Paper:
Reed, MS, Fazey, I, Stringer, LC, Raymond, CM, Akhtar-Schuster, M, Begni, G, Bigas, H, Brehm, S, Briggs, J, Bryce, R, Buckmaster, S, Chanda, R, Davies, J, Diez, E, Essahli, W, Evely, A, Geeson, N, Hartmann, I, Holden, J, Hubacek, K, Ioris, I, Kruger, B, Laureano, P, Phillipson, J, Prell, C, Quinn, CH, Reeves, AD, Seely, M, Thomas, R, van der Werff Ten Bosch, MJ, Vergunst, P and Wagner, L (2011) *Knowledge management for land degradation monitoring and assessment: an analysis of contemporary thinking.* Land Degradation and Development, 24 (4). 307 - 322 (16). ISSN 1085-3278

http://dx.doi.org/10.1002/ldr.1124

Land Degradation & Development

Knowledge management for land degradation monitoring and assessment: an analysis of contemporary thinking

Journal:	*Land Degradation & Development*
Manuscript ID:	Draft
Wiley - Manuscript type:	Research Article
Keywords:	land degradation, environmental management, monitoring and assessment, knowledge management, knowledge exchange, knowledge transfer, knowledge brokers, social learning

Knowledge management for land degradation monitoring and assessment: an analysis of contemporary thinking[1]

Reed MS[1], Fazey I[2], Stringer LC[3], Raymond CM[4], Akhtar-Schuster M[5], Begni G[6], Bigas H[7], Brehm S[8], Briggs J[9], Bryce R[10], Buckmaster S[11], Chanda R[12], Davies J[13], Diez E[14], Essahli W[15], Evely A[10], Geeson N[16], Hartmann I[17], Holden J[11], Hubacek K[3], Ioris I[18], Kruger B[19], Laureano P[20], Phillipson J[21], Prell C[22], Quinn CH[3], Reeves AD[23], Seely M[24], Thomas R[7], van der Werff Ten Bosch MJ[25], Vergunst P[17], Wagner L[26]

[1] Aberdeen Centre for Environmental Sustainability and Centre for Planning and Environmental Management, School of Geosciences, University of Aberdeen, St Mary's, Aberdeen AB24 3UF, UK
[2] School of Geography and Geosciences, Irvine Building, University of St. Andrews, North Street, St. Andrews KY16 9AL, Fife, UK
[3] Sustainability Research Institute, School of Earth & Environment, University of Leeds, Leeds, West Yorkshire LS2 9JT, UK
[4] Centre for Rural Health and Community Development, University of South Australia, and Enviroconnect Pty Ltd. GPO Box 190, Stirling South Australia 5152, Australia
[5] Secretariat DesertNet International (DNI), c/o Biocentre Klein Flottbek and Botanical Garden, University of Hamburg, Ohnhorststr.18, 22609 Hamburg, Germany
[6] MEDIAS-FRANCE-CNES, Mediterranean Coordinating Office for START, 18 Avenue Edouard, F-31055 Toulouse, France
[7] United Nations University, Institute for Water, Environment and Health, Suite 204, 175 Longwood Road South, Hamilton, Ontario, Canada L8P 0A1
[8] League for Pastoral Peoples and Endogenous Livestock Development, Pragelatostrasse 20, 64372 Ober-Ramstadt, Germany
[9] Department of Geographical & Earth Sciences and Director of the Glasgow Centre for International Development, University of Glasgow, 10 The Square, University of Glasgow, Glasgow G12 8QQ, UK
[10] Aberdeen Centre for Environmental Sustainability, University of Aberdeen & The Macaulay Institute, School of Biological Sciences, Tillydrone Av., Aberdeen AB24 2TZ, UK
[11] School of Geography, University of Leeds, Leeds LS2 9JT, UK
[12] Department of Environmental Science, University of Botswana, Private Bag 00704, Gaborone, Botswana
[13] IUCN, the International Union for Conservation of Nature, Wasaa Conservation Centre, Mukoma Road, PO Box 68200, 200 Nairobi, Kenya
[14] UNESCO Chair for Spatial Planning and the Environment, Ed. Departamental II Of. 241, Rey Juan Carlos University, 28933 Mostoles, Madrid, Spain
[15] Community of Sahara and Sahel States, BP 4041, Tripoli, Libya
[16] Osservatorio MEDES (Observatory for economic problems associated with desertification in Mediterranean areas), Viale dell'Ateneo Lucano 10, Potenza 85100, Italy
[17] Amoud University, Borama, Somaliland
[18] School of Geosciences, University of Aberdeen, St Mary's, Aberdeen AB24 3UF, UK
[19] Emerging Commercial Farmers' Support Programme, Private Bag 13255, Windhoek, Namibia
[20] Via Roma 595, 50012 Bagno a Ripoli, Firenze, Italy
[21] Centre for Rural Economy, School of Agriculture, Food and Rural Development, Newcastle University, Newcastle NE1 7RU, UK
[22] Department of Sociological Studies, University of Sheffield, Sheffield S10 2TU, UK
[23] Geography, School of Social and Environmental Sciences, University of Dundee, Dundee DD1 4HN, UK
[24] Desert Research Foundation of Namibia, P.O. Box 20232, Windhoek, Namibia
[25] Both ENDS, Nieuwe Keizersgracht 45, 1018 VC Amsterdam, The Netherlands
[26] International Institute for Sustainable Development (IISD), Reporting Services Division, 300 East 56th Street #11A, New York, New York 10022, USA

[1] This paper was prepared as part of the White Paper of the Dryland Science for Development Consortium's Working Group 3 presented at the first UNCCD CST Scientific Conference, held at COP-9, 22-24 September, 2009 in Buenos Aires, Argentina.

