 2). Following the principles of the grazing gradient approach, areas distant from water sources that were rarely used by livestock were used as "control" non-degraded sites (13-18 km from water), sample sites close to water sources (0.75-1.5 km) were used to represent degraded land and a number of sample sites (6-8 km from water) were located in between these areas to represent land in intermediate condition.

At each sample site, indicators were measured along 5 and 30 m transects using the line intercept method. All participants were trained in the use of this method. The line intercept method is particularly well suited to sampling sparse vegetation communities (Kent & Coker, 1996) such as those that occur in the study areas, as particularly large quadrats are required to obtain the minimal area to represent sufficient species richness (Cain, 1938) in sparse vegetation. As quadrat size increases, estimating cover becomes increasingly subjective, and objective measures (for example point quadrats) become increasingly time consuming to use.

As many as possible of the indicators elicited from communities that they perceived to be accurate and easy to use were tested empirically. At all sites, trees and bushes intercepting 30 m lines were identified, and the length of their canopies measured, to derive percentage cover. The height of all trees intercepted was also measured. Dead trees were identified by the characteristics of the wood when a branch was broken. Height of exposed roots and nebkha dunes were measured. Ground layer species were measured along three 5 m lines located at the ends and middle of each 30 m line. Evidence of Harvester Termite activity was identified from grass tillers that had been cut cleanly at variable heights. Soil measurements were made at the centre of each 5 m line intercept. Soil was classified as consolidated or unconsolidated by probing with a blunt instrument. 10 g samples were taken from the soil surface (taking care to remove litter where present) at each point and mixed to obtain a representative sample for each 30 m intercept. These were tested for organic carbon and conductivity (evidence of salinisation) at the Government Soils Laboratory at Botswana Agricultural College, Sebele. The number of cattle tracks crossing each 30 m intercept and the amount of dung (presence/absence at 1 m intervals) was counted to estimate grazing intensity at each study area (following method of Perkins & Thomas, 1993).

In addition to these measurements, tree girth and presence of flowers and fruit were noted in Study Area 1. In Study Area 2, a number of additional measurements were made to test indicators specific to the study area. Ten leaves were picked from each intercepted *C. mopane* tree, and checked for edible insect cases. Rocks (> 5 cm) and plant litter were measured along three 5 m lines located at the ends and middle of each 30 m line. Presence of edible fruits on all plants was noted. Evidence of a white crust or crystals formed by salt was assessed at each sample point. Evidence of diarrhoea was noted during dung measurements. Due to the flat topography of Study Area 2, visibility at each 30 m intercept was determined by measuring the distance to the point where a person disappeared from sight (one of the indicators suggested by land users in this area). Cattle condition at and between intercepts was assessed visually by using a subjective scale based on the prominence of ribs and shoulders, and coat condition (c.f. Krugmann, 1996).

In Study Area 3, a number of additional measurements were made to test indicators specific to the area. Distance from each intercept to the crest of the nearest two sand dunes was measured, and the height of each sand dune was measured using a clinometer. At each measurement site, a 30 m line intercept was made at both dune valley and (nearest) dune crest locations, as these each have distinct soil and vegetation types. Availability of firewood along each line intercept was noted.

Insect specimens were collected in Study Area 1 during 2003 using pit-fall and bait traps located along a grazing gradient (Jew, 2005). Insect specimens were stored at the Natural History Museum and plant specimens were stored at the Botswana National Herbarium.

The grazing gradient or "piosphere" approach (described above) assumes that disturbance from animals using fixed water points is the primary driver of environmental change. Following this widely applied approach, it is possible to correlate environmental variables with distance from water to determine the nature of grazing-induced environmental change. In this case, environmental variables were selected to represent proposed degradation indicators. Each of these were correlated with distance from water using linear regression in Sites 1 & 2. In Study Area 3, where it was not possible to measure indicators along grazing gradients, independent t-Tests were used to determine if there were significant differences between indicator values in different degradation zones.

An indirect ordination was performed on the floristic data from each site using Detrended Correspondence Analysis (DCA) to test the assumption that distance from water was the primary factor determining environmental change along grazing gradients, and that degradation zones identified from participatory mapping were valid. Using this technique, it was also possible to identify additional environmental gradients from the data that could be related to land degradation (e.g. different gradients in tree and ground layers of vegetation, or gradients dominated primarily by vegetation or soil processes).

DCA was performed using the DECORANA computer programme (Hill, 1979; Hill & Gauch, 1980). DCA arranges line intercepts in a multi-dimensional ordination space according to their floristic differences. Intercepts that are floristically similar are grouped together, and floristically dissimilar intercepts are separated in the ordination space. By correlating environmental variables to ordination axes with high eigenvalues, it is possible to determine the environmental gradients that account for most floristic variation.

According to Cavender-Bares *et al*. (2004: 638), "DCA...is generally the most widely used and cited ordination technique in the ecological literature". DCA was devised to overcome mathematical distortions of data point positions in ordinations produced by correspondence analysis and reciprocal averaging (CA/RA), on which it was based (Hill & Gauch, 1980). Gauch *et al.* (1981) made comparisons between these techniques, polar ordination and principle components analysis (PCA), and found that DCA gave the most accurate results. There is no evidence that non-metric multidimensional scaling (NMDS) (Anderson, 1971) gives better results than other ordination methods (Gauch *et al.,* 1981), and its use has generally been limited (Kent & Coker, 1996). Rydgren (1996) compared DCA to PCA and NMDS, and found that DCA and NMDS performed significantly better than PCA due to the influence of outliers in the latter approach. Although Canonical Correspondence Analysis (CCA) (ter Braak, 1985) can more conveniently analyse the relationship between species distributions and environmental variables, it can only be performed effectively if comprehensive environmental data has been collected for each data point. However, the environmental variables measured in this study were selected to reflect the indicators being tested, and were therefore not sufficiently comprehensive to use CCA.

As outliers can significantly affect the results of DCA, these were omitted during the analytical procedure and rare species were down-weighted (these are options in DECORANA). Percentage cover data was used (it was not transformed to presence/absence). Four ordination axes were calculated.

Ordination axes were correlated against distance from water (or village in the case of Study Area 2, where water points were very closely spaced) using linear regression to determine which axis (if any) represented a degradation gradient. Dung frequency was used to test the validity of degradation zones in Study Area 3 instead of proximity to water, as it had not been possible to arrange intercepts along a gradient from a water source. Indicator measurements were then correlated against ordination axes to determine which indicators accounted for most change in degradation status. Indicator measurements were also correlated against the other ordination axes with high eigenvalues, to see if they could account for any of the variation these axes represented.

Finally, the results of ecological and soil-based indicator testing were presented to communities for evaluation in focus groups. Discussion focussed on indicators for which no empirical evidence could be found. These discussions informed final indicator selection.

4.6 Step 4: Indicator application by communities

Indicators were integrated with management strategies in a Decision Support System for each Study Area (chapter 8, Appendix 4). This consists of a Rangeland Assessment Manual that was designed using indicators and management strategies relevant to each study area.

Information about potential management strategies was integrated from interviews and literature through focus group discussions. Strategies that were not relevant to the biophysical or socio-economic setting of the study area were either rejected or adapted through these discussions. Each indicator was then cross-referenced to strategies that could help prevent, reduce, or reverse the kinds of problems identified by the indicator. In this way, it was possible to provide land users with a range of options which they can select according to their capacity. For example, there are a range of bush management strategies which require differing levels of financial capital or labour. Given the heterogeneity of rural communities in the study areas, it is essential to provide a wide range of options to ensure the system benefits all sectors of society.

Draft manuals have been produced in English. These have been peer-reviewed by academics and policy-makers. Revised drafts will be translated into local languages and trialed with local communities prior to publication. Literacy levels are high in each of the study areas: 65% and 98% in Study Areas 1 and 2 respectively. Although rates are not known in Study Area 3, key informants believe they are above average (average literacy levels in Botswana are 81%). There have been discussions at District level in the Ministry of Agriculture about the possibility of extension workers using the DSS to support illiterate stakeholders, who are often amongst the poorest in the community. This group tends to have significantly less contact with extension workers at present (Reed & Dougill, 2002). Therefore, by facilitating rangeland monitoring and management decisions amongst the majority of stakeholders, the DSS will enable agricultural extension services to focus their efforts on the poorest members of the community.

4.7 Conclusion

The learning process proposed in the previous chapter is not meant to be prescriptive. Instead, it emphasises the flexible use of multiple methods to capture and triangulate information from communities in diverse and dynamic conditions. This chapter has described the range of qualitative and quantitative methods that were used to apply the learning process with pastoralist communities in the Kalahari, Botswana. The methods that were applied with communities in the first study area over a number of months were streamlined and applied over six weeks with communities in two very different study areas to test the transferability of the learning process. This application emphasised the iterative nature of the learning process, testing and refining information from local communities through a combination of qualitative and quantitative techniques, and the interactive interpretation of results by both stakeholders and researchers.

5

Establishing Context: Study areas and livelihoods analysis

Summary

This chapter presents results from step 1 of the learning process: "establishing context". It is an account of the society, institutions and environment in three parts of the Kalahari, based on a combination of livelihoods analysis from semi-structured interviews, wealth ranking focus groups, oral histories and literature. Livestock production was the main source of livelihoods in each study area, and an important part of local culture. The majority of people worked in syndicates on communal rangeland supplied with water from boreholes. Study Area 1 was located between Tsabong and Werda in the southern Kalahari bush savanna zone of south Kgalagadi District. It appeared to be the most affluent study area, perhaps due to its good connection with international markets through the Government's Botswana Meat Commission (BMC). Livestock ownership in the area was high, although it was concentrated particularly amongst a small number of commercial farmers. Since the expansion of the livestock sector in response to borehole provision in the 1970s, bush encroachment became an increasing problem in the study area, with over half of respondents citing this as a major livelihood constraint. Study Area 2 was located in pan grasslands and *Colophospermum mopane* woodlands near the Makgadikgadi Pans, Mid-Boteti, Central District, and was the poorest region studied, with people here more constrained by social, physical and financial capital than either of the other two study areas. Poverty was frequently blamed on low levels of livestock ownership which in turn were constrained by quarantine conditions imposed by the BMC. In addition to this, livelihood options from fishing and flood plain agriculture had been lost due to the drying of the Boteti River. Study Area 3 was located in the arid bush savanna zone of south Kgalagadi District. The culture of these communities was very different to other study areas, being based on migrations from South Africa at the turn of the century, and smallstock ownership far outweighed cattle. Livestock marketing was constrained by access to transport, condition of roads and distance to markets. There were shortages of certain rangeland products, particularly firewood.

5.1 Introduction

To accurately interpret the results of environmental degradation and sustainability assessments, it is necessary to understand the context in which they are conducted. Building on the national context discussed in chapter 2, this chapter describes the environmental, socio-economic and institutional context in which sustainability indicators were developed in three Kalahari study areas, following step 1 from the learning process in chapter 3 (Figure 3.2). The methods that were used to do this were described in section 4.3.

5.2 Stakeholder and System Identification

Rangeland stakeholders were identified through focus groups in each study area. The same four groups of stakeholders were identified in each area:

- Communal livestock owners;
- Commercial livestock owners;
- Livestock herders; and
- Those who do not own or herd livestock, but used rangeland products (it was noted that all the above groups also used rangeland products).

The last group included those who relied primarily on government welfare and/or family support (many of whom were pensioners or “destitutes”), as well as salaried workers (including herders) and business people who did not own livestock but used rangeland products. Traditional doctors were also included in this group in Study Area 1.

The system of interest was identified through key informant interviews as the rangeland system. The majority of livelihoods in each of the study areas depend primarily on livestock (either directly or indirectly through livestock-related employment), and there are major concerns about the sustainability of the rangeland system under current management practices. Although there was limited arable production in Study Area 2, this was not a significant component of local livelihoods in the selected study areas, and so it was not considered as part of the system of interest. Sustainable Livelihoods Analysis (Scoones, 1998) was used as a conceptual tool to better understand the components of the rangeland system and their interlinkages, through the use of a range of participatory research methods (section 4.4).

Before a detailed discussion of these results, a summary is provided of livelihoods in each study area (Table 5.1). After each livelihood asset had been discussed, respondents were asked to report whether any aspect of each asset significantly constrained their livelihood – the results of this are summarised in Figure 5.1. People were most constrained by natural capital in Study Area 1, mainly due to encroachment by *Acacia mellifera* thorn bushes. Social capital constrained more people in Study Area 2 than elsewhere, mainly due to the stated lack of information about animal husbandry and rangeland management alternatives. This was generally attributed to poor access to extension services (32% had no contact compared to 10% and 21% in Study Areas 1 & 3 respectively) and low membership of Farmers Associations (25% compared to 39% and 41% in Study Areas 1 & 3 respectively). Physical capital was also most constraining in Study Area 2, mainly due to poor access to transport. 50% of respondents stated that they had no access to either a motor vehicle or donkey cart. This was particularly problematic given the shortage of

Table 5.1 Summary of livelihood information collected in each study area (percentages refer to the proportion of respondents in each study area based on 67, 40 and 53 respondents in Study Areas 1, 2 and 3 respectively; SD = Standard Deviation)

Livelihood Asset	Study Area 1 (Tsabong-Werda)	Study Area 2 (Mid-Boteti)	Study Area 3 (Bokspits)
Natural Capital			
Use communal rangeland	73%	85%	90%
Own rangeland (fenced)	27% (19%)	15% (<1%)	10% (10%)
Rent or own arable land	None	53% (growing maize, beans, sorghum, water melon and/or pumpkin on small scale)	None
Average no. cattle	165 (SD: 492)	34 (SD: 52)	20 (SD: 43)
Average no. goats	70 (SD: 77)	17 (SD: 26)	66 (SD: 87)
Average no. sheep	42 (SD: 95)	2 (SD: 9)	88 (SD: 201)
Main rangeland products used	Firewood, fruit, hunting, medicine, vegetables, gums	Building poles, thatching grass, firewood, fruits, vegetables, medicine, Mopane worms and hunting	Firewood, building materials, fruit, vegetables, and medicine
Livelihood significantly constrained by natural capital	52%	23%	39%
Social Capital			
Members of farming groups	41%	25%	39%
Access to farming magazines, TV or radio programmes	85%	42%	45%
Frequent, some or no contact with agricultural extension	58%, 32% and 10%	32%, 35% and 32%	21%, 58% and 21%
Livelihood significantly constrained by social capital	15%	45%	24%
Physical			
Access to motor vehicle	89%	23%	31%
Access to donkey cart	53%	36%	55%
Sole or family owners of borehole or well	39%	37%	24%
Distance to sell livestock	Mainly local, or approx. 200 km to BMC abattoir on tar road	Mainly local, or approx. 200 km to BMC abattoir on tar road via quarantine	Mainly local, or approx. 400 km to BMC abattoir, half on sand road
Distance to buy supplies	Local	Local	Local
Access to telephone	60%	63%	31%
Livelihood significantly constrained by physical capital	21%	53%	38%
Human			
Average no. of family labourers	0.8 (SD: 1.4)	2.5 (SD: 2.3)	4.9 (SD: 4.5)
Average no. of paid labourers	4.5 (SD: 7.3)	0.7 (SD: 1.1)	1.1 (SD: 1.5)
Average years in formal education	6.4 (SD: 5.9)	5.6 (SD: 3.9)	6.2 (SD: 4.5)
Main sources of informal education	Parents, extension workers, South African farmers they worked for	Parents, extension worker through Farmers Association	Parents, South African farmers they worked for, training courses run by extension service
Constrained by health	16%	17%	40%
Livelihood significantly constrained by human capital	32%	25%	35%
Financial			
Main income sources	Livestock, government	Government welfare	Livestock, government

	welfare support, small business	support, diamond mines, livestock, small business	welfare support
Access to savings	90%	50%	29%
Access to credit	94%	44%	35%
Livelihood significantly constrained by financial capital	38%	65%	43%

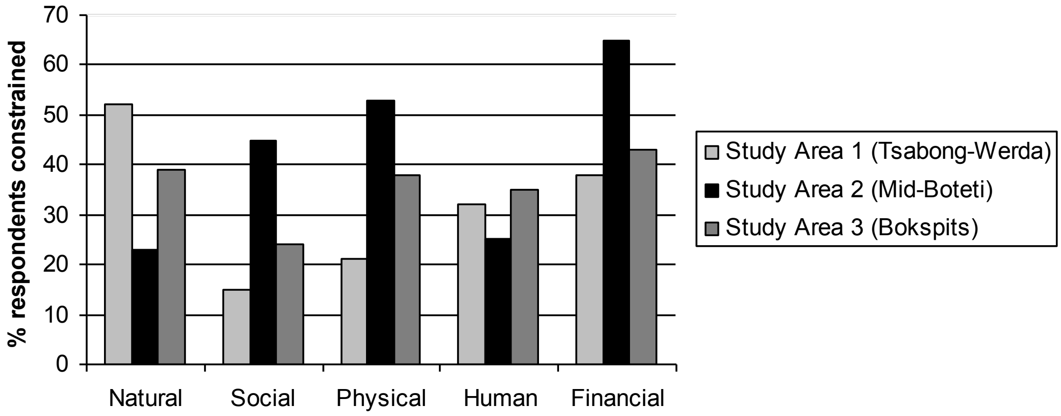


Figure 5.1 Proportion of respondents who perceived their livelihoods to be constrained by different capital assets in each study area

Table 5.2 Wealth indicators identified by focus groups in each of the study villages in Study Areas 2 & 3

Study Area 2 (Mid-Boteti)		
Mopipi	*Mokoboxane*	*Kedia*
> 50 Cattle	> 50 Cattle	> 20 Cattle
Motor vehicle	Single owner of borehole	Motor vehicle
Fenced yard	Own business	2 room house
Tiled roof		Tin or tiled roof
Study Area 3 (Bokspits)		
Bokspits[1]	*Struizendam*	*Rapplespan*
> 1000 smallstock	> 200 smallstock	> 300 smallstock
> 200 cattle	> 30 cattle	> 100 cattle
Own a fenced ranch	Motor vehicle	Motor vehicle
Own borehole or in syndicate	Own borehole or in syndicate	Own borehole
Own business	Own business	Own business
	> 6 rooms	> 2 rooms

[1] Vaalhoek and Inversnuit were grouped with Bokspits due to their close proximity, and members of all three communities were involved in the focus group.

firewood nearby. Human capital was not a major constraint for respondents in any of the Study Areas. However, financial capital was a particular constraint in Study Area 2. 40% of respondents reported that they were reliant primarily on government welfare for their incomes. This is partly because the study area is in a quarantine zone, which significantly reduces returns on livestock sold to the Botswana Meat Commission and depresses local livestock prices (see section 5.4).

Table 5.2 shows wealth indicators selected by communities during focus group discussions in Study Areas 2 & 3 (wealth ranking was not conducted in Study Area 1). In Study Area 2, communities divided people into “rich” and “poor”, and identified indicators that could help distinguish between these groups. In Study Area 3, an additional “very poor” group were identified, who had none of the wealth indicators, and very few or no livestock (<200 smallstock and <30 cattle in Bokspits, the most wealthy of the villages; <25 smallstock and <3 cattle in Struizendam; and <16 smallstock and <6 cattle in Rapplespan).

The following sections provide more detailed descriptions of the rangeland system in each study area, based on a combination of livelihoods analysis from semi-structured interviews (summarised above), oral histories and past literature.

5.3 Study Area 1: Tsabong-Werda

The first study area consisted of nine villages and their surrounding areas with a total population of 22,097 (Central Statistics Office, 2001): Tsabong, Omaweneno, Maralaleng, Kisa, Phepheng, Draaihoek, Makopong, Werda and Bray, located in south Kgalagadi District (Figure 2.6). Although these villages were widely dispersed across approximately 200 km, the study area was well connected by tar road to the main livestock market in Lobatse, where the main Botswana Meat Commission (BMC) abattoir is based. This Government body has a monopoly on livestock exports, and provides a set price for livestock (by weight) all year round. Although there were complaints that prices were too low, the system protects farmers from the kinds of price crashes that are seen elsewhere in southern Africa during drought. Having said this, the majority of farmers sold their livestock locally, either to commercial farmers (who transported stock to the Bray farms in the northern part of the study area for fattening), other communal farmers or butchers. Supplies and veterinary services were available in most of the study villages through the Ministry of Agriculture’s Livestock Advisory Centres and extension services.

Livestock provide an uncertain livelihood given the highly variable rainfall regimes. In Tsabong (the only weather station in Study Area 1), an average of 315 mm rainfall falls during the summer months (October-April) (Meteorological Services data). However, this varies considerably from year to year: interannual rainfall variability is around 45% (Bhalotra, 1987). The lowest and highest annual rainfall records were 54 mm and 664 mm in 1992 and 1976. Analysing rainfall data from 1880 to 1972, Tyson *et al*. (1975) suggested that the Kalahari experiences droughts in an approximately 18 year cycle (see Box 5.1 for an account of historic droughts). The research reported here was carried out in relatively good rainfall years: receiving 390 mm, 508 mm and 278 mm in 2000, 2001 and 2002 respectively. Over 90% of the people interviewed in this study area owned livestock. On average these people each owned 165 cattle, 70 goats and 42 sheep (this average includes a number of large land owners).

However, many pastoralists have noticed a steady decline in the condition of their rangeland, particularly since the government improved access to ground water in the 1970s (see boxes 5.1 and 5.2). More than half of those interviewed said their livelihoods were constrained by the condition of the rangeland, mainly due to thorny bush encroachment. The natural vegetation in this area was classified as “southern Kalahari bush savanna” in Weare and Yalala’s (1971) vegetation map of Botswana, consisting of perennial tufted grasses and sparse woody vegetation (Figure 5.2).

Figure 5.3 shows representative images of non-degraded rangeland during dry season and wet season. The main tree species are *Acacia erioloba*, *A. leuderitzii, Terminalia sericea* (on deep sand) and *Boscia albitrunca*. The shrub layer is dominated by *A. mellifera, A. hebeclada* and *Grewia flava.* The herb layer is dominated by perennial grasses such as *Stipagrostis uniplumis*, *Eragrostis lehmanniana* and *Schmidtia pappaporhoides*. Annual grasses and herbs are more abundant after good rains. These include *Schmidtia kalahariensis* and *Aristida congesta* (Figure 5.4). But due to borehole-driven expansion of the livestock sector in this District, there is now an increased abundance of annual grasses (especially *S. kalahariensis*) and thorn bushes, in particular *A. mellifera* (Figure 5.5). In some areas (e.g. around Draaihoek and Makopong), bush encroached zones around water points are coalescing, where they can extend up to 9 km from individual boreholes, resulting in impenetrable stretches of bush for tens of kilometres. This is shown in a participatory map in Figure 5.6 (see section 4.5.1 for the methods used). Oral histories suggest that this level of encroachment occurred over the last 30 years (see Boxes 5.1 and 5.2).

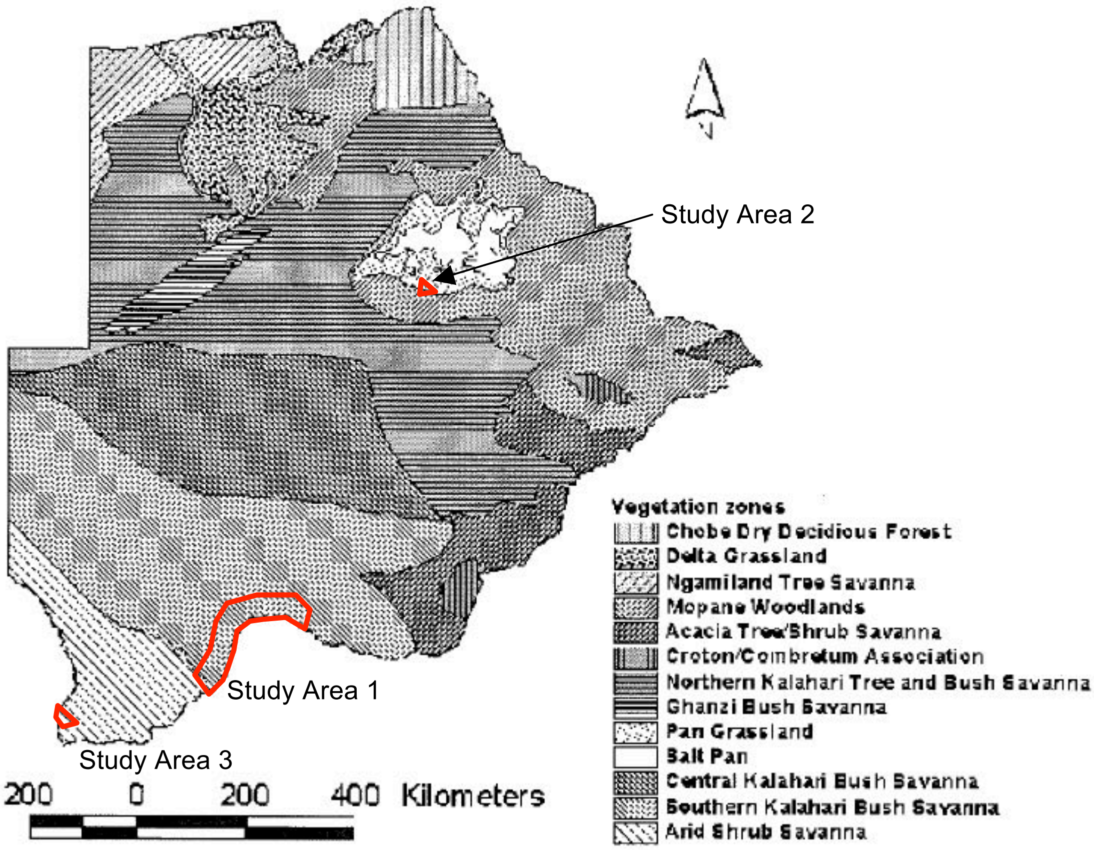


Figure 5.2 Botswana vegetation distribution (Weare & Yalala, 1971) showing location of study areas

Figure 5.3 Representative images of (non-degraded) southern Kalahari bush savanna during dry season (left) and wet season (right) (photo: M. Reed)

Figure 5.4 Annual grasses *Schmidtia kalahariensis* (left) and *Aristida congesta* (right) are becoming increasingly abundant due to intense cattle grazing in this study area (photo: M. Reed)

Figure 5.5 Bush encroachment by *Acacia mellifera* around Draaihoek village (photo: M. Reed)

Kalahari sands (“arenosols” according to FAO classification) are extremely infertile (Skarpe & Bergstrom, 1986), contain low amounts of organic matter (typically < 0.01%) and have a low water-holding capacity (Dougill *et al*., 1998). The sand varies in thickness from a few metres to more than two hundred metres (Peart & Meixner, 1984). Every now and then the vegetation opens out into pans: depressions of calcareous soil that collect water for a few weeks each summer (Figure 5.8). They typically measure a few hundred meters across, and cattle can extend their foraging range considerably during the summer by drinking from these natural water holes.

Batswana were the predominant tribal group in the study area. They first arrived in the area at the beginning of the 19th century, following a similar hunter-gatherer way of life to the Basarwa who dominated the area until that time. Nomadism ceased in the first quarter of the 20th century when people started sinking wells in the margins of pans (Kuper, 1970). In the 1940s, the Government started reticulating water from South Africa for human consumption in the study area. Some of this was reticulated further by wind or donkey pumps for livestock consumption. Some people worked for commercial farmers in South Africa in return for water to maintain larger herds. However, water remained a major factor limiting livestock production until the Government started drilling boreholes in the 1970s.

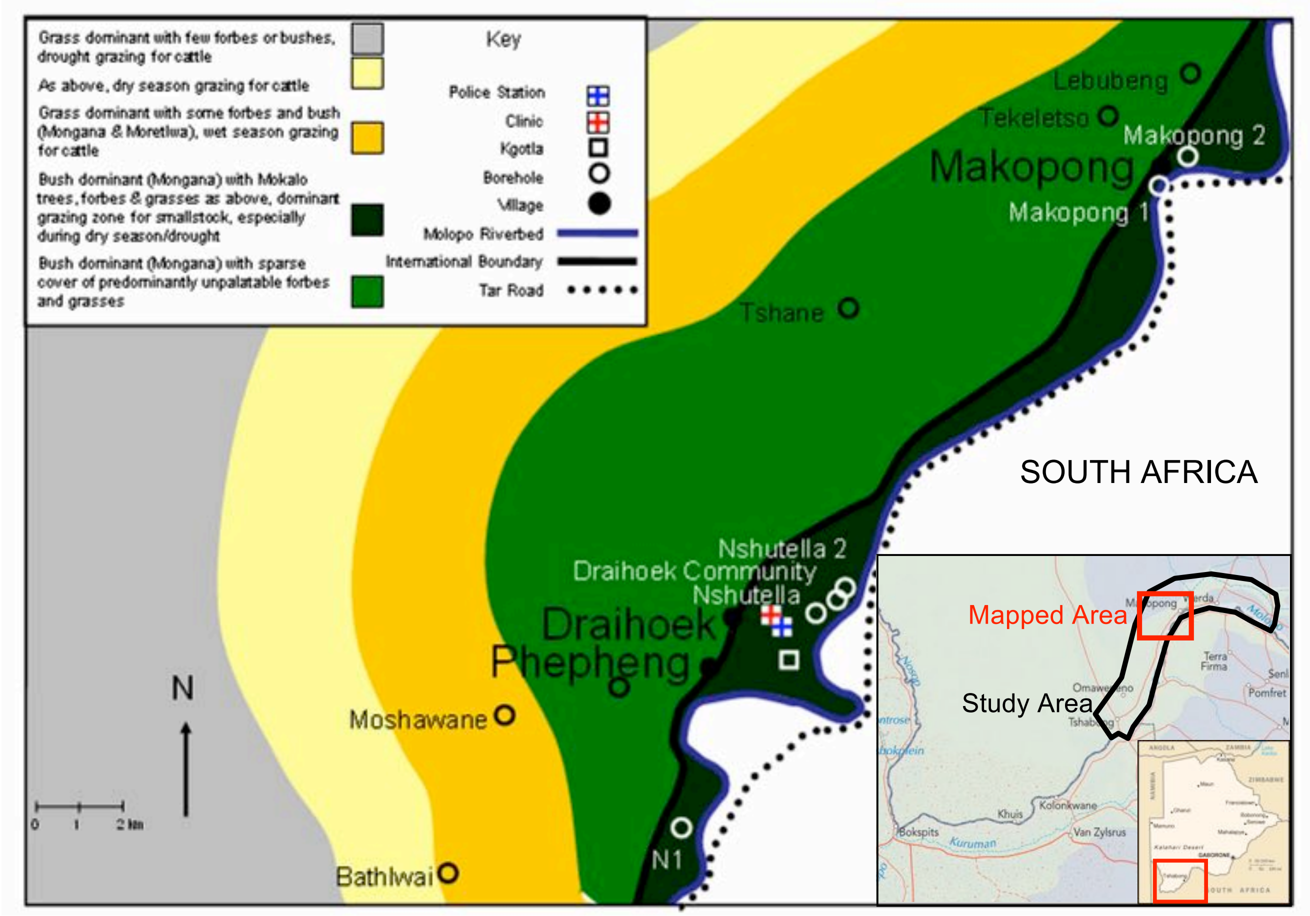


Figure 5.6 Bush encroachment around the villages of Draaihoek, Phepheng and Makopong, showing its location in study area 1 (inset)

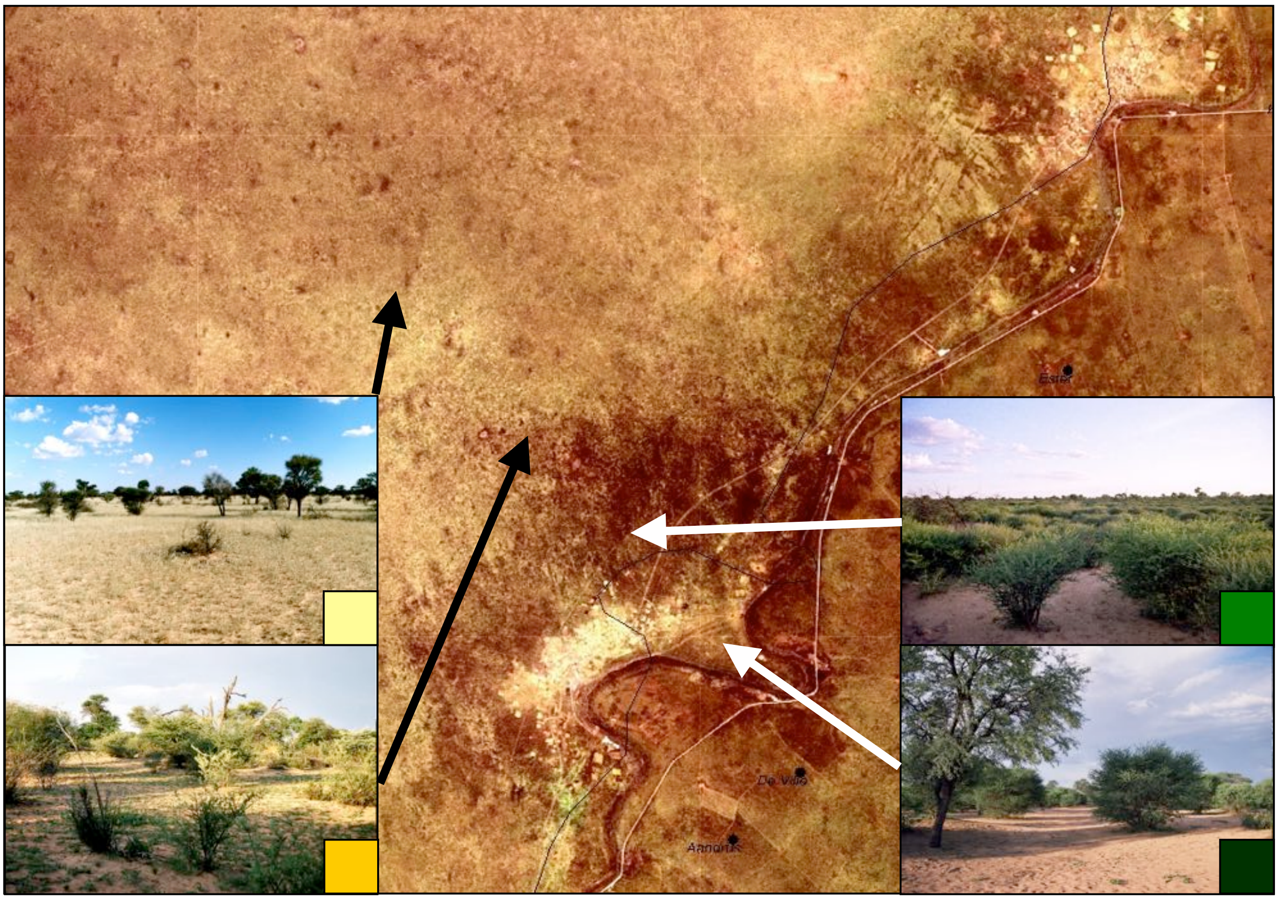


Figure 5.7 Satellite image of the area mapped in Figure 5.6 showing bush encroachment in darker shades (Redtailcanyon, 2005) and photgraphs of locations within each vegetation zone (photos: M. Reed)

Herero were the second largest ethnic group in the area. They arrived much later than the Ngologa, fleeing an "extermination order" from the German colonial Government of Namibia (then South West Africa) in 1904. In addition to these groups, there were a number of other much smaller ethnic groups including Eurasian whites and Basarwa (also known as San or "Bushmen").

