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Corresponding Author: Dr Mark S Reed, BsC (hons) MSc PhD PGCLTHE FRGS

Corresponding Author's Institution: University of Leeds

First Author: Mark S Reed

Order of Authors: Mark S Reed; Andrew J Dougill

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Manuscript

Linking Degradation Assessment to Sustainable Land Management: a decision support system for Kalahari pastoralists

M.S. Reed[*], A.J. Dougill

Sustainability Research Institute, School of Earth & Environment, University of Leeds, Leeds, W. Yorkshire LS2 9JT

Abstract

This paper 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 communal pastoralists in three study areas in the Kalahari, Botswana. Separate manuals were developed for each study area in response to the differences in indicators and management options deemed relevant for each by local communities. The design of the DSS has been optimised using an "innovation-decision" approach combined with local and external expert review to enhance the likelihood of widespread uptake and application by land managers. 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.

[*] Corresponding author
Email addresses: m.reed@see.leeds.ac.uk (M.S. Reed), a.dougill@see.leeds.ac.uk (A.J. Dougill)

1. Introduction

Adaptive rangeland management depends on effective monitoring to detect detrimental change early. As such, rangeland monitoring is integral to effective management. Rangeland monitoring in southern Africa has traditionally been the domain of researchers and extension workers. However, agricultural extension services in Botswana are currently over-stretched and extension advice is geared towards fenced systems that are usually managed by the more wealthy (see handbooks by Hendzel (1981) and Field (1978), used by most extension workers). Existing Decision Support Systems[1] (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 paper therefore aims to:

- Review current rangeland monitoring techniques in southern Africa;
- Integrate land degradation indicators with sustainable management options to develop a manual-style DSS each of three study areas, that is designed for common property land managers to easily collect data and monitor progress towards sustainability goals; and

[1] 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).

- Optimise the design of the DSS following an innovation-decision theoretical approach.

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 stable climax vegetation communities. 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) desirable "decreaser" species that decrease in abundance under intense grazing; ii) "increasers" that increase in abundance with overgrazing ("increaser I") or undergrazing ("increaser II"); and iii) "invader" exotic invasive species (Foran *et al*., 1978). The cover of each species group was assessed subjectively by researchers and extension workers against a benchmark site (in desired condition) and scores were discounted for soil erosion, bush encroachment or poor vigour of decreasers. This

1 system was modified in various ways, e.g. increasing the number of variables and
2 sophistication of analysis (e.g. Tainton *et al.,* 1980; Heard *et al.,* 1986).
3 Recognising that these techniques were rarely used by land owners due to their
4 complexity (Mentis, 1982; Hardy & Hurt, 1989), attempts were made to develop less
5 complex procedures that could be used easily and rapidly in the field. The resulting
6 methods focussed on easily identifiable indicator species that could assess rangeland
7 condition and grazing capacity more subjectively (e.g. Trollope, 1990). Jordaan *et al*.
8 (1997) evaluated the accuracy of five such techniques, concluding that the
9 "degradation gradient" (Mentis, 1983; Stuart-Hill *et al*., 1986) and "weighted key
10 species" (Heard *et al*., 1986; Hardy & Hurt, 1989) techniques were best suited to
11 southern African rangelands. However, training was still necessary for farmers to use
12 these techniques, and they remained largely in the domain of extension workers
13 (Zacharias, 2003). Savory's (1988) rangeland monitoring technique was used more
14 widely by farmers who adopted his "Holistic Resource Management" approach to
15 ranching. Similarly, he proposed a combination of plant, animal and soil indicators of
16 range condition, but the recommended data collection methods were too time
17 consuming to gain widespread uptake (Milton *et al*., 1998).
18 Decision Support Systems gained wider uptake by South African ranchers.
19 Published DSSs range from book-style manuals (e.g. Milton *et al*., 1998) to complex
20 software applications incorporating GIS technology (e.g. Giupponi *et al*., 2004).
21 Barac & Kellner's (2002) and Zimmerman *et al.*'s (2003) computerised decision
22 support systems are designed to disseminate rangeland management advice to farmers
23 and extension workers in southern Africa on the basis of diagnostic questions about
24 degradation indicators. Although these techniques have been used by Kalahari
25 ranchers in South Africa and Namibia, uptake is not widespread partly due to 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 species composition, vegetation cover, plant vigour, surface condition, and insect and rodent damage were recorded. 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). Similarly, Milton *et al*. (1998) developed a rangeland health assessment technique for farmers, 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.* Hendzel, 1981).