Abstract

It is increasingly recognised that land degradation monitoring and assessment can benefit from incorporating multiple knowledges, using a variety of methods at different scales, including the perspectives of scientists, land managers and other stakeholders. However, the knowledge and methods required to achieve this are often dispersed across individuals and organisations at different levels and locations. Appropriate knowledge management mechanisms are therefore required to more efficiently harness these different sources of knowledge and facilitate their broader dissemination and application. This paper examines what knowledge is, how it is generated, and explores how it may be stored, transferred and exchanged between knowledge producers and users before it is applied to monitor and assess land degradation at the local scale. It suggests that knowledge management can also benefit from the development of mechanisms that promote changes in understanding and efficient means of accessing and/or brokering knowledge. Broadly, these processes for knowledge management can: i) help identify and share good practices and build capacity for land degradation monitoring at different scales and in different contexts; and ii) create knowledge networks to share lessons learned and monitoring data amongst and between different stakeholders, scales and locations.

Keywords: land degradation; environmental management; monitoring and assessment; knowledge management; knowledge exchange; knowledge transfer; knowledge brokers; social learning.

1 Introduction

"Land degradation is in the eye of the beholder" (Reed *et al.*, 2008: 1267): it depends on who is doing the monitoring and assessment, where and when. As a process, and as a concept, land degradation is highly dynamic and unpredictable. Land degradation is a function of the context in which it occurs and the values of those who perceive it. One person's degradation may be the next person's opportunity. For example, thorny bush encroachment represents a green desert to cattle but a valuable browse resource for a goat farmer (Reed *et al.*, 2008; Figure 1). For these reasons, there can be no simple, universal system for land degradation monitoring and assessment. Instead, land degradation monitoring and assessment must incorporate multiple knowledges (e.g. local or indigenous knowledge as well as external expertise and scientific knowledge), using a variety of methods and scales. This must include the potentially conflicting perspectives of those who use the land, and those who may benefit from a wide range of ecosystem services who may be located far away from the places where land degradation is occurring.

Monitoring and assessment of land degradation can be data intensive and may be viewed as a continual process of learning and adaptation (Cundhill and Fabricius, 2009), as different indicators are used at different times in relation to the management goals of the system. Effective monitoring and assessment also requires knowledge of complex socio-ecological systems, operating at a variety of spatial and temporal scales. As different stakeholders involved in monitoring and assessment operate at scales ranging from the local to the international, the knowledge required to develop a more complete picture of environmental change and degradation is often dispersed. Calls for land management and policy decisions to be based on evidence from monitoring at a variety of scales (e.g. UNCCD, 1994; MA, 2005; Reid *et al.*, 2006; WOCAT, 2007; Jessop *et al.* 2008) creates an important challenge. This is complicated further by the highly fractured nature of the current knowledge base, combined with structural and procedural barriers that prevent the flow of knowledge between those who are monitoring land degradation at these different scales (Stringer *et al.*, 2007a,b; WOCAT, 2007; Bauer and Stringer, 2009). The capacity for monitoring at each scale also differs markedly from place to place. With little co-ordination or integration between monitoring activities, those working at national and international levels are rarely able to tap into the data and expertise held by those who manage the land. In turn, land managers rarely see the benefits of (often expensive) national and international monitoring programmes (Reed *et al.*, 2006). There is, however, an increasing awareness of the need to break down these barriers and a recognition that knowledge must be merged and managed from wide ranging sources including academic, local, national and international (Raymond *et al.*, in press). If knowledge about land degradation and its monitoring and assessment can be managed more effectively, it may be possible to provide a more robust evidence-base that can support more sustainable land management policies and practices and allow their broader dissemination. This could provide multiple benefits across spatial and temporal scales for a range of different stakeholders and groups.

To understand how we can better manage knowledge for land degradation monitoring and assessment, this paper will identify the different forms of knowledge that we may draw upon to monitor and assess land degradation at local scales, and evaluate the potential advantages of, and available methods for, sharing and integrating knowledge from different sources and scales. It then proposes a conceptual framework for knowledge management, showing how knowledge is generated, with the potential to store, transfer or exchange knowledge between producers and users of knowledge before it is applied to monitor and assess land degradation. This framework is then explored in the context of local land degradation monitoring and assessment in drylands. In this way, we hope to draw on the widest possible range of relevant knowledge to facilitate more sustainable land management in some of the most food insecure countries of the world.

2 Different Knowledges for Land Degradation Monitoring and Assessment

To manage knowledge effectively, we need to understand what knowledge is and how different people define it. To do this, we distinguish between data (raw numbers and facts), information ("useful data" i.e. that has been processed/analysed and interpreted) and knowledge ("information that is known" by an individual or group). Knowledge may include different types of information that an individual holds. This information may have been derived from a range of activities and sources, including personal experience, observations, research results etc. This view of knowledge sits between two extremes: one that sees knowledge as something that has "universal truth", and another that considers knowledge as entirely dependent on the unique interpretation and reality of each individual (Zermoglio *et al.*, 2005). Raymond *et al.* (in press) further suggest that knowledge is strongly influenced by the personal epistemological beliefs of the individual, and the processes through which these beliefs are shared and redefined.

There are many different kinds of knowledge and ways of knowing (Fazey *et al.* 2006a). "Tacit knowledge" represents the knowledge we hold but of which we are not consciously aware. An example of this is our ability to recognise a face, yet not know why or how we "know" this (Polanyi 1997). Tacit knowledge by definition cannot be made explicit. 'Implicit' knowledge is that which can, but has not yet been, articulated (Fazey *et al.* 2006a). Such knowledge can be useful for managing complex systems if it can be articulated, for example providing detailed information about how systems work on the basis of many years experience living and working with a system (Olsson et al 2004; Fazey et al 2006b). 'Explicit knowledge' is that which has been articulated in written or spoken form (Polanyi, 1962, 1967; Nonaka, 1994).