Although less than half the people interviewed were members of a Farmers Association, most people had frequent contact with other farmers. Although over three-quarters of people had received formal education (on average for 6 years), most people's knowledge of farming came from parents and other farmers. In addition, radio and farming publications (such as the Ministry of Agriculture's widely circulated AgriNews) were useful sources of information about farming. Although the majority of people had family help, most people also employed people to look after their livestock (Table 5.1).

Box 5.1: Oral History, Mr Letebele[16], Makopong

Of Namibian grandparents, Mr Letebele was born in Tsabong in 1901. He moved to Makopong in 1947 and Kokotshani Cattle Post (33 km northeast of Werda) in 1984. At that time, there was no water, and life was very hard. Water had been reticulated from South Africa with the help of the colonial Government of Botswana, but it was only sufficient for human consumption. At that time, they used only wind and donkey pumps to reticulate water from the main line to farms. People reared livestock, but their numbers were severely restricted by water availability. For a time, he worked with nearby Boers across the border in South Africa, who gave him access to water for his livestock in return for his labour.

When he arrived in Makopong in 1947, there were many wild animals in the rangeland, including cheetah and leopards. Predators were (and to an extent still are) a problem for livestock production. At this time, there was also a lot of grass in the rangeland. The most common species at that time were *Eragrostis uniplumis*, followed by *E. lehmanniana*, *S. kalahariensis, A. congesta* and *A. stipitata.* There were also more trees at that time, in particular *B. albitrunca, A. erioloba* and *Ziziphus mucronata*. There were also more bushes, in particular *A. haematoxolon*. He believed that this is because many of the trees and bushes were felled when people arrived in the area for building huts, kraals and fences.

The most severe drought Mr Letebele experienced was in 1933, while he still lived in Tsabong. The drought lasted for one year. Having no other option, he stayed in Tsabong, and lost almost all his livestock. There was no grass anywhere in the rangeland during the drought. Trees and bushes lost their leaves and some died. Dry grass did exist further from water points, but they did not allow livestock to wander far for fear of predation. Dry grass was therefore cut and taken to the livestock. The droughts in the 1970s and 1980s were small by comparison; there was still grass (albeit dry), and some bushes still provided fodder. In the drought of 1970, he moved his cattle to a cattle post of a family member, and lost far less cattle than he had in the previous drought. The drought of 1982-87 was not as bad; despite a lack of water, there was plenty of (dry) grass.

[16] Real names have not been used.

Box 5.2: Oral History, Mrs Hambira, Makopong

Born in 1932, Mrs Hambira moved from Tsabong to Makopong with her new husband, in 1951. There was a shortage of water from the donkey pumps in Makopong, so her family moved to Draaihoek to find work with Boers who gave them access to water in return for their labour. For a time, they moved north to Estress, but there was too little water there too (livestock and people began to die as a result). They moved back to Makopong in 1971 after the Government drilled boreholes there in 1968-9. Despite being able to use the Molopo River (which flowed most years) there was still too little water. She approached the Government with two others to drill their own borehole in 1979. They were granted permission, but the government reclaimed the borehole during the drought of 1989. Soon after this happened, pumping equipment fell down the borehole, rendering it useless, and the Government told them they could reclaim the borehole if they were able to get it working again. Mrs Hambira and her family gave money to Government drillers to do the work, but the money went missing and the work was never done. She is currently approaching a private contractor for an estimate. The village council drilled a new borehole in 2000 and granted the whole community access. She currently uses this source.

In 1951, the condition of the rangeland was very good. 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 *G. flava* bushes in the 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 has watched the bush encroached area steadily expand. She explained, “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’t even get through them – they have to use the tracks like you or me.”

A mass mortality of *A. mellifera* occurred in 1993, when it was infected with a disease by “small 6-legged spiders with wings”. They arrived in a swarm, and although they would only eat very small quantities of the leaves, individuals upon which they had landed would subsequently die. She thinks around 40-50% mortality occurred, with large individuals affected most severely. There are now almost as many *A. mellifera* in the affected areas, but they only reach waist height.

This study area appeared to be the most affluent of those investigated. It had the lowest proportion of respondents constrained by financial capital. The majority of people interviewed had access to a motor vehicle (in most cases owning one), and over half had access to a telephone (approximately half of these owned a mobile telephone). Livestock ownership was significantly higher in this study area: on average people owned 277 livestock compared to 54 in Study Area 2 and 174 in Study Area 3. However, this average includes a number of commercial farmers with over 1000 livestock, and wealth ranking was not conducted in this study area, so there is a possibility that the interview sample was biased towards rich farmers. Alternatively, the affluence of the area could be explained by its much better connections to international markets through the BMC. These are constrained by quarantine conditions in Study Area 2 and a combination of distance and poor roads in Study Area 3.

Figure 5.8 Pans fill with water during the short rainy season (left) but soon dry out to expose calcareous soils (photo: M. Reed)

5.4 Study Area 2: Mid-Boteti

Study Area 2 is in the Mopipi Extension Area, Mid-Boteti sub-district, Central District, Botswana (Figure 2.6). It includes three villages: Mopipi, Kedia and Mokoboxane (Figure 5.9). The Mopipi Extension Area is located 90 km west of the main sub-district town, Letlhakane, between the Central Kalahari Game Reserve (CKGR) and the Makgadikgadi Pans National Park (MPNP). The total population the three villages is 7,768 with 72%, 17% and 11% from Mopipi, Mokoboxane and Kedia respectively (Central Statistics Office, 2001). Kedia is a Remote Area Dweller settlement and currently gets most of its services from Mopipi (29 km to the southwest). The Remote Area Dweller Programme provides support to communities in isolated areas through service provision and economic opportunities. According to data from the Government's Meteorological Services (Orapa weather station), the area receives an average of 372 mm annual rainfall, but has an interannual variability of 35%. Highest and lowest records are 834 mm in 2000 and 67 mm in 1968.

The study area contains a mixture of *Colophospermum mopane* woodland and pan grassland (Figures 5.2 and 5.10). Although the flora of the *C. mopane* zone of southern Africa is not particularly diverse (White, 1983), it is of global significance for vertebrate (particularly mammal) diversity (Werger & Coetzee, 1978; Turpie & Crowe, 1994). In addition to *C. mopane,* the main trees growing in the area are *Acacia tortilis, Boscia albitrunca, Boscia foetida* and *Terminalia prunoides*. The shrub layer is sparse in both vegetation types, but includes *Grewia flava*, *Rhigozum* spp. and *Rhus* spp.. The ground layer is dominated by grasses, particularly *Cynodon dactylon* and *Eragrostis pallens*.

Until the 1930s, the study area was sparsely populated and Basarwa (San) were the predominant ethnic group. The Bakalanga are now the largest ethnic group in the area. Unlike either of the other study areas, the majority of people interviewed had migrated to the area (average residence 14 years).

Fishing was also an important seasonal livelihood activity until approximately 10 years ago when the Boteti river stopped flowing through the study area (Box 5.3). This is thought to be due to unsustainable water extraction rates upstream (Ringrose *et al*., 1996). The resulting system of pans is too saline for arable agriculture, and limits the growth of grass in many areas (Figure 5.10).

Livestock production is now the main livelihood for most households in the study area. Statements like "how can you survive without livestock?" were common. In addition to boreholes (spaced every 8 km under the TGLP Act of 1975), numerous (unauthorised) wells have been dug to water livestock. The study area is considered a non-European Union Beef Zone by the BMC due to risks from foot and mouth disease. The BMC only buy livestock from the study area three times a year after 21 days quarantine. If there is a foot and mouth disease outbreak, no livestock will be purchased from the area for four years. This presents numerous problems for local people (e.g. Box 5.3). Capital tied up in livestock cannot easily or reliably be released, and destocking during drought is impractical as underweight livestock die in quarantine. Despite these difficulties, the BMC is still the most significant market for livestock in this area. Supplies and veterinary services are available through the

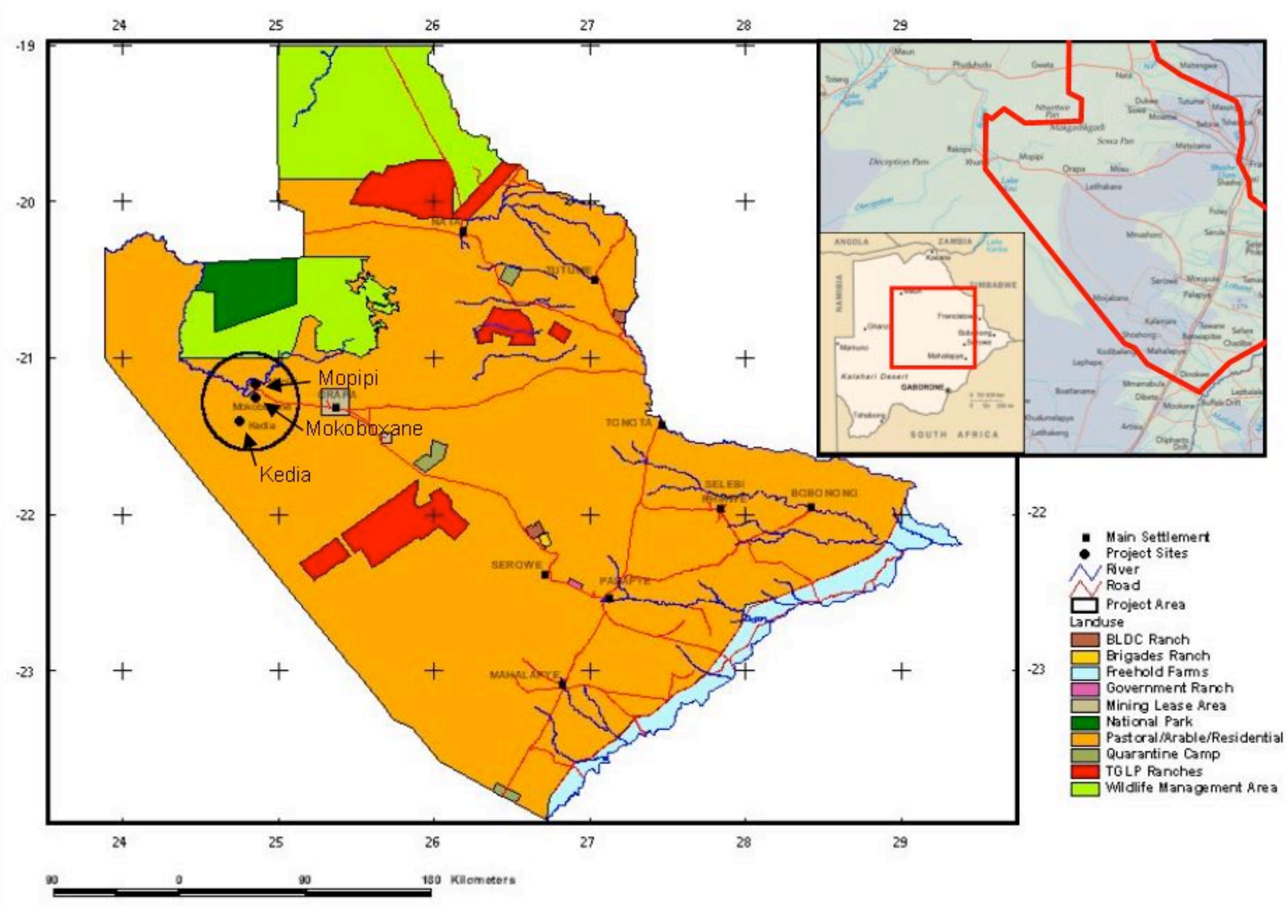


Figure 5.9 Location of three study villages in Study Area 2 (IVP, 2002)

Figure 5.10 Representative images of pan grassland (bottom) and *Colophospermum mopane* woodland (top) in study area 2. Salt pans (left) have been left at Mopipi Dam since the Boteti River stopped flowing to the area approximately 10 years ago (photo: M. Reed)

Ministry of Agriculture's Livestock Advisory Centre in Mopipi and local extension services.

Perhaps as a result of these restrictions, livestock ownership was much lower in this study area than the other two. On average, the people interviewed owned 34 cattle, 17 goats and 2 sheep. Although the vast majority of these were kept in communal land, large parts of the study area are about to be fenced by the Government for private allocation.

A small proportion of those interviewed were members of a Farmer's Association (based in Mopipi). Members were unanimously positive about extension services (the group received regular visits from the local Agricultural Demonstrator). Non-members' views were more mixed, and many had not had any contact with extension services. The Indigenous Vegetation Project had established active local rangeland management committees in this study area, and there was considerable overlap between this group and the Mopipi Farmers Association. Like people in the other study areas, most people's knowledge of farming came primarily from their parents.

Limited arable farming is also practiced at two of the study villages (soil salinity prevents arable agriculture at Kedia). Maize, beans, sorghum, water melon and pumpkin are mainly grown for subsistence, although cultivation provides a limited seasonal income for some people.

A variety of rangeland products were also used, including building poles, thatching grass, firewood, wild fruits and vegetables, medicine and Mopane worms[17]. Although these products were used mainly for subsistence, some families derived significant income, for example from the sale of traditional beer brewed from wild fruits. Illegal hunting was also practiced, but it was difficult to determine how significant this was because respondents did not feel comfortable talking about it. Thatching grass was increasingly hard to find in the study area. Firewood was a problem for families without access to transport, as trucks from a nearby town have been used to transport firewood from the study area (Figure 5.11).

There are limited employment opportunities in the study area, although some people commute to the nearby diamond mines in Orapa and Letlhakane, and there are a few shops large enough to employ staff in Mopipi. Government support was a major source of income in this study area: 40% of respondents received some form of Government support, partly due to Kedia's status as a RAD settlement. This ranged from work through the Drought Relief Programme (allocated to the poorest members of the community for one month a year in drought years) and allowances for looking after orphans to pensions and welfare benefits (a "destitute" allowance of P55 (approx. £7) per month plus food). For political reasons, drought status is declared for the purposes of this programme in most years. Approximately half of these people, mainly pensioners and "destitutes" depended primarily on Government support.

Box 5.3: Oral History, Mr Makunda, Mopipi

Born in 1943, Mr Makunda and his family moved to Mopipi in 1966 to be pastor at a local church. He has always owned livestock, but in those days he owned very few. In 1973, Debswana mining company built a dam at Mopipi to supply its diamond mines at Orapa. Mr Makunda and his sons used to fish in the lake at Mopipi Dam, and his wife used to practice "molapo" farming in the seasonal flood plain, growing vegetables for the family and sometimes for market. However, during the droughts of the 1980s, the Boteti River stopped flowing into the local lake system. The river returned twice in the late 1980s but hasn't reached this area since the early 1990s. He still prays that one day it will return, and he has kept his nets and boat, but he is not hopeful. He now has a small plot of land in which he grows maize and beans – he gets a crop most years, but there is rarely enough to sell. He no longer works for the church and, like his neighbours, depends more on livestock than ever before. Firewood is an increasing problem nowadays – over the last five years, people from the nearest town, Rakops have been collecting firewood from this area in trucks. He now has to travel up to 10 km by donkey cart to collect firewood.

[17] The caterpillar of the Mopane Moth, *Imbrasia belina.*

Figure 5.11 Firewood is difficult to collect for those without access to transport (photo: M. Reed)

5.5 Study Area 3: Bokspits

This study area is comprised of five villages: Bokspits, Vaalhoek, Inversnuit, Struizendam and Rappelspan in the southwest corner of Kgalagadi District (Figure 2.6). Figures 5.12 and 5.13 show land use and vegetation in the study area, developed through a participatory mapping exercise. The area is in the driest part of Botswana, receiving on average 150-200 mm per year (Thomas & Leason, 2005). Interannual variability exceeds 50%; the lowest recorded annual rainfall was 77 mm in 1998 and the highest was 317 mm in 2000 (Thomas & Leason, 2005). Average daily minimum and maximum temperatures range between 19-35 ^{o}C, with winter and summer temperatures reaching –8 ^{o}C and 45 ^{o}C respectively.

The natural vegetation in this area was classified as "arid bush savanna" by Weare & Yalala (1971), consisting of perennial tufted grasses and sparse woody vegetation (Figure 5.2). The landscape is dominated by fossil linear dunes composed of deep Kalahari sands, around 5–25 m high with a crest to crest spacing of between 200 m and 2 km. Satellite imagery shows these formations clearly (Figure 5.14). Although the majority of these dunes are stable relics of a former drier climate over the last 20 000 years (Wiggs *et al*., 1995), Figure 5.14 shows areas of (lighter) unvegetated, active dunes around settlements. Figure 5.15 shows representative images of (non-degraded) arid bush savanna. Grasses are dominated by *Stipagrostis* spp. and *Eragrostis* spp., with dune crests dominated by *S. amabilis*. Trees and shrubs are sparse, dominated by *Acacia* species (especially *A. haemotoxolon* and *A. mellifera*) and *Boscia albitrunca*. Under intense grazing pressure, interdune areas become dominated by the annual grass *Schmidtia kalahariensis* and thorny shrub *Rhigozum trichotomum*. Encroachment by *R. trichotomum* has been identified as a particular problem across the border in South Africa, adjacent to the study area, and large areas have been cleared (van Rooyen, 1998). Pan vegetation and *A. erioloba* dominate the dry riverbed and nearby calcrete outcrops.

Villages in the study area are supplied with water from boreholes in the dry Nossob riverbed. The main road through the study area follows the riverbed, which

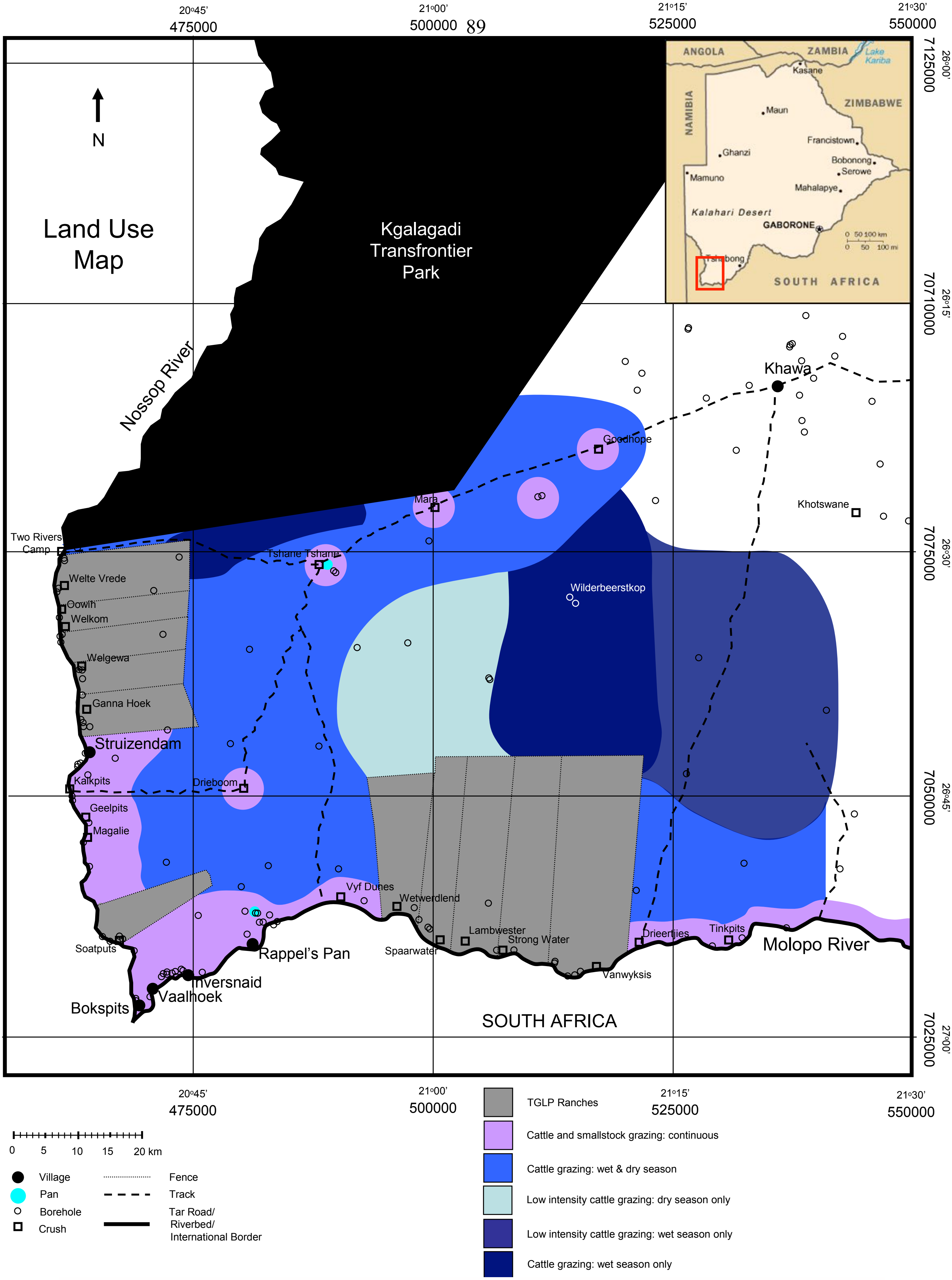


Figure 5.12 Land use in study area 3, developed through a participatory mapping exercise

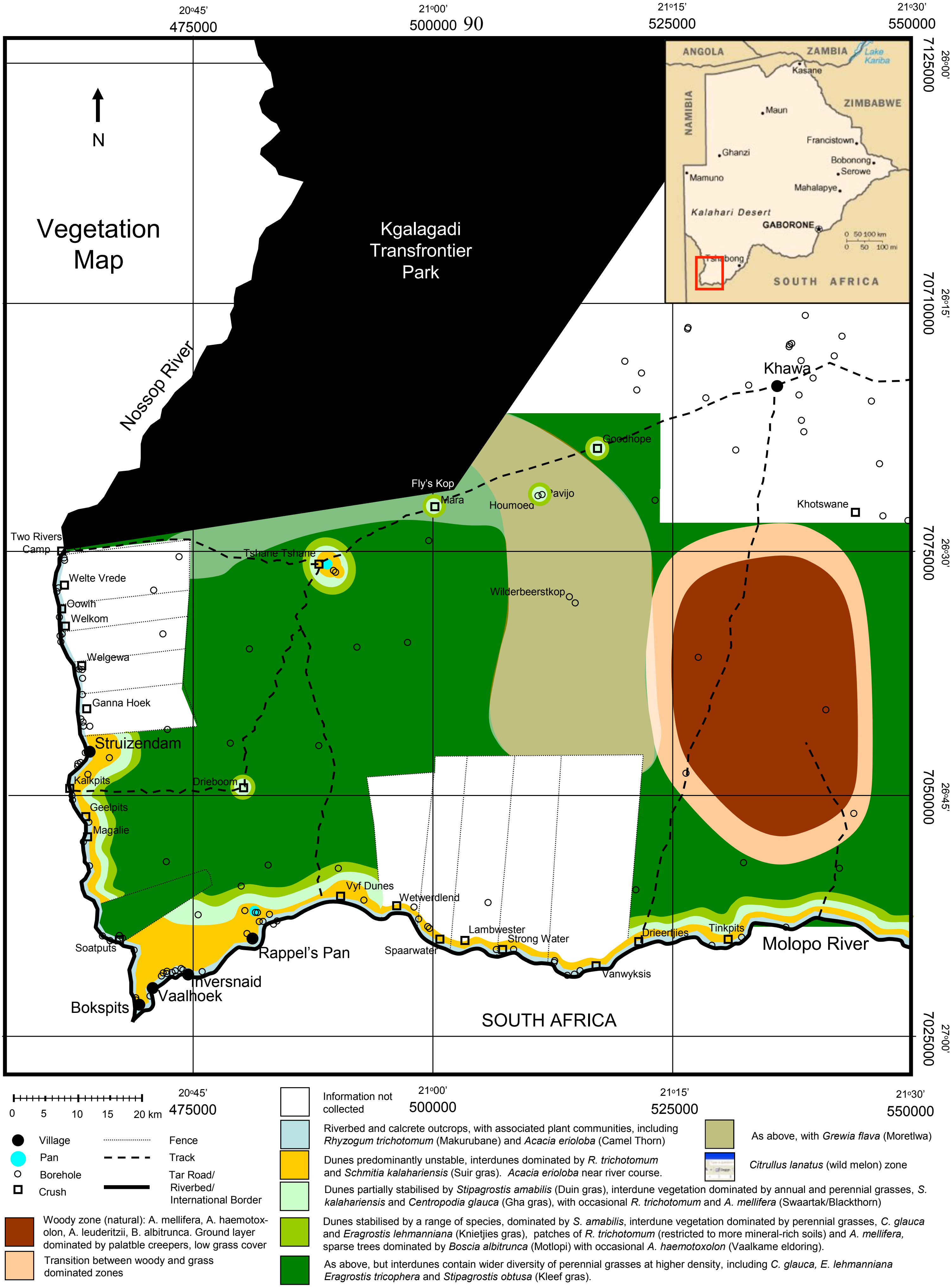


Figure 5.13 Land use in study area 3, developed through a participatory mapping exercise

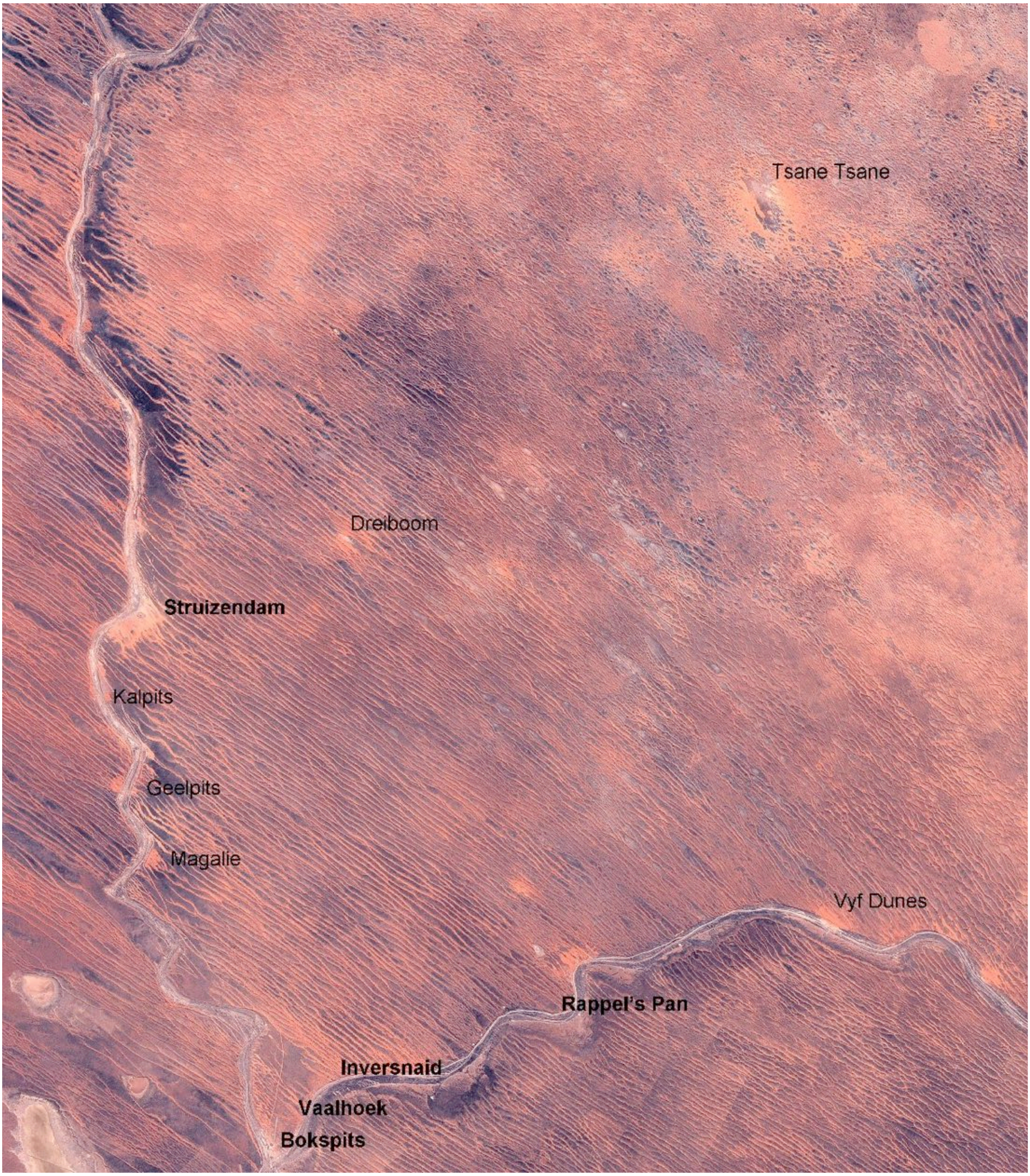


Figure 5.14 Satellite image of part of Study Area 3 showing parallel dunes and areas of unvegetated active dunes around settlements (image: Redtailcanyon, 2005)

Figure 5.15 Representative images of arid bush savanna in Study Area 3, showing tufted perennial grasses and sparse trees lining parallel dunes (top and bottom left), and *Acacia erioloba* lining the heavily used dry Nossob riverbed and nearby calcrete outcrops (photos: M. Reed)

Figure 5.16 Dune formation along the Nossob, formed from riverbed sediment (left) and Kalahari sands (top), are an increasing problem in the study area (bottom) (photos: M. Reed)

also acts as a border between South Africa and Botswana. The majority of livestock are watered at boreholes along the riverbed, and this has resulted in a loss of vegetation cover, leading to wind erosion and active dune formation (Figures 5.14 and 5.16). There are fewer palatable perennial grasses in this area, and more annual grasses and thorny shrubs. However, the extent of this area is limited mainly to within 5 km of the riverbed. This is consistent with research by Thomas & Twyman (2004) showing the retreat of perennial grasses and increased bare ground up to 10 km from Struizendam. In areas inland from the riverbed, such as Goodhope, there was very little bare ground, and cover of palatable perennial grasses was high at 1 km from the borehole.

