An adaptive learning process for developing and applying sustainability indicators with local communities

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Abstract

Sustainability indicators based on local data provide a practical method to monitor 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 paper is to analyse the literature on developing and applying sustainability indicators at local scales to develop a methodological framework that summarises best practice. First, two ideological paradigms are outlined: one that is expert-led and top-down, and one that is community-based and bottom-up. Second, the paper assesses the methodological steps proposed in each paradigm to identify, select and measure indicators. Finally, the paper concludes by proposing a learning process that integrates best practice for stakeholder-led local sustainability assessments. By integrating approaches from different paradigms, the proposed process offers a holistic approach for measuring progress towards sustainable development. It emphasizes the importance of participatory approaches setting the context for sustainability assessment at local scales, but stresses the role of expert-led methods in indicator evaluation and dissemination. Research findings from around the world are used to show how the proposed process can be used to develop quantitative and qualitative indicators that are both scientifically rigorous and objective while remaining easy to collect and interpret for communities.

Keywords: Sustainability Indicators, Community Empowerment, Stakeholders, Local, Participation

1. Introduction

To help make society more sustainable, 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"[1] has become an integral part of international and national policy in recent years. The academic and policy literature on sustainability indicators is now so prolific that King *et al.* (2000) refer to it as "*…an industry on its own*" (pg. 631). However, it is increasingly claimed that indicators 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, p. 2)

Partly this is a problem of scale since the majority of existing indicators are based on a top-down definition of sustainability that is fed by national-level data (Riley, 2001). This may miss critical sustainable development issues at the local level and may fail to measure what is important to local communities. For example, the widely quoted environmental sustainability index (Global Leaders, 2005) provides an assessment of national progress towards sustainable development. National rankings are based on indicators chosen by a group of American academics and reflect their conceptualization of sustainability. This is contrary to the spirit of Local Agenda 21 that puts local involvement at the front of any planning process and challenges policy makers to allow local communities to define sustainability for themselves. As a result, the ESI has been thoroughly critiqued for ignoring local contextual issues (Morse and Fraser, in press).

A second problem is that 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). As a result, it is now widely agreed that local communities need 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 other words, indicators must

[1] We define sustainability indicators as the collection of specific measurable characteristics of society that address social, economic and environmental quality.

not only be relevant to local people, but the methods used to collect, interpret and display data must be easily and effectively used by non-specialists so that local communities can be active participants in the process. Indicators also need to evolve over time as communities become engaged and circumstances change (Carruthers & Tinning, 2003). Consequently, sustainability indicators can go far beyond simply measuring progress. They can stimulate a process to enhance the overall understanding of environmental and social problems, facilitate community capacity building, and help guide policy and development projects.

On the other hand, the participatory approaches, popular amongst post-modern scholars, have their failings too. Community control in and of itself is irrelevant to sustainability if local people fall prey to the same beliefs and values that have led to current unsustainable positions. Development hungry local agencies are just as capable of allowing urban sprawl as national governments, so divesting power from central governments down to municipalities, thereby returning power to communities, may not serve the needs of sustainable development. What is needed is to provide a balance between community and higher level actions.

The aim of this paper is to contribute to finding this balance. This will be done by critically analyzing existing top-down and bottom-up frameworks for sustainability indicator development and application at a local level. After systematically evaluating the strengths and weaknesses of published methodological approaches by analysing a range of case study examples, we present a learning process that capitalises on their various strengths. To this end, the paper will:

1. Identify different *methodological paradigms* proposed in the literature for developing and applying sustainability indicators at a local scale;
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 practice and offers a framework that can guide users in the *steps* needed to integrate top-down and bottom-up approaches to sustainability indicator development and application.

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 one that is community-based and bottom-up. The first finds its epistemological roots in scientific reductionism and uses explicitly quantitative indicators. This reductionist 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 dynamic systems, but do not necessarily emphasise the complex variety of resource user perspectives. The second paradigm is based on a bottom-up, participatory philosophy (referred to this as the "conversational" approach by Bell and Morse, 2001). It draws more on 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). Proponents 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 1 provides a summary of sustainability indicator literature and 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 often fails to engage local communities. Indicators from bottom-up methods 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 capacity for 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 our analysis is designed to inform these ongoing debates.