This includes mechanistic scientific knowledge, which is typically systematised, decontextualised and presented in forms that are widely transferable (Norgaard, 1984; Ingram, 2008). Of course, many different forms of knowledge inform and are developed within science, one of the ways science moves forward is by trying to solve disagreements between those who hold different knowledge, informed by different methods and epistemologies (Lane, 2001). What is important is that we are aware of the advantages and limitations of the various approaches and types of knowledge so that they can be managed and utilized. Lundvall and Johnson (1994) refer to scientific knowledge as ''know-why'', since scientific knowledge partly attempts to understand the underlying principles and theory behind observable phenomena. They contrast this with the "know-how" of local[2] knowledge, which is primarily tacit, informal, context-dependent and rooted in experience and practice (Ingram, 2008). During the 1970s international bodies emphasized "science" as a key resource for decision-makers, but since then the value of local knowledge and the practices derived from it have been increasingly recognised by international bodies, notably the UNCCD, and by interpretativist and post-modern researchers seeking alternatives to the top-down "transfer of technology" paradigm (Brokensha *et al.*, 1980; Long Martello, 2004).

Another important distinction between knowledge types is the difference between expert and non-expert knowledge. 'Expertise' is a depth of knowledge about a system, process, or issue that is distinctly different from the knowledge of non-experts (and may or may not be associated with formal qualifications or credentials). The characteristics of expertise are varied and do not always easily equate to 'more robust' or 'accurate' explicit knowledge. This is because much of the knowledge is tacit and context dependent. Experts tend to have a deep understanding of a particular issue or system, and are able to draw on their extensive appreciation of it to tackle complex problems. When using expertise for environmental management, it is crucial to know the extent of the expertise of a person and ensure that it is directly relevant to the issue under consideration (Fazey *et al.* 2006a, b).

Different types of knowledge operate at different spatial scales (Wilbanks, 2006), from local knowledge that is generated and applied at the local scale to scientific knowledge that is often more generalized, up to the global scale (Raymond *et al.,* in press). However knowledge

[2] This is sometimes referred to as traditional knowledge, endogenous knowledge, appropriate technologies, indigenous techniques, nature-based knowledge, sustainable knowledge, folk knowledge and cultural knowledge (Warren 1993; Tahoun 2003 and UNCCD resolution ICCD/COP(3)/CST/3)

may be produced and applied at multiple scales (see Holling 1992; Brenner 2001). The challenge for knowledge managers is to facilitate two-way interaction between experts, institutions and local interests across these scales. This echoes calls by Ostrom (1990) and more recently by Reynolds *et al.* (2007), for knowledge about human-environmental systems to be hierarchical, nested and networked across multiple scales. Choices of scale also have political implications because they privilege some knowledges over others. For example, choices of geographical scale and boundaries influences decisions about who is a stakeholder (often referred to as the framing of the problem) and hence who's knowledge is considered valid (Brenner 2001; Cox 1998; Meadowcroft 2002; Ostrom 2005). Knowledge management systems must therefore make scale choices transparent and explicit (Lebel, 2006), and recognize the potential for cross-scale linkages between different knowledge systems (Cox 1998; Berkes 2002). While a number of studies provide frameworks for linking institutions and individuals both horizontally across geographic space and vertically across levels of organization (e.g., Berkes, 2002; Dietz *et al.*, 2003; Ostrom, 2005; Berkes, 2009), the different ways of managing this knowledge is rarely considered.

Stringer and Reed (2007) argued that by hybridising more explicit scientific knowledges with more implicit local knowledges, it may be possible for scientists and other stakeholders to inform more relevant and effective environmental policy and practice to monitor and tackle land degradation. Sometimes this may be a process of eliciting, combining and building on tacit, implicit and explicit knowledge from different groups to co-generate new knowledge. More often, this is a process of developing the necessary level of shared knowledge necessary to facilitate the exchange of existing explicit knowledge between different groups. However, this is frequently easier said than done. Boyo (2009), for example, traces the tensions between local farmers and agricultural experts in Malawi. Here, farmers' strategies on fertiliser use, mixed cropping and the use of cassava as a nutrient recycling crop are seen as backward, "unmodern" and regressive by external experts, despite the fact that the farmers' strategies offer a manageable approach for them in the context of local environmental and social conditions. Scientific knowledge is often given greater legitimacy than tacit and local knowledge, partly by virtue of it being recorded and made explicit (Jordan and Jones, 1997), and also because of its perceived 'power' as being 'objective', 'dispassionate', 'controlled', 'replicable' and 'testable' (Agrawal, 1995; Briggs, 2005). Indeed, Mackinson and Nottestad, (1998) suggest that scientific and local knowledge are "grotesquely unequal" in leverage, particularly with respect to policy formation, where the latter is often entirely overlooked.

In contrast, the approach proposed here (and espoused in the text of the UNCCD) views each form of knowledge as complementary. As such, local knowledge of land degradation indicators may be compared against evidence from research literature (c.f. Reed and Dougill, 2002; Stringer and Reed, 2007; Reed *et al.*, 2008). This sort of approach is common in mixed methods research designs, where qualitative research is traditionally used to access local knowledge in an exploratory mode, to generate hypotheses, which are then tested using more quantitative methods (Holland and Campbell, 2005; Morgan, 2007). However, such analyses are problematic due to their implication that scientific knowledge is superior and can be used to "validate" local knowledge. Significantly, the World Bank sought to promote the use of indigenous knowledge in the development effort, but only after it has been tested and legitimised by formal "scientific proof" (World Bank, 1998, p6). As Briggs and Sharp (2004, p667) point out: "… it is still the scientific view, in all its wisdom, that can decide which indigenous knowledge is worthy of serious investigation and dissemination elsewhere".