The vast majority of people living in the study area are mixed race or "coloured". They migrated from South Africa in the first two decades of the 20th century (see Box 5.4). The population of the area is now around 1,600 (IVP, 2003). As South African migrants, the community was initially ignored by the Colonial Government for many years, and developed its own system of local government and amenities, including health and education. Despite being officially recognised now, with a full range of Government services, there is still a feeling that the community is ignored by the Government. Repeated promises to build a tar road between Bokspits and Tsabong have failed to materialise and are often cited as an example of continued marginalisation. This sense of abandonment has been deepened by the recent failure of the Southern African Development Community Kalahari-Namib project to secure further funding. A pilot project was financed which initiated dune stabilisation work and raised expectations of significant improvements in the standard of living. However, the project failed to secure funding to continue the work.

Box 5.4: Oral History, Mrs Bok

Mrs Bok did not know how old she was, but her granddaughter and great grandson thought that she must be well over a hundred. She came from a mixed race or "coloured" community that migrated from South Africa to Botswana in the first two decades of the 20th century. Many had suffered ill treatment as labourers and livestock herders on white farms. They came with livestock they had obtained from South African Boers either through barter or as payment for their labour. At this time, the Nossob flowed each year. After the water receded, Mrs Bok used to grow a number of crops in the riverbed, including cereals and fruit (such as grapes). However, the river stopped flowing around the 1950s, and no crops are now grown in the area.

Around 1930, the colonial Government evicted the community to make way for the National Park. Almost everyone moved to the southwest tip of Botswana where the Bok family had dug a well ("pit" in Afrikaans). The village that sprung up was named Bokspits. Gradually, families started spreading beyond Bokspits in search of potable water for their livestock. Titus Matthys took his family west to Rappelspan where they dug a well. Others spread northeast, digging wells at Gelpits, Kalpits and Francesdam on the way. One of the most productive wells was located on the border, and conflicts arose with South African farmers who claimed rights to the water. The Botswana community eventually won rights to the water and named the village Struizendam which means "conflict dam".

Around 20% of those interviewed received Government welfare, mainly in the form of pensions, destitute payments and drought relief work, but few of these people relied completely on these payments. The only formal employment opportunities in the area are through Government positions (e.g. as teachers, extension and health workers), which are mainly filled by people from outside the community. There is still little integration between these two groups. Almost all those interviewed (apart from the first migrants) had been born and brought up in the study area. The spirit of self-reliance and community support lives on today: farmers in the study area were particularly well informed through a combination of strong farmers associations (almost 40% of those interviewed were members) and (mainly South African) farming publications. In addition to this, the Indigenous Vegetation Project has established active local rangeland management committees in this study area. In contrast, few people felt supported by Government extension services, which are based in Tsabong, approximately 200 km away on a sand road.

Like people from other study areas, most people's knowledge of farming came principally from their parents. Much of this knowledge in turn came from commercial farmers in South Africa for whom their parents or grandparents had worked.

Livestock production remains the main source of livelihoods in the area. There are significant cultural differences between the people living in this study area, compared to the other two. Primary among these is their perception of cattle: although livestock are an important part of local culture, cattle ownership is not tied to social status in these communities. As a consequence, smallstock production (which many argue is better suited to the arid climate in this part of Botswana) is far more important. Karakul sheep (bred for their lambs' pelts) were an important source of income for many respondents until the market declined in response to animal welfare protests in Europe in combination with droughts and increased charges from middle-men in South Africa in the 1980s. On average, people interviewed in this area kept 20 cattle, 66 goats and 88 sheep.

Marketing options are poor as the nearest BMC abattoir in Lobatse is hundreds of kilometers away along poor roads. Although some farmers club together to hire transport, most livestock are sold locally for lower prices. One of the commercial farmers from Study Area 1 makes an annual visit to buy cattle from the area. Most people rely on family labour, but around half also employ people to help look after livestock. A number of private ranches were created in this area under the Tribal Grazing Land Policy in the 1970s and 80s. However, like elsewhere in Botswana owners often retain communal grazing rights, keeping fenced land in reserve for drought (Perkins, 1996; Figure 5.17).

Figure 5.17 Soatpits ranch: rangeland fenced under the Tribal Grazing Lands Policy is often retained by owners as drought reserves (photo: M. Reed)

People use a range of rangeland products, including firewood, building materials, wild fruit and vegetables, and medicinal plants. Firewood is critically scarce, with people searching up to 60 km away from villages, sometimes across the border in South Africa. This is a particular problem for the majority of people who do not have access to transport, who often have to purchase wood. Although alternative building materials can easily be sought, without electricity there are few alternatives to wood for cooking. The medicinal Grapple plant (*Harpagophytum procumbens*) was once collected for sale to pharmaceutical companies in South Africa, but is no longer abundant in the area.

5.6 Conclusion

This chapter has identified relevant stakeholders in the rangeland system of three selected study areas. Sustainable Livelihoods Analysis has been used as a conceptual tool to explore this system in relation to other linked systems through a combination of participatory research methods. Livestock production was the main source of livelihoods in each study area, and an important part of local culture. The majority of people worked in syndicates on communal rangeland supplied with water from boreholes. Study Area 1 appeared to be the most affluent study area, perhaps due to its good connection with international markets. Since the expansion of the livestock sector in response to borehole provision in the 1970s, bush encroachment became an increasing problem in the study area, with over half of respondents citing this as a major livelihood constraint. Study Area 2 was the poorest region studied, with people here more constrained by social, physical and financial capital than either of the other two study areas. Poverty was frequently blamed on low levels of livestock ownership which in turn were constrained by quarantine conditions imposed by the BMC. In addition to this, livelihood options from fishing and flood plain agriculture had been lost due to the drying of the Boteti River. The culture of communities in Study Area 3 was very different to other study areas, being based on migrations from South Africa at the turn of the century, and smallstock ownership far outweighed cattle. Livestock marketing was constrained by access to transport, condition of roads and distance to markets. There were shortages of certain rangeland products, particularly firewood. The next chapter establishes sustainability goals for each study area and identifies a range of management options that could be used to help communities make progress towards these goals.

6

Establishing Goals and Strategies for Sustainable Rangeland Management

Summary

This chapter presents results from step 2 of the learning process: "establishing goals and strategies". It identifies sustainability goals and strategies for the rangeland system with stakeholders in each of the three study areas. To reach these sustainability goals, current practice and possible management options to prevent, reduce, reverse or adapt to land degradation are identified from the literature. However, much of the published literature is aimed at private ranchers. It is therefore necessary to evaluate the relevance of these options carefully with potential users in common property tenure settings. In addition, innovation may be an important source of new responses to environmental degradation which should be considered alongside current practice and strategies from the literature. For this reason, interviews and focus groups were carried out with land managers from each of the three study areas to evaluate and adapt management options from the literature and identify alternatives. Numerous relevant management strategies were identified by participating communities for use in common property rangeland systems. Although not all strategies suggested by rangeland stakeholders were innovative, there were a number of innovators within each study community who were willing to share their ideas. However it was noted that many of the strategies that were suggested could only be applied effectively under common property regimes. Institutional reform may therefore be necessary to reverse the trend of privatising communal rangelands and instead stimulate local adaptation and sustainable management by strengthening common property management regimes.

6.1 Introduction

Once the relevant context has been established for a sustainability assessment (see previous chapter), the next step in the learning process (Figure 3.2) is to establish sustainability goals, and identify strategies that could be used to reach them. Within the scope of this thesis, this chapter focuses on *environmental* sustainability goals and strategies. To identify appropriate strategies, the chapter starts by reviewing literature on current environmental management practices and options in the semi-arid rangelands of southern Africa. However, much of the published literature is geared towards privately owned and fenced rangeland (e.g. Field, 1977; Hendzel, 1983; Milton *et al*., 1998; Tainton, 1999). It is therefore necessary to evaluate the relevance of these options carefully with potential users before they can be applied in communal tenure settings.

Despite numerous assessments of the sensitivity and resilience of land to degradation in drylands (chapter 2), there has been little research into the way affected communities adapt to degradation. Traditionally, pastoralists have often been viewed as agents of land degradation by researchers and policy makers (e.g. Stebbing, 1935; Bollig & Schulte, 1999). However, during the 1970s and 80s, with the rise of participatory research, a number of studies began to recognise the value of local pastoral knowledge (e.g. Swift, 1975; Dahl & Hjort, 1976; Western, 1982; Breman & de Wit, 1983). Innovation[18] may be an important source of new responses to environmental degradation (Reij & Waters-Bayer, 2001; Bassett & Crummey, 2003) that should be considered alongside current practice and strategies from the literature. For this reason, interviews and focus groups were carried out with rangeland stakeholders from each of the three study areas to evaluate and adapt management options from the literature and identify innovative alternatives. This chapter therefore aims to:

- Identify goals for sustainable rangeland management with stakeholders in each of the three study areas;
- Identify current practice and possible management options to prevent, reduce, reverse or adapt to land degradation from the literature; and
- Evaluate these options with rangeland stakeholders and identify innovative alternatives through a combination of semi-structured interviews and focus groups.

6.2 Identifying sustainability goals

Rangeland stakeholders in each study area were asked to articulate sustainability goals for their rangeland system during semi-structured interviews. In each study area, answers centred on income generation, and the prevention, reduction or reversal of rangeland degradation (Table 6.1). There were differences in emphasis between study areas, mainly reflecting local issues (e.g. firewood was scarce in Study Areas 2 and 3, but abundant in Study Area 1), but by and large, these goals have a lot of convergence.

[18] This can be defined as "an idea, practice, or object that is perceived as new by an individual or other unit of adoption" (Rogers, 1995, p. 11). An innovation does not need to be universally new – ideas that an individual has not formerly encountered may also be considered innovations (Rogers, 1995).

Table 6.1 Rangeland sustainability goals articulated by stakeholders in each study area

Study Area 1 Goals	Study Area 2 Goals	Study Area 3 Goals
Have more and better quality livestock	Generate more income from livestock	Have more and better quality livestock
Have less bushes	Have more livestock	More trees for firewood
Have more drought tolerant and profitable cattle breeds	Have healthier livestock	Have more palatable grasses and bushes
Have access to more water that is less salty	Have more firewood	Have stable dunes around villages
Have more palatable grass	Have more thatching grass	Have less livestock concentrated around villages
Fence farm	Have more palatable grass	Have more medicinal plants
Be allowed to reticulate water into areas with salty aquifers	Have less dust storms	
Cattle won't have to walk so far to reach good grass	No further expansion of *C. mopane* dominated rangeland	
Know when to move or sell cattle before irreversible rangeland damage occurs		
Reduce stocking density around villages		

In order to move towards the goals in Table 6.1, a number of management strategies were suggested by rangeland stakeholders during semi-structured interviews. Respondents were asked to focus on strategies to prevent, reduce or reverse rangeland degradation, rather than to generate additional income. This was partly due to a widespread recognition among stakeholders that livestock herd size and condition were primarily limited by rangeland condition. In addition, IVP were independently pursuing a variety of income generating projects with communities in the second two study sites in parallel with this research. Although funding was provided to a youth project to grow and sell vegetables in Study Area 2 through international research contacts, income generation work was left to the IVP and is not reported here. Strategies elicited from interviews were added to existing options from regional rangeland management literature and discussed in focus groups. Current management practice and strategies from the literature are therefore reviewed briefly in the next section, before discussing results from interviews and focus groups in section 6.4.

6.3 Current management practice and strategies from the literature

Traditional "opportunistic" management systems tend to conserve productivity and biodiversity through the close control of grazing activities and their diverse economic base (e.g. different animal species, small-scale arable farming and occasional use of medicinal plants, and hunting and gathering) (Behnke *et al*., 1993; Scoones, 1995). A range of opportunistic practices have been used to manage semi-arid rangelands in Botswana for centuries under common property land tenure. Some of these practices are no longer relevant in contemporary social and economic contexts. However, some persist and others have been adapted for modern use. For example, taboos have traditionally prevented the overuse of certain species (such as the restriction of medicinal plant collection to traditional doctors) at certain times (e.g. rules against cutting certain trees during drought) (Hitchcock, 2002). Some of these rules are still widespread, for example cutting the Shepherd's tree (*Boscia albitrunca*) is taboo throughout most of its Kalahari range due to its value as a fodder and shade resource during drought (van der Walt & le Riche, 1999).

In the past, it was common for livestock managers to burn rangeland to maintain grass dominance in addition to securing a supply of rangeland fruit and vegetables and hunting (Powell, 1994). However, this practice was banned in the 1980s (Perkins, 1996). As a consequence, fires have become more intense and widespread especially on wildlife-dominated rangeland due to increased fuel loads (Perkins *et al*., 2002). Lower fuel loads in heavily grazed and/or bush encroached land (due to lower grass cover) have led to less frequent and intense fires throughout most livestock-dominated rangelands, a factor that is widely 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 kind of vegetation change that has resulted from selective grazing by cattle-dominated herds (such as a shift towards less palatable annual grasses and bush encroachment). Bayer & Waters-Bayer (1995) argue that this can also help rebuild herds 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. Despite the dominance of cattle over the last thirty years or so, the last decade has seen an exponential increase in smallstock populations and there are now more smallstock than cattle (Figure 2.10).

Seasonal livestock movement has been a key component of livestock management in the Kalahari for many decades. During drought, cattle are often sent to less affected, higher value grazing areas with herd boys, sometimes over a hundred kilometres away. They are left there with relatives in the short-term, or looked after for longer periods 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 are able to reduce the risks of livestock mortality during drought. This livestock loan system, called "mafisa", is unique to southern Africa (Hitchcock, 2002).

Although the system is still widely used (an estimated 11.2% of households in 2002 were recipients of mafisa cattle (BIDPA 2002)), there are an increasing number of barriers to its effective use. Trekking livestock to new locations requires sufficient, trained labour (Scoones, 1995), but 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 lands (Twyman *et al*., 2001).

In addition to destocking and movement, there are a range of other techniques that can help livestock better match rainfall-induced 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 & Waters-Bayer, 1995). People 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). It is possible to reduce the diseases and parasite loads that prevent livestock from effectively tracking fodder during drought (Scoones, 1995). Local fodder availability can be increased by buying in feeds, growing drought-resistant fodder crops such as saltbush (*Atriplex* sp.), fencing fodder banks as a reserve or by making tree foliage and pods available to animals (Bayer & Waters-Bayer, 1995; Rothauge, 1998). Grass can be cut and transported from places where there is little grazing pressure such as Wildlife Management Areas[19] (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 & 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 utilization of semi-arid African savanna."

However, opportunistic strategies are not currently promoted by extension services in Botswana, who recommend fixed carrying capacities based on Clementsian succession theory. 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 two-year (or more) droughts 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 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 result was that previous analyses failed to account for economic losses due to drought-induced mortality and the costs of capital tied up in livestock. They point to the large amounts of public funds used to rebuild herds after drought in southern Africa (Richardson, 1986) as further evidence for the cost of opportunistic strategies. As a consequence, they argue that government marketing systems designed to facilitate rapid destocking 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 were 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, and 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 at the on-set of drought. Instead, the Botswana Government subsidises supplementary feed and provides drought relief for the poorest members of society through paid work and rations.

[19] Buffer zones around the National Parks in Botswana.

Behnke & 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. However, Rothauge (1998) warns against restocking more rapidly than recovering rangeland can sustain, as this may lead to long-term degradation. Alternatively, if the rangeland management committees that are currently being piloted by the Indigenous Vegetation Project are more widely applied, it may be possible to implement a destocking policy through grassroots institutions.
Neither Illius *et al*. (1998) nor Campbell *et al*. (2000) considered livestock movements, focussing instead on market-based destocking strategies. In contrast, Morton & 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.

6.4 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 with pastoralists for the second step in the proposed learning process (Figure 3.2) evaluated options from the literature and elicited numerous adaptive management strategies from communities that have the capacity to prevent, reduce, reverse or help people adapt to land degradation in common property rangeland. Table 6.2 shows the breadth of innovation among Kalahari pastoralists in response to rangeland degradation.

Many of the strategies were species-specific, for example a number of new uses were suggested for the encroacher species, Threethorn (*Rhigozum trichotomum*). Some 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. 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) in the exclosures.

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 demonstrate non-equilibrium dynamics, with livestock mortality driven primarily by lack of rainfall. Figure 6.1 shows the different drought coping strategies that they used. Approximately half those interviewed had used the mafisa system during the last two droughts. The other half had relied on some form of supplementary feeding. However, Figure 6.1 suggests that strategies based on movement were least likely to result in heavy livestock mortality. According to interviews, only 17% of people who moved their cattle during the last two droughts lost the majority of their cattle. Most of these pastoralists moved their livestock to family members within a 100 km radius. In contrast, 50% of those who did not move their livestock lost the majority of their herd (Figure 6.1). The majority of these people did not know anyone in less affected areas who could care for their livestock, i.e. their social network was insufficiently large, strong or geographically wide. Although it is argued that open access to communal rangeland is necessary for the mafisa system to work (Behnke *et al*., 1993), only 12% 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 6.1). Only three of the respondents completely destocked by selling animals before the onset of drought (none of these suffered drought-related mortality). 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% of cattle survived if they were moved during early onset of drought, compared to 23% survival for those who moved later and 3.3% survival for those who remained where they were. Twyman *et al*. (2001) also emphasised the importance of strong family ties for successful livestock movement in the Namibian Kalahari.

Given the extent of bush encroachment (e.g. Moleele *et al*., 2002), and the emphasis that respondents put on it during interviews and focus groups, bush management options will be discussed in depth for the rest of this section. The low biodiversity of bush encroached systems and their low fodder value for cattle has raised concerns from pastoralists, policy-makers and researchers alike (Scholes & Walker, 1993; Archer, 1996; Dougill *et al*., 1999). 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, leading landowners to drill additional boreholes in remaining grass dominant areas that then rapidly become bush encroached (Perkins & Thomas, 1993; Sporton & Thomas, 2002). This is especially troubling given the amount of rangeland ecology literature that suggests a dryland region's ability to support livestock depends on maintaining diverse and heterogeneous fodder resources (Scoones, 1995; Dougill *et al*., 1999).

Given the costs and difficulties associated with eradicating established stands of bush (especially *Acacia mellifera*), preventing establishment in the first place is preferable. However, where woody plants have already gained dominance, two broad management strategies were suggested by stakeholders: control and adaptation.

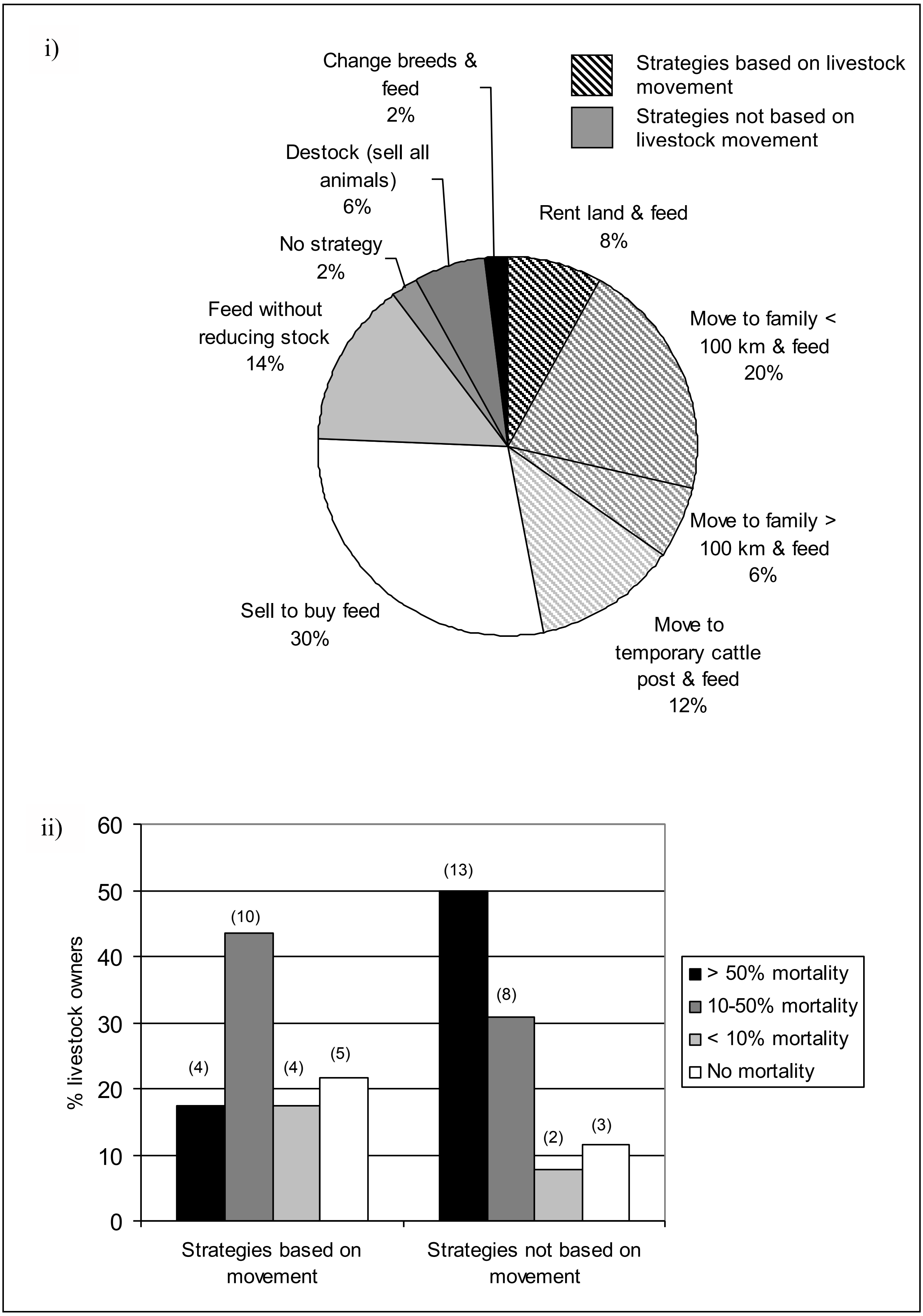


Figure 6.1 i) Drought coping strategies used by pastoralists in Study Area 1; and ii) Percentage of pastoralists (number in brackets) using different strategies based on movement or not, and the proportion of their herd lost during droughts in the 1980s and 1990s (n = 49)

Table 6.2 Management options to prevent rangeland degradation or rehabilitate degraded rangeland in Botswana, suggested by land users during semi-structured interviews and evaluated in village focus groups

Management Option	Summary	Benefits	Requirements	Technique	Limitations
Borehole Rotation	Livestock from at least three boreholes are combined into a single syndicate. The borehole with the most damaged rangeland is rested in the first year, while the herd is split between the remaining boreholes in the syndicate. The resting borehole is rotated each year.	• Regular resting improves rangeland health and can facilitate long-term sustainable livestock production; • During drought, rangeland around the resting borehole can be used to reduce pressure on other boreholes in the super-syndicate. This can be done without reducing the herd sizes and prevents livestock from damaging rangeland during drought when it is most vulnerable.	• The capacity to combine syndicates and successfully manage a large group of livestock owners; • Boreholes should not neighbour each other (to prevent cattle returning to their original borehole) and should have high yields of palatable water.	1. Form a large syndicate with farmers from at least two other boreholes that do not neighbour each other; 2. Rest the rangeland that is worst condition first by moving all livestock to the other boreholes in the syndicate. Although some livestock will inevitably use the area, pressure will be much less, giving the rangeland a chance to recover; 3. Take manure from kraals around the boreholes that are being used, and place piles of it in the rangeland around the resting borehole (see Management Option 3); 4. 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 in very poor health, supplementary feeding may be necessary until rangeland around each borehole in the syndicate has been rested. In future years, regular resting and good rangeland health should enable the herd to be maintained sustainably around fewer boreholes.	• It can be a challenge to make a large syndicate work effectively; • 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 move elsewhere or sell livestock.
Better use of *Rhigozum trichotomum*	Two options for making more productive use of the thorn bush *R. trichotomum* are suggested: 1) grinding the bushes up to make livestock feed; 2) the harvesting of flowers and pods for storage and later use.	Although *R. trichotomum* is highly prized by all kinds of livestock (especially smallstock) for its highly nutritious flowers and pods, the flowers only last for 14 days and once the pods have been used, the bush has little value for livestock. The bush is most common in heavily used areas where it out-competes grass, and it is viewed as a problem in South Africa where it is often cleared. However, given its high value for part of the year, opinion is split about *R. trichotomum* in Botswana.	• Grinding by hand is difficult, so a hammer mill is usually required; • Somewhere dry and dark to store dried flowers and pods	**Grinding** 1. Young bushes (1-2 years) make the most nutritious fodder. Areas of old bushes must therefore be cut first. They should not be uprooted – in this way they are able to re-sprout from their base and the roots reduce erosion. The bushes can be cut near the ground using a tractor with bush cutting attachments, or can be cut by hand. This material has been used successfully to stabilise dunes in South Africa (once dunes are stable, grass can begin to take root); 2. The following year, branches that have re-sprouted can be harvested; 3. These can then be fed into a hammer mill to produce fodder that can be used by all kinds of livestock. **Harvesting flowers and pods** 1. Many more flowers and pods are produced than can be consumed by livestock each year. However, it is possible to harvest surplus flowers and pods. This is best done 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. However where it is unlikely that it	Because *R. trichotomum* only flowers and fruits after 3 years, you can *either* grind whole bushes *or* harvest flowers and pods in any one area. It is not possible to grind whole bushes after they have flowered and fruited as they are too old to be valuable as ground fodder. However, different areas of bush can be used for grinding and

Management Option	Summary	Benefits	Requirements	Technique	Limitations
Protect and improve the soil	There are a range of different options for protecting and improving the soil that take little time or effort, such as pollarding to keep tree cover around boreholes, rotating kraal locations and soil protection and improvement strategies associated with bush clearance.	By protecting and improving the soil, you can produce more nutritious fodder that will benefit livestock production.	A shovel, and a vehicle or donkey cart for transporting manure	• 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 around regularly so that they do not make soils toxic; • Place piles of manure in rangeland beyond the vicinity of the borehole (where soils are already enriched). The sun dries the manure so that it can be spread around by the wind. In order to prevent the spread of bushes species that are not palatable to cattle, avoid using smallstock manure. If there is limited browse available, smallstock manure may be used to promote these species; • If clearing bush, leave strips of bush lined against the prevailing wind to reduce wind erosion; • If clearing bush, break bushes up and lay over the soil. In addition to protecting the soil, they will protect grass seedlings from grazing until they well established. As they break down, nutrients will be returned to the soil.	It may take time for dung to be properly distributed and incorporated into the soil. The time it takes will depend to an extent on weather conditions (wind and rain) and these are never predictable.
Shifting Grazing	Rest rangeland around villages by a) reducing smallstock browsing pressure in the dry season; and b) reducing cattle grazing pressure in the wet season. Smallstock can be moved to cattle posts away from the village and provided with water by donkey cart or vehicle during the dry season. Herding can be made easier by allocating herds to different valleys between parallel dunes. Cattle can be herded to areas rich in *Citrullus lanatus* (Tsama melons) during the wet season.	Rangeland around villages tends to be heavily used by livestock, and can become easily damaged. By resting it annually it may be possible to reduce the amount of damage done, and prevent the area from becoming worse.	• A donkey cart or vehicle • A container for transporting water • Knowledge of where *C. lanatus* grow and at what times of the year	1. 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 to be possible with current levels of labour; 2. Identify areas where *C. lanatus* 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.	This strategy will not work during drought

6.4.1 Bush control strategies

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

i) Follow up above-ground stem-cutting with intense smallstock browsing;
ii) 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 documentary evidence to support their claims, and some focus group participants remained sceptical; and
iii) Hollow out the ground around the base of the bush and cut stems 10-60 cm beneath the ground (cutting lower beneath the ground for larger bushes), 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 no known parallel 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 likely to be relatively labour-intensive, but although there have been no formal measurements taken from these plots, the results are visually impressive (Figure 6.2).

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 small 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

Figure 6.2 i) Ministry of Agriculture bush clearance exclosure between Makopong and Werda, showing cleared (right) and control plots (left); and ii) individual stem burning of bushes on Hereford Farm, near Bray, Botswana (photos: M. Reed)

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*. However there is little evidence to support this view. 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 un-cleared areas, in addition to increased basal cover and yield of palatable grasses.

In contrast to rangeland management literature suggesting that prescribed fires are cheaper than chemical or mechanical bush control (Trollope, 1992; Buss & Nuppenau, 2003), respondents downplayed the importance of prescribed fire as a control option. They pointed out that in heavily encroached sites (e.g. many parts of 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. The literature identifies other limitations. Although prescribed fires require no capital and few labour inputs, the opportunity costs are high due to lost grazing land (Trollope, 1992). In addition, other methods are still necessary to prevent re-growth or coppicing of bushes after fire (such as browsing). Trollope (1974) showed that despite achieving over 80% top-kill of bush stems (particularly young bushes), intense fires generally killed less than 10% of bushes. He showed that bush mortality could be as low as 1.3 %.

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 (Figure 6.2). 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 may be 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 & Walker, 1976; Story, 1952), and prevent further spreading of bush cover (Tainton, 1999; Mahanjana & Cronje, 2000; Scogings, 2003). Du Toit (1972) used stem cutting in conjunction with continuous goat browsing of coppice growth to achieve 63% mortality (rotational browsing resulted in only 31% mortality). Goats have also been used to reduce bush cover in conjunction with prescribed burning in South Africa and Namibia (e.g. Trollope, 1974; Zimmerman *et al*., 2003). Coppice growth is more palatable than old growth and hence preferentially browsed. Hurt (1992) argues that this further drains reserves that have been lost to the fire, reducing bush vigour and eventually leading to mortality. Trollope & Dondofema (2003) compared a combination of continuous goat browsing and rotational grazing during winter after annual burning between 1973-2001 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. This treatment also resulted in 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 herbicides such as Picloram (also known as Access and Tordon Super) 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 ground water or the food chain. However, one respondent noted that urea-based herbicides are capable of enhancing soil fertility in the long-term as they break down (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 years. However Smit *et al*. (1999) points 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 time-frame for most farmers (Buss & Nuppenau, 2003), and may give negative returns on investment (Quan *et al*., 1994). They also require considerable expertise and equipment. For this reason, Trollope *et al*. (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, bushes are too dense for animals to penetrate or are unpalatable.