Two rangeland management "handbooks" currently exist in Botswana (Field, 1978; Hendzel, 1981). 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.

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 paper was therefore primarily designed for use by pastoralists under common property tenure.

3. Methods

To identify and evaluate land degradation indicators and management options in Botswana, land degradation "hotspots" were identified qualitatively through interviews with an international panel of advisors (Reed *et al*., 2007). This provided a wide choice of potential study areas (outlined in Figure 1). To test the transferability of the approach, three study areas were selected to represent different biophysical (rainfall, soil and vegetation type) and cultural settings (details in Reed *et al*., 2007).

Following an experiential learning approach (Kolb, 1984), the methodology was designed to be an ongoing process of learning and negotiation between stakeholders and researchers. Experiential learning theory suggests it is necessary to reflect on and learn from past experiences to ensure that environmental management captures the complexity of a multi-stakeholder world. Kolb (1984) proposes that learning takes place in four generic phases, upon which our methodological framework is based:

1. Identify land degradation indicators, current management practice and possible management options from the literature ("concrete experience");
2. Identify local knowledge of degradation indicators and management strategies to reduce or adapt to land degradation through semi-structured interviews ("reflective observation");

3. Evaluate options from interviews and literature in multi-stakeholder focus groups ("abstract conceptualization") and

4. Use outputs from these focus groups to produce a DSS for each region, providing stakeholders with management options that they can experiment with ("active experimentation").

Data were collected between 2001-2003. For details of methods used to develop indicators, see Reed *et al*. (in press), and for detailed methods used to develop management strategies, see Reed *et al*. (2007).

<*insert Figure 1 around here*>

4. The Decision Support System

4.1. The Design Approach

Rogers (1995) innovation-decision process was used to develop a theoretical framework to optimise DSS design (Figure 2). This framework 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 (Reed, 2007). The framework is iterative, recommencing as needs, objectives and 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.

<*insert Figure 2 around here*>

The relative advantage of innovative management options in the DSS is likely to be considerably greater than alternative DSSs in the target area (handbooks for private ranchers; Field, 1978; 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. 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). Since farmers are characteristically risk averse (Binswanger, 1980; Reeves & Lillieholm, 1993), 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 (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 local context.

The extent to which an innovation can be adapted to meet dynamic user demands and specifications may also 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). 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 is too resource or time-intensive, or does 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.

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). The need for comparative monitoring over years is therefore emphasised in the DSS.

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 (Reed *et al*., 2007).

4.2. 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 was 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 work with poorer farmers who tend to be less literate.

Separate manuals have been developed for each study area in response to the different indicators and management options deemed relevant for each area by local communities (Reed *et al*., 2007; in press). They have been peer-reviewed by international experts and policy stakeholders and are currently being translated into local languages.

Manuals are designed for regular use by pastoralists to identify detrimental environmental change and to guide sustainable management responses. 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. The recommended assessment procedure is relatively flexible, and designed to make recording and interpretation of results simple for users (Table 1). Wheel diagrams (Figure 3) 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 (Figure 4). Detailed photographs or diagrams are provided to help identify key species where necessary. Each indicator is cross-referenced to a range of management options (Figure 5). There are a range of options to suit different budgets and time-frames.

The Decision Support System described in this paper 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.