Instead, methods are needed that can evaluate, combine and integrate local and scientific knowledge. In response to this need, a growing range of methods and approaches have been developed that can be used for this purpose. These range from participatory, often more qualitative methods where stakeholders and researchers evaluate and co-generate knowledge together to more top-down, often more quantitative methods such as the use of decision-support tools to enhance learning between researchers and stakeholders. For example:

- Focus groups and field visits have been used as tools to exchange local knowledge between land managers and researchers from different backgrounds and countries (e.g. Curtin and Western, 2008; Stringer *et al.*, 2008);
- Affected communities can systematically and critically evaluate local and scientific knowledge of land degradation indicators themselves, using participatory decision-support tools such as multi-criteria evaluation (c.f. Ferrarini *et al.*, 2001). For example, using multi-criteria evaluation, Reed *et al.* (2008) evaluated local knowledge of land degradation indicators with local communities in focus groups, assessed the indicators deemed most robust through field-based research, and then enabled local communities to

evaluate the results of this research through further structured discussions in focus groups;

- Raymond and Brown (2006) and Raymond (2008) used participatory mapping to integrate local and scientific knowledge, expressed as values, for conservation areas in Victoria and South Australia. They were able to measure the level of spatial agreement and disagreement between local and scientific conservation values. The level of spatial overlap of local and scientific knowledge could be used to prioritise investment in environmental management;
- "Mediated modeling" and "dynamic systems modeling" provide tools that can build on local knowledge of how complex systems work, basing models of land use systems on a more comprehensive knowledge base relevant to land manager needs and priorities (van den Belt, 2004; Prell *et al.*, 2007; Dougill *et al.*, in press; Fazey *et al.*, 2006b). Dynamic systems models allow users to vary the assumptions upon which the models are built, exploring how sensitive a system is to uncertainties and gaps in knowledge, and identifying potential "tipping points" and "leverage points" in the system where land management or policy decisions may have disproportionate effects. Many of the variables included in such models have the potential to be effective land degradation indicators, and by varying their values it is possible to evaluate the relative sensitivity of indicators that are based upon an integrated knowledge base; and
- Computer-based Decision Support Tools (sometimes including simulation models, statistical models, remote sensing or GIS) support decision making by offering functionalities to assess the extent or risk of desertification, to monitor land changes, or to show scenarios of different policy alternatives (e.g. Diouf and Lambin, 2001; Holecz *et al.*, 2003; Ochola and Kerkides, 2004). Recent research on the application and usefulness of computer-based decision support tools in desertification policy and management suggests that they play a role in improving communication between stakeholders and in promoting local participation in decision making (Diez, 2008), thereby having the potential to be useful in the integration of local and scientific knowledge. However, current designs have a number of pitfalls that need to be overcome to fully exploit the benefits that computer-based decision support tools may offer in knowledge management

(e.g. low quality of output information in terms of reliability, relevance and completeness, and the "black-box" nature of their outputs).

Finally, it should be noted that despite the growing range of methods available for integrating different types of knowledge, a number of recent studies are questioning whether it is possible (or advisable) to distinguish between different types of knowledge. For example, Bruckmeier and Tovey (2009) suggest that local and scientific categories are social constructions and are difficult to classify into separate systems of knowledge at the local scale (c.f. Berger and Luckmann, 1967). As such, the merit of categorizing, comparing and contrasting local and scientific knowledge can be debated. Indeed, most producers and users of local knowledge do not distinguish between scientific and local knowledge in everyday practice. For example, Briggs *et al*. (2007) have shown how Bedouin in the Eastern Desert of Egypt incorporate environmental knowledge from all sorts of sources. If it makes sense and can be used within prevailing socio-economic and physical environments, then it is adopted, replacing previous (and now often redundant) ideas. The binary of local and scientific knowledge is irrelevant for these Bedouin in everyday practice.

While some argue that knowledge cannot be categorized on local and scientific grounds (e.g. Bruckmeier and Tovey 2009; Raymond *et al.*, in press), others acknowledge differences, but contend that the two (or more) perspectives viewed in unison produce a more balanced understanding of environmental problems (Sillitoe 1998; Stringer and Reed, 2007). Raymond *et al.* (in press) summarise this as a series of overlapping continua that represent the extent to which knowledge is: (1) locally specific or generalised across regions; (2) formalised; (3) expresses expertise; (4) articulated in ways accessible to others; and (5) is embedded in traditional cultural rules and norms derived from longstanding association and feedback with ecological processes (Figure 2).

3 A Conceptual Framework for Knowledge Management

3.1 Moving from knowledge transfer to knowledge management: a conceptual framework

Building on the discussion of types of knowledge in the previous section, we define knowledge management as a process of generating, storing and circulating *new* knowledge, and identifying, bringing together, and applying *existing* knowledge to achieve specific objectives (in this case land degradation monitoring) (c.f. von Krogh 1998; Alavi and Leidner, 2001). In some contexts, knowledge management may also include building the capacity of different stakeholders to articulate, share and use knowledge.

Early knowledge management literature focussed on "knowledge transfer" from the producers of knowledge (in the field of land degradation, typically scientists) to those who use it (typically policy makers and land managers) (Polanyi, 1962, 1967). In the context of land degradation, this was embodied in the "transfer of technology" paradigm, which reached its height during the so-called "green revolution" of the 1960s, where mechanised agricultural intensification led to the polarisation of rich and poor, and economic/technological dependence on donor countries (Martin and Sherington, 1997). The transfer of knowledge may well involve its codification or packaging within new technologies, policies, guidelines and protocols. As a result, what was once explicit knowledge may well become 'black boxed' and hence implicit, and harder to transfer beyond the context for which it has been designed.