For all these 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:

i) 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.
ii) Alternatively, respondents suggested using whole uprooted bushes as fencing to keep livestock out of resting areas. However, this does not recycle nutrients as effectively, and 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 (Behnke & Scoones, 1993; Dougill *et al*., 1999). The potential benefits of bush cover for reducing wind erosion have been discussed by Perkins & Thomas (1993). Dougill *et al*. (1999) also suggest that remnant bushes can provide potentially valuable fodder during drought, and protect palatable grasses from grazing that can then act as a seed source for surrounding rangeland. The use of thorn bush branches to cover the soil is another example of an innovative approach to protect recovering rangeland from both livestock in the absence of fencing. This has been trialed in communal farms in the northern Cape Province of South Africa to stabilise sand dunes, yielding promising results (van Rooyen, 1998).

6.4.2 Bush adaptation strategies

In addition to the wide range of control strategies discussed above, a number of adaptation options were suggested by land managers for bush encroached systems. For example, it may be possible to shift from cattle to smallstock production, particularly goats, in order to utilise bushes as a browse resource. In areas where bushes have been dominant for many years, there tends to be less browse available than in areas that have been invaded more recently (as bushes grow older, they become more widely spaced and with much of the foliage out of reach for smallstock). Usually bushes invade around boreholes first, and gradually spread out into the surrounding rangeland. 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 was also suggested as an alternative adaptation to bush encroachment. The primary reason given for this was their greater resistance to drought than livestock. In addition to this, Cooke (1985) argues that wildlife management has advantages over livestock farming in the Kalahari because game need less water per head than cattle, and are less likely to cause damage to rangeland vegetation (especially bush encroachment) as they browse bushes and are less choosy in what they graze. This makes game farming particularly suitable in bushy areas (although these are less well suited to game viewing). It may be possible to supplement game farming for meat with photographic tourism and the sale of hunting licences (at different times of the year). For these reasons, it is 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 CMNRM 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 deliver the socio-economic gains that the promised to local communities (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). 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 (see section 4.5.1 for methods), which had the greatest problems with bush encroachment

(Tables 6.3 & 6.4). Both pastoralists and extension workers ranked stem-burning and below-ground stem-cutting as the most appropriate control techniques. Their reasons were similar: both techniques were considered to be cheap and effective. Although capital was limited for bush control, few considered labour to be a limiting factor. Although extension workers viewed shifting towards smallstock production as the best adaptation option, 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.

Table 6.3 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; seen it work 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

Table 6.4 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
	By individuals	No additional comments
	By paying herd boys	No additional comments
	Through community action	No additional comments
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

6.5 Conclusion

This chapter has identified sustainability goals for the rangeland system with stakeholders in each of the three study areas. In order to reach these goals, current practice and possible management options to prevent, reduce, reverse or adapt to land degradation were first identified from the literature. These options were then evaluated with rangeland stakeholders and innovative alternatives were identified through a combination of semi-structured interviews and focus groups.

Despite the wide variety of methods available in the literature for preventing, reducing, reversing or adapting to bush encroachment, few are suitable for use by communal farmers in the Kalahari. Many are not compatible with communal land tenure, for example requiring stock exclusion (which is not possible without fencing). Similarly, mechanical and chemical methods are too expensive or labour-intensive for most pastoralists to use, and raise issues over who pays in communal systems. Nevertheless, by evaluating options from the literature with local stakeholders, and identifying innovative strategies from the community, it has been possible to identify a number of relevant options.

Although not all strategies suggested by rangeland stakeholders were innovative, there were a number of innovators within each study community who were willing to share their ideas. However, 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. Institutional reform may therefore be necessary to stimulate farmer innovation and adaptation. In this context, Waters-Bayer *et al*. (2003) suggest that socio-organisational and institutional innovation is often more important than technological innovation in pastoral systems. The IVP is attempting to create an institutional environment conducive to farmer innovation primarily by assisting communities to gain formal user rights over rangeland resources in their vicinity, thus promoting a sense of ownership of these resources. Creating the appropriate institutional context (in particular common property regimes) and forming fruitful partnerships with researchers or extentionists, may foster local innovation that can reduce land degradation severity or provide ways for people to adapt to it. In this way, it may be possible to enhance the capacity for communities to prevent, reduce, reverse or adapt their livelihoods to environmental degradation.

7

Identification, evaluation & selection of indicators

Summary

This chapter presents results from step 3 of the learning process: “identifying, evaluating and selecting indicators”. Although it is increasingly recognised that local communities need to participate more actively in sustainability monitoring, there is concern among some researchers that community-derived sustainability indicators lack sufficient objectivity and rigour. This chapter investigates the extent and nature of local knowledge about sustainability indicators in the Kalahari, Botswana. This knowledge is then evaluated by community members before being tested empirically using ecological and soil-based techniques. There was considerable overlap between scientific and local knowledge, and the majority of indicators suggested by land users were validated through empirical work. By building on local knowledge, the indicators were highly familiar to land users who had the capacity to apply them without any need for specialist training or equipment. Despite the wealth of knowledge about rangeland sustainability indicators as a community, this knowledge was thinly spread. By testing and disseminating this information, the research was able to build upon and share valuable local knowledge among communities. This knowledge was more holistic than many published indicator lists for monitoring rangelands, encompassing vegetation, soil, livestock, wild animal and socio-economic indicators. Furthermore, land user preferences for vegetation and livestock indicators match recent shifts in ecological theory suggesting livestock populations may reach equilibrium with dry season or drought forage resources in semi-arid environments. Early warning indicators tended to focus on vegetation and soils. Despite considerable overlap between indicators elicited from each of the three study areas (30 out of 140 were elicited in all areas), there were still significant differences between study areas due to biophysical differences. For this reason, it is essential for indicator-based decision support systems to be site-specific.

7.1 Introduction

The next step in the learning process is to identify potential sustainability indicators, evaluate them and select those that can be used to collect data to monitor progress towards sustainability goals (Figure 3.2). Sustainability indicators have been embraced by researchers and policy-makers at local, national and international scales to monitor progress towards sustainable development goals (UNCED, 1992; UNCCD, 1994; Bell & Morse, 1999). Despite the recognition that these goals can only be met with the active participation from local communities, the majority of indicators are developed by researchers for use by policy and academic communities. While often accurate, these indicators are rarely accessible, meaningful or useful to people who manage the land. Applying such indicators usually requires time, money and specialist training or equipment that is rarely available to land managers. For this reason, the results of sustainability monitoring are rarely noticed or acted upon by land managers (Innes & Booher, 1999; Carruthers & Tinning, 2003).

Participation from local communities can help indicators be interpreted in their socio-economic context. They can also stimulate local action to improve the sustainability of land management. Although it is increasingly recognised that local communities need to participate more actively in sustainability monitoring (Estrella & Gaventa, 2000), there is a concern amongst some researchers that community-derived indicators lack sufficient objectivity and rigour (Abbot & Guijt, 1997; White, 2001). This chapter therefore:

- Identifies potential environmental sustainability indicators from local stakeholders (task 5 in Figure 3.2);
- Evaluates potential indicators with stakeholder groups (task 6 in Figure 3.2); and
- Empirically tests these indicators (task 7 in Figure 3.2).

The research focuses on the environmental sustainability of rangeland management in places where the majority of people's livelihoods depend on livestock. Each study area is perceived to be experiencing environmental degradation (chapter 2), and reducing or reversing this is a shared goal for local communities.

7.2 Indicator identification

> "Staying in an area too long is like wearing the same dress for years; it gets worn out."
>
> Female farmer, age 65, Six Mile Cattle Post

A significant number of potential sustainability indicators representing a wide range of agro-ecological system components were elicited from local pastoralists. These were collected as land degradation indicators, which can be reversed to obtain sustainability indicators (see section 4.5.1). A total of 84, 79 and 64 indicators were elicited in Study Areas 1, 2 & 3 respectively[20], making a total of 140 different indicators. Of these, 38, 64 and 42 were considered by land users to be both accurate and easy to use in Study Areas 1, 2 & 3 respectively (Appendix 1). Although many were site-specific, 30 of the indicators that were considered accurate and easy to use were elicited in all three study areas.

[20] From 67, 40 and 53 interviews in Study Areas 1, 2 and 3 respectively.

Despite the wealth of knowledge about sustainability indicators in communities, this knowledge was thinly spread: although 140 indicators were suggested in total, on average, individuals could only describe 6, 8 and 7 indicators each in Study Areas 1, 2 & 3 respectively. For this reason, the focus groups that were used to shortlist potential indicators acted as a valuable learning opportunity: they very quickly provided the community with collective knowledge that was not known to any single individual. Although certain indicators were cited by many land users (e.g. grass cover was cited by 67%, 35% & 21% respondents in Study Areas 1, 2 and 3 respectively), there was little overlap between the knowledge or conceptualisation of individual community members.

In Study Areas 1 & 3, land users were more reliant on vegetation indicators (52% and 57% of those elicited compared to 38% in Study Area 2). People used less soil indicators in Study Area 3 (9% compared to 23% and 19% in Study Areas 1 and 2) (Figure 7.1).

In Study Area 1, formal education was a good predictor of indicator conceptualisation (Figure 7.2; $p < 0.01$; $r^2 = 0.25$; see section 4.5.2 for statistical methods). In addition to knowing more indicators, better educated respondents cited proportionately less vegetation and more wild animal indicators than less educated farmers who relied more on vegetation and livestock indicators. Men knew significantly more indicators than women in Study Area 2 (on average 7 and 12 indicators respectively) (Figure 7. 3; $p < 0.01$), however there was no difference in the balance between the kind of indicators they knew. In Study Area 3, there was no relationship between indicator conceptualisation and any of the factors that were assessed.

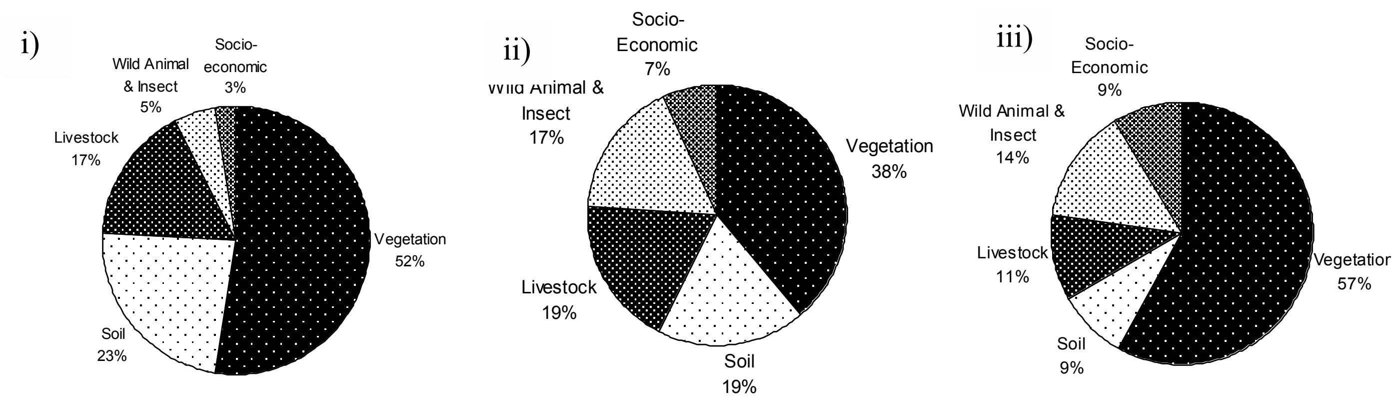


Figure 7.1 Proportion of vegetation, soil, livestock, wild animal & insect, and socio-economic indicators cited by land users in i) Study Area 1; ii) Study Area 2; and iii) Study Area 3

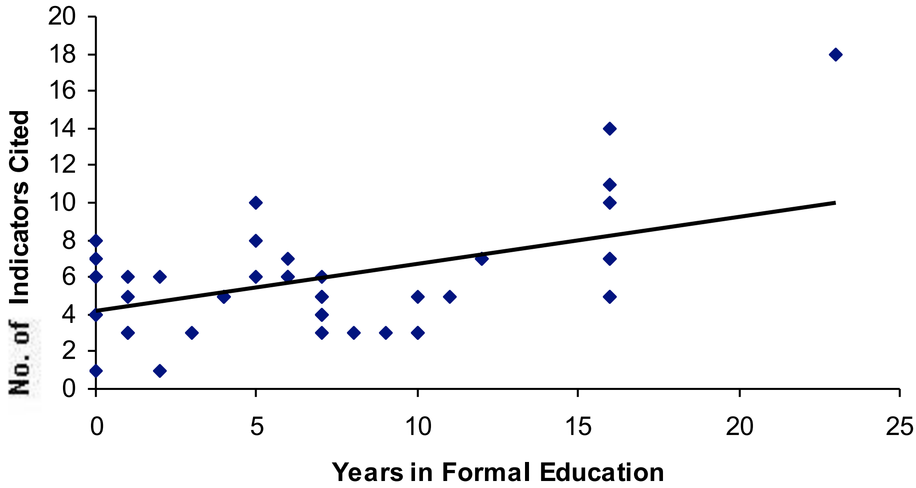


Figure 7.2 Relationship between indicator conceptualisation and formal education in Study Area 1 ($p < 0.01$; $r^2 = 0.25$)

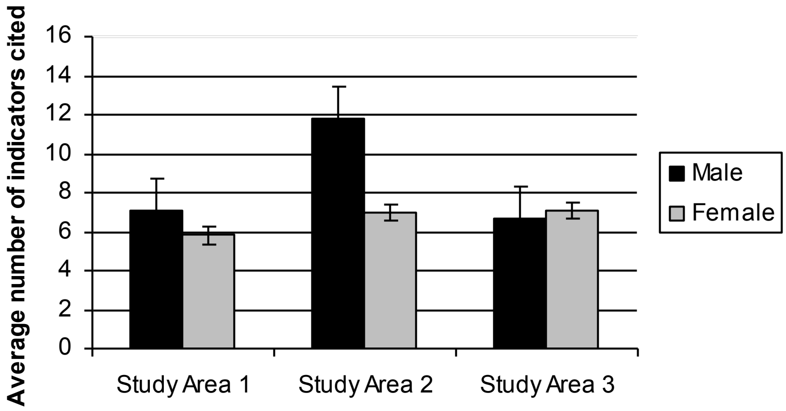


Figure 7.3 Average number of indicators cited by men and women in each Study Area

7.3 Indicator evaluation among stakeholder groups

Indicators that land users considered to be both accurate and easy to use were shortlisted using Multi-Criteria Evaluation (section 4.5.1) and tested using ecological and soil-based techniques (section 4.5.2). Criteria for evaluating locally derived indicators were developed with pastoralists in Study Area 1. These included suggestions that indicators should be: easy and rapid to use, relevant to the target area, use existing skills and knowledge, be reliable over space and time, encompass a diverse a range of parameters and be possible to monitor visually on a daily basis. These were summarised as: 1) accuracy criteria; and 2) ease of use criteria. This is consistent with published criteria for evaluating sustainability indicators which can be logically classified under these categories (chapter 3). Using these criteria, Multi-Criteria Evaluation resulted in short-lists of 38, 63 and 42 (out of the original 84, 79 and 64) indicators that were perceived to be both accurate and easy to use by communities in Study Areas 1, 2 and 3 respectively (Appendix 1).

In Study Area 1, formal education was a good predictor of indicator conceptualisation. The best educated group with best ability to conceptualise indicators were commercial ranchers. In addition to parents, local farmers and extension services, many communal farmers learned much of their knowledge from commercial farmers they had worked for in South Africa. Some indicator experts came from other backgrounds, for example the respondent who knew most indicators (18) had a successful career in the capital city, and had only recently obtained livestock in the communal rangelands of his home village. He had three Arts degrees from the Universities of Botswana, Oxford and Rhodes (South Africa). This suggests that better educated respondents were able to conceptualise and articulate indicators more easily than less educated respondents. The difficulty of conceptualising and articulating indicator knowledge may also account for the apparent thin spread of knowledge across the community. The majority of those who took part in the Multi-Criteria Evaluation felt able to comment on the accuracy of most indicators, suggesting a level of familiarity with the information they had been presented with. It is possible that different people were able to articulate different parts of a predominantly shared subconscious knowledge or “intuition” about environmental change.

Less educated land users relied more on livestock and vegetation indicators. This may be a reflection of their management objectives which were more likely to focus on improving herd size and quality, and income generation (chapter 5). Better educated land users 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. Perhaps as a consequence, this group tended to be able to conceptualise a more diverse range of indicators.

The range of indicators elicited was far broader than many published indicator lists, encompassing vegetation, soil, livestock, wild animal and socio-economic indicators. The majority of rangeland monitoring manuals aimed at land managers focus entirely on vegetation and/or soil indicators (e.g. Foran *et al.*, 1978; Vorster, 1982; Tongway, 1994; Milton *et al.*, 1998; NRC, 2000). However, there is evidence that reliance on a narrow range of indicators may produce misleading results for rangeland assessment (Stocking & Murnaghan, 2001). The breadth of indicators used by communities in the Kalahari matches the call by the UN Convention to Combat Desertification for “integrated sets of physical, biological, social and economic indicators” (UNCCD, 1994). It should be noted however, that different kinds of indicators were cited in different study areas. In Study Areas 1 and 3, land users were more reliant on vegetation indicators than those in Study Area 2, and people used less soil indicators in Study Area 3 than the other areas (Figure 7.2).

Pastoralists’ preference for vegetation-based indicators in all study areas 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. Field, 1977; Foran *et al.*, 1978; Vorster, 1982). However these assessments have tended to be predominantly 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, 2000). 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 on semi-arid ecological change and degradation (e.g. Illius & O'Connor, 1999; 2000; Sullivan & Rhode, 2002). Pastoralists' focus on vegetation and livestock indicators is at variance with the non-equilibrium concept that livestock populations are not coupled to their forage resources as their numbers are regulated in a non-density-dependant manner by stochastic rainfall events (Ellis & Swift, 1988; Scoones, 1995). Contrary to non-equilibrium claims that "the risks of environmental degradation in non-equilibrium environments are limited, as livestock populations rarely reach levels likely to cause irreversible damage" (Scoones, 1995: iv), pastoralists claim that livestock are capable of causing permanent damage to forage resources, inducing a transition to a less productive ecological state (as predicted by non-equilibrium state-and-transition models for the Kalahari (Dougill *et al.*, 1999)). Such claims are consistent with recent challenges to non-equilibrium theory that suggest livestock can reach equilibrium with the key forage resources they depend on during the dry season or drought (Illius & O'Connor, 1999; 2000).

The absence of livestock indicators from previous rangeland condition assessment manuals also contrasts with information provided by Kalahari pastoralists. Previous attempts to identify livestock indicators tended to be highly specialised, 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 Massai in dryland Kenya monitor livestock condition to inform rangeland management (Kipuri, 1996).

Men were able to conceptualise significantly more indicators than women in Study Area 2. In contrast to the other two study areas, men at this area owned significantly more livestock than women ($p < 0.01$): on average 81 compared to 26 cattle, sheep and goats. As more active livestock managers, men are likely to know indicators relating to the livestock system in this study area. A much lower proportion of indicators were empirically validated in Study Area 2 (35% compared to 67% and 86% in Study Areas 1 and 3). This is probably because the short-listing process was not as successful in Study Area 2: 80% of indicators elicited from interviews were deemed to be both accurate and easy to use by focus groups in Study Area 2 compared to just 45% and 66% in Study Areas 1 and 3. This may be due to the much lower attendance at focus groups in Study Area 2: an average of 6 people per focus group, compared to 12 in both Study Areas 1 and 3.

The majority of indicators elicited were "state" and "impact" indicators, according to the Driving Force-Pressure-State-Impact-Response terminology (EEA, 1998)[21]. In addition to this, community members were asked to identify more process-based indicators which could provide early warning of detrimental change (section 4.5.1): "pressure indicators" according to EEA's (1998) framework. 14, 14 and 12 early warning indicators were identified in Study Areas 1, 2 and 3 respectively (Table 7.1). Many people found this distinction difficult to make and cited only state and impact indicators. This is consistent with Kipuri's (1996) findings from work with pastoralists in Kenya, and may be related to the apparency of state and impact

[21] Following OECD's (1993) widely applied Pressure-State-Response (PSR) framework, indicators are identified to characterise human *pressures* on the environment, the *state* of the environment and societal *responses* to environmental change (e.g. Christesen, 2002; Bricker *et al*., 2003). Additional indicator categories have been devised, for example *driving forces* of environmental change (DSR framework; Gallopín, 1997) and *impacts* on the environment (DSPIR framework; EEA, 1998).

indicators. However, the extra information available in early warning indicators makes them vital to develop effective indicator-based management tools and enhance extension advice. Wider dissemination of such indicators may facilitate timely adaptation to environmental change and potentially enhance the sustainability of rangeland management. Early warning indicators tended to focus on vegetation and soils. There was an absence of socio-economic and few livestock early warning indicators.

By building on local knowledge, the indicators developed in this research are familiar to land users who have the capacity to apply them without any need for specialist training or equipment. Although most of the indicators cited by communities are found in the literature (Table 7.2), communities can often provide more meaningful interpretations of existing indicators, with non-technical means of measuring complex variables. Rain use efficiency is an example of an indicator which would conventionally require too much specialist training and equipment for most pastoralists to use. However it was used in a simplified form by a number of pastoralists who defined it as "plants responding to rain with greater growth". Similarly, some pastoralists used the "dirtiness" of the sand as a surrogate for soil organic matter, which would normally require laboratory facilities to measure. Surrogates such as these are necessarily qualitative, but pastoralist experience shows that the information provided by these surrogates is sufficiently accurate to support management decisions.

Many indicators from the literature were not cited by pastoralists. Discussions in village focus groups showed that most of these were considered too difficult to measure. This included soil crusts, which have been used as indicators of rangeland condition in manuals targeted at land users elsewhere in the region (Milton *et al.*, 1998). Some indicators from the literature were considered irrelevant to the study area, such as soil compaction. Compaction is not a problem in Kalahari soils due to their consistently high proportion of fine sands (Dougill *et al.*, 1998).

In some instances, communities took issue with indicators from the literature. For example, in Study Area 1, unsustainable livestock practices are likely to lead to increased fuelwood availability due to bush encroachment (most bush species have relatively short life-spans, producing large amounts of dead wood). This contrasts with the other study areas and literature based on areas where deforestation is a threat to sustainability (e.g. Ottichilo *et al.*, 1990). In addition, contrary to evidence in the literature citing decreased soil infiltration rate as a degradation indicator (Bellows, 1995; Tongway, 1994; Weixelman *et al.*, 1997; Sharma, 1998), communities viewed this as a positive sign, indicative of more consolidated sand with higher organic matter content. This is probably due to differences in soil type between this study area (dominated by fine sands) and those in the literature. Unconsolidated soils with high infiltration rates tend to have low biological soil crust cover (a widely cited degradation indicator (Milton *et al.*, 1998; Berkeley *et al.*, 2005)), can cause "Long Claw" in cattle (a condition where hooves become deformed due to walking on soft sand) and makes travel difficult without a four-wheel-drive vehicle.

Tree-based indicators tended to be cited frequently as early warning indicators; notably tree stunting, decreased abundance of trees and an increased proportion of trees dropping branches and leaves or dead. 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 intense grazing, especially during drought events (Illius & O'Connor, 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.

Table 7.1 Early warning indicators identified by focus groups in each study area. Indicators in bold were suggested in at least two study areas. For empirical evidence see Appendix 1

Study Area 1	Study Area 2	Study Area 3
	Vegetation	
Decreased grass cover	**Decreased grass cover**	**Decreased grass cover**
Decreased abundance of palatable grasses and increased abundance of unpalatable grasses	**Trees become increasingly stunted**	**Trees and bushes increasingly stunted**
Decreased abundance of trees	**Decreased abundance of trees**	**Decreased abundance of trees**
Increased bare ground/ decreased vegetation cover	**Increased bare ground/ decreased vegetation cover**	**Increased bare ground/ decreased vegetation cover**
Increased proportion of trees dropping branches and leaves or dead	**Increased quantity of dead trees**	Decreased abundance of palatable creepers ("opslag")
Decreased abundance of fruit & flowers	Decreased availability of thatching grasses	**Decreased abundance of wild fruit**
Increased abundance of unpalatable forbs and shrubs	Ability to see further into distance	Increased abundance of the shrub, *Rhigozum trichotomum*
Increased abundance of the shrub, *Acacia mellifera*	Decreased rain use efficiency (veg responds less rapidly & vigorously to rainfall)	
	Decreased grass height	
	Soil	
Increased soil looseness	Soil becomes softer or more powdery/dusty (decreased grain size)	**Increased soil looseness**
Increased water infiltration rate (rain soaks into soil faster)	**Increased water infiltration rate (rain soaks into soil faster)**	Increased abundance of unvegetated sand dunes
Cannot use 2WD vehicles and bicycles any more	**Increased evaporation rate (soil dries out faster after rain)**	**Increased evaporation rate (soil dries out faster after rain)**
	Increased dust storm incidence & severity	
	Livestock	
Declining livestock condition/weight	None cited	Livestock walk further from water
Livestock spend more time eating bushes		
Declining herd size		
	Wild Animal & Insect	
None cited	**Decreased abundance of game and predators**	**Decreased abundance of game and predators**
		Decreased abundance of grasshoppers
		Increased abundance of Harvester Termites
		Increased abundance of *Pachycondyla* sp. ants ("malelekatou")

7.4 Empirical indicator evaluation

There was considerable overlap between scientific and local indicator knowledge (Table 7.2). 19, 33 and 26 indicators were evaluated using ecological and soil sampling in Study Areas 1, 2 and 3 respectively. This is equivalent to 49%, 53% and 62% of the indicators that were deemed accurate and easy to use by local communities. Of these, evidence from field-work was found to support 67%, 35% and 80% of indicators in Study Areas 1, 2 and 3 respectively (excluding indicators for which there was insufficient data to draw reliable conclusions). Indicators were measured along land degradation gradients to determine their capacity to represent degraded land states i.e. accurate degradation indicators should be present in degraded land and absent from non-degraded land, evidenced by a decreasing frequency of indicator measurements along degradation gradients.

7.4.1 Identification of degradation gradients

Land degradation gradients were identified in the field following the widely applied piosphere approach that uses distance from water sources to represent grazing-induced land degradation in drylands (e.g. Mentis, 1983; Stuart-Hill *et al*., 1986; Pickup *et al*., 1998; Dougill *et al*., 1999; Thomas *et al*., 2000; van der Westhuizen *et al*., 2005). Floristic data was then analysed using Detrended Correspondence Analysis (DCA; Hill, 1979; Hill & Gauch, 1980) to identify primary and secondary degradation gradients, and these were validated against key widely cited degradation indicators from peer-reviewed literature (e.g. distance to water and dung frequency) using regression analysis (see section 4.5.2 for full methods).

Regression analysis following DCA showed that the majority of floristic variation between sample sites in each of the study areas was related to degradation gradients. Significant correlations were found between the primary ordination axis and distance from water at each study area. In addition to this, the majority of other variation between sample sites was associated with well established land degradation indicators, suggesting a secondary degradation gradient in each Study Area:

- The secondary axis in Study Area 1 was significantly correlated with bare ground, grass cover and a shift towards less palatable grass species (well known indicators of land degradation e.g. Whitford *et al*., 1998; Kerley & Whitford, 2000; de Soyza *et al*., 2000; Oba & Kotile, 2001) (Figure 7.4);
- There was a significant increase in the abundance of the encroacher, *Colophospermum mopane* (Timberlake, 1995, 1999; Smit, 2004), along the secondary axis in the Mopane-veld sample sites in Study Area 2 (Figure 7.7); and
- The secondary ordination axis at Study Area 3 was correlated positively with dung frequency and dune spacing (suggesting that a combination of grazing-induced degradation and wind erosion processes[22] were determining floristic composition) (Figure 7.8).

Linear regression showed that a number of other variables were significantly associated with floristic variation along degradation gradients. These variables could therefore be used accurately to indicate degraded rangeland. The evidence for each of these indicators will now be presented in detail.

Before this is done, it should be noted that it was not possible to collect sufficient data to test the validity of some indicators (e.g. abundance of wild fruits due to season; abundance of certain species that were not found in the sample sites that may have been found in a larger sample). Given the lack (or seasonality) of available data, many of these indicators would be difficult for most land managers to use. For example, although communities in all study areas cited a reduction in the abundance of medicinal plants, it was not possible to substantiate this. Although some species

[22] Most of the dunes in south Kgalagadi are Quarternary relics (Wiggs *et al*., 1995), but according to oral histories, the narrow strip of dunes that line the heavily grazed Nossob River bed are much more recent; a consequence of wind erosion due to reduced vegetation cover.

7.2 Indicators considered accurate and easy to use by rangeland stakeholders in all study areas (for all indicators see Tables A1-3, Appendix 1). As many indicators as possible were measured in the field and correlated (using linear regression) against degradation gradients that were determined using DCA (N/S = not significant; ** p < 0.01; * p < 0.05; - = not tested)

Indicator	**Literature Evidence**	**Empirical Evidence**		
Vegetation		*Study Area 1*	*Study Area 2*	*Study Area 3*
Decreased grass cover	Supported by: Gillieson *et al.* (1996); Moleele *et al.* (2002); Nangula & Oba (2004)	**	**	**
Decreased abundance of wild fruits	Supported by: Riginose & Hoffman (2003)	-	-	-
Decreased abundance of trees	Contradicted by: Reid & Ellis (1995)	N/S	**[1]	*
Increased abundance of dead trees	No literature	*	N/S	N/S
Decreased abundance of *Grewia flava*	Supported by: Dougill *et al.* (1999); Moleele& Chanda, 2003	N/S	Insufficient Data[2]	Insufficient Data[2]
Decreased vegetation cover/ increased bare ground	Supported by: Behnke & Scoones (1993); de Soyza *et al.* (1998); Whitford *et al*. (1998); Manzano & Navar (2000)	**	**	**
Decreased rain use efficiency	Supported by: Pickup (1996); Snyman (1998); Prince *et al*. (1998); Diouf & Lambin (2001)	-	-	-
Trees and bushes are increasingly stunted	Contradicted by: Pickup (1996); Oba (1998); Oba & Post (1999)	N/S	N/S	N/S
Decreased abundance of medicinal plants	No Literature	Insufficient Data[3]	Insufficient Data[3]	Insufficient Data[3]
Decreased plant diversity	Supported by: Wang *et al*. (2002); Buttolph & Coppock (2004). Contradicted by: Todd & Hoffman (1999)	*	N/S	N/S
Soil				
Increased soil looseness	Contradicted by: Lamotte *et al*. (1998)	N/S	* (grassland) N/S (woodland)	**
Decreased soil organic matter content	Supported by: Bellows, 1995; Dougill *et al*., 1999; Hamblin, 1998; Hill & Schütt, 2000	-	** (grassland) N/S (woodland)	**
Increased density of cattle tracks	No literature	*	Insufficient Data[4]	Insufficient Data[4]
Livestock				
Declining livestock condition/ loss of weight	Supported by: Behnke & Scoones (1993); Kipuri, 1996; Fynn & O'Connor (2000); Mugasi *et al.* (2002)	-	-	-
Livestock walk further from water/ spend longer between drinking	No literature	-	-	-
Decreased calving rate	Supported by: Behnke & Scoones (1993); Mugasi *et al*. (2002)	-	-	-
Increased livestock mortality/ declining herd size	Supported by: Ottichilo *et al.* (1990); Behnke & Scoones (1993); Mugasi *et al*. (2002)	-	-	-
Decreased milk production	Supported by: Bartels *et al* 1990; Behnke & Scoones (1993); Kipuri, 1996; Mugasi *et al*. (2002)	-	-	-
Increased incidence of Aphosphorosis (Stiff Sickness) due to consumption of poor grasses	No literature	-	-	-

Wild Animal & Insect				
Decreased abundance of game (grass-eating antelope disappear first) & predators	Supported by: Du Toit & Cumming (1999)	-	-	-
Decreased abundance of birds	Supported by: Smith *et al*. (1994); James *et al.* (1999); Tankersley (2004)	-	-	-
Increased abundance of Harvester Termites ("Makaka")	No Literature	-	-	-
Socio-Economic				
Increased polarisation of rich and poor	Supported by: Matteucci & Colma (1997); Adams *et al*. (2002)	-	-	-
Increased household expenditure on products formerly obtained from rangeland & decreased income from range products	Supported by: Thomas *et al*. (2000); Evans *et al*. (2003)	-	-	-
Out-migration of farmers	Supported by: Kharin (1990)	-	-	-

[1] Tree density actually increased with land degradation in woodland areas dominated by encroacher *C. mopane;*
[2] Despite these the range of this species extending into Study Areas 2 & 3 according to Van Wyk & van Wyk (1997), no specimens were encountered along line intercepts;
[3] It was not possible to determine the medicinal properties of all species that were recorded;
[4] Due to soil conditions at these Study Areas, it was not possible to accurately count cattle tracks.

with known medicinal properties were found to be less common in degraded sites (e.g. *Boscia albitrunca* and *Cynodon dactyolon*), many medicinal species were degradation indicators (e.g. *Senna italica* and the bush encroachers, *Acacia mellifera* and *Dichrostachys cinerea*). However it is difficult to assess this indicator without knowledge of the medicinal properties of all species found. More ethnobotanical research is required to determine these properties. This indicator would be difficult for land users to use unless they had a good knowledge of plant medicinal properties. In most communities, this knowledge was concentrated in herbalist or traditional doctors.