[Table 1 approximately here]

3. Steps and Tools

Notwithstanding epistemological differences, it is notable that indicator frameworks from both schools set out to accomplish many of the same basic steps (Table 2). First, sustainability indicator frameworks must help those developing indicators to establish the human and environmental context that they are working in. Second, sustainability indicator frameworks provide guidance on how to set management goals for sustainable development. Third, all sustainability indicator frameworks provide methods to choose the indicators that will measure progress. Finally, in all frameworks data is collected and analysed. The following discussion analyses methodological issues for use of both bottom-up and/or top-down approaches in each of these steps in turn.

[Table 2 approximately here]

Step 1: Establishing Human and Environmental Context

There are two primary components to establishing context: (1) identifying key stakeholders, and (2) defining the area or system that is relevant to the problem being studied. With regard to the first issue, in most top-down processes stakeholders are often identified in a somewhat informal fashion. For example, researchers and policy-makers using the OECD's (1993) Pressure-State-Response (PSR) framework typically only identify stakeholders if they are the source of human pressures on the environment (e.g. farmers using irrigation in dryland Australia (Hamblin, 1998) or people living in watersheds (Bricker *et al.*, 2003)). On the other hand, there is a growing body of participatory research that is more precise and formal when it comes to identifying stakeholders. For example, some suggest it is useful to begin an analysis by interviewing key informants who can suggest other relevant stakeholders using snowball-sampling techniques (Bryman, 2001). Key stakeholders can also be identified using wealth based stratified sampling techniques (Rennie & Singh, 1995). There are considerable limitations to both these procedures, and research has shown that social stratification may alienate some stakeholders (Rennie & Singh, 1995). Alternatively, a "Stakeholder Analysis" (Matikainen, 1994) can be used where stakeholders are identified and described by researchers, assisted by local informants. This method is based on the notion of social networks, defined as a set of individuals or groups who are connected to one another through socially meaningful relationships (Prell, 2003). The purpose of this exercise is two-fold: first to understand the roles that different groups play in a community, and second to understand how different groups interact with each other. By doing this, it is possible to target opinion leaders at the start of a project, and develop strategies to engage community input, identify conflicts and common interests between stakeholders, and thus to ensure a representative sample of stakeholders is involved.

For example, ongoing sustainability assessment research in the Peak District National Park in northern England started by identifying all groups with a stake in land use management, defining their stake, exploring their relationship with other key stakeholders, and identifying the most effective way for researchers to gain their support and active involvement. This was done through a focus group with key stakeholders, and triangulated through interviews with representatives from each of the initially identified stakeholder groups to ensure no groups had been missed (Hubacek *et al.*, 2005).

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, 1998). 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 identify social and ecological indicators that help explain why Irish society in 1845 was so vulnerable to the outbreak of a relatively common potato blight'. More generally, panarchy uses ecological pathways, or the connectivity of landscape units, to define relevant spatial boundaries. As yet there has been limited application of this approach to social systems.

The bottom-up paradigm uses a variety of participatory tools to define and describe the system that is being assessed. One of the most widely used methods is Soft Systems Analysis (Checkland, 1981). This starts by expressing the "problem situation" with stakeholders. Using informal and unstructured discussions on people's daily routines, as well as quantitative structured questionnaires, the 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. The methods used in Soft Systems Analysis have considerable overlap with participatory tools that are often used to describe livelihood systems, such as transect walks, participatory mapping, activity calendars, oral histories, daily time use analysis and participatory video making (e.g. Chambers, 2002). Such approaches can be used to provide a longer-term view of how environmental changes or socio-economic shocks affect the 'vulnerability context' or the way in which a community is vulnerable to external shocks.

Top-down approaches have advantages in that they provide a more global assessment of problems. This is increasingly important in light of climate change models that suggest the poorest, most remote communities are 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 issues. Although this approach is better suited to community-based projects, a combination of both is necessary to place the community in its relevant regional or global context and to identify external threats and shocks.