More recently, there has been a shift in emphasis within knowledge management literature and practice towards:

i) Two-way knowledge exchange through partnerships between knowledge producers and users (including academics, policy makers, businesses, practitioners and communities). Recognition of multiple bases of expertise suggests a need to move from linear models of *knowledge transfer* to more iterative models of *knowledge exchange* between these groups (Phillipson and Liddon, 2008). Knowledge exchange is also increasingly focusing on south-south and south-north knowledge sharing, as opposed to traditional north-south flows (Stringer *et al.*, 2008);

ii) Knowledge generation, where knowledge users can become knowledge producers, potentially collaborating with those who traditionally generate knowledge (scientists) to co-generate knowledge (e.g. Phillipson and Liddon, 2008; Berkes, 2009).

There are contexts where one-way knowledge transfer is the most appropriate mode of knowledge management. There are also cases in which existing knowledge is sufficient and there is no need to generate new knowledge. In such cases there may nevertheless be a pressing need to exchange, transfer and/or transform existing knowledge so that it can be put to most effective use (perhaps at other scales or in other locations).

Figure 3 illustrates this view of knowledge management, showing how knowledge is generated, with the potential to store, transfer or exchange knowledge between producers and users of knowledge before it is applied. Knowledge users are a very diverse and dynamic group. As such, people and organisations (e.g. scientists and members of policy and wider stakeholder community) may take on different roles in different parts of the knowledge management cycle. Hence knowledge producers can become knowledge users, and knowledge users can become knowledge producers, thus providing the potential for different actors to co-generate knowledge.

As new knowledge is generated, it may be stored in a variety of ways, for example using memory and mimicry from person to person through generations, or through documentation of knowledge from transcripts of interviews to hierarchical documentation systems (e.g. Enting *et al.*, 1999). Preventing the erosion or complete loss of knowledge is a key challenge for maintaining knowledge management systems in the long term. For example, the internet provides a valuable medium to store, transfer and exchange knowledge around the world between those who have access. However, the information on many websites is lost when project funding runs out.

3.2 Knowledge management mechanisms

Individuals gain knowledge through a process of changing the way they understand something or the way in which they relate to the world (Fazey and Marton, 2002). This process is generally termed 'learning'. Thus to understand the mechanisms through which knowledge spreads and can be managed, it is necessary to understand the conditions, processes, and sorts of practices that influence how people learn, and through what channels and sources they increase their knowledge.

Learning may occur at the scale of individuals, groups, organisations, "communities of practice" or societies, and a vast literature has developed to understand how learning occurs at these different scales (Blackmore, 2007). Learning may also occur between these scales. For example, there is evidence that local knowledge can pertain to ecological, biological, geographical or physical processes well beyond their immediate environment (Juma 1989; Norgaard 1984). Berger and Luckmann (1967) argue that informal institutions (in which attitudes and worldviews are embedded) or "norms" guide people's behaviour. These informal institutions are a product of a specific local context (place, time and shared by a specific group of people), and may gradually change over time e.g. as a result of external influences (Vergunst, 2008, 2009).

Of particular interest in the context of global land degradation are mechanisms that can facilitate learning at community or societal scales, from person to person through social networks – "social learning" (Reed *et al.*, in press, Fazey *et al.*, in press). Knowledge exchange and transfer often take place through informal networks as well as through formalised and depersonalised forms of communication such as the mass media. Therefore, a key challenge in knowledge management is to stimulate new exchanges and networks where links are undeveloped (such as the local to national level) and to tap into networks that already exist. In this context, social learning is presented as a way to facilitate shared understanding among and between different types of knowledge through peer-to-peer interactions within social networks (Armitage *et al.*, 2008; Reed *et al.*, in press). By stimulating social learning about land degradation monitoring, it is argued that it may be possible to facilitate the adoption of monitoring tools and approaches, and possibly change attitudes, behaviour and underlying world views towards sustainable land management, at a far greater scale than could otherwise be achieved. Despite this, it should be noted that some knowledge may be traditionally 'patented' and thus kept confidential by specialized knowledge holders e.g. herbalists/traditional doctors, rainmakers, water prospecting and seasonal predictors. Linked to this, social learning processes may infringe intellectual property if not conducted sensitively[3].

Linked to this, there is a great deal of literature and research on the role of social networks, "knowledge brokers" of "intermediaries" and their role in the diffusion of information and knowledge (Hargadon, 2002; Howells, 2006; Klerkx and Leeuwis, 2008; Klerkx *et al.*, 2009). There is a rapidly growing literature describing and explaining the way knowledge flows between individuals through social networks, and how this may influence natural resource

[3] This point was made by the Holy See and Brazilian delegations during questions at the first CST Scientific Conference, UNCCD COP-9

management (e.g. applications of Social Network Analysis by Prell *et al.*, 2008, 2009). These methods can be used to explain and potentially predict how knowledge is likely to flow through social networks, depending on the characteristics of the individuals through which it flows. This flow may lead to knowledge "clumps" in certain areas where knowledgeable groups of individuals fail to pass on their knowledge to others (Nissen and Levitt, 2004). By understanding knowledge dynamics in this way, it may be possible to predict how interventions designed to facilitate grass-roots monitoring are likely to play out, and hence to design better interventions. Linked to this, researchers are now coupling agent-based models with models of land management systems to explore how the likely behaviour of land managers may affect ecological functioning and agricultural productivity (Chapman *et al.*, 2009), and to better understand the role of knowledge brokers (Dobbins *et al.*, 2009) and boundary (or bridging) organisations (Cash *et al.*, 2003) in knowledge exchange.