7.4.2 Empirical evidence for indicators in Study Area 1 (Tsabong-Werda)

Floristic variation in Study Area 1 was determined primarily by the degradation gradient represented by axis 1 of the ordination. Over-used sites closer to water sources were dominated by more ($p < 0.01$; $r^2 = 0.40$) and taller ($p < 0.01$; $r^2 = 0.32$) encroaching *A. mellifera* bushes and a higher proportion of tree canopies were dead ($p = 0.01$; $r^2 = 0.19$). Each of these were suggested as degradation indicators by land users. The trees, *Acacia leuderitzii* ($p < 0.01$; $r^2 = 0.30$) and *B. albitrunca* ($p < 0.01$; $r^2 = 0.46$), were more abundant in less degraded sites (Figure 7.4). Increased abundance of the latter species had been suggested as a degradation indicator.

The secondary axis in Study Area 1 represented ground layer responses to land degradation (Figure 7.4). It was significantly correlated with a reduction in vegetation cover ($p < 0.01$; $r^2 = 0.56$) and grass cover ($p < 0.01$; $r^2 = 0.61$) and a shift towards less palatable grass species. Each of these had been suggested as degradation indicators by land users (Appendix 1). Degraded sites were characterised by increasing abundance of the unpalatable sedge, *Fimbristylis hispidula* ($p = 0.01$; $r^2 = 0.16$) and *S. italica* (a creeping medicinal plant) ($p < 0.01$; $r^2 = 0.21$), and decreasing abundance of *Schmidtia pappophoroides* (high grazing value) ($p < 0.01$; $r^2 = 0.40$), *Eragrostis lehmanniana* (intermediate grazing value) ($p < 0.01$; $r^2 = 0.22$) and *Aristida stipitata* (low grazing value) ($p < 0.01$; $r^2 = 0.23$) (palatability according to Van Oudtshoorn, 1999). A reduction in the abundance of *S. pappophoroides* and *E. lehmanniana* have been associated with land degradation in other studies (e.g. Makhabu *et al*., 2002; Skarpe, 2002).

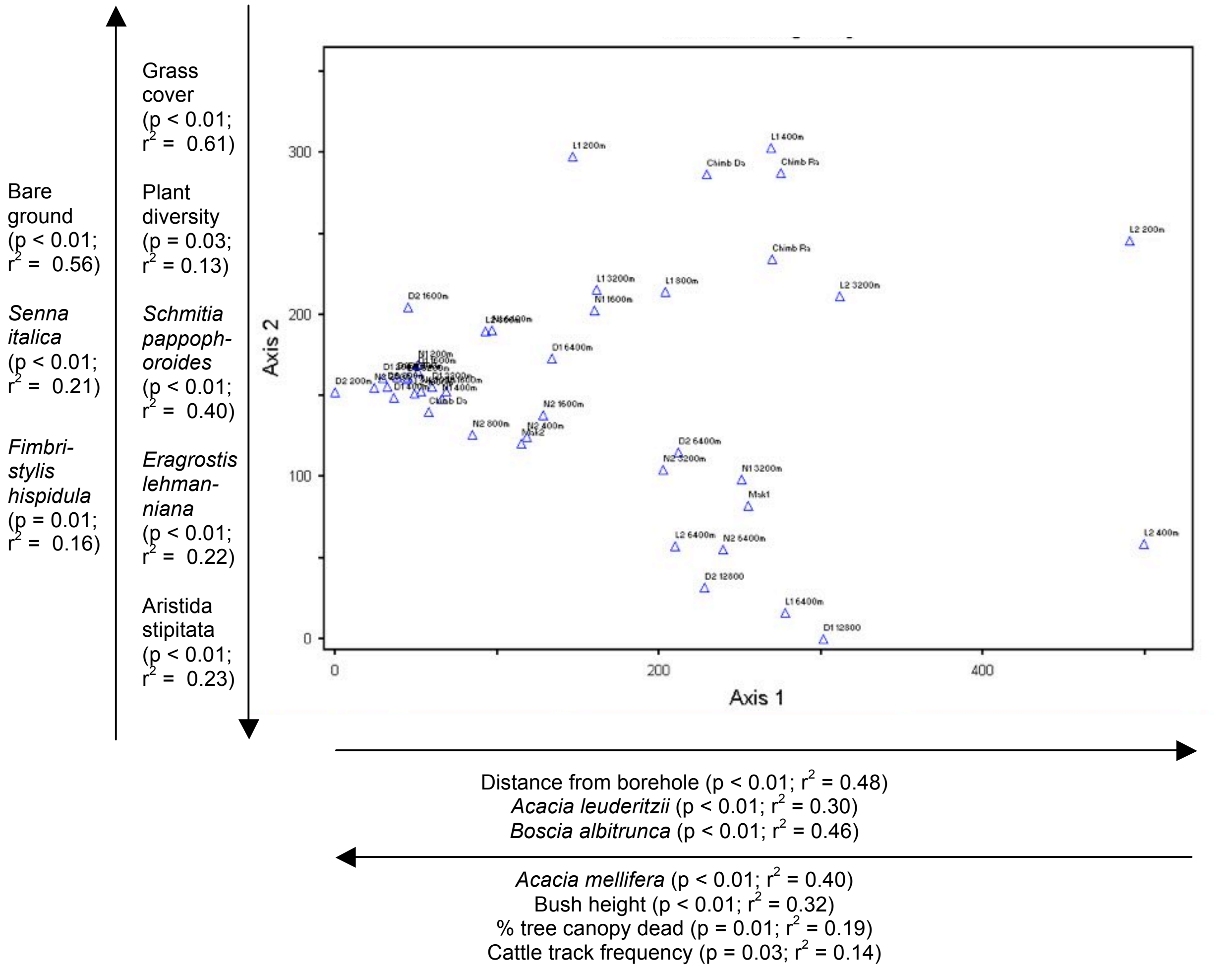


Figure 7.4 DCA ordination plot of axes 1 & 2 for Study Area 1 intercepts (eigenvalues: Axis 1 = 0.77; Axis 2 = 0.46)

Although soils were significantly stronger under bush canopies than between bushes ($p < 0.01$) (mainly due to biological soil crusts), there was no evidence for a decrease in soil strength along degradation gradients, as proposed in the soil looseness indicator (and associated capacity to use 2WD vehicles and bicycles). This is consistent with data collected by others in Study Area 1 indicating significant soil crusting under *A. mellifera* bushes (Berkeley *et al*., 2005). There was no evidence that there were less wild fruit or flowers in degraded land or that trees became stunted.

7.4.3 Empirical evidence for indicators in Study Area 2 (Mid-Boteti)

The principal floristic differences between sample sites in Study Area 2 were between sites in *C. mopane* dominated areas and grassland sites on the flood plains (Figure 7.5). These represent two distinct ecosystems within the study area. An inverse relationship between the encroacher, *C. mopane* and grass cover is well established (Smit, 2004).

Floristic variation between sample sites in both grassland and *C. mopane*-dominated sites was primarily determined by proximity to village and water respectively (significant correlation between first axis and distance to village/water in grassland ($p = 0.016$; $r^2 = 0.35$; Figure 7.6) and *C. mopane* dominated sites ($p < 0.01$; $r^2 = 0.34$; Figure 7.7)). Although there was no significant correlation between proximity to village/water and either cattle tracks or dung frequency at either site, distance to village/water was assumed to represent a utilisation gradient, which was used as a proxy for a degradation gradient to test indicators. Current dung frequency cannot be used to infer grazing history, and line intercepts were too short to intercept enough cattle tracks to determine statistical significance. However, there was a significant decline in grass cover along this degradation gradient ($p = 0.05$; $r^2 = 0.24$).

No *Grewia* spp. were found in any of the Study Area 2 sample sites, despite the fact that the ranges of a number of species extended into the study area (Van Wyk & van Wyk, 1997). This may reflect a significant decline in the abundance of *Grewia* spp. in the study area, which would support the validity of *Grewia* spp. as indicator species'. Loss of this species is suggested as an indicator of degradation by Moleele *et al*. (2003). A reduction in the abundance of a number of other species were suggested as degradation indicators by communities, but were not found in the sample sites: *Ximenia* spp., *Cencrus ciliaris, Acacia hebeclada* and *Cleome gynandra*. Although the disappearance of these species may therefore be accurate indicators of degradation, their current absence or low abundance in the study area means they are unlikely to be sensitive or easy to use. In addition to this, some species were found at abundances which were too low to conduct statistical analysis: *Dichrostachys cinerea* (one dead individual was found)*, Sporobolus fimbriatus, B. albitrunca, Boscia foetida* and *Acacia tortilis*. It is possible that a larger sample size may have found some of the missing species, and made it possible to statistically analyse more of the data (results are based on 32 line intercepts). *Acacia tortilis* and *D. cinerea* are well known encroacher species however (Molelee *et al*., 2002), so an increase in the abundance of these species may usefully be applied as degradation indicators. Given the importance of *Boscia* spp. for surviving drought, a significant decrease in their abundance would reduce the resilience of livestock production. As a valuable source of browse, individuals growing under intense browsing pressure will inevitably become stunted and regenerate poorly. Given the taboo associated with felling them, any browsing-induced decline in the number of *Boscia* sp. trees in the landscape is likely to be a slow process.

There is evidence for the validity of the indicator "decreased abundance of grasses palatable for cattle". In grassland areas, there was a significant positive correlation between the abundance of the most palatable grass (*C. dactylon* which is palatable for cattle and donkeys according to local knowledge, Appendix 2) and distance from village. There was also a negative correlation between the abundance of the thatching grass *E. pallens* and distance from village. However, this appears to contradict local suggestions that a decrease in thatching grass indicates land degradation.

Tree density decreased significantly along the degradation gradient, axis 1 ($p < 0.01$; $r^2 = 0.34$), with highest densities in most degraded areas (Figure 7.7). This is directly at variance with community perceptions that tree density declines with degradation, however is supported by literature suggesting *C. mopane* is an encroacher species, favoured by intense grazing (Smit, 2004). The local perception that there are less trees in degraded areas may be influenced by fuel-wood shortages in this area. However, fuel-wood shortages are driven primarily by over-harvesting, rather than grazing-induced land degradation, which in fact increases tree density.

The proportion of leaves affected by mopane worms (the caterpillar of the Mopane Moth, *Imbrasia belina*) and percentage cover of *C. mopane* are the next most significant differences between plots in *C. mopane* dominated areas (significant correlation with second ordination axis in Figure 7.7; mopane worms: $p = 0.01$; $r^2 = 0.75$; percentage cover *C. mopane*: $p = 0.04$; $r^2 = 0.22$). Although not statistically significant ($p = 0.08$), there is a relatively strong correlation between the proportion of mopane leaves affected by mopane worms and *C. mopane* percentage cover ($r^2 = 0.48$). This may be because closer spacing of *C. mopane* trees facilitates the spread of mopane worms. However, neither *C. mopane* percentage cover nor the proportion of leaves affected by mopane worms correlate with the degradation (first) axis or distance to water, suggesting that this ecological gradient exists independent of degradation processes.

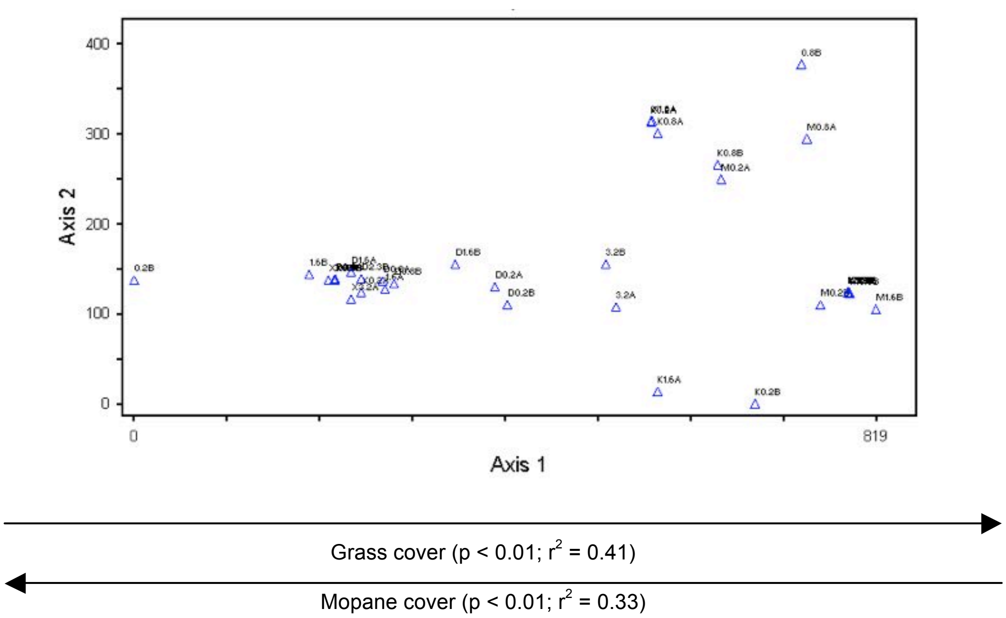


Figure 7.5 DCA ordination plot for Study Area 2 intercepts (eigenvalues: Axis 1 = 0.98; Axis 2 = 0.57)

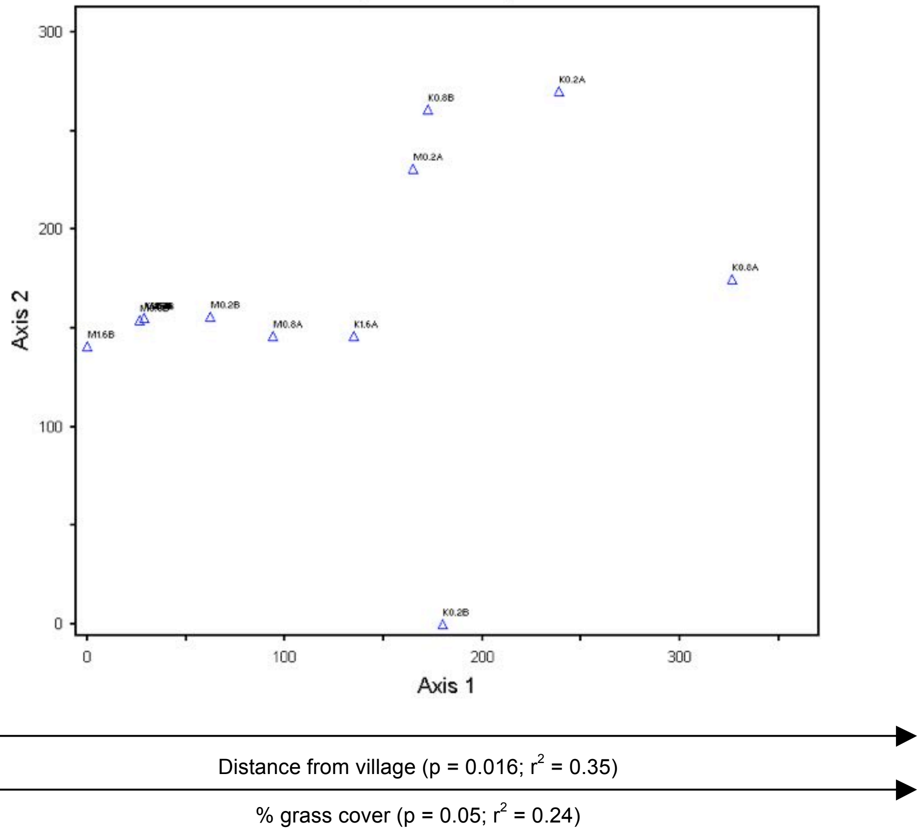


Figure 7.6 DCA ordination plot for Study Area 2 grassland intercepts (eigenvalues: Axis 1 = 0.88; Axis 2 = 0.40)

Although total grass cover was not correlated with the first ordination axis, percentage cover of the unpalatable thatching grass, *Eragrostis pallens*, was a primary factor determining differences between sample sites in the *C. mopane* dominated area (significant correlation with first ordination axis; $p = 0.03$; $r^2 = 0.23$). Although this supports the suggestion that increased abundance of unpalatable grasses is a degradation indicator, it is at variance with the suggestion that thatching grass becomes less abundant in degraded rangeland. Again, the perception that thatching grass declines in degraded land is probably due to over-harvesting near villages, and is not a grazing-induced land degradation process.

There was clear visibility for at least a kilometre in all grassland sites. Visibility was reduced by trees in *C. mopane* dominated sites. Although was no correlation between visibility and either tree density or % *C. mopane* cover at sample sites, no tree-based measurements were made on visibility transects. There was no correlation between visibility and distance from water, casting doubt over the validity of this as a degradation indicator. It is possible that this indicator is only valid during the wet season, when there is more vegetation which may make differences in visibility between degraded and non-degraded areas more pronounced.

In grassland sites, soils were increasingly less consolidated with proximity to water sources ($p = 0.02$; $r^2 = 0.34$), validating the "increased soil looseness" indicator. This was probably due to lower levels of Soil Organic Carbon (SOC) closer to water ($p < 0.01$; $r^2 = 0.49$). There was no correlation between the proportion of soil samples that were consolidated or % SOC, and proximity to water in *C. mopane* dominated sites. Despite claims by some land users that soil salinisation mainly occurs in degraded sites, there was no correlation between soil conductivity and either distance from water or any of the ordination axes.

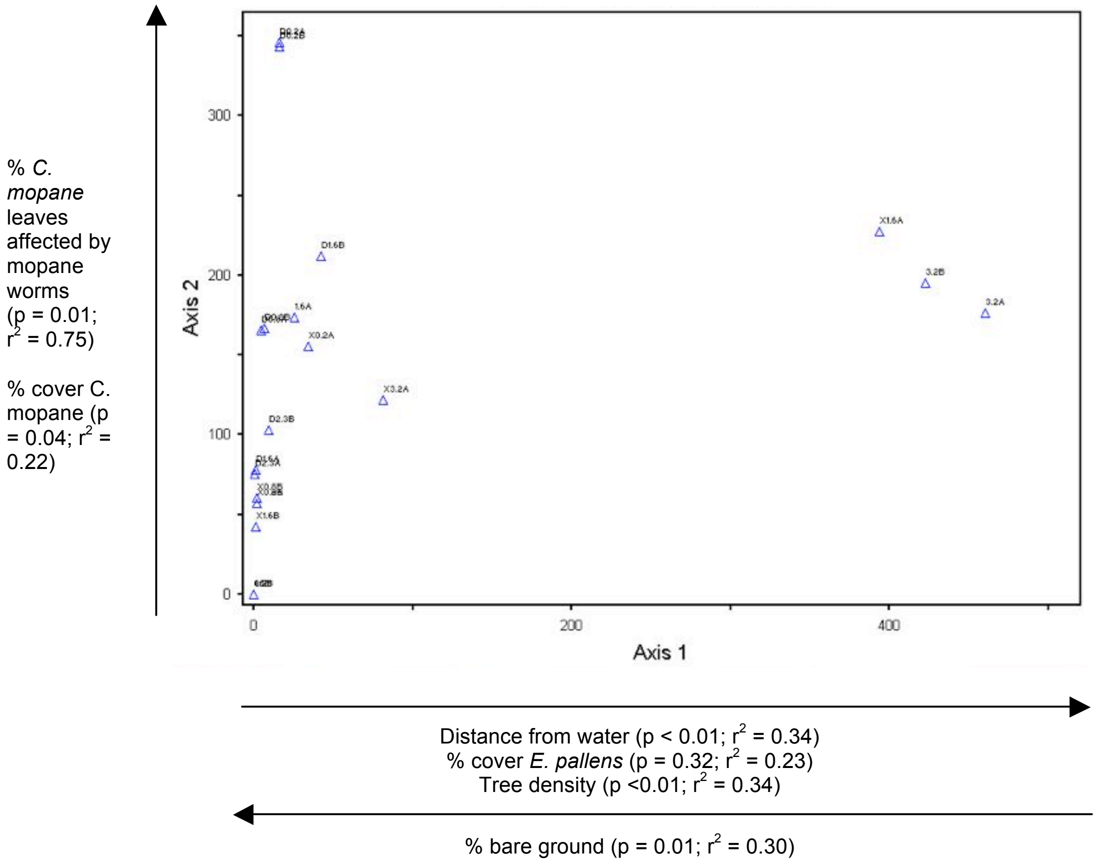


Figure 7.7 DCA ordination plot for Study Area 2 intercepts in the *C. mopane* dominated area (eigenvalues: Axis 1 = 0.79; Axis 2 = 0.62)

7.4.4 Empirical evidence for indicators in Study Area 3 (Bokspits)

Since it was not possible to follow degradation gradients by vehicle for sufficient distances (they were intersected by numerous high and insurmountable parallel dunes), Study Area 3 was divided into utilisation zones using participatory mapping (see section 4.5.2) and interviews were used to identify areas where palatable vegetation responded the same or less vigorously to rain as it did in the past. These were then used as degraded, non-degraded and intermediate sites.

The most significant differences between south Kgalagadi sample sites were between degraded interdune sites (dominated by *Schmidtia kalahariensis* and *Rhigozum trichotomum*) and all other sample sites, represented by the first ordination axis (eigenvalue: 1.00). In order to explore other differences between sample sites, Axes 2 and 3 were analysed in more detail (Figure 7.8).

Dung frequency correlated significantly with the second ordination axis ($p < 0.01$; $r^2 = 0.31$), suggesting that this represents a utilisation gradient that could be used as a proxy for a degradation gradient. This was supported by the fact that significantly more dung was intercepted in degraded versus non-degraded sites ($p = 0.02$).

Dune spacing increased significantly along the degradation axis ($p = 0.03$; $r^2 = 0.42$), although there was no trend in dune heights, or any significant difference between the height of dunes in degraded or non-degraded sites. Contrary to land user suggestions, this would appear to suggest that there were fewer sand dunes in degraded areas. However, dunes in degraded and intermediate sites were significantly less vegetated compared to non-degraded sites ($p = 0.05$), and therefore likely to be more active (e.g. Figure 7.9). All but one of these sites had less than 14% vegetation cover; the observed threshold for dune activity in this part of the Kalahari (Wiggs *et al*., 1995). Communities had specified an increase in *non-vegetated* dunes, and suggested that sand in degraded areas was more mobile. The results appear to support these suggestions.

Although there was significantly more grass cover in degraded versus non-degraded sites ($p = 0.02$), this was due to the significantly higher abundance of the annual, *S. kalahariensis* in degraded sites ($p = 0.03$). The palatable, perennial grasses, *Centropodia glauca* and *E. lehmaniana,* were significantly less abundant in degraded areas ($p = 0.01$ for both species). In addition to this, the thatching grass, *A. meridionalis* was significantly less abundant in degraded areas ($p = 0.04$). This is further supported by the negative correlation between the degradation axis (2) of the ordination (Figure 7.8) and the somewhat palatable dune grass, *Stipagrostis amabilis*, which is used for thatching, suggesting that this species is indicative of less degraded sites. The bush encroacher, *R. trichotomum*, were significantly more abundant in degraded areas ($p = 0.03$). *Acacia haemotoxolon* was significantly more abundant in non-degraded sites ($p = 0.04$). Abundance of the encroacher *A. mellifera* correlated significantly with the degradation gradient (axis 2) in the ordination (Figure 7.8), suggesting that it is a degradation indicator. This indicator was suggested by one member of the community, however, others suggested that *A. mellifera* was in fact less abundant in degraded areas due to over-browsing by goats and sheep. Focus group discussions about this indicator agreed with the latter assessment, which contradicts the ecological data. although it was contradicted in focus groups. This discrepancy was due to the difference in scale between local observations and ecological measurements. Smallstock were much more important in this community than in the other two study areas, and the majority of local observations by smallstock owners focussed on the 2-3 km area around settlements where most browsing occurs. In this area, over-browsed areas may have less *A. mellifera*. However, ecological measurements were taken over a much wider area, up to 20 km from settlements. Participatory maps show that the most distant areas that were measured (effectively used as control sites) experience very little livestock activity and have a much lower abundance of A. mellifera. So in the context of the wider landscape, *A. mellifera* is an effective degradation indicator.

Dune soils were significantly less consolidated than inter-dune soils ($p < 0.01$). Both dune and inter-dune soils in degraded sample sites were significantly less consolidated than soils from intermediate and non-degraded sites ($p < 0.01$). As would be expected, dune crest soil samples had significantly less Soil Organic Carbon (SOC) than inter-dune samples ($p < 0.01$). In addition to this, for both dune crests and inter-dunes, there was significantly more SOC in non-degraded sample sites, compared to degraded and intermediate sample sites ($p < 0.01$). Dune crest soils in degraded and intermediate sites also had significantly higher conductivity than non-degraded sites ($p < 0.01$).

A positive identification could only be made for one ant species that had been suggested as a degradation indicator by land users in Study Areas 2 and 3: *Pachycondyla* sp. (Ponerinae) ("malelekatou" in Setswana). This species was only caught in degraded sites (bush encroached and sacrifice zones), suggesting that it is a useful indicator.

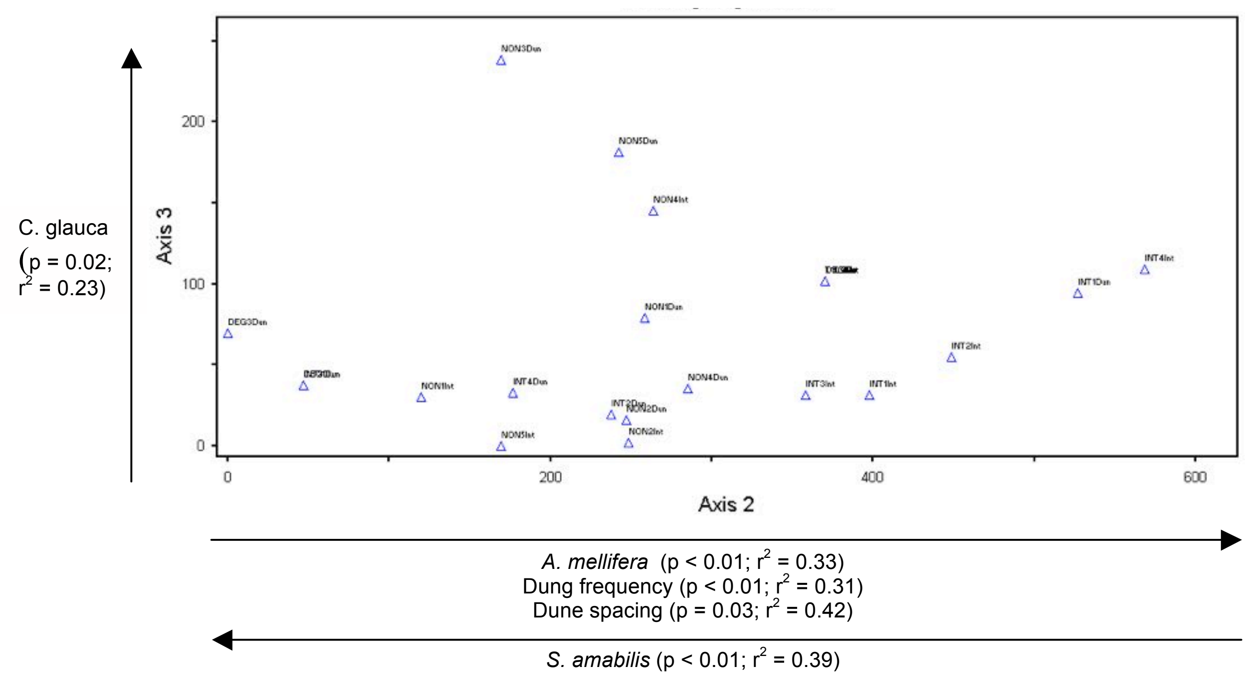


Figure 7.8 DCA ordination plot of second and third axes for Study Area 3 intercepts (eigenvalues: Axis 2 = 0.89; Axis 3 = 0.41)

Figure 7.9 In Study Area 3, dunes typical of degraded sites (left) were less vegetated and more active than dunes typical of non-degraded sites (right)

7.5 Integrating scientific and local indicator knowledge

It has been suggested that the use of indicators by non-specialists will inevitably involve a trade-off between meaningful participation and scientific rigour (Abbot & Guijt, 1997). The considerable overlap between scientific and local knowledge, and the results of empirical testing suggests that such a trade-off is by no means inevitable (Table 7.2). However, indicators elicited from local communities are not always sufficiently accurate or reliable enough for objective sustainability assessment. For example, indicators elicited from the local community may only be valid during certain seasons, at certain scales, or may be difficult to distinguish from indicators of drought (see section 7.4). It is therefore necessary to take a critical approach to indicator development with local communities. On the other hand, although most of the sustainability indicators developed and used by researchers are accurate and reliable, they are rarely applied by local people and hence have little effect on the sustainability of land management. Clearly there is a need to strike a balance between developing indicators that can achieve widespread uptake and application whilst providing accurate and reliable results. By integrating qualitative participatory research with more quantitative natural science, it has been possible to develop environmental sustainability indicators that have the potential to do this.

Indicators for which no evidence was found were discussed in focus groups. For example, in Study Area 1 there was no evidence that rangeland fruits and flowers were less abundant in degraded land. Focus groups explained that this was because many of the encroaching species flower and fruit prolifically during the wet season when measurements were made, but claimed that fruit and flowers were indeed less prolific in degraded land during the dry season. Problems with some of the tree-based indicators were blamed on sample size. Although there was not time to address these suggestions through additional sampling, they have been used in conjunction with evidence from peer-reviewed literature to interpret ecological sampling results.