Step 2: Setting goals and strategies

Sustainability indicators are not only useful for measuring progress but also for identifying problems, setting sustainable development goals and identifying suitable management 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 formally, as project goals are generally pre-determined by funding agencies or Government offices. In contrast, bottom-up frameworks such as Sustainable Livelihoods Analysis and Soft Systems Analysis provide 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 (Scoones, 1998). Using this approach, community members identify and describe the financial, natural, human, physical, institutional and social capital assets they have access to, and discuss how these assets have been used to overcome past problems (Hussein, 2002). Soft Systems Analysis also provides a wide variety of participatory tools to explore "problem situations" 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. There are also a number of approaches to goal setting from decision making literature. This suite of approaches was used when developing the goals of a community based urban greening programme in Bangkok, Thailand (Fraser, 2002). In this case, communities were encouraged to elect a working group that then mapped the assets present in the community. This map formed the basis of a series of urban green plans that the communities executed with help from local municipalities. In this case, the project was catalyzed by two external non-governmental organizations though the goals were established by local residents. An alternative approach is to use the rational comprehensive model (Mannheim, 1940) where goals are weighted and cost benefit analysis used to select the most efficient strategy to meet them.

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 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 reference condition. Targets may take longer to reach than anticipated, but 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. Scenario analysis is a flexible method 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 by using statistical methods to assess past trends (NAS, 1999). Alternative scenarios can also be visualised using tools such as Virtual Reality Modelling (Lovett *et al.*, 1999). For example, in research with UK upland stakeholders, future land use scenarios were identified in semi-structured interviews and developed into storylines and supported by photographs for presentation in focus groups (Hubacek *et al.*, 2005). In this forum, stakeholders discussed scenarios and identified adaptive management strategies that could help them reach desired sustainability goals or adapt to unwanted future change. Back-casting techniques (Dreborg, 1996) were also used to work back from sustainability goals to the present, to determine the feasibility of proposed goals and management strategies required.

Decision Support Systems (DSS) can also be used to identify sustainability goals and strategies. DSS's can range from book-style manuals that provide practical, usually 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 form of DSS whose use is increasingly advocated is Multi-Criteria Decision Analysis (MCDA) in which 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, our research experiences suggest it is possible to use participatory approaches to foster community support and involvement and to improve project goals and strategies. For example, in an urban management project in Thailand, NGOs 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 used to help resolve conflicts between competing stakeholders and help groups to evaluate and prioritise goals and strategies. For example, Reed and Dougill (2003) used MCDA to evaluate sustainability indicators successfully in the Kalahari, Botswana. Local communities in focus groups evaluated indicators that had been suggested by community members during interviews. They were evaluated against two criteria that had been derived from interviews: accuracy and ease of use. The resulting short-list was then tested empirically using ecological and soil-based sampling. Management strategies that could be used to prevent, reduce or reverse land degradation were identified through interviews and evaluated in further focus groups. These strategies were then integrated with sustainability indicators (supported by photographs) in a manual-style decision support system to facilitate improved rangeland management (Reed, 2004). These experiences in Thailand and Botswana, display the importance of using participatory methods to contextualise sustainability issues for communities concerned over the future of their natural resource use.

Step 3: Identifying, evaluating and selecting indicators

The third step in developing and applying local sustainability indicators 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 possible for local users to apply them. These two broad categories can be broken into a series of sub-criteria summarised in Table 3. 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, it is argued that 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. 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.

[Table 3 approximately here]

There are many quantitative tools for identifying indicators. These include statistical methods such as cluster analysis, detrended correspondence analysis, canonical correspondence analysis and principal components analysis. These methods determine which indicators account for most of the observed changes, and which are therefore likely to be the most powerful predictors of future change. 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 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 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, a problem encountered between two Kalahari sites that produced significantly different indicator lists despite being located on Kalahari sands within 200 km of each other (Reed & Dougill, 2003). As such, different rangeland assessment guides had to be produced for each of these study areas (Reed, 2004) and also had to address the significant differences between indicators used by commercial and communal livestock-owners in each area (Reed & Dougill, 2002). The problems of the localised scale of indicator lists derived from bottom-up approaches can be reduced by running local sustainability assessment programmes alongside regional and/or national initiatives. For example, a "sneaker index" of water quality was developed in Chesapeake Bay, Maryland, USA based on the depth of water through which you can see white training shoes (Chesapeake Bay, 2005). This index has been widely used by community groups over the last 17 years and runs alongside a more comprehensive and technical assessment at the Watershed scale, which feeds into national Environmental Protection Agency monitoring. This is one good example of the way in which top-down and bottom-up approaches can work hand-in-hand to empower and inform local communities and also deliver quantitative data to policy-makers.