Knowledge brokers and boundary (or bridging) organisations are individuals or institutions that rest between people, groups or institutions that are not connected to each other in any way, facilitating knowledge transfer and exchange between those in their networks. In this position, knowledge brokers and boundary organisations can play both positive and negative roles in the spread of knowledge. For example, they can bring together pieces of information that are scattered throughout a network or at different spatial scales to develop new ideas and applications for existing knowledge that could not have been developed by those holding partial information (Ostrom, 2005; Prell *et al.*, 2008; forthcoming). They may also customise knowledge and technologies for particular end users (Howells, 2006). Their position in the network enables them to diffuse this information and knowledge to parts of social networks that it may otherwise not reach (c.f. Rogers, 1995). Researchers and extension workers can often play this brokering role, documenting and then sharing local knowledge among communities, and potentially adapting this knowledge to new contexts and purposes. For example, Reed and Dougill (2009) developed a decision-support system for Kalahari pastoralists in which they brought together stakeholders who were known as innovators within their communities to evaluate local knowledge from different communities alongside scientific knowledge, to develop new strategies to tackle land degradation. However, a broker may strategically decide to keep certain pieces of information to themselves rather than pass on all information. In a similar fashion, a broker could potentially distort information as they pass it on to a different individual or group (Burt, 1992; Freeman, 1978; Gould and Fernandez, 1989; 1994).

The role of knowledge broker and boundary organisation may be carried out by a range of organisations and individuals, including think-tanks, consultancies, skills development agencies, knowledge networks and advisers. Knowledge brokers and boundary organisations working at the local level can help local communities articulate their opinions and preferences, transforming implicit knowledge into a form of knowledge upon which monitoring programmes can be based. At the inter-organisational level, those working within a common area must also aim for cooperation as a means to achieve better data exchange and data sharing. For example, Drynet is performing the role of boundary organisation between NGOs, CBOs, scientists and policy-makers working in the field of land degradation and sustainable land management (Box 1). Similarly in Namibia, the Forum for Integrated Resource Management (FIRM) works with farmers associations to create a boundary organisation where farmers and service providers get together at grassroots level to exchange information and knowledge on a regular basis (Box 2). As such, NGOs and CBOs may have the capacity to communicate monitoring information from the local level upwards.

Thus, from the preceding discussion, the following could be distilled as the key principles of knowledge management for land degradation monitoring:

1. Knowledge is contextual and usually comprises both tacit and explicit elements;
2. The flow of knowledge can be either inter-level/inter-scale (i.e. vertical) or intra-level/intra-scale (i.e. horizontal) in nature. Commonly there would be co-occurrence of the two flow patterns;
3. Instrumental (i.e. applied) knowledge (e.g. for land degradation monitoring) flows in multiple directions, consisting of knowledge transfer (uni-directional) and knowledge exchange (bi- or multi-directional). The predominant mode would be determined by context; and
4. Knowledge management requires sustainable and efficient means of knowledge storage, access and/or brokerage.

4 Knowledge Management for Local Land Degradation Monitoring and Assessment

Local knowledge, both current and historic, is essential to monitor land degradation, as it is uniquely adapted to the contexts in which it has been developed and applied, and so can diagnose the sorts of land degradation issues most relevant in any given locale. In addition, indicators[4] based on local knowledge are more likely to be used by land managers, as they are already likely to be familiar and are less likely to require specialist training or equipment (Reed *et al.*, 2006, 2008). Thus, development and use of grassroots indicators may help to reduce barriers to more widespread uptake of land degradation monitoring. If clear links are also made between monitoring and land management, it may be possible to create incentives that could facilitate more widespread monitoring by affected communities (Reed and Dougill, 2009). However, the dynamic and context-dependant nature of land degradation means that monitoring needs and relevant indicators may change over time.

Although no evidence exists to assess the current capacity for land degradation monitoring among affected communities, there is evidence that land managers have a comprehensive and nuanced capacity for monitoring, even in recently established agricultural systems. For example, Maasai in Kenya monitor livestock condition to inform their rangeland management (Kipuri, 1996). Similarly, Oba and Kaitira (2006) document how pastoralists characterize semi-arid rangelands in Tanzania as degradable or non-degradable in response to grazing pressure, with reference to soils and vegetation type, and use this information to regulate seasonal grazing across heterogeneous landscapes. Pastoralists in the Sahel monitor grazing pressure and rangeland condition to inform decisions about rotating or relocating livestock (Niamir-Fuller, 1998). Ngugi and Conant (2008) mapped key resource areas in Kenyan semi-arid rangelands with pastoralists, ranchers, scientists and government officials, relying on accessibility and ecological indicators. Similarly, Raymond *et al.* (2009) mapped threats to ecosystem services with Australian land managers and community representatives, and prioritized areas where action was needed by assessing the value of the services under threat.

To fully harness local knowledge for land degradation monitoring and assessment, institutional reform may also be necessary. For example, there has been considerable research on understanding the conditions necessary for long-term monitoring and assessment of natural

---

[4] We define an indicator as a physical, chemical, biological or socio-economic measurement, statistic or value that can be used to assess natural resources and environmental quality.

resources under common property regimes (Baland and Platteau 1996; Ostrom 1990). From this, two general lessons are evident. Firstly, reasonably small commons with clear boundaries on resources and resource users allow individuals to continually monitor conditions as part of their daily activities, by keeping the transaction costs of monitoring low (Quinn *et al.,* 2007). Secondly, traditional institutions tend to have high levels of social capital and facilitate community empowerment and actions. Such mechanisms are built on trust and a history of negotiation and decision making that can overcome the problems of free-riding or the absence of well-defined property rights (Katz, 2000). That is not to say that traditional common property regimes are a panacea for the problems of land degradation. There is evidence for success and failure in the management of natural resources using all types of management regime, from common property to private property (Acheson, 2006). Increasing populations, technology change, global markets and insecure land tenure have all contributed to the failure of traditional common property regimes to prevent resource degradation (Attwell and Cotterill, 2000; Campbell *et al.,* 2001). In contrast, re-coupling communities to their environment can create a vested interest in long-term management of resources (Twyman *et al.*, 2001). For example, the BIOTA Southern Africa project[5] has trained local 'para-ecologists' to carry out degradation assessments and monitoring, allowing communities access to up-to-date information that is used to inform local management decisions (Schmiedel, 2006). The security inherent in communities that have autonomy over local resource management can benefit conservation through sustainable resource use. Chhartre and Agrawal (2009) found that communities were more likely to conserve the resources in community-owned forest commons for future use compared to government-owned forest where communities extracted resources of livelihood benefit at a higher rate.