The majority of vegetation indicators suggested by local communities were validated through ecological sampling. For example, reduced grass cover and increased bare ground were identified by community members and supported by field observations at all study areas. Similarly, decreased plant diversity was suggested by land users in Study Area 1, and there was evidence for a negative correlation between plant diversity (according to Shannon-Weiner index) and land degradation status in this study area. Other studies using grazing gradients in semi-arid rangelands have found similar correlations (e.g. Metzger *et al*., 2005). However, there was no such correlation in Study Area 3 ($p = 0.09$; $r^2 = 0.24$), or the grassland ($p = 0.59$; $r^2 = 0.02$) or *C. mopane* intercepts ($p = 0.06$; $r^2 = 0.18$) in Study Area 2, where community members had not suggested this indicator. There was no evidence of raised diversity at intermediate values along degradation gradients in any of the study areas, as might be suggested by Connell's (1978) intermediate disturbance hypothesis.

Soil looseness had been suggested as a potential indicator by land users in all sites. This was validated in Study Area 3 and grassland parts of Study Area 2. In Study Area 3, both dune and interdune soils from degraded areas were less likely to be consolidated than soils from intermediate and non-degraded sites. There was also significantly more SOC in non-degraded parts of Study Area 3, compared to degraded and intermediate areas: another indicator suggested by local land users. Dune crest soils in degraded and intermediate sites also had significantly higher conductivity than non-degraded sites. This may be a consequence of higher evaporation rates on unvegetated dune crests. Increased evaporation rates had been proposed as an indicator by land users, but this was not tested.

There are very few tree-based indicators in the literature, and yet a number were suggested by land users as early warning indicators. In Study Area 1, over-used sites close to water sources had a higher proportion of tree canopies that were dead. The trees *A. leuderitzii* and *B. albitrunca* were more abundant in less degraded sites. A reduction in the density of trees was suggested as an indicator of land degradation in all study areas. However, it was only supported by measurements in Study Area 3, where there were significantly less trees in degraded versus non-degraded sites ($p = 0.04$). There were no significant changes in tree density across Study Area 1. However, despite these results, local communities continued to support the validity of this indicator, suggesting sample size as a potential reason for the absence of a statistically significant relationship in Study Area 1. Given the sparse tree cover throughout this study area (average 6 m tree spacing recorded along intercepts), 30 m intercepts may not have been long enough and 44 intercepts may have been too few. In Study Area 2 there was actually an increase in tree density along degradation gradients in *C. mopane* woodland. This is supported by literature suggesting *C. mopane* is an encroacher species, favoured by intense grazing (Smit, 2004). There have been suggestions from elsewhere in Africa, that human activity can favour tree cover. For example, Fairhead & Leach (2001) found that there were more trees around human settlements in Ghana and there is evidence from semi-arid Kenya that pastoralism increases the recruitment of *Acacia tortilis*, which is a highly valued tree in that area (Reid & Ellis, 1995).

Although woody plants were significantly shorter in degraded parts of Study Area 3, this was probably due to differences in species composition, with degraded sites dominated by the naturally dwarf *R. trichotomum* and non-degraded areas dominated by the naturally taller *A. haemotoxolon* (Figure 7.10). Due to the mutual exclusivity of these species, it was difficult to assess the extent to which individuals of the same species were stunted by browsing. However, there was no significant difference between the height of *A. haemotoxolon* individuals growing in intermediate and non-degraded sites (p = 0.30). This is supported by Oba & Post (1999), who found evidence that browsing stimulates twig production in some *Acacia* species. Although this does not affect tree growth in terms of girth (Oba & Post, 1999), it does significantly increase biomass accumulation (Oba, 1998).

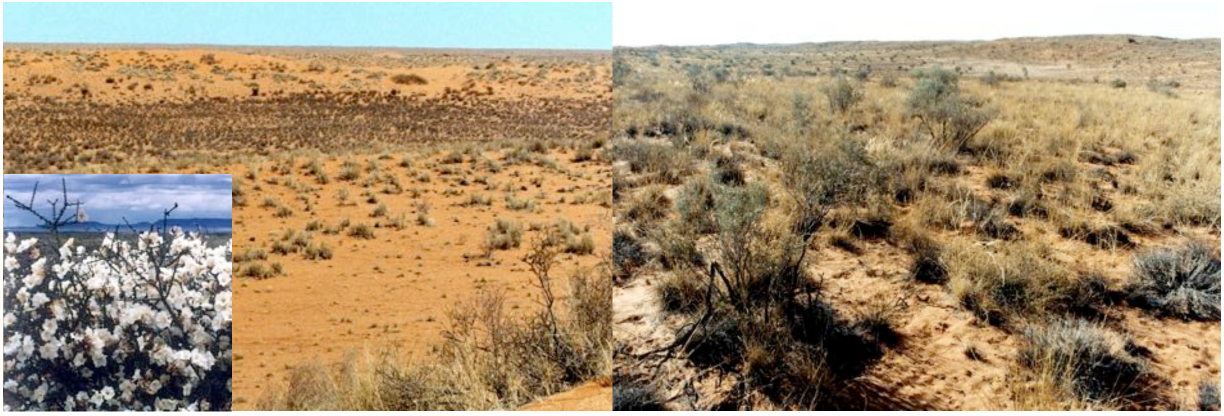


Figure 7.10 Degraded interdune area dominated by *Rhigozum trichotomum* (flowering in inset) (left) and non-degraded interdune area dominated by *Acacia haemotoxolon* (photos: M. Reed)

There were questions over the reliability of some indicators that empirical research had shown to be accurate, as a number of land degradation indicators temporarily occur during drought. There are examples in the literature where such indicators (e.g. increased wind erosion and dust storms) have been used to infer severe land degradation which has disappeared as soon as the rains returned (Ringrose *et al.*, 1996). The difficulty that many community members have distinguishing between (short-term, reversible) drought events and (long-term, irreversible) land degradation processes has been cited by other researchers working in Botswana (Thomas *et al.*, 2000), and drought is often blamed as the sole (or main) cause of land degradation (Ringrose *et al.*, 1996; R. Chanda, pers. comm.). This research was no exception:

> "Here in Botswana, drought is the cause of all our problems. If we have rain, then we have no problems. We just need rain."
>
> Male farmer, 34, Werda

> "In Setswana, we use the words "drought", "degradation" and "desertification" interchangeably. What is the difference?"
>
> Extension worker, Mopipi

Great care was therefore taken to define land degradation and distinguish it from drought in every interview (Appendix 3). Indicators were checked at the time of interview to ensure they were not just drought indicators, by asking if they would still be present after heavy rains. However, most degradation indicators are equally valid as drought indicators (for example, decreased grass cover, increased wind erosion, increased time cattle spend between visits to water and decreased milk production). For this reason, it is recommended that users apply indicators after rains have occurred, and base management decisions on changes from baseline conditions over a number of years (see next chapter).

7.5 Conclusion

Despite the wealth of knowledge about rangeland sustainability indicators as a community, this knowledge was thinly spread. By testing and disseminating this information, the research was able to build upon and share valuable local knowledge. The indicators developed through this research are therefore highly familiar to land managers who have the capacity to apply them without any need for specialist training or equipment. Land managers also had the opportunity to reject or adapt indicators (from other study areas or literature) that were not considered to be relevant locally.

Local knowledge was more holistic than many published indicator lists for monitoring rangelands, encompassing vegetation, soil, livestock, wild animal and socio-economic indicators. Reliance on single or few indicators can provide misleading results, but it is easier to reliably interpret a number of indicators representing different system components. Land manager preferences for vegetation and livestock indicators match recent shifts in ecological theory suggesting livestock populations may reach equilibrium with dry season or drought forage resources in semi-arid environments. Early warning indicators tended to focus on vegetation and soils (there was an absence of socio-economic indicators and few livestock early warning indicators). Tree-based indicators (which are rare in the literature) tended to be cited frequently as early warning indicators. There was evidence for a number of tree indicator species, and two other tree-based indicators were validated at two study areas.

Despite considerable overlap between indicators elicited from each of the Study Areas (30 out of 140 were elicited in all study areas), there were still significant differences between the indicators proposed for each Study Area. In addition to this, results from ecological and soil-based research sometimes gave very different results for the same indicators in different study areas. For this reason, it is essential for indicator-based monitoring tools to be site-specific. Although there were differences in indicator knowledge according to education and gender in two of the Study Areas, these differences were not deemed significant enough to target different indicators towards different social groups within Study Areas. For this reason, a different Decision Support System was developed for each Study Area, based on the indicators collected through this research. The Decision Support System and its potential use in pastoralist decision making is described in the following chapter.

8

Collecting data to monitor progress: a Decision Support System for rangeland monitoring and management in Botswana

Summary

This chapter presents results from step 4 of the learning process: “collecting data to monitor progress”. It describes a manual-style Decision Support System that integrates land degradation indicators with adaptive management options and is designed for land managers to easily collect data and monitor progress towards environmental sustainability goals. A number of similar tools have been developed for ranchers in southern Africa, but there has been little help for land managers under common property regimes. Manuals were therefore primarily designed for use by the latter group. To date, manuals have been drafted for two of the study areas, and a third is being developed. Separate manuals have been developed for each study area in response to the differences in indicators and management options deemed relevant for each area by local communities (chapters 6 and 7). The design of the DSS has been optimised using an innovation-decision approach (Rogers, 1995) combined with expert review to enhance the likelihood of widespread uptake and application by land managers. As part of this process, manuals will be translated into local languages and trialed by land managers prior to publication. Manuals are designed for regular use by pastoralists to identify detrimental environmental change early, and guide sustainable management responses. The recommended assessment procedure is flexible, and designed to make recording and interpretation of results simple for users.

8.1 Introduction

The next step in the learning process (Figure 3.2) is to facilitate the collection of data by local communities to monitor and inform progress towards sustainability goals. To do this, the following chapter integrates monitoring and management knowledge (chapters 6 and 7) in a Decision Support System[23] (DSS) that can be used easily by rangeland managers (included on CD-ROM in Appendix 4).

Adaptive rangeland management depends on effective monitoring to detect detrimental change as early as possible. As such, rangeland monitoring is integral to effective rangeland management. Rangeland monitoring in southern Africa has traditionally been the domain of researchers and extension workers. Agricultural extension services in Botswana are currently over-stretched and extension training is geared towards fenced systems that are usually managed by the more wealthy (see handbooks by Hendzel (1981) and Field (1977) that are used by most extension workers). The only existing DSSs for the region have been designed for private ranchers in different ecosystems, and have only involved users in trials towards the end of the design process (e.g. Milton *et al*., 1998; Barac & Kellner, 2002; Zimmerman *et al*., 2003). There has been no attempt to develop a DSS for rangeland stakeholders using common property regimes, or involve end-users at every stage of a design process that builds on traditional knowledge. This chapter therefore aims to:

- Review current rangeland monitoring techniques in southern Africa;
- Integrate land degradation indicators with sustainable management options with a view to providing a manual-style DSS for each of the three study areas that is designed for common property land managers to easily collect data and monitor progress towards sustainability goals; and
- Optimise the design of the DSS following an innovation-decision theoretical approach before trialing it with local users.

8.2 Rangeland monitoring techniques in southern Africa

A variety of techniques have been developed for use by farmers in the semi-arid rangelands of southern Africa, many of which have been applied in the Kalahari. However, their use has generally been limited to ranch owners with sufficient time, capital, equipment and formal education.

Many of these techniques are based on equilibrium successional dynamics (Clements, 1916), assuming that fire-induced sub-climax vegetation is most useful for animal production, and that set stocking densities can maintain that stable climax vegetation community. Deviations from this "optimum" condition could be caused by overgrazing (resulting in lower successional stages) or under-grazing (going beyond the fire sub-climax towards a climatic climax). The first formal range condition assessment developed in South Africa (Foran *et al*., 1978) was based on the approach of Dyksterhuis (1949). This technique classified grass species into: i) "decreasers", desirable species that decrease in abundance under intense grazing; ii) "increasers", species that increase in abundance with overgrazing ("increaser I") or undergrazing ("increaser II"); and iii) "invaders", which are exotic invasive species (Foran *et al*.,

[23] At its broadest definition, a DSS is "any methodology that is helpful to a decision maker to resolve issues of trade-offs through the synthesis of information" (Lawrence & Shaw, 1999: 324). A DSS usually synthesises this information in a form that can provide users with a structured, replicable approach to solve problems within specified constraints (Lawrence & Shaw, 1999).

1978). The cover of each species group was assessed subjectively by researchers and extension workers against a benchmark site (in desired condition) and scores could be discounted for soil erosion, bush encroachment or poor vigour of decreasers. This system was modified in various ways over the years, increasing the number of variables and sophistication of analysis (e.g. Tainton *et al.,* 1980; Heard *et al.,* 1986).

Recognising that these techniques were rarely used by land owners due to their complexity (Mentis, 1982; Hardy & Hurt, 1989), attempts were made to develop less complex procedures that could be used easily and rapidly in the field. The resulting methods focussed on easily identifiable indicator species that could be used to assess rangeland condition and grazing capacity more subjectively (e.g. Trollope, 1990). Jordaan *et al*. (1997) evaluated the accuracy of five such techniques, concluding that the "degradation gradient" (Mentis, 1983; Stuart-Hill *et al*., 1986) and "weighted key species" (Heard *et al*., 1986; Hardy & Hurt, 1989) techniques were best suited to southern African rangelands. However, training was still necessary to facilitate the use of these techniques by farmers, and they still remained largely in the domain of extension workers (Zacharias, 2003). Savory's (1988) rangeland monitoring technique was used more widely by farmers who adopted his "Holistic Resource Management" approach to ranching. Similarly, he proposed a combination of plant, animal and soil factors as indicators of range condition, but the recommended data collection methods were too time consuming to gain more widespread uptake (Milton *et al*., 1998).

Decision Support Systems gained wider uptake by South African ranchers. Published DSSs range from book-style manuals (e.g. Milton *et al*., 1998) to complex software applications incorporating GIS technology (e.g. Giupponi *et al*., 2004). Barac & Kellner's (2002) and Zimmerman *et al.*'s (2003) computerised decision support systems are designed to disseminate rangeland management advice to farmers and extension workers in southern Africa on the basis of diagnostic questions about key degradation indicators. Although these techniques have been used by Kalahari ranchers in South Africa and Namibia, uptake is not widespread partly due to the lack of internet connections (Zimmerman, pers. comm.). There is no evidence that they have been used in Botswana's more extensive communal land tenure systems.
Van Zyl (1986) proposed a full ecological survey, in which questions about species composition, vegetation cover, plant vigour, surface condition, and insect and rodent damage were answered. Answers were scaled from 1–10 and weights allocated to each question. Scores from each question were multiplied by the relevant weights and summed to give an index score. Reference ranges could then be used to determine rangeland condition or grazing capacity (with reference to rainfall tables). Similar to this, Milton *et al*. (1998) developed a rangeland health assessment technique for farmers that was designed to be "quick, easy, interesting and effective". They used similar plant and soil variables to Van Zyl (1986) in a similar scoring system, but used reference photographs to help farmers determine scores more objectively (*cf.* photographic techniques in Hendzel's (1981) Range Management Handbook for Botswana).

Two rangeland management "handbooks" currently exist in Botswana: Field's (1978) "Handbook of Basic Ecology for Veld Management in Botswana" and Hendzel's (1981) "Range management handbook for Botswana". However these publications are based on Clementsian ecology, only published in English, highly technical and aimed at private fenced systems. As a consequence, they are predominantly used by extension workers to provide advice to wealthy ranchers.

There are also a number of conventional ecological guides to grass and tree species for the whole of Southern Africa in English and Afrikaans which can be used to assess the extent and nature of ecological change (e.g. van Wyk & van Wyk, 1997; van Ousthoorn, 1999). Although van Ousthoorn (1999) includes information about the palatability of grass species for cattle, these publications do not provide non-English-speaking pastoralists or extension workers with the kinds of tools necessary to identify the multiple ecological dimensions of environmental change in this area. Indeed they have been criticized as giving starkly different assessments of rangeland degradation than those perceived by local pastoralists who are responsible for rangeland management (Thomas & Twyman, 2004).

Despite numerous attempts to develop more user-friendly techniques, rangeland assessment in the Kalahari has remained largely in the hands of external experts. Rangeland assessment and management techniques have tended to be developed by specialists for use by specialists. As a consequence, range scientists and extenstionists have many techniques to choose from, but few land managers are capable of using them effectively without additional training, equipment, finance and/or time. The few DSSs that have been developed for land managers are aimed at ranchers using fenced rangeland. The DSS developed in this chapter was therefore primarily designed for use by pastoralists under common property tenure. It is designed to be used easily, rapidly and cheaply by local communities without the need for support by extension services to gather clear and objective information about environmental change.

8.3 The Decision Support System

8.3.1 The Design Approach

The design approach was participatory and interdisciplinary, integrating qualitative and quantitative data from a variety of sources (Chapters 6 and 7). There is a growing awareness that agricultural research and development must build upon farmer expertise; identifying, facilitating and building upon local innovation. As the "transfer of technology" paradigm is increasingly replaced in the development community by the drive to facilitate "participatory technology development" or "appropriate technology", it is becoming evident that researchers and extentionists need to develop a more facilitatory role (Chambers, 1994; Reij & Waters-Bayer, 2001). Farmer experimentation must be supported, innovators and their innovations identified, and where necessary it may be possible to work with innovators to optimise their innovations, and disseminate them to other land managers who may benefit from them (Reij & Waters-Bayer, 2001). A better understanding of factors influencing the development of optimal technologies can facilitate wider participation and co-operation between land managers, extentionists and scientists, to optimise DSS technologies for widespread uptake and diffusion to enhance rural livelihoods.

Rogers (1995) proposed an "innovation-decision process" (dashed arrow in Figure 8.1) which may facilitate a better understanding of the factors that are likely to influence the uptake and application of indicators and management options in a DSS. In turn, this information can be used to optimise DSS design for maximum benefit to users. In Rogers' (1995) process, land managers:

(a) Gain knowledge of an innovation (such as a DSS);
(b) Seek information about the likely consequences of adoption and form an attitude towards it;

(c) Decide to adopt or reject the innovation;
(d) Implement the innovation; and
(e) Confirm their innovation decision by seeking re-enforcement, and discontinue it if exposed to conflicting experiences and messages.

Rogers (1995) identifies five key characteristics of innovations that determine their adoption potential: relative advantage, trialability, compatibility, observability and complexity. The most significant of these are usually high relative advantage, high compatibility and low complexity (Tornatzky & Klein, 1982).

The indicators and management options developed through this research can be viewed as innovations, given the thin spread of indicator knowledge in study communities (chapter 7), the concentration of management knowledge in certain individuals (chapter 6) and the amount of local management innovation (chapter 6). An innovation does not need to be universally new – ideas that an individual has not formerly encountered may also be considered "innovations" (Rogers, 1995). The DSS that was designed to integrate and communicate indicators and management options to users can be viewed as a technology using the following definition:

> "The practical application of knowledge especially in a particular area" or "a manner of accomplishing a task especially using technical processes, methods, or knowledge."
>
> Merriam-Webster (2005, online)

Rogers (1995) innovation-decision process was therefore used to develop a theoretical framework that could be used to optimise DSS design. The theoretical framework in Figure 8.1 adds adaptability to Rogers (1995) adoption characteristics; integrates them with farmer needs, objectives and capital assets; and provides a role for communication in the innovation-decision process. The framework is iterative, recommencing as needs and objectives change, and as capital assets change. Land user needs and objectives are the primary stimulus for new innovations and technologies, and these are influenced in turn by their capital asset endowments. The characterisation of farmer needs and objectives, and the opportunities and constraints presented by their capital assets have been discussed extensively in the sustainable livelihoods literature (e.g. Carney, 1998; Ashley, 2000).

People often innovate to sustain their livelihoods ("livelihood constraints and strategies" in Figure 8.1), in response to population pressure on a limited natural resource base ("natural assets" in Figure 8.1) (Boserup, 1965; Reij & Waters-Bayer 2001). Whether an innovator chooses to disseminate their innovation, or other land managers observe the innovation for themselves, the mode of communication through which land managers become aware of a technology will influence their perception of it. Different communication channels are more effective at different stages in the innovation-decision process. For example, mass media channels are relatively more important at the knowledge forming stage, whereas interpersonal channels such as other land managers and extension workers are relatively more important at the attitude forming stage (Copp, 1958). Evaluation of an innovation is to a large extent based on the experience of similar individuals (who share socio-economic status, education, beliefs etc). Communication tends to be more frequent and more effective between such individuals than between more dissimilar individuals (Lazerfield & Merton, 1964). However, this phenomenon can hinder the spread of ideas through diverse communities (Granovetter, 1973). If an innovation is communicated effectively, its perceived complexity may be reduced, and observability and adaptability increased, enhancing its adoptability. This is the primary role for the DSS.

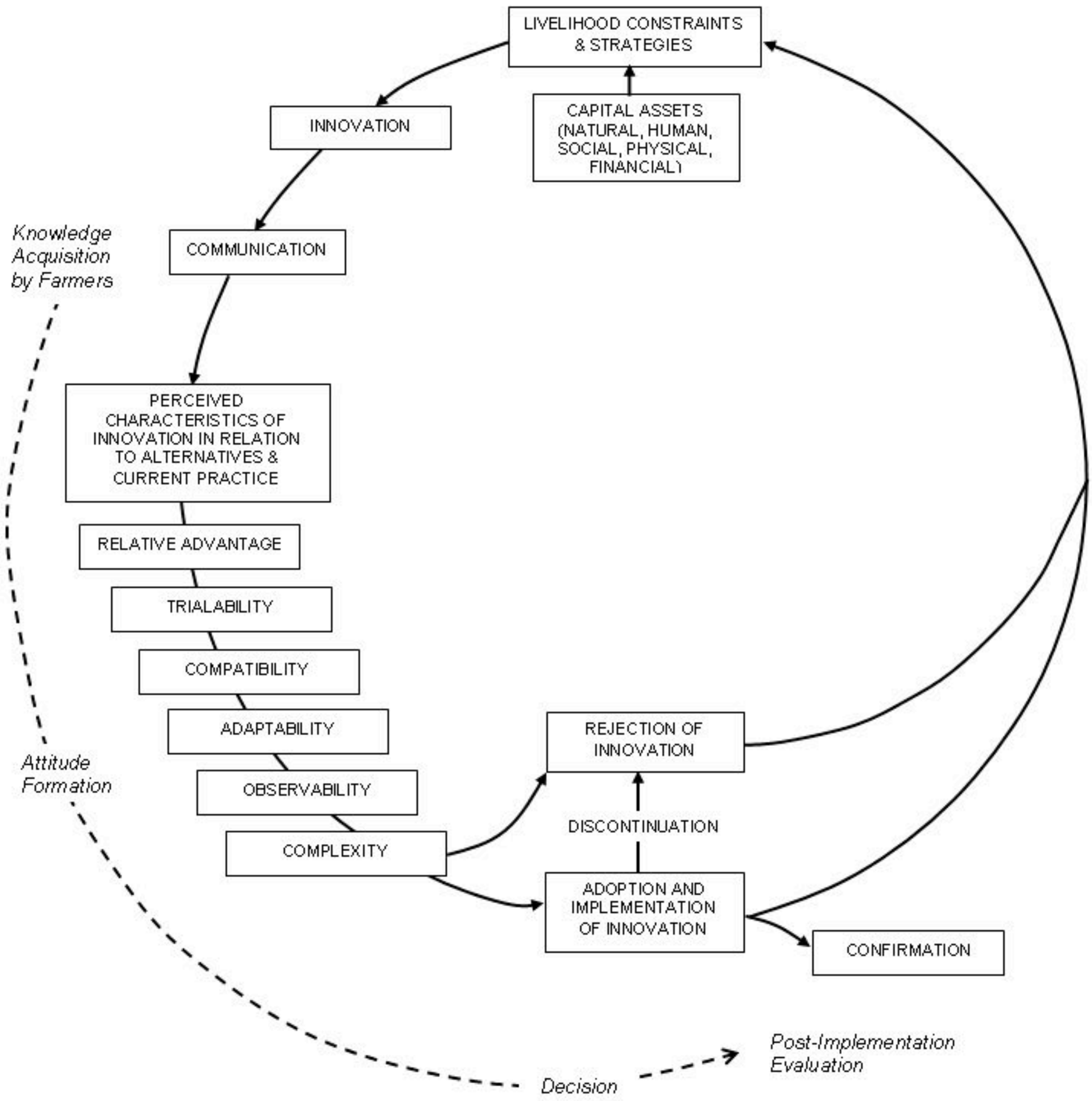


Figure 8.1 Conceptual framework for optimising the design of a Decision Support System incorporating numerous innovations, based on Rogers (1995) innovation-decision process (dashed line)

Depending on the outcome of this evaluation by land managers, the proposed innovation will be adopted and implemented, or rejected. If it is adopted and implemented, re-enforcement will be sought: if the innovation meets the needs and objectives of the user satisfactorily, and they are not exposed to conflicting messages about the innovation, their decision is likely to be confirmed. If the converse is experienced, the innovation may be discontinued. In order to meet the needs and objectives that persist, land managers will acquire knowledge about alternative strategies, and repeat the process. Alternatively, the innovation may be adapted, and depending on the characteristics of the modified innovation, it may be adopted and implemented, or rejected.

Once land managers have become aware of an innovation, they begin to seek information about the likely consequences of adoption and form an attitude towards it in relation to alternatives and current practice. During this process, innovations are evaluated using up to six criteria relating to innovation characteristics: relative advantage, trialability, compatibility, adaptability, observability and complexity. These were used to design a DSS that optimises the likelihood that the innovative monitoring and management options it contains are likely to achieve widespread uptake.

The relative advantage of innovations in the DSS (Appendix 4) is likely to be considerably greater than alternative DSSs (handbooks for private ranchers by Field (1978) and Hendzel (1981)), as they are adapted to the tenure and resources of communal land managers. The monitoring and management options contained in the DSS were developed in collaboration with local communities who wanted to find more sustainable alternatives to current practice. The DSS will be distributed to land managers free of charge, so there will be no start-up costs associated with adopting the technology. By basing the monitoring and management options on local knowledge and expertise, it is not necessary for users to invest in any additional equipment or training to use the DSS.

Ability to experiment with an innovation on a trial basis increases the likelihood of adoption (Rogers, 1995). "Trialability" is a more important factor for early adopters than for late adopters, who tend to substitute the experience of others for their own trial (Ryan, 1948). Farmers are characteristically risk averse (Binswanger, 1980; Reeves & Lillieholm, 1993), and trials offer a valuable means of reducing perceived risk (Evans, 1988; Scherr, 1992). It is possible for land managers to easily trial the DSS without incurring significant opportunity costs. If the person does not want to adopt the DSS after the trial, there are no costs associated with terminating the trial.

For a technology to be adoptable, it must be compatible with the environmental and socio-cultural context in which it is introduced, in addition to farmer needs and objectives (e.g. Hassinger, 1959). The DSS is designed to be compatible with the land tenure context of target users. By building on and validating local knowledge, the learning process that was used to develop the DSS ensures that the monitoring and management options it contains are compatible with user needs and objectives, and the Kalahari environmental and socio-cultural context.

The extent to which an innovation can be adapted to meet dynamic user demands and specifications can influence its adoption potential. In addition to the characteristics of the technology itself, adaptability depends on the adaptive capacity of farmers (influenced by factors such as education level, access to credit and risk aversion). Votsi *et al*. (1997) describe these two components of adaptation as agronomic and socio-economic "agility". Understanding an innovation is a prerequisite to effective adaptation, as adaptation without the appropriate knowledge can result in technologies that are ineffective, inefficient and sometimes counterproductive (Larsen & Agarwala-Rogers, 1977). The DSS is designed to be highly adaptable, providing users with a variety of management options to deal with problems identified through monitoring. If one option does it too resource or time-intensively, or not work, an alternative may be selected. By basing the options on local knowledge, they are likely to be familiar to users. As a consequence, they are more likely to feel competent to adapt management options to local requirements where necessary.

For example, wind erosion indicators are linked the following choice of management options: dune stabilisation strategies; soil protection and improvement strategies; reducing livestock densities during drought; borehole rotation; annual or seasonal shifting grazing; changing livestock breeds; and managing trees. Taking dune stabilisation as an example, two options are provided: 1. fence off and re-seed; and 2. stabilise with bush cuttings from encroached areas (a cheaper alternative) (see Appendix 4 for details).

If the effect of an innovation is highly visible, it will be adopted more readily (Rogers, 1995). Unfortunately, given the high interannual variability of rainfall in the Kalahari, monitoring results will be most useful after a number of years, which limits the observability of the DSS. Although some management options have highly visible effects over a relatively short time-frame (e.g. bush clearance), others may take many years to yield results (e.g. dune stabilisation).

Innovations which are difficult to understand and implement are less likely to be adopted than technically simple innovations (Rogers, 1995). The complexity of an innovation depends on the characteristics of the innovation and the land manager. For example, young and more educated farmers are more likely to adopt new technologies and are likely to adopt them before other sectors of society (D'Souza *et al.,* 1993). Key informant interviews suggested that a manual format for the DSS would be the simplest for users. All indicators and management options were evaluated by land managers in focus groups, and only those that were deemed easy to use were incorporated in the DSS (chapters 6 & 7). The DSS will be trialed and optimised by land managers prior to publication to ensure it is simple to use.

8.3.2 Draft DSS specification

Literacy levels are high in Botswana (average 81%): 65% and 98% in Study Areas 1 and 2 respectively (rates are not known for Study Area 3 but are believed by key informants to be above average) (Central Statistics Office, 2004). In Study Area 1, where literacy is lowest, interviews showed that overstretched extension services tended to focus on more wealthy farmers. It is therefore hoped that manuals can free up extension workers to concentrate on working with poorer farmers who tend to be less literate.

To date, manuals have been drafted for two of the study areas (Appendix 4), and a third is being developed. Separate manuals have been developed for each study area in response to the differences in indicators and management options deemed relevant for each area by local communities (chapters 6 and 7). The first two have been peer-reviewed by eight international experts and policy stakeholders (see section 8.3.3 for details). Next, revised manuals will be translated into local languages and trialed by land managers prior to publication.

Manuals are designed for regular use by pastoralists to identify detrimental environmental change and to guide sustainable management responses. Their purpose is to enable farmers to:

1. a) Recognise early warning indicators that suggest rangeland condition is likely to become worse in the future;
   b) Change rangeland management to prevent this from happening; and

2. a) Recognise areas of rangeland that are already badly damaged; and
   b) Focus efforts on these areas to restore them to better condition.

Although some of the worst land degradation occurs during drought, the manuals are not designed to help farmers predict when a drought will occur. However, they can help farmers work out if lasting damage has been caused by livestock during a drought (or at any other time) and choose the best way to respond.

The manuals also provide basic practical information about rangeland management. This covers the causes of a variety of common problems and identifies four key principles of good rangeland management: 1. Manage the rangeland, not just the livestock; 2. Set targets for your rangeland; 3. Prioritise and plan your management; and 4. Manage for variety (for details, see chapter 3 of draft manuals in Appendix 4).

The recommended assessment procedure is relatively flexible, and designed to make recording and interpretation of results simple for users. The manual provides the following summary (for more detailed instructions, see chapter 2 of the manuals in Appendix 4):

1. Find the kind of rangeland you are aiming for. Find parts of the rangeland you know recover well from drought to support livestock year after year. If this is not possible, find an area that is used less by livestock but beware that this is an unrealistic target unless you are prepared to reduce your herd. Check that your target rangeland is in healthy condition using indicators from this manual (see Step 4). Once you have been looking for indicators for a few years, you can start comparing your rangeland to the way it used to be instead, which will give you a more accurate indication of whether your management is having the desired effect.