Another challenge of stakeholder involvement is that if their goals, strategies or practice are not consistent with the principles of sustainable development 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. Experience in UK uplands has shown that many of the stakeholder groups accused of unsustainable practices (e.g. farmers and game keepers) have a different perception of sustainability (that encompasses social and economic aspects in addition to the environment) to conservation organisations (Hubacek *et al.*, 2005). Each group shares a 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 the Peak District uplands as being in "unfavourable condition" (English Nature, 2003).

The generation of indicators through participatory approaches therefore necessitates objective validation. However, this is rarely done, partly due to fact that stakeholder involvement can lead to a large number of potential indicators (for example, in a participatory process to develop indicators of sustainable forestry in Western Canada, stakeholders chose 141 social indicators and a similar number of environmental ones (Fraser *et al.*, 2005)), 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-based approaches (Stocking & Murnaghan, 2001). In the Kalahari experience, biophysical research found an empirical basis for the majority of indicators that had been elicited from local communities (Reed & Dougill, 2003).

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 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 provides a more comprehensive theoretical framework for classifying indicators (see Step 1). Bossel (1998) further sub-divides these capital assets into nine "orientors", suggesting that indicators need to 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).

Although bottom-up methods are capable of generating 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, the participatory process with forest stakeholder groups in British Columbia created such a long list of indicators that the process took significantly longer than had originally been expected and the final report was submitted almost a year late. This reduced impact that public participation had on developing forest policy in the region (Fraser *et al.*, 2005). Participatory indicator development with Kalahari pastoralists overcame this problem by short-listing indicators with local communities in focus group meetings (see Step 2).

Both top-down and bottom-up approaches have merits but clear frameworks are required to enable better integration. The research case studies referred to here show that the divide between these two ideological approaches can be bridged and that by working together community members and researchers can develop locally relevant, objective and easy-to-collect sustainability indicators capable of informing management decision-making.

Step 4: Indicator application by communities

The final step in sustainability indicator frameworks is to collect data that can be used by communities (or researchers) to monitor changes in sustainability that emerge over time and space between communities or regions. Fraser (2002) used a participatory process to monitor environmental management programmes in Bangkok and concluded that increased community awareness of the environment and an enhanced capacity to improve environmental conditions was the most important aspect of development interventions.

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. 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 participatory 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 table 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. Such single indices 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.*, 2005).

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 using MCDA (Ferrarini *et al.*, 2001). This is often difficult to justify and changing weights can significantly alter overall scores. 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. One approach is to plot sustainability indicators along standardised axes, representing different categories or dimensions of sustainability. 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). In the decision support manual for Kalahari pastoralists (Reed, 2004), users record results on "wheel charts" to identify problem areas ("dents" in the wheel), which are then linked to management options (Figure 1). A range of management options were devised (e.g. bush management options included use of herbicides, stem cutting, stem burning and goat browsing) to suit pastoralists with different access to resources. In this way, it was possible to link specific management strategy options to sustainability monitoring.

[Insert Figure 1 approximately here]

4. An adaptive learning process for sustainability indicator development & application

The need for integration

Empirical research from around the world shows the benefits of engaging local communities in sustainability monitoring. The indicators developed have often been shown to be as accurate as (and sometimes easier to use than) indicators developed by experts (Fraser, 2002; Reed & Dougill, 2003; Stuart-Hill *et al.*, 2003; Hubacek *et al.*, 2005). However, there remain important ways in which the skills of the expert can augment local knowledge. Although qualitative indicators developed through participatory research can promote community learning and action (e.g. work with Kalahari pastoralists and 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 may 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 through reductionist research 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. By listening to community reactions to these results, researchers can learn more about the indicators they have tested. For example, Reed and Dougill (2003) empirically tested sustainability indicators that had been initially identified and short-listed by Kalahari pastoralists, and presented the results to communities in focus groups. Participants suggested reasons why it had not been possible to find empirical evidence to support the validity of some indicators, for example highlighting problems with sampling design and seasonal effects.

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.

An Adaptive Learning Process

The purpose of this final section is to present an adaptive learning process that integrates bottom-up and top-down approaches into a framework that combines best practice from the different methods into a single framework to guide any local sustainability assessment. To do this, we draw on systems theory (von Bertalanffy, 1968) that is by its nature interdisciplinary, using both qualitative and quantitative methods. We also draw on social learning (Bandura, 1977; Pahl-Wostl & Hare, 2004), to develop a process that stimulates change of individuals and systems through an ongoing process of learning and negotiation. This approach emphasises communication and perspective sharing to develop adaptive strategies in response to changing social and environmental conditions.