To further harness local knowledge for monitoring and assessment there is an urgent need to identify and share good practice in monitoring and assessment amongst affected communities, both within given locales and between affected communities in similar contexts internationally. This is especially important given the erosion of local knowledge in many affected communities (e.g. through the effects of HIV/AIDS). The long-term retention, implementation and evolution of inter-generational local knowledge are threatened by a range of factors. For example, the sedentarisation of nomads in the semi-arid and arid north-eastern Sudan is leading to a loss of

[5] www.biota-africa.org

environmental knowledge as it becomes less relevant to successive generations (Akhtar and Schutzbar, 1994). This is also happening among Bedouin from the Eastern Desert of Egypt, who migrated from the desert to the Nile Valley towns (Briggs *et al*., 2007). Not only is this knowledge lost by the next generation, but even for the migrants themselves, detailed environmental knowledge is quickly lost or only fuzzily remembered within 5-10 years. Formal education may lead to further losses, given the low value afforded to local knowledge in many education systems. Elsewhere, pressure to continue providing more food for rapidly growing populations has compelled many communities to abandon (both the use and transmission to future generations of) valuable local knowledge and skills in monitoring and responding to land degradation. Although there have been many successful attempts to protect local knowledge through documentation and inventories (e.g. Sallu *et al*., 2009), knowledge is only shared, preserved and developed if it is used. Thus, developing better understanding of the wider proximate and ultimate drivers and factors that are reducing tendencies and processes for communities to learn and share information about land degradation will be required if existing capacities are to be maintained (Fazey *et al.*, In Press)

Identifying local good practice in land degradation monitoring and assessment is vital. However, despite frequently being seen as a panacea for a new and sustainable development, the use of local knowledge systems is not unproblematic. For example, understanding complex power relations within communities can be a challenge, and because local knowledge is so empirically rooted, there may be a tendency to ignore power relations and so there may be no check on whose view might be the legitimate one (Kapoor, 2002). Nonetheless, this issue cannot be sidestepped, and the power and positionality of actors in these debates must be evaluated critically (Twyman, 2000). There is also the potential danger of romanticising local knowledge systems (Schroeder, 1999; Maddox *et al*., 1996), or seeing them as static and unchanging (Bebbington, 1993; Kalland, 2000). Some writers are equally concerned about the decontextualisation of local knowledges, and stress that they are fundamentally embedded within the societies within which they were developed and therefore should always be interpreted within their economic and socio-cultural contexts (see, for example, Pottier, 2003).

Local knowledge is not always gender or class neutral. For example, Tlhalerwa (2007) revealed the gender-specific nature of local knowledge in Botswana and cautioned that the use of local knowledge may perpetuate or even exacerbate gender gaps. Research in Egypt has reached similar conclusions, but, in addition, noted that such gender gaps in knowledge can result in women's greater empowerment in the household and sometimes beyond (Sharp *et al*., 2003; Briggs *et al.,* 2003), and Andresen (2001), working in Nigeria, has drawn attention to the fact that women's environmental knowledge repertoires can be rather different from those of men, something that Engel-Di Mauro (2003) suggests is related to the everyday lived practice of agricultural activity.

Equally, scientific knowledge should not be uncritically accepted without evaluating the uncertainty and associated value judgments in the claims being made (Failing *et al*., 2007). For example in Australia, Aboriginal knowledge has been repeatedly used to expose the limitations of short-term ecological research (Baker and the Mutitjulu community, 1992). If local and scientific knowledge are both to be used, it is still necessary to subject each to an appropriate level of scrutiny before considering what exactly may be integrated to deliver what may be termed "socially robust" indicators that are both understood and will be applied by stakeholders (Nowotny, 2003). Raymond *et al.* (in press) provide a process for scrutinizing both local and scientific knowledge during both project design and delivery.

After good practices in land degradation monitoring have been identified, integrating local and scientific knowledge where appropriate, it can be helpful to share these lessons as broadly as possible among affected communities. To do this, different mechanisms are relevant at different scales. At local scales, there are a wide range of participatory tools that can achieve this. For example, Reed *et al.* (2008) used village focus groups and multi-criteria evaluation to disseminate indicator knowledge amongst the affected communities they worked with, and then used decision-support manuals to disseminate these indicators and related sustainable management strategies more widely (Reed and Dougill, 2009). At district scales, Raymond and Brown (2006) used participatory mapping to integrate local and scientific knowledge, expressed as values, for conservation areas in Victoria, Australia. They were able to measure the level of spatial agreement and disagreement between national park designations identified based on local values and scientific values, respectively, with the results used to prioritise investment in environmental management. Local communities represent an essential source of information for many of the variables relevant to land degradation monitoring, some of which cannot be collected through conventional research methods or are difficult to obtain within the timeframe of single projects. Whatever the scale, a key aspect of good practice is to find ways of embedding local or other stakeholders in a process that facilitates learning and interaction (Pahl Wostl, 2009). This potentially changes the way knowledge generation is perceived, with practice, learning and research becoming more intertwined and where distinctions between knowledge generation, dissemination, and implementation become increasingly blurred.

Of course, there are many limitations to participatory approaches (Cooke and Kothari, 2001; Campbell and Vainio-Mattila 2003), a principle one being the limited spatial scales at which they can operate effectively. Focus groups and field visits have been used as tools to exchange local knowledge between land users from different countries, but this is generally quite rare (see Box 1). Most knowledge management systems share local knowledge at this sort of scale using Information Technology (IT) (for example, WOCAT). However, IT has its drawbacks: it is not accessible to everyone, and though it makes information widely accessible, knowledge exchange (as opposed to just information exchange) takes place most effectively from person to person through shared dialogue and learning (Pahl-Wostl, 2009). Having said this, there may be opportunities to use IT for knowledge exchange by gathering local knowledge across large and disparate areas, then refining, harmonising and redistributing the collated information between comparable sites at broader spatial scales (e.g. WOCAT).