2. Choose where you want to regularly check the health of your rangeland. Choose a number of different places, close to the borehole, further away and in between (at least two places in each area). Make sure you can find these places the following year (e.g. choose places near landmarks or paint trees or poles).

3. Choose which warning indicators you will use. Choose indicators (chapter 4 of the manual) that you will look for regularly in each of the places you have chosen. Choose at least three from each of the following categories: i) plants; ii) soil; and iii) insects & wild animals/ livestock/ or people. Write each indicator next to a spoke on a wheel chart (Figure 8.2). Use the same indicators each year so that you can see how they change. You will notice that there are also wheel charts with *early warning* indicators – these have been chosen to show if there is a danger that future problems are *about to happen* in your rangeland.

4. Look for the warning indicators. At each of the places you have chosen: (1) look for the indicators you have chosen; and (2) look for the early warning indicators listed in chapter 4 of the manual and marked on the smaller wheel charts in the middle of the manual. Decide if they are very healthy, quite healthy, quite unhealthy or very unhealthy and place a mark on the relevant spoke of each wheel chart. Join up the marks you have made on the spokes to see what shape of wheel represents your rangeland (it may be easier to see if you colour in the shape).

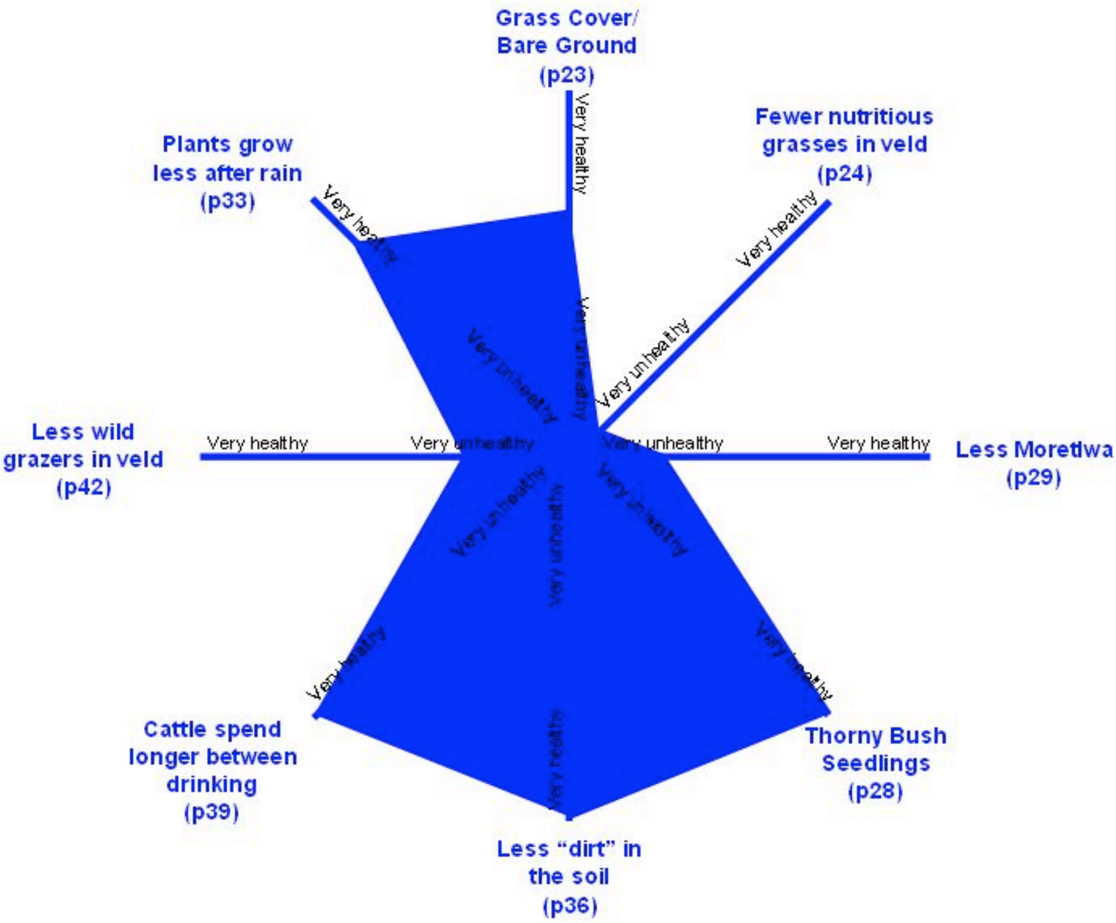
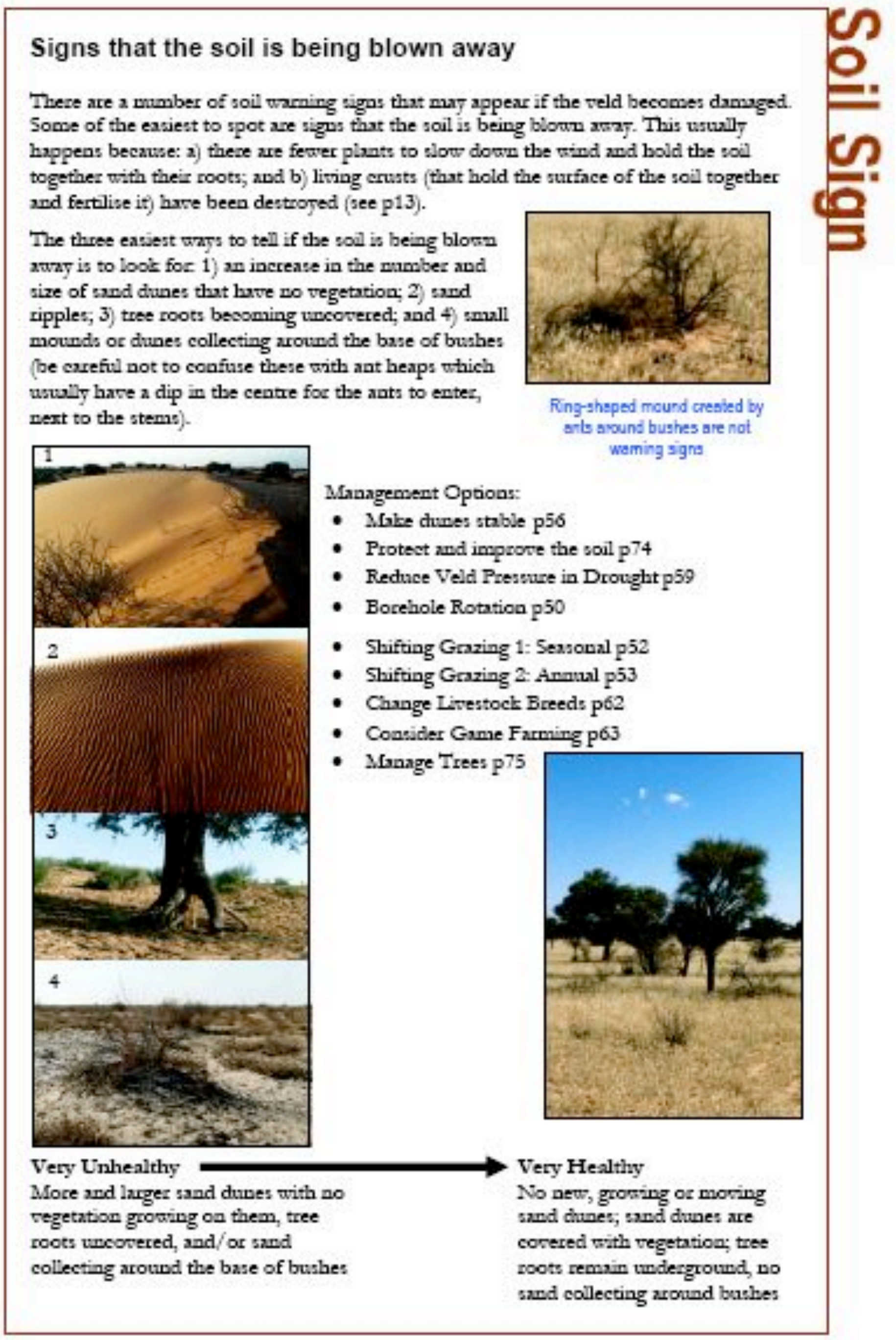


Figure 8.2 An example of a wheel diagram for recording measurements of early warning indicators

5. Decide what to do about the current health of your rangeland. On the large multicoloured wheel chart, look at the lumps (quite and very healthy indicators that show your rangeland is doing well) and dents (quite and very unhealthy indicators that show you have problems) in your wheel. If your wheel is generally large and circular (most indicators are quite or very healthy), your rangeland is healthy – keep up the good work. If it is small (most indicators are quite or very unhealthy) or there are particularly big dents in certain places, you may need to take action. Refer back to the pages describing the indicators that were unhealthy (chapter 4 of the manual), and these pages will suggest management options you could try to improve the quality of your rangeland.

6. Decide what to do about the future health of your rangeland. On the second (smaller) wheel chart, look for the lumps (quite and very healthy indicators that show your rangeland is going to be healthy in the future) and dents (quite and very unhealthy indicators that show you are going to have problems in the future) in your wheel. If it is small (most indicators are quite or very

unhealthy) or there are particularly big dents in certain places, you may need to take action to prevent future problems from happening. Refer back to the pages describing the indicators that were bad (chapter 4 of the manual), and these pages will suggest management options you could try to prevent future problems in your rangeland (chapter 5 of the manual).



Soil Sign

Signs that the soil is being blown away

There are a number of soil warning signs that may appear if the veld becomes damaged. Some of the easiest to spot are signs that the soil is being blown away. This usually happens because: a) there are fewer plants to slow down the wind and hold the soil together with their roots; and b) living crusts (that hold the surface of the soil together and fertilise it) have been destroyed (see p13).

The three easiest ways to tell if the soil is being blown away is to look for: 1) an increase in the number and size of sand dunes that have no vegetation; 2) sand ripples; 3) tree roots becoming uncovered; and 4) small mounds or dunes collecting around the base of bushes (be careful not to confuse these with ant heaps which usually have a dip in the centre for the ants to enter, next to the stems).

Ring-shaped mound created by ants around bushes are not warning signs

1
2
3
4

Management Options:
- Make dunes stable p56
- Protect and improve the soil p74
- Reduce Veld Pressure in Drought p59
- Borehole Rotation p50
- Shifting Grazing 1: Seasonal p52
- Shifting Grazing 2: Annual p53
- Change Livestock Breeds p62
- Consider Game Farming p63
- Manage Trees p75

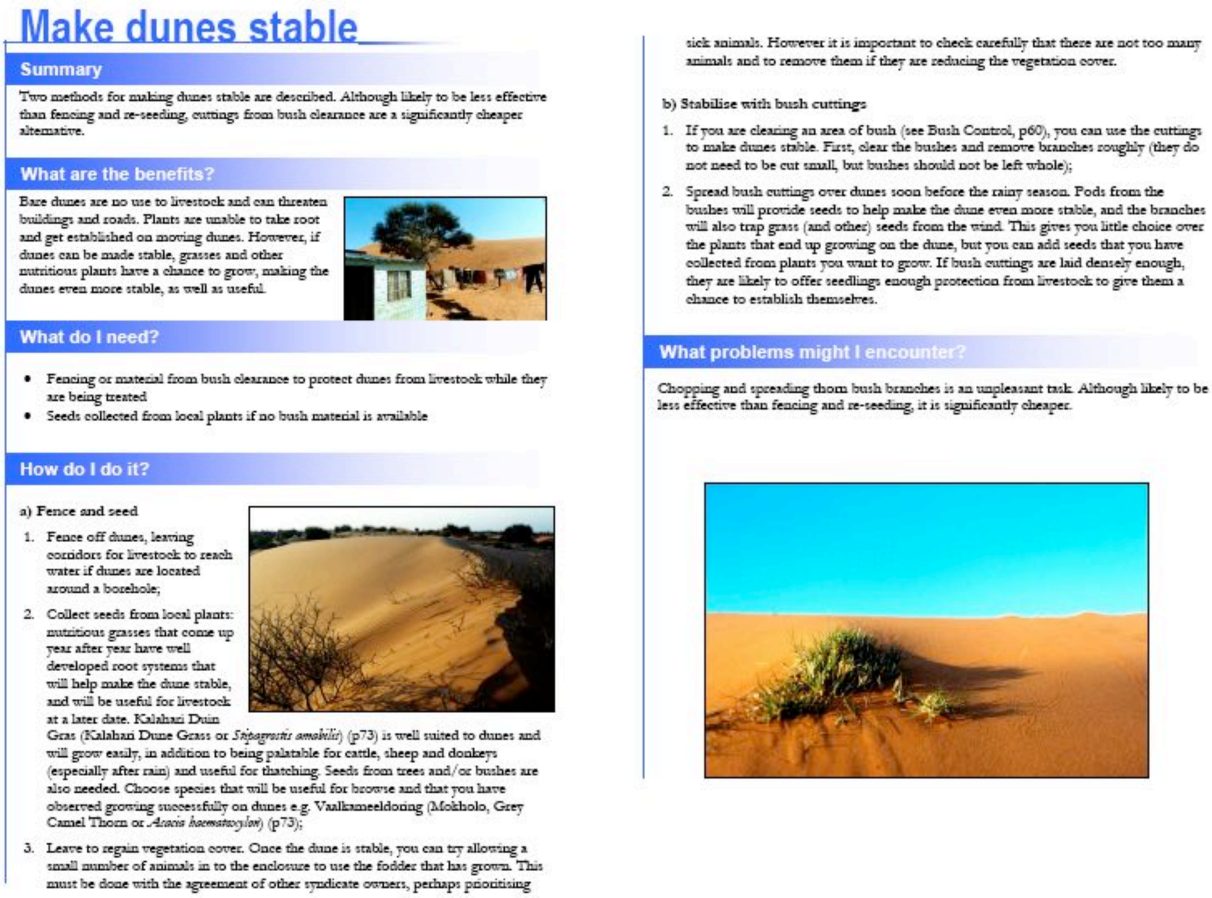
Very Unhealthy
More and larger sand dunes with no vegetation growing on them, tree roots uncovered, and/or sand collecting around the base of bushes

Very Healthy
No new, growing or moving sand dunes; sand dunes are covered with vegetation; tree roots remain underground, no sand collecting around bushes

Figure 8.3 Example page from Study Area 3 Manual showing indicator description

Wheel diagrams borrow conceptually from published visualisation techniques such as sustainability polygons (Herweg *et al.*, 1998), sustainability AMEOBAs (Ten Brink *et al.*, 1991), sustainability webs (Bockstaller *et al.*, 1997), kite diagrams (Garcia, 1997) and sustainable livelihood asset pentagons (Scoones, 1998).

Short textual descriptions of indicators are illustrated with photographs representing healthy and unhealthy rangeland states (see Figure 8.3 for an example). Detailed photographs or diagrams are provided to help identify key species where necessary. Each indicator is cross-referenced to a range of management options (see Figure 8.4 for an example). There are a range of options to suit different budgets and time-frames.



Make dunes stable

Summary

Two methods for making dunes stable are described. Although likely to be less effective than fencing and re-seeding, cuttings from bush clearance are a significantly cheaper alternative.

What are the benefits?

Bare dunes are no use to livestock and can threaten buildings and roads. Plants are unable to take root and get established on moving dunes. However, if dunes can be made stable, grasses and other nutritious plants have a chance to grow, making the dunes even more stable, as well as useful.

What do I need?

- Fencing or material from bush clearance to protect dunes from livestock while they are being treated
- Seeds collected from local plants if no bush material is available

How do I do it?

a) Fence and seed

1. Fence off dunes, leaving corridors for livestock to reach water if dunes are located around a borehole;
2. Collect seeds from local plants: nutritious grasses that come up year after year have well developed root systems that will help make the dune stable, and will be useful for livestock at a later date. Kalahari Duin Gras (Kalahari Dune Grass or *Stipagrostis amabilis*) (p73) is well suited to dunes and will grow easily, in addition to being palatable for cattle, sheep and donkeys (especially after rain) and useful for thatching. Seeds from trees and/or bushes are also needed. Choose species that will be useful for browse and that you have observed growing successfully on dunes e.g. Vaalkameeldoring (Mokholo, Grey Camel Thorn or *Acacia haematoxylon*) (p73);
3. Leave to regain vegetation cover. Once the dune is stable, you can try allowing a small number of animals in to the enclosure to use the fodder that has grown. This must be done with the agreement of other syndicate owners, perhaps prioritising sick animals. However it is important to check carefully that there are not too many animals and to remove them if they are reducing the vegetation cover.

b) Stabilise with bush cuttings

1. If you are clearing an area of bush (see Bush Control, p60), you can use the cuttings to make dunes stable. First, clear the bushes and remove branches roughly (they do not need to be cut small, but bushes should not be left whole);
2. Spread bush cuttings over dunes soon before the rainy season. Pods from the bushes will provide seeds to help make the dune even more stable, and the branches will also trap grass (and other) seeds from the wind. This gives you little choice over the plants that end up growing on the dune, but you can add seeds that you have collected from plants you want to grow. If bush cuttings are laid densely enough, they are likely to offer seedlings enough protection from livestock to give them a chance to establish themselves.

What problems might I encounter?

Chopping and spreading thorn bush branches is an unpleasant task. Although likely to be less effective than fencing and re-seeding, it is significantly cheaper.

Figure 8.4 Example page from Study Area 3 Manual showing a management option

8.3.3 Reviewer responses

There were two broad responses from reviewers to the draft manual described above:

1. Academic reviewers[24]: suggested the DSS should contain more detail, explaining degradation processes and the principles underlying management suggestions. One reviewer suggested the use of more precise, technical language (e.g. "benchmark" instead of "target rangeland" and "eroded" instead of "blown away"); and

[24] Wolfgang Bayer (Independent Advisor in Livestock Systems Development, Germany), P. Croal (Southern African Institute for Environmental Assessment), C.F. Cupido (Government of South Africa), K. Esler (University of Stellenbosch), K. Kellner (North West University, Potchefstroom), S. Milton (University of Cape Town), Anne Waters-Bayer (ETC Ecoculture), R. White (Natural Resource Services Pty., Gaborone), I. Zimmerman (Polytechnic of Namibia).

2. Ministry of Agriculture reviewers[25]: asked for the DSS to be further simplified, using less text, and possibly focusing only on monitoring.

Comments from Ministry of Agriculture staff were motivated by a desire to make the DSS accessible to all land managers. Given their regular contact with land managers, and the importance of keeping the technology as simple as possible (section 8.3.2), drafts will be simplified considerably before being trialed with land managers. However, this group of reviewers identified a need for a separate, more technical DSS for extension workers that could complement existing handbooks that are targeted at private ranchers. This version of the DSS will usefully incorporate the academic reviewer suggestions. It will be published in English and incorporate indicators and management options from all three study areas in three separate sections.

8.4 Conclusion

The Decision Support System described in this chapter integrates land degradation indicators with adaptive management options in a manual that is designed to be easy for land managers to use. The design of the DSS has been optimised using an innovation-decision approach combined with expert review to enhance the likelihood of widespread uptake and application by land managers in the Kalahari. As part of this process, trials by land managers are pending. However, the success of this DSS depends to a large extent on institutional reform, as many of the management options are only likely to be effective under common property tenure. Grass-roots institutions for common property management are currently being developed and trialed through the IVP. The DSS will be trialed with management committees from this project, but more widespread uptake of this approach depends on the extent to which the IVP can influence Government policy on land tenure.

[25] G. Bartels, R. Kwerepe, M. Taylor, V. Tlhalerwa

9

Conclusions

9.1 Introduction

This thesis proposes a learning process (Figure 3.2) to help local stakeholders and researchers work together more effectively to monitor environmental sustainability and respond appropriately. It was tested in three parts of the Kalahari, Botswana, that are considered to be experiencing rangeland degradation.

9.2 Key findings

This work produced the following key findings:

- Multi-source, multi-scale land degradation assessment can provide more accurate and reliable results than the use of any single assessment technique alone. Expert opinion and remote sensing can provide degradation assessments at coarse spatial scales that are replicable, rapid and cost-effective. However, to interpret an assessment in an appropriate environmental and socio-economic context, it is essential to supplement this information with participatory, ecological and economic data at different spatial scales. The qualitative nature of participatory data makes it impossible to quantitatively integrate with other data sources. However, a qualitative process of combining rangeland degradation information from different sources through triangulation can provide a context in which results can be interpreted more reliably;
- By applying a learning process between local communities, policy-makers and researchers in Botswana, a wide range of adaptive management options were identified that could prevent, reduce, reverse or help people adapt to rangeland degradation. However, many of the management strategies that were suggested could only be applied effectively under common property regimes. Institutional reform may therefore be necessary to reverse the trend of privatising communal rangelands and instead stimulate local innovation and adaptation by strengthening common property regimes;
- There was considerable overlap between local and scientific knowledge of sustainability indicators, and the majority of indicators suggested by land users were validated through field-based research. Research findings were used to select indicators that were most likely to accurately and sensitively represent land degradation processes, and these recommendations were discussed by communities to arrive at a final selection. By building on local knowledge, the indicators were highly familiar to land users who had the capacity to apply them without any need for specialist training or equipment. Despite the wealth of knowledge about rangeland sustainability indicators as a community, this

knowledge was thinly spread. By testing and disseminating this information, the research was able to build upon and share valuable local knowledge among communities. Local knowledge was more holistic than many published indicator lists for monitoring rangelands, encompassing vegetation, soil, livestock, wild animal and socio-economic indicators. Early warning indicators tended to focus on vegetation and soils;

- Despite considerable overlap between indicators elicited from each of the three study areas, there were still significant differences between the indicators proposed for each study area. In addition to this, results from ecological and soil-based research sometimes gave very different results for the same indicators in different study areas. For this reason, it is essential for indicator-based decision support systems to be site-specific. Although there were differences in indicator knowledge according to education and gender in two of the study areas, these differences were not deemed significant enough to tailor decision support systems to different social groups within study areas;
- Indicators and management options were combined in a Decision Support Systesm (DSS) that is designed for land managers to easily collect data and monitor progress towards sustainability goals. Short textual descriptions of indicators were illustrated with photographs representing healthy and unhealthy rangeland states. Each indicator was cross-referenced to a range of management options designed to suit different budgets and time-frames. The design of the DSS was optimised following an innovation-decision theoretical approach before future trials with local users;
- However, the future success of this work depends to a large extent on institutional reform, as many of the management options are only likely to be effective under common property tenure. Grass-roots institutions for common property management are currently being developed and trialed through the UNDP/UNEP Indigenous Vegetation Project (IVP) (based in the Ministry of Agriculture). The DSS will be trialed with management committees from this project, but more widespread application of the proposed learning process in Botswana depends on the extent to which the IVP can influence Government policy on land tenure.

9.3 Reflections on the learning process

These findings emphasise the value of local knowledge in environmental monitoring and adaptive management. However, they also emphasise the need to integrate this with the knowledge of researchers, and open dialogue about environmental sustainability between communities, researchers and policy-makers. Many of the proposed adaptive management options could only work effectively under common property regimes. If the grass-roots institutions that are being piloted by IVP are deemed successful by the Ministry of Agriculture, assurances have been given to the project funders that common property regimes will be considered as a serious alternative to privatisation by policy-makers in Botswana.

For this institutional experiment to work, it is vital to start re-building the local capacity for sustainable land management that has been eroded by 30 years of ineffective controls from Government institutions. Although this capacity is now thinly dispersed amongst local communities, traditional knowledge has survived. However, given the environmental, social and economic changes that have occurred over the last 30 years, much of this knowledge is no longer relevant in contemporary Botswana. But 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 role of the researcher was significant in this group learning process, bringing stakeholders together and sharing innovative ideas from other communities and the literature.

Local knowledge of sustainability indicators was just as valuable, and here the benefits of integrating this knowledge with research findings were particularly evident. By building on local indicator knowledge, it was possible to develop indicators that were familiar to people and that they could use easily without specialist training or equipment. However, not all community indicators could be used accurately or reliably to monitor land degradation or environmental sustainability. For example, some were also drought indicators. By testing local indicator knowledge empirically, it was possible to help communities make an informed short-list of the indicators that could be used most sensitively and reliably to detect long term environmental degradation. In this way, it was possible to combine qualitative insights from participatory research with insights from more top-down empirical research to produce more accurate and relevant results than either approach could achieve alone. Real-world problems do not respect disciplinary or epistemological boundaries, and neither do the local communities and policy-makers who are grappling with these issues. If research is to meaningfully engage with these issues, academics must be prepared to combine methods from a variety of disciplinary and epistemological traditions.

The following examples show how the learning process used in this research facilitated meaningful, two-way communication between researchers and communities to devise potential solutions to shared problems. They also illustrate the challenges and potential problems associated with conducting participatory research. The received wisdom that participation is in and of itself a “good thing” has been been increasingly challenged in recent years (e.g. Mosse, 1994, 1996; Cooke & Kothari, 2001). Conceptual and political concerns have been added to methodological concerns (Cooke & Kothari, 2001). Participatory research does not take place in a power vacuum: the empowerment of previously marginalised groups may have unexpected and potential 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 & Wright, 1995), creating “dysfunctional concensus” (Cooke, 2001: 19). Depending on the way in which they are perceived, external facilitators may stand in the way of meaningful dialogue and learning (Mohan, 2001). Critiques have focussed on both the technical limitations of the tools that are used (e.g. Bastian & Bastian, 1996) and on an over-emphasis on tools and formulas (Buhler, 2002). In addition, many participatory research projects have been accused of raising false expectations, and failing to deliver promises to stakeholders (Buhler, 2002).

The learning process facilitated learning by researchers through in-depth semi-structured interviews and focus group discussions with local people. Communities were able to learn from each other and researchers through focus groups at various stages in the research. Initial focus groups emphasised learning from others in the community through Multi-Criteria Evaluation of their indicator knowledge. Although this included a few indicators from literature that had not been cited by the community, these indicators were rarely deemed useful. Later focus groups that centred on potential management options, included more discussion about options from the literature, and facilitated learning from both researchers and other community members. Finally, field-based research results were presented to communities. This was a learning experience for both researchers and communities, who sometimes provided explanations for empirical results.

Despite anticipated cultural challenges, close collaboration with staff from the Ministry of Agriculture (who were often members of the local community) facilitated effective communication between researchers and communities. This was of course not without any difficulties, for example focus groups were initially held in village "Kgotlas". These function like Town Halls (but are made of a circle of tightly packed fence posts) and are the focal point of every village where meetings are usually held. However, traditionally women were not allowed to speak in the Kgotla if there were men present. Although this tradition is rarely adhered to nowadays, it inhibited women from expressing themselves in some villages. As soon as the cause for their inhibition was identified, focus groups were held elsewhere, and a number of focus groups were held specifically for women.

Another challenge was the research culture divide between Government and University ecologists. Government range ecologists use a number of rapid assessment techniques that lack the precision and replicability desired by researchers. To solve this conflict, Government techniques were used where they were unlikely to reduce data quality (for example not subtracting gaps in bush and tree canopies from their intercept distance). However, where rapid assessment techniques were likely to cause bias or inaccuracy (for example not distinguishing between different species of forb), they were not used. By learning from each other, the group of ecologists were able to complete the work much faster and more accurately than either group could have done alone. Interaction between natural and social scientists from Universities (in this case the Universities of Leeds and Botswana) was much more straightforward.

Opening dialogue between researchers and policy-makers was not straightforward either. At district level, where Government officers had not had contact with researchers before, it was easy to gain trust. However, national policy-makers had experienced many negative interactions with researchers in the past. In some cases, researchers had failed to complete research or report their findings to Government; in others, participatory research did not meet the expectations that had been claimed. Only through a process of patient re-engagement with people at all different levels in Government, and the presentation of preliminary results over the course of a year was it possible gain their trust, and open a meaningful two-way dialogue.

The interactions between members of local communities facilitated by this work were particularly productive. Given the thin spread of knowledge (particularly about indicators), focus group Multi-Criteria Evaluations provided rapid dissemination of knowledge through the community. A similar process occurred in adaptive management focus groups, but in addition to sharing knowledge, these fora led to the creation of new knowledge through the interaction of innovators and researchers. However, focus group participants were self-selecting, and is not possible to tell the extent to which this knowledge spread to non-participants.

It requires considerable extra effort (beyond what might be considered necessary to collect adequate participatory or ecological data) to develop the trust and rapport that are necessary to facilitate effective communication and constructive relationships between such diverse groups of people. In this research, many months were spent establishing close working relationships with other researchers, Government officials, policy-makers and communities. This led to the development and facilitation of two 3-week workshops for Government extension workers and range ecologists (Reed & Dougill, 2003). It also led to the involvement of interested members of the local community in participatory and ecological data collection. Workshops with students at the University of Botswana[26] and local schools were undertaken, and long-term funding for a community horticulture project was provided through international research contacts[27]. Although these activities appear additional to what was strictly required for the research, the success of this research was founded on effective communication and healthy relationships. These principles are central to the proposed learning process and, as everyone knows, they can be both hard work and rewarding.

9.4 Future Work

A number of refinements could be made to improve the proposed learning process and facilitate more widespread application of the approach. This thesis has identified a global need for multi-source, multi-scale degradation assessment that can link to grass-roots action to enhance the sustainability of land management. However, for the proposed approach to be applied at this scale, significant savings in cost and time would be necessary. The Botswana case study showed that significant savings can be made: fieldwork in Study Area 1 took two years to complete, but was replicated in Study Areas 2 and 3 in three weeks at each study area. Although analysis took considerably longer than three weeks, it is possible that a streamlined method could be developed to develop site-specific monitoring, mitigation and adaptation strategies with local communities in a country's degradation hotspots in a matter of months.

Given the fine spatial scale at which these strategies are developed, it might be necessary to consider how they could be applied beyond the hotspots in which they were developed. After all, the results show that many of the indicators and management options were site-specific. Figure 9.1 shows one potential approach to this problem. First, a combination of expert opinion and remote sensing could be used to identify potential land degradation hotspots (Streams 3 and 4 in Figure 9.1). Ecological sample sites (Stream 2) could then be selected to represent each agro-ecological zone, ensuring potential hotspots are sampled. Where possible, efficiency gains could be made by using existing long-term ecological monitoring sites (e.g. from the International Long Term Ecological Research Network). Land degradation indicators could then be developed in collaboration with local communities for each major land use in each agro-ecological zone (Stream 1). The relevance of these indicators may be tested in ecological sample sites, and checked against agricultural productivity data (Stream 5) and land user interpretations of land degradation (Stream 1) in each area. Management options for degraded land can be collected from literature and land user communities and integrated with indicators in a Decision Support System for use by land management committees. Information from these different sources could be collected and combined in a GIS map of degradation extent and severity, identifying specific degradation issues and policy recommendations. This would form a baseline from which trends could be detected from data collected

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[26] Some of the materials are available online: http://www.env.leeds.ac.uk/~mreed/ub/

[27] For details see: http://www.newearth.info/nuevas/michaeltaylor.html

in future years. This work is currently being discussed with the FAO's Land Degradation in drylands (LADA) project.