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1 Table 1. Recommended assessment procedure for Kalahari rangeland decision support system,

2 based on text from the manual

3

Instruction	Description
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 3). 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).
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).

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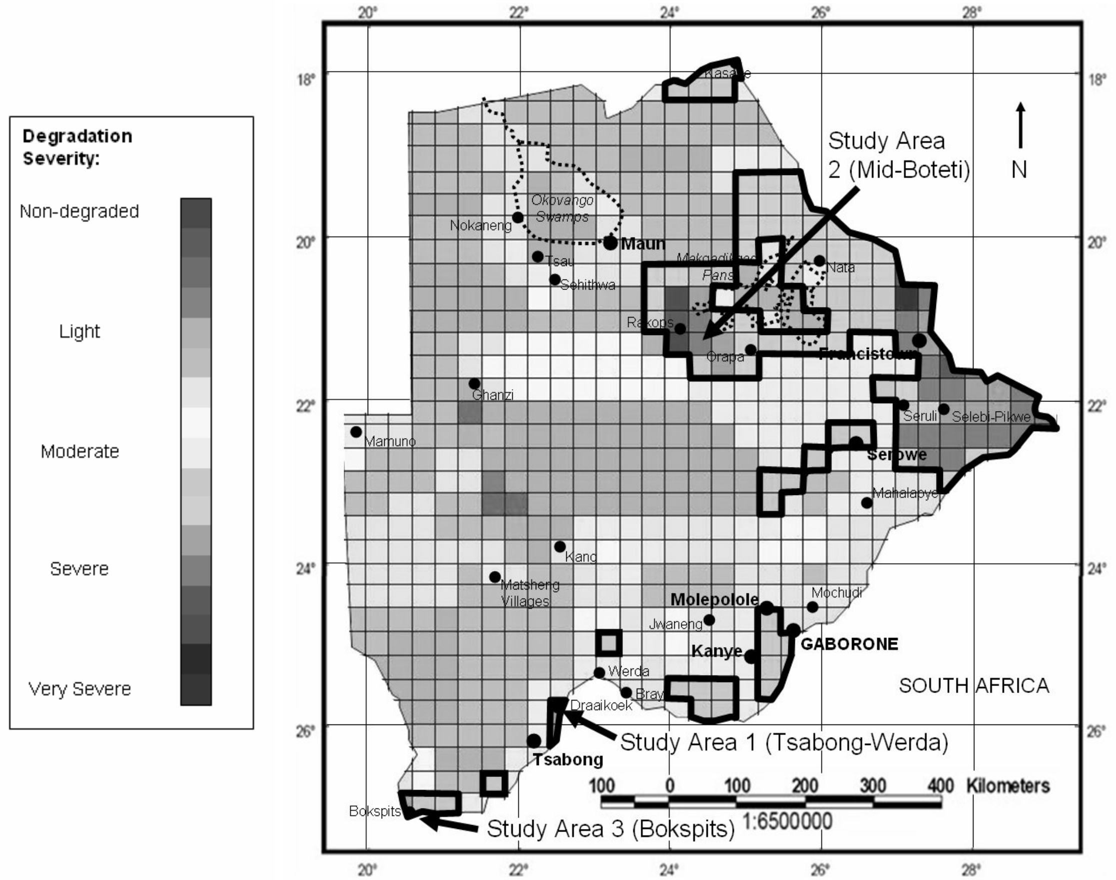

4

5

6 Fig. 1. Land degradation map of Botswana, from the combined opinions of eight national experts, with
7 degradation "hotspots" outlined in black (based on interviews and mapping exercise in Reed *et al*.,
8 2007), showing study areas where case study research was conducted (for colour version see: Reed *et*
9 *al*., 2007)