Our analysis extends initial attempts that have been made to integrate methods in other published frameworks reviewed in this paper (e.g. Bossel, 2001; Reed & Dougill, 2002; Fraser *et al.*, 2003). Following the review of methods presented here, it is possible to go beyond these previous attempts, combining the strengths of existing frameworks into an integrated framework applicable to a range of local situations. To this end, an adaptive learning process for sustainability indicator development and application at local scales is provided in Figure 2. This is a conceptual framework that describes the order in which different tasks fit into an iterative sustainability assessment cycle. The process does not prescribe tools for these tasks. It emphasises the need for methodological flexibility and triangulation, adapting a diverse sustainability toolkit to dynamic and heterogeneous local conditions, something that remains a key research skill in engaging communities in any sustainable development initiative.

[Insert Figure 2 approximately here]

The process summarised in Figure 2 could be used by 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). In practical terms, it is a process that we (as researchers) have tested in UK, Thailand and Botswana in projects that we feel have successfully empowered communities. Whether this empowerment is then translated to the wider goals of local sustainability depends on the institutional structures and support to communities required to facilitate the community-led planning process and management decision-making (Fraser *et al.*, 2005 discuss this regional implementation in further detail).

Following the proposed adaptive learning process (1)[2], practitioners must first identify system boundaries and invite relevant stakeholders to take part in the sustainability assessment. We recommend that this should 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) 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 to reach these goals (4). Tools like MCDA and focus groups can be used to evaluate and prioritise these goals and establish specific strategies for sustainable management. The fifth step is for the practitioner to identify potential indicators that can monitor progress towards sustainability goals (5). Although this step is often the domain of researchers and policy-makers, all relevant stakeholders must be included if locally relevant indictor 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 MCDA that can objectively facilitate the evaluation of indicators by local communities (6). Experience using MCDA with community focus groups in three distinct Kalahari study areas suggests that they can produce significantly shorter lists of locally relevant indicators (Reed, 2004). The practitioner may also evaluate indicators using empirical or modelling techniques to ensure their accuracy,

[2] The numbers in parentheses refer to tasks in Figure 2.

reliability and sensitivity (7). Depending on the results of this work, it may be necessary to refine potential indicators (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 possible, community members and researchers should also collect information about thresholds over which problems become critical. This will further improve the value of monitoring. Such thresholds are often difficult to identify, however, due to the dynamic and interactive nature of transitions in managed ecosystems (Dougill *et al.*, 1999; Gunderson & Holling, 2002). 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 experts, decision support systems can facilitate analysis and interpretation by local communities. In the Kalahari research, this has been achieved through production of separate rangeland decision support manuals for three regions (Reed, 2004). If necessary, information collected from monitoring indicators can then be used to adjust management strategies and sustainability goals (12). 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 different methodological frameworks, Figure 2 builds on the strengths of each and provides a more holistic approach for sustainability indicator development and application. Although we emphasise the importance of participatory 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 paper 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. Therefore, it should be 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 into one integrated learning process.

5. Conclusion

In conclusion, this paper suggests that it is possible to build on the strengths of both top down reductionist and scientific methods to measure sustainability and bottom up, community-driven participatory methods in the adaptive learning process outlined in figure 2. Figure 2, therefore, can be viewed as both a combination of different methods that are tailored to distinct tasks and as an integration of methods to accomplish the same task (triangulation). By combining the methods reviewed in this paper we suggest that sustainable development practitioners should start by defining stakeholders, systems of interest, problems, goals and strategies through qualitative research. Relevant qualitative and quantitative methods should then be chosen to identify, test, select and apply sustainability indicators. This leads to an integrated series of general steps and specific methods that are evaluated using data from different sources, using a range of different methods, investigators and theories. The inclusion of both bottom-up and top-down stages in the proposed process is vital in achieving the hybrid knowledge required to provide a more nuanced understanding of environmental, social and economic system interactions that are required to provide more informed inputs to local sustainable development initiatives.

We are under no illusions that application of such a learning process will necessarily result in smooth environmental decision-making. Results from different stages may not always be complementary. Conflicts will emerge. But, by following the process identified here, the differences between the outputs of different methods, investigators and theories have been found to lead to the identification of more appropriate stakeholders, systems of interest, problems, goals and strategies, and thus to the formulation of more relevant sustainability indicators.