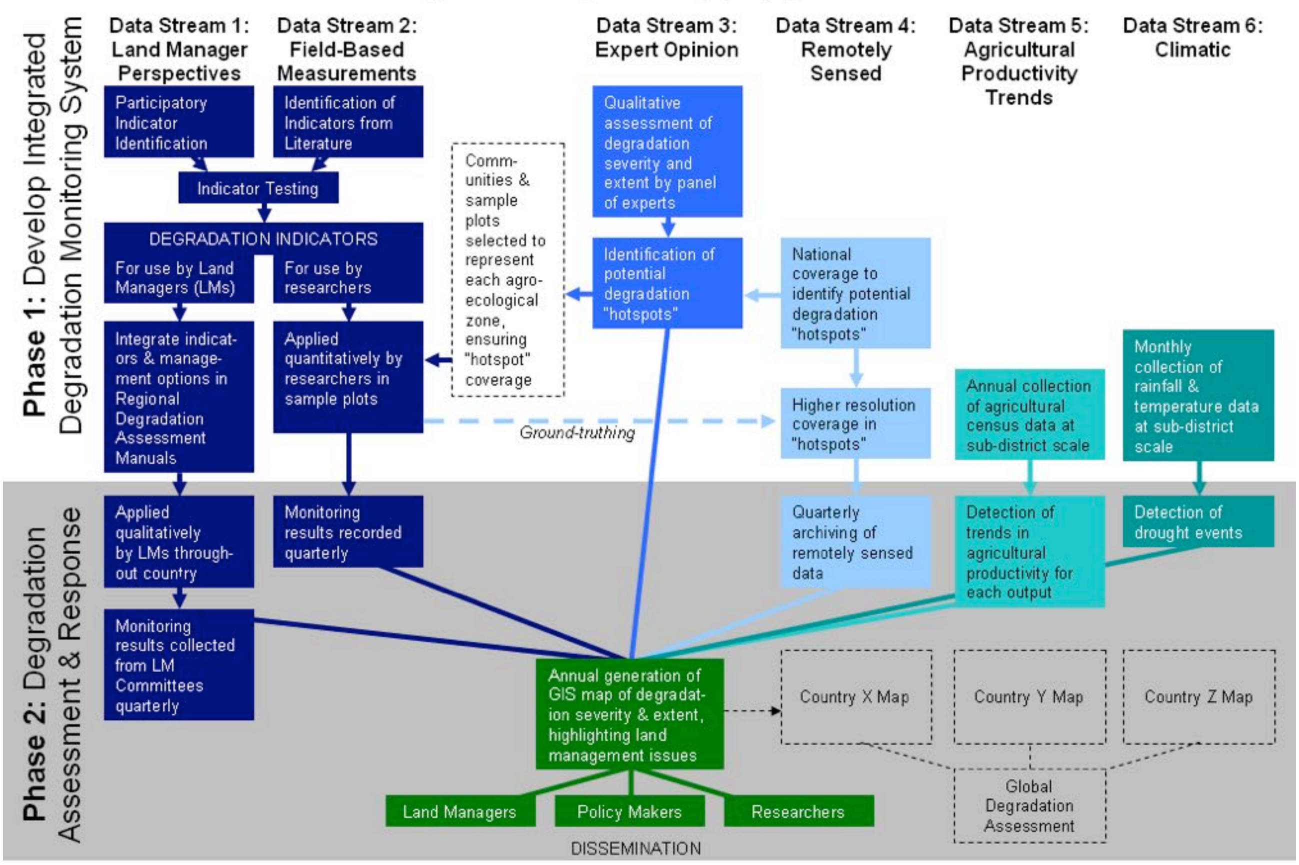

Figure 9.1 Possible structure for a global degradation monitoring system that can stimulate grass-roots action to improve the sustainability of land management

Although the learning process was replicated in three different ecological zones in Botswana, it is not known how replicable it would be in very different agro-ecological zones or in different socio-economic contexts. To this end, a scoping study funded by the UK Research Councils is currently adapting the approach used in this thesis to examine the challenges of land degradation in UK uplands[28]. Through this research, a number of refinements have been made to the approach. Conceptually, it takes the approach beyond environmental sustainability to develop indicators and management strategies that can also monitor and enhance social and economic sustainability. It also involves a much wider range of stakeholders, including *inter alia* water companies and recreation interests in addition to farmers and policy-makers. The most significant methodological refinements are its use of scenario analysis and integrated biophysical, economic and social modelling. By identifying a range of likely future land use scenarios, it is possible to identify adaptive strategies for a range of possible futures.

[28] See http://www.env.leeds.ac.uk/sustainableuplands for details.

9.5 Conclusion

In conclusion, this thesis has proposed a learning process that can facilitate two-way and meaningful interaction between local communities, researchers and policy-makers to monitor environmental sustainability and respond appropriately. Application of this process in Botswana has shown that multi-source, multi-scale land degradation assessment can provide more accurate and reliable results than the use of any single technique alone. Detailed participatory and ecological research in degradation “hotspots” has identified a wide range of innovative adaptive management options that could prevent, reduce, reverse or help people adapt to rangeland degradation. Communities also identified a range of environmental sustainability indicators, the majority of which were validated through field-based research. By building on local knowledge, the indicators and management options were familiar to land users who could apply them without specialist training or equipment.

These findings emphasise the value of local knowledge in environmental monitoring and adaptive management. They also emphasises the need to integrate this with the knowledge of researchers, and open dialogue about environmental sustainability between communities, researchers and policy-makers. By combining qualitative insights from participatory research with more top-down empirical research it was possible to produce more accurate and relevant results than either approach could have achieved alone.

However, the future success of this work depends to a large extent on the ability of the IVP to influence Government policy on land tenure, as many of the management options are only likely to be effective under common property tenure. If communities are given effective control over their natural resource base, the learning process outlined in this thesis has the potential to enhance their understanding of environmental problems and empower them to maintain a sustainable livelihood in the face of environmental change. 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.” Through dialogue with policy-makers, sustainability monitoring and adaptive management has the potential to help relocalise and enrich sustainable development policy, meet UNCCD targets, and enhance the environmental sustainability of rural livelihoods.

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Appendix 1:
Degradation indicators elicited from land users

Table A1 Study Site 1 degradation indicators ranked by the number of times they were cited by land users in semi-structured interviews and grouped thematically. Results of focus group evaluation summarised under "accuracy" and "ease of use". As many as possible of those deemed both accurate and easy to use were then tested in the field. Indicators highlighted in grey were deemed particularly accurate and easy to use. Those in black were removed from the process due to inaccuracy and/or difficulty to use. Results of indicator testing are summarised in the far-right column.

Rank	Indicator	Times Cited	Accu-racy	Ease of Use	Empirical Evidence
	Vegetation				
1	Decreased grass cover	45	✓	✓	✓
2	Increased abundance of unpalatable forbes and shrubs	34	✓	✓	✓
3	Increased abundance of unpalatable grasses	17	✓	✓	✓
4	Decreased abundance of palatable grass species	16	✓	✓	✓
5	Increased proportion of dead branches and tree mortality	12	✓	✓	✓
6	Decreased abundance of palatable forbes and shrubs	11	✓	✓	✓
7	Decreased abundance of trees	9	✓	✓	X
8	Decreased abundance of medicinal/edible plants	6	✓	✓	Insufficient data
9	Grass becomes grey and brittle (and is less nutritious)	5	X	✓	
10	Vegetation responds less vigorously to rainfall (decreased rain use efficiency)	4	✓	✓	Not tested
	Increased abundance of hollow grasses	4	X	X	
11	Increased proportion of bare ground	3	✓	✓	✓
	Trees become stunted	3	✓	✓	X
	Increased abundance of *Boscia albitrunca*	3	✓	✓	✓
	Increased abundance of creeping plants	3	X	✓	
	Decreased abundance of fruit and flowers in the veld	3	✓	✓	X
12	Lower grass height	2	X	✓	
	Decreased plant diversity	2	✓	✓	✓
	Cattle have to walk further from borehole to reach grass	2	✓	✓	Not tested
13	Cattle are able to uproot grass as they graze	1	X	X	
	Only old trees (with large girth) are left	1	✓	✓	X
	Decreased abundance of *Boscia albitrunca*	1	X	✓	
	Decreased abundance of *Terminalia sericea*	1	✓	✓	Not tested
	Introduction of exotic species	1	X	✓	
	Decreased frequency of veld fires	1	✓	X	
	Decreased abundance of leaf litter	1		✓	X
	Decreased availability of firewood	Literature	X	✓	
	Increased abundance of short forbes	1	X	✓	
	Increased abundance of leaf litter	Literature	X	✓	
	Increased availability of firewood	1	X	✓	
	Increased abundance of evergreen species (apart from *B. albitrunca*)	Literature	X	✓	

Soil

1	Increased soil looseness	20	✓	✓	X (soil strength)
2	Increased abundance of unvegetated sand dunes	10	X	✓	
3	Increased abundance of nebkha dunes (around bushes)	4	X	?	
	Soil is dry despite rain (high infiltration rate)	4	✓	X	
4	Can no longer use 2WD vehicles and bicycles due to soil looseness	3	✓	✓	X (soil strength)
	Increased number of gullies due to water erosion	3	X	?	
	Increased density of cattle tracks	3	✓	✓	✓
	Increased frequency and severity of dust storms	3	✓	X	
	Soil salinisation	3	X	X	
5	Decreased soil organic matter content ("soil becomes less dirty")	2	✓	✓	Not tested
6	More pronounced soil microtopography	1	?	X	
	More dung lies on soil surface (not decomposed)	1	✓	✓	X
	Sand begins to cover roads	1	X	✓	
	Increased soil compaction	1	X	?	
	Decreased litter cover	Literature	X	✓	
	Decreased abundance of soil micro-organisms	Literature	?	X	
	Increased run-off (poor infiltration)	Literature	X	✓	
	Decreased abundance of biological soil crusts	Literature	✓	X	
	Biological crusts become less flexible	Literature	?	X	
	Biological crusts are more broken	Literature	?	X	
	Soil water and nutrients are more spaced/patterned over the landscape	Literature	?	X	

Livestock

1	Livestock loose weight and/or look in poor condition	46	✓	✓	Not tested
2	Livestock graze further from borehole	7	✓	✓	Not tested
3	Decreased calving rate	5	✓	✓	Not tested
	Increased incidence of disease (in general)	5	X	✓	
4	Declining herd size	3	X	✓	
5	Livestock eat refuse	2	X	X	
	Pregnancy % drops	2	X	✓	
	Increased incidence of Botulism due to consumption of refuse	2	X	X	
6	Livestock browse bushes and trees	1	✓	✓	Not tested
	Increased cattle ticks	1	X	X	
	Increased incidence of Aphosphorosis (Stiff Sickness) due to consumption of poor grasses	1	✓	✓	Not tested
	Increased incidence of Anaplasmosis (Gall Sickness) due to consumption of poor grasses	1	✓	✓	Not tested
	Increased incidence of Long Claw due to walking on soft sand	1	✓	✓	Not tested
	Decreased milk production	1	✓	✓	Not tested
	Lower nutrient content in milk	1	X	X	
	Increased abundance of cattle spoor and dung further from borehole	1	✓	✓	Not tested
	Lower nutrient content of dung	Literature	?	X	

Wild animals, birds and insects

1	Increased abundance of Harvester Termites (Isoptera: Hodotermitidae)	5	X	✓	
2	Decreased diversity of mammals and insects	2	✓	✓	Not tested
	Decreased abundance of large herbivores e.g. Gemsbok, Springbok, Eland, Hartebeest and Wildebeest	2	✓	✓	Not tested
	Increased abundance of Blister Beetles (Coleoptera: Melioidae)	2	?	X	

	Decreased abundance of birds	2	✓	✓	Not tested
3	Decreased abundance of burrowing mammals and insects	1	✓	✓	Not tested
	Concentration of wild grazers in non-degraded rangeland	1	✓	✓	Not tested
	Increased number of holes in the soil made by grasshoppers and locusts	1	?	X	
	Increased abundance of recently built ant hills in good condition	1	X	X	

Socio-Economic

1	Ranches require more inputs e.g. supplementary feeds and de-bushing	3	✓	✓	Not tested
2	Increased incidence of ranch bankruptcy	3	X	X	
3	Reduced farm profits	2	X	X	
4	Increased out-migration	1	✓	✓	Not tested
	Increased malnutrition in human population	Literature	✓	X	
	Increased conflict between farmers and other groups over resources	Literature	X	X	

Table A2 Study Site 2 degradation indicators ranked by the number of times they were cited by land users in semi-structured interviews and grouped thematically. Results of focus group evaluation summarised under "accuracy" and "ease of use". As many as possible of those deemed both accurate and easy to use were then tested in the field. Indicators highlighted in grey were deemed particularly accurate and easy to use. Those in black were removed from the process due to inaccuracy and/or difficulty to use. Results of indicator testing are summarised in the far-right column.

Rank	Indicator	Times Cited	Accu-racy	Ease of Use	Empirical Evidence
	Vegetation				
1	Decreased grass cover	14	✓	✓	✓
5	Decreased abundance of wild fruits	9	✓	✓	Insufficient data
7	Increased abundance of dead trees	7	✓	✓	X
7	Decreased abundance of trees	7	✓	✓	X
8	Decreased abundance of *Grewia* spp. (Mogwana, Moretlwa, Motsotsojane)	5	✓	✓	Insufficient data
10	Increased visibility (ability to see into the distance)	3	✓	✓	X
10	Decreased abundance of grasses palatable for cattle	3	✓	✓	✓ - grass
10	Decreased availability of thatching grasses	3	✓	✓	X - mopane
10	Decreased abundance of *Ximenia* spp. (Moretologa)	3	✓	✓	Insufficient data
10	Increased bare ground/ decreased vegetation cover	3	✓	✓	✓ - mopane
11	Decreased rain use efficiency (vegetation responds less rapidly and vigorously to rainfall)	2	✓	X	N/A
11	Increased abundance of *Acacia tortilis* (Mosu)	2	✓	✓	Insufficient data
11	Trees become increasingly stunted (due to high intensity of smallstock browsing)	2	✓	✓	X - mopane
12	Decreased grass height	1	✓	✓	Not tested
12	Increased abundance of annual grasses	1	✓	X	N/A
12	Decreased abundance of perennial grasses	1	✓	X	N/A
12	Decreased availability of plants used as vegetables	1	✓	✓	Insufficient data
12	Decreased abundance of *Sporobolus fimbriatus* (Moshanje) (palatable perrenial grass)	1	**	**	Insufficient data
12	Decreased abundance of *Cencrus ciliaris* (Molekangwetsi) (palatable perrenial grass)	1	**	**	Insufficient data
12	Decreased abundance of *Acacia hebeclada* (Setshi)	1	✓	✓	Insufficient data
12	Increased abundance of *Dichrostachys cinerea* (Moselesele)	1	✓	✓	Insufficient data
12	Decreased abundance of *Albizia anthelmintica* (Monoga)	1	X	✓	N/A
12	Increased abundance of *Viscum rotundifolia* (Palamela) (saprophytic epiphyte on most trees except Acacias)	1	✓	X	N/A
12	Decreased availability of mushrooms	1	✓	✓	Not tested
12	Only large trees left	1	✓	✓	X
12	Decreased abundance of *Cleome gynandra* (Rothwe)	1	✓	✓	Insufficient data
12	Decreased abundance of *Boscia foetida* (Mopipi)	1	✓	✓	Insufficient data
12	Decreased abundance of *Boscia albitrunca* (Motlopi)	1	✓	✓	Insufficient data
12	Less veld fires	1	X	X	N/A
	Increased abundance of unpalatable grasses	Literature	✓	✓	✓ - mopane
	Increased abundance of creeping plants	Literature	X	X	N/A

	Soil				
2	Soil becomes softer or more powdery/dusty (decreased grain size)	13	✓	✓	Not tested
3	Increased incidence and severity of dust storms	11	✓	✓	Not tested
9	Increased number of tree roots exposed	4	✓	✓	X
9	Increased incidence of nebkha dunes (around bushes) in rangeland, or dunes around houses etc in villages	4	✓	✓	X
10	Increased soil looseness	3	✓	✓	✓ - grass
10	Increased number of stones on soil surface	3	✓	✓	Insufficient data
11	Lower soil organic matter content ("sand becomes less dirty or lighter")	2	✓	✓	✓ - grass
11	Salinization of soil (white mineral crust or crystals form on soil surface)	2	✓	✓	X
12	Less plant litter covering soil	1	✓	X	N/A
12	Increased water infiltration rate (rain soaks into soil faster)	1	✓	✓	Not tested
12	Increased evaporation rate (soil dries out faster after rain)	1	✓	✓	Not tested
12	Increased area of bedrock exposed	1	✓	✓	Insufficient data
12	Increased density of cattle tracks	1	✓	✓	X
12	Increased incidence of gullies	1	X	✓	N/A
	Increased abundance of biological soil crusts	Literature	✓	X	N/A
	Livestock				
4	Declining livestock condition/ loss of weight	10	✓	✓	Not tested
6	Increased livestock mortality/ declining herd size	8	✓	✓	Not tested
10	Increased incidence of botulism	3	✓	✓	Not tested
11	Decreased calving rate	2	✓	✓	Not tested
11	Change in colour of livestock (black animals become dull, white animals look dirty)	2	✓	✓	Not tested
11	Livestock fur looses gloss and becomes matted	2	X	X	N/A
12	Increased incidence of anthrax	1	✓	✓	Not tested
12	Increased incidence of pasturella	1	✓	✓	Not tested
12	Increased incidence of diseases that cause diahorrea	1	✓	✓	X
12	Increased incidence of "quata" (symptoms: limps before death, carcass rots quickly)	1	✓	✓	Not tested
12	Increased incidence of "Sekalaitho" (symptoms: eyes protude, become weak)	1	✓	X	N/A
12	Increased incidence of Aphosphorosis (Stiff Sickness) due to consumption of poor grasses	1	✓	✓	Not tested
12	Livestock walk further from water/ spend longer between drinking	1	✓	✓	Not tested
12	Livestock start eating toxic plants and die	1	X	X	N/A
	Increased incidence of "long claw"	Veterinary Services	X	X	N/A
	Wild animals, birds and insects				
8	Decreased abundance of game (grass-eating antelope disappear first) and predators	5	✓	✓	Not tested
9	Decreased abundance of insects in general	4	*	*	Not tested
11	Decreased abundance of birds (in particular Pulepule)	2	✓	✓	Not tested
11	Decreased abundance of Harvester Termites (Makaka) (due to absence of grass)	2	✓	✓	Not tested
12	Dogs are more frequently successful killing spring hares and impala	1	X	✓	N/A
12	Decreased abundance of red ants	1	✓	✓	Insufficient data
12	Increased abundance of "Silomotopane" ants (small, black, biting)	1	✓	✓	Insufficient data

12	Increased abundance of "malelekatou" (Setswana) ants (large black with grey abdomen and smell bad)	1	✓	✓	✓
12	Decreased abundance of flies	1	✓	✓	Not tested
12	Decreased abundance of grasshoppers	1	✓	✓	Not tested
12	Increased abundance of ticks	1	✓	✓	Not tested
12	Increasingly difficult to find wild honey	1	✓	✓	Not tested
12	Less edible insect cases on Mopane leaves	1	✓	✓	X
	Socio-economic				
7	Increased household expenditure on products formerly obtained from veld and decreased income from veld products	7	✓	✓	Not tested
10	Increased incidence of malnourishment in population	3	✓	✓	Not tested
12	Increased use of bricks and tin roofs	1	✓	✓	Not tested
12	Greater dependence on government welfare	1	✓	X	N/A
12	Increased polarisation of rich and poor (poor rely most heavily on veld)	2	✓	✓	Not tested

* Specific insect indicators were evaluated

** Used as examples for the indicator, "decreased abundance o f perrenial grasses"

Table A3 Study Site 3 degradation indicators ranked by the number of times they were cited by land users in semi-structured interviews and grouped thematically. Results of focus group evaluation summarised under "accuracy" and "ease of use". As many as possible of those deemed both accurate and easy to use were then tested in the field. Indicators highlighted in grey were deemed particularly accurate and easy to use. Those in black were removed from the process due to inaccuracy and/or difficulty to use. Results of indicator testing are summarised in the far-right column.

Rank	Indicator	Times Cited	Accu-racy	Ease of Use	Empirical Evidence
	Plants				
1	Increased abundance of unvegetated sand dunes	20	✓	✓	✓
2	Decreased vegetation cover/ more bare ground	14	✓	✓	✓
3	Decreased grass cover	11	✓	✓	✓
4	Decreased abundance of *Harpagophytum procumbens* (Grappel Plant, "Singaparile")	8	✓	✓	Insufficient data
6	Increased abundance of grasses less palatable for cattle	6	✓	X	N/A
7	Increased abundance of *Prosopis* sp.	5	X	✓	N/A
8	Decreased abundance of grasses palatable for cattle	4	✓	X	N/A
8	Decreased abundance of trees	4	✓	✓	Not tested
8	Decreased abundance of *Citrullus lanatus* (wild melon)	4	✓	✓	Insufficient data
8	Decreased abundance of wild fruits	4	✓	✓	Insufficient data
9	Decreased abundance of *Acacia haemotoxolon*	3	✓	✓	✓
9	Decreased abundance of thatching grass	3	✓	✓	✓
9	Decreased abundance of wild cucumber	3	✓	✓	Insufficient data
9	Decreased abundance of *Grewia flava* (Moretlwa)	3	✓	✓	Insufficient data
9	Increased abundance of *Rhigozum trichotomum* (Makurubane)	3	✓	✓	✓
10	Decreased diversity of Opslag (palatable creepers)	2	✓	✓	Insufficient data
10	Increased abundance of *Schmidtia kalahariensis* (Kalahari Sour Grass/ Africaans)	2	✓	✓	✓
10	Increased abundance of *Acacia mellifera* (Black thorn/ Swartak)	2	X	X	N/A
10	Decreased abundance of *Acacia heblacada*	2	X	X	N/A
10	Decreased abundance of Opslag (palatable creepers)	2	✓	✓	Insufficient data
10	Tree drop branches and leaves become yellow even after rain	2	X	X	N/A
10	Increased abundance of Acacia erioloba	2	X	✓	N/A
10	Decreased abundance of medicinal plants	2	✓	✓	Insufficient data
11	Decreased rain use efficiency (vegetation responds less vigorously and more slowly to rainfall)	1	✓	✓	Not tested
11	Decreased abundance of *Acacia mellifera* (Black thorn/ Swartak)	1	✓	✓	X
11	Decreased abundance of *Acacia erioloba*	1	X	✓	N/A
11	Decreased abundance of *Ximenia caffra*	1	X	X	N/A
11	Decreased abundance of veld vegetables	1	✓	✓	Insufficient data
11	Increased abundance of *Gnidia polycephella*	1	✓	✓	Insufficient data
11	Decreased abundance of *Boscia albitrunca* (Motlopi)	1	✓	✓	Insufficient data
11	Trees and bushes are increasingly stunted	1	✓	✓	X
11	Some trees stop flowering	1	X	X	N/A
11	Increased visibility (can see a snake from afar)	1	✓	X	N/A
	Increased abundance of unpalatable grasses	Literature	✓	✓	✓
	Soils				

5	Sand shifts more easily in wind	7	✓	✓	Not tested
8	Increased soil looseness	4	✓	✓	✓
9	Increased incidence and severity of dust storms	3	✓	✓	Not tested
11	Increased incidence of gullies	1	✓	X	N/A
11	Clay soils become more compacted	1	✓	X	N/A
	Increased abundance of biological soil crusts	Literature	✓	X	N/A
	Lower soil organic matter content (“sand becomes less dirty or lighter”)	Boteti Community	✓	X	N/A
	Increased water infiltration rate (rain soaks into soil faster)	Boteti Community	✓	X	N/A
	Increased incidence of nebkha dunes (around bushes) in rangeland, or dunes around houses etc in villages	Boteti Community	✓	X	N/A
	Increased density of cattle tracks	Boteti Community	✓	X	N/A
	Increased evaporation rate (soil dries out faster after rain)	Boteti Community	✓	✓	Not tested
	Livestock				
2	Declining livestock condition/ loss of weight	14	✓	✓	Not tested
9	Livestock walk further from water/ spend longer between drinking	3	✓	✓	Not tested
9	Increased livestock mortality/ declining herd size	3	✓	✓	Not tested
9	Reduced milk yield	3	✓	✓	Not tested
10	Meat takes less time to cook, meat and bones are softer	2	X	X	N/A
11	Decreased wool production from sheep	1	X	X	N/A
	Increased incidence of "long claw"	Veterinary Services	✓	✓	Not tested
	Increased incidence of Aphosphorosis (Stiff Sickness) due to consumption of poor grasses	Boteti Community	✓	✓	Not tested
	Increased incidence of botulism	Boteti Community	✓	X	Not tested
	Wild Animals & Insects				
2	Decreased abundance of game and predators	14	✓	✓	✓
8	Increased abundance of mosquitos	4	X	X	N/A
8	Decreased abundance of grasshoppers	4	✓	✓	Not tested
9	Decreased abundance of butterflies	3	X	X	N/A
10	Increased abundance of Meercats	2	X	X	N/A
11	Increased abundance of mice	1	✓	✓	✓
11	Increased abundance of Harvester Termites (Makaka)	1	✓	✓	Not tested
11	Increased abundance of parasitic insects on trees	1	X	X	N/A
	Decreased abundance of birds	Boteti Community	X	X	N/A
	Increased abundance of "malelekatou" (Setswana) ants (large black with grey abdomen and smell bad)	Boteti Community	✓	✓	Not tested
	Socio-Economic				
9	Increased distance to firewood	3	✓	✓	✓
10	Out-migration of farmers	2	✓	✓	Not tested
10	Reduced income from veld products	2	X	X	N/A
11	Increased dependance on government welfare	1	✓	X	N/A
11	Increased polarisation of rich and poor	1	✓	✓	Not tested

Appendix 2: Species lists

The following species lists include only those species that were positively identified. All specemins were left at the Botswana National Herbarium.

Species list for Study Area 1

Acacia erioloba
Acacia heblacada
Acacia luederitz
Acacia mellifera
Aristida congesta
Aristida stipitata
Boscia albitrunca
Crotalaria recta
Eragrostis lehmanniana
Fimbristylis hispidula
Gisekia pharnaceoides
Grewia flava
Indigofera daleoides
Indigofera flavicans
Mollugo cerviana
Nolletia arenosa
Phylanthus sp.
Rhigozum brevispinosum
Rhus tenuinervis
Schmitdia kalahariensis
Schmitdia pappophoroides
Senna italica
Sida cordifolia
Stipagrostis uniplumis
Terminalia sp.
Tragus sp.
Verbesina encelioides
Zizyphus mucronata

Species list for Study Area 2

Acacia tortilis
Aristida congesta
Baikiaea plurijuga
Bluma gariepina
Boscia albitrunca
Boscia foetida
Colophospermum mopane
Combretum apiculatum
Combretum imberbe
Combretum zeyheri
Commiphora pyracanthoides
Cyanodon dactylon
Digitaria sp.
Dychrostachys cinerea
Eneapogon cenchroides
Eragrostis pallens
Eragrostis rigidor
Fimbristylis hispidula
Grewia bicolor
Hoodia officianalis
Lycium cinereum
Oddysea sp.
Otoptera burchellii
Pechnel-loeschea leubnitzae
Phragmites australis
Rhus sp.
Rhigozum sp.
Setaria vericiliata
Sida cordifolia
Sporobulus fimbriatus
Stipagrostis uniplumis
Terminalia prunoides
Terracytis sp.
Trianthema parvifolia
Tridentea marientalensis
Uroehloa sp.

Species list for Study Area 3

Acacia haemotoxolon
Acacia mellifera
Aristida meridionalis
Centropodia glauca
Eragrostis lehmaniana
Eragrostis tricophera
Gnidia polycephella
Helichrysum arenicola
Helichrysum argyrosphaerum
Hirpicium gazaniodes
Molluga sp.
Rhigozum trichotomum
Salsola sp.
Schmitdia kalahariensis
Senecio eenii
Stipagrostis amabilis
Stipagrostis ciliata
Stipagrostis obtusa
Stipagrostis uniplumis

Appendix 3:
Semi-Structured Interview Check-List

Wealth Ranking (tick)					
Struizendam		**Bokspits**		**Rapplespan**	
>200 sm/stck		>1000 sm/stk		>300 sm/stock	
<25 sm/stck		<200 sm/stk		<16 smallstock	
>30 cattle		>200 cattle		>100 cattle	
<3 cattle		<30 cattle		<6 cattle	
Vehicle		Fenced ranch		Vehicle	
Own/syndt b/h		Own/syndt b/h		Own borehole	
Business		Business		Business	
>6 rooms				>2 rooms	

Sustainable Livelihoods Analysis (approximately 15-20 mins)

1. Natural Assets

Fenced ranch? (size):

Cattle: Sheep:

Goats: Donkeys: Horses:

After rain, is your range better, worse or the same as it used to be after rain in the past?

If it is worse, does this significantly affect your ability to support your life, or is it not a big problem?

Do you use the rangeland for firewood, building materials, vegetables, fruit, medicine or other uses (tick appropriate)?

After rain, can you find these products as easily now as you used to after rain?

If they are harder to find, does this significantly affect your ability to support your life, or is it not a big problem?

What are your future veld management goals?

Name:______________________

Intro

- IVP & one sentence summary
- Time now or come back later? (45 mins - 1 hr)
- Aim to optimise production from the land now whilst protecting it for future generations
- Indicators & management options from community
- Degradation assessment manuals
- Opinion about approach & questions?

2. Social Assets

Year moved here (born here?)

How many people do you know outside this sub-district who would take your livestock during drought?

How many outside the district?

Farming (or other land use) group member?

Which farming publications do you read (how regularly?):

How often do you have contact with extension services (helpful?):

Do any of the above *significantly* affect your ability to support your life (specify)?

3. Physical Assets

How many?:

Motor vehicles Donkey carts

Syndicate/sole owner of borehole?:

How far to sell livestock/crops:

Distance to buy supplies (e.g. feed):

Access to telephone (number):

Do any of the above *significantly* affect your ability to support your life (specify)?

4. Human Assets

Number of family labour:

Number of paid labour:

Formal education status:

Informal education (where have you learned about farming/other land use?):

Does your health affect your ability to manage the land they you want to (don't ask for details)?

Do any of the above *significantly* affect your ability to support your life (specify)?

5. Financial Assets

Access to savings:

Savings (circle):

A lot Some A little None

Do you have any debts?

A lot Some A little None

Do any of the above *significantly* affect your ability to support your life (specify)?

2 Visual Signs (Indicators) of Land Degradation (20-25 mins)

Think about rangeland you are familiar with:

• That in the past, was very productive after it had rained. If you put your livestock there in those times, they would grow fat, and you could find many veld products

• But now due to over-use (not drought), when it rains there is little production. If you put your livestock there, they will not grow fat and you will find few veld products

Question:

• If you were walking through this area, what would you see (or not see) that tells you this land is poor?

Alternative Phrasing

A long time ago, the rangeland in the close surroundings of this village produced a lot of fodder and veld products after it rained. Due to the pressure people have put on it, there is now less fodder and veld products after it rains.

Question:

• In what ways is the rangeland different now from the way it used to be after the rain in the past?

Prompts: What changes/differences would you see in the **(1) vegetation; (2) soil; (3) livestock; (4) wild animals and insects; (5) people who use the land** (socio-economics) in that area?

Check: Are these degradation or drought indicators? Check by asking:

• Do you still find these indicators after it has rained?

3 Early Warning Signs (5 mins)

Which of the above signs would you expect to appear first (circle these signs above)?

(Alternative phrasing: What is the first thing you would see that would make you suspect that an area of land was going to decline/become poor/unproductive?)

Indicators (continued)

Name:

Postal address (to which manual will be sent):

M/F: Age:

Borehole/Farm name(s):

Interviewer(s):

Management Options (10-15 mins)

How can you prevent your tikologo from becoming unproductive/poor?

Can you suggest ways in which these ideas can be put into practice in this community?

What can you do to make unproductive/poor areas productive again (rehabilitate them)?

Can you suggest ways in which these ideas can be put into practice in this community?

Can you think of any traditional practices that could help protect or rehabilitate degraded lands?

Do you have/have you heard of any new/unusual ideas that could help protect or rehabilitate degraded lands? (write overleaf)

Appendix 4:
Rangeland Monitoring and Management Manuals

See CD-ROM in sleeve inside back cover.