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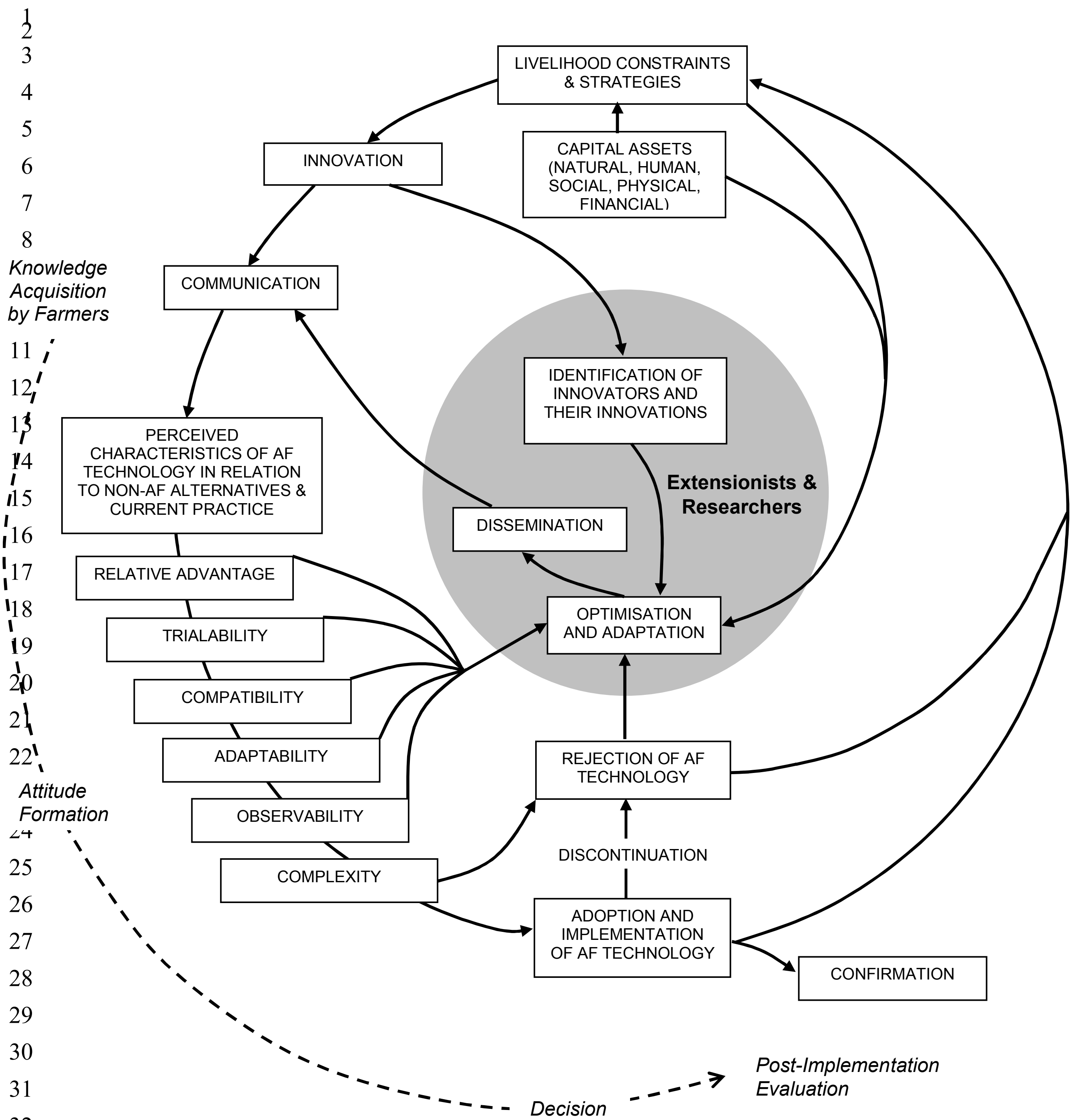


33
34 **Figure 2.** Conceptual framework for optimising the design of a Decision Support System incorporating
35 numerous innovations, based on Rogers (1995) innovation-decision process (dashed line) (reproduced with
36 permission from: Reed, 2007)