Acknowledgements

We are grateful to Stephen Morse, Klaus Hubacek, Christina Prell and an anonymous reviewer for their detailed and useful comments on previous drafts of this paper. The authors research case studies have been funded by the Rural Economy & Land Use Programme (a joint UK Research Councils programme co-sponsored by Defra and SEERAD), Global Environment Facility/ United Nations Development Programme, Explorer's Club, Royal Scottish Geographical Society, Royal Geographical Society, Royal Society, the Canadian International Development Agency (and partners The International Centre for Sustainable Cities, and the Thailand Environment Institute) and University of Leeds.

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Tables & Figures

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Table 2: Description of methodological frameworks for developing and applying sustainability indicators at a local scale

Table 3: Criteria for evaluating sustainability indicators

Figure 1: An example of a wheel diagram for recording indicator measurements as part of a decision support manual for Kalahari pastoralists

Figure 2: Adaptive learning process for sustainability indicator development and application

Table 1: 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

Table 2: 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 (PSR, DSR & DPSIR) (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 (UNCSD, 2001)	Identifies indicators in each of the following sectors or themes: environmental, economic, social and institutional, often subdividing these into policy issues

Table 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 and Bochet, 1998; (7) UK Government, 1999; (8) Zhen & Routray 2003; (9) UNCSD 2001; (10) Freebairn & King, 2003; (11) Mitchell *et al.*,, 1995

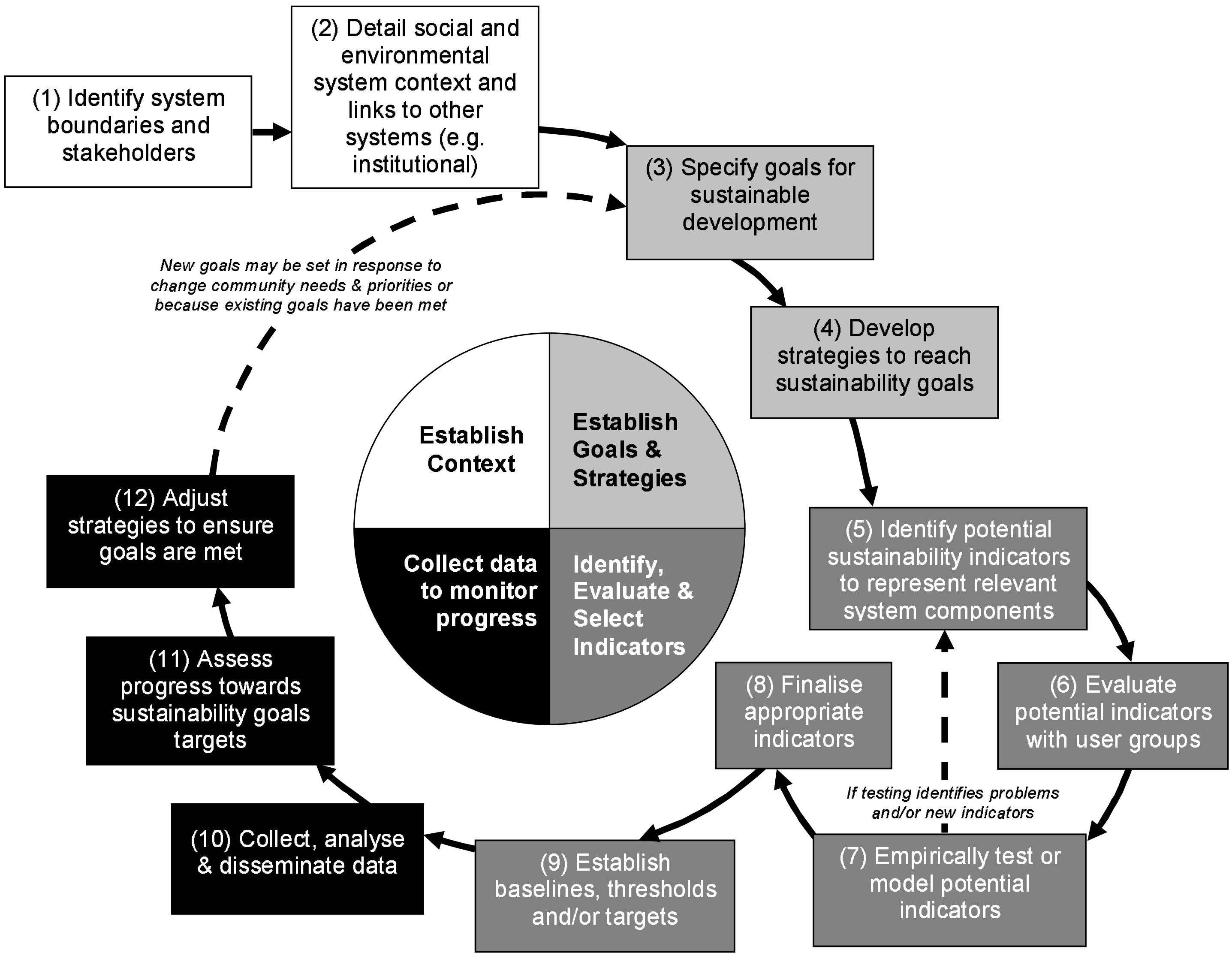

Figure 1: Adaptive learning process for sustainability indicator development and application

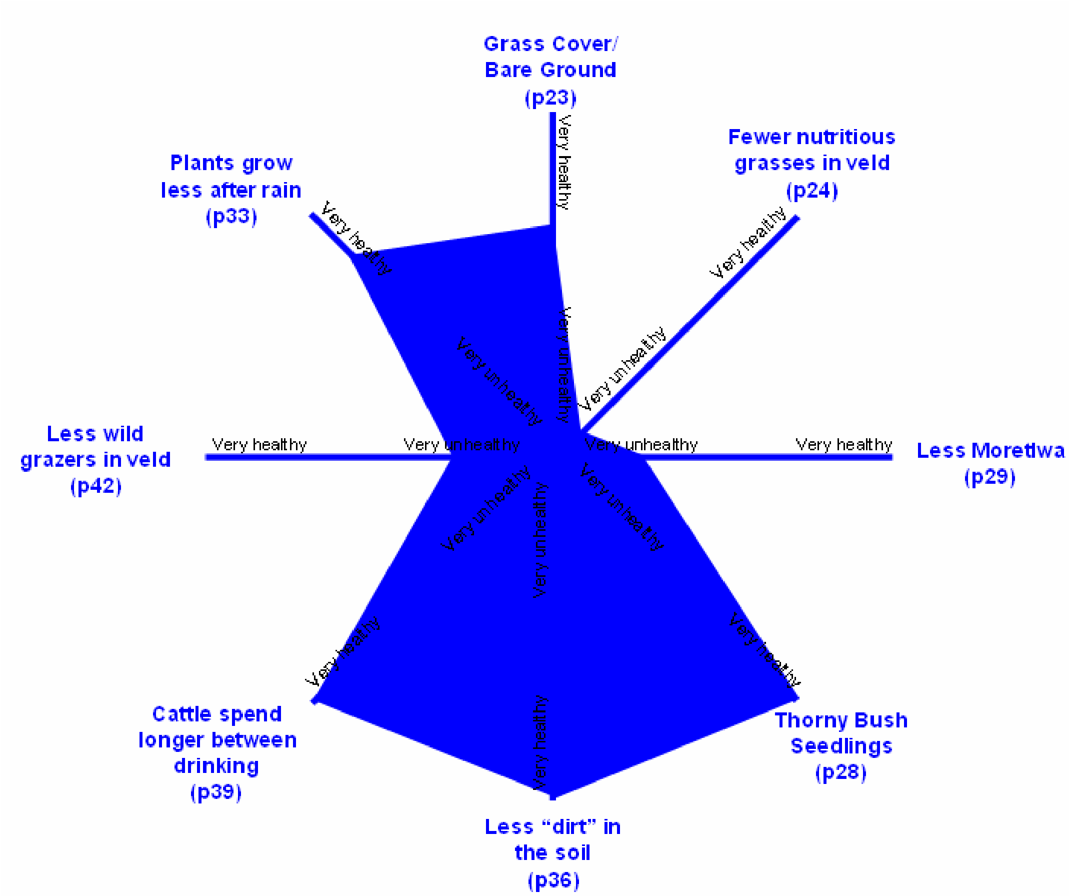

Figure 2: An example of a wheel diagram for recording indicator measurements as part of a decision support manual for Kalahari pastoralists (Reed, 2004)