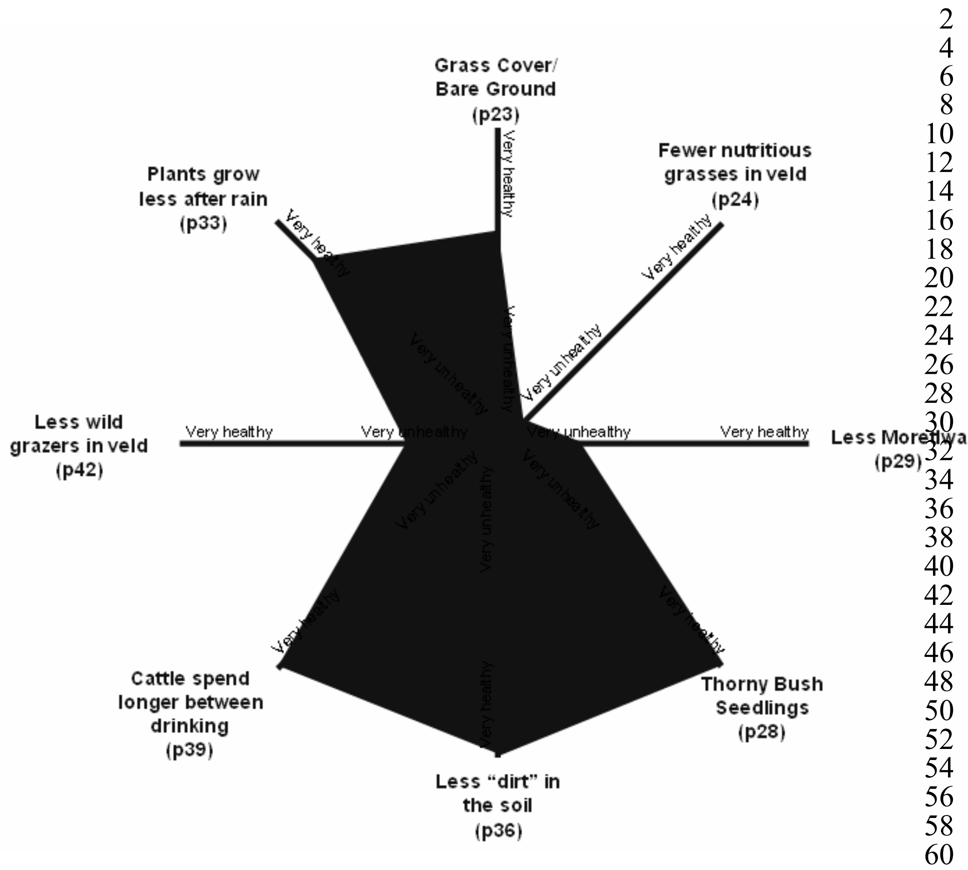


Fig. 3. An example of a wheel diagram for recording measurements of early warning indicators

Soil Sign

Signs that the soil is being blown away

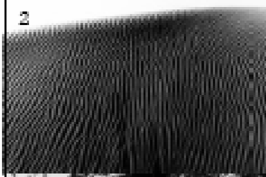
There are a number of soil warning signs that may appear if the veld becomes damaged. Some of the easiest to spot are signs that the soil is being blown away. This usually happens because: a) there are fewer plants to slow down the wind and hold the soil together with their roots; and b) living crusts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

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

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

1
2 Fig. 4. Example page from Study Area 3 Manual showing indicator description

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.

Fig. 5. Example page from Study Area 3 Manual showing a management option

*** Revision Notes**

Revision notes:

The article has now been formatted correctly - sorry that this was not done properly before.

The text or the article is now 2387 words long. This does not include the abstract, acknowledgements or references. If it should, please advise and accept my apologies, and I'll further shorten it.