Finally, for land degradation monitoring and assessment to be adopted and reported by land managers, it must effectively contribute to decision-making, providing real benefits to those who make the measurements. However, conventional decision-support systems are often difficult to implement and information derived is too generic and too late for local land users to make appropriate pro-active decisions (Klintenberg *et al.*, 2008). For this reason there are a growing number of attempts to develop decision-support tools in which land managers can use the results of monitoring and assessment themselves to enhance the sustainability of land management and agricultural production (e.g. Kellner and Moussa, 2009; Reed and Dougill, 2009; Box 2). Organizing and recruiting stakeholders to these activities – and keeping their interest during monitoring and decision-making processes that unfold slowly – is a particular challenge when the object of monitoring and assessment is relatively intangible and in the absence of a perceived 'crisis' or 'threat'. Box 2 suggests that farmers may be motivated to continue collecting data if it feeds into immediate decision-making. Others may want to be assured that results will feed into higher level decision-making processes at national scale (Pahl-Wostl and Hare, 2004). A better understanding of what would enhance the transfer of local results to decision makers may increase participant motivation. A lack of transparency regarding the processes and pathways linking research, managers and decision makers at different levels may discourage stakeholders from attempting to influence decisions on a larger scale and contribute to a sense that their contributions are not acknowledged or valued.

5 Conclusion

In summary, knowledge management is a process that does not just involve the generation and exchange of data or information: it also requires the development of mechanisms that promote change in understanding of the individuals involved and the cogeneration of new knowledge through the networks and participation of a wide range of individuals. Knowledge management also involves maintaining stocks or reservoirs of knowledge. It may also prevent outdated knowledge from leading to counter-productive responses to land degradation. Knowledge management requires sustainable and efficient means of access and/or brokerage. When carefully designed, such processes have the potential to change basic understandings of key issues. They can also facilitate changes in the higher order thinking that influence the broad strategies that are used to achieve the desired outcomes, such as improved monitoring, assessment and management of land degradation.

The scientific literature offers us many options for monitoring and assessing land degradation. But if we are to capture the dynamic, context-dependant and value-laden nature of land degradation, we cannot overlook the equally valuable but often unrecognised knowledge of local communities and the NGOs, CBOs and Civil Society Organisations that work with them. Some argue that local knowledge is not reliable enough to inform monitoring and assessment. But there are just as many who are disillusioned with scientists who got it wrong and who may have inadvertently contributed to the design of poorly implemented processes that failed to capitalize on local motivations, interests, and needs. Knowledge that is available from different sources needs to be critically assessed, recognising the different epistemological perspectives and ways of knowing of land managers and scientists. This needs to be conducted in ways that ensure that the most relevant knowledge is used and that combines and shares insights from many different sources. By doing this, we have the potential to monitor and assess land degradation more effectively and more efficiently.

Acknowledgements

This paper was prepared as part of the White Paper of the Dryland Science for Development Consortium's Working Group 3 and presented by Mark Reed as a plenary talk at the first UNCCD CST Scientific Conference, held at COP-9, 22-24 September, 2009 in Buenos Aires, Argentina. We would like to thank all the other members of Working Group 3. Authors are funded by: the ESRC and Rural Economy and Land Use programme Sustainable Uplands project (Reed, Stringer, Buckmaster, Holden, Hubacek; Phillipson, Prell and Quinn); ESRC/BBSRC/MRC Be-Wel Network (Reed, Prell); a British Academy Research Development Award (Reed, Stringer); EU Framework 6 Desertification Mitigation & Remediation of Land – a Global Approach for Local Solutions (DESIRE) project (Reed, Stringer, Chanda, Diez, Geeson, Holden, Hubacek); and NERC and EU Framework 6 Ecocycles Project (Bryce, Reed).

References

Acheson JM. 2006. Institutional failure in resource management. *Annual Review of Anthropology* **35**: 117-134.

Agrawal A. 1995. Dismantling the divide between indigenous and scientific knowledge. *Development and Change* **26**: 413-439.

Akhtar M, Schutzbar RV. 1994. *Ecolgocial and Anthropogenic Restrictions for Animal Husbandry in Animal Research and Development*. Vol. 39, Institute for Scientific Co-operation, Tuebingen, Federal Republic of Germany;147-156.

Alavi C, Leidner N. 2001. Knowledge management and knowledge management systems: conceptual foundations and research issues. *MIS Quarterly* **25**: 107-136.

Andresen PR. 2001. Gender and indigenous knowledge: experiences in Nigeria and the USA. *Indigenous Knowledge and Development Monitor* **9-1**; http://www.iss.nl/ikdm/IKDM/IKDM/9-1/andres.html.

Armitage D, Marschke M, Plummer R. 2008. Adaptive co-management and the paradox of learning. *Global Environmental Change-Human and Policy Dimensions* **18**: 86-98.

Attwell CAM, Cotterill FPD. 2000. Postmodernism and African conservation science. *Biodiversity and Conservation* **9**: 559-577.

Baland JM, Platteau JP. 1996. *Halting degradation of natural resources: Is there a role for rural communities?* FAO & Clarendon Press: Oxford.

Baker LM, Mutitjulu Community. 1992. Comparing two views of the landscape: Aboriginal traditional ecological knowledge and modern scientific knowledge. *Rangeland Journal* **14**: 174-189.

Bauer S, Stringer LC 2009. The role of science in the global governance of desertification. *The Journal of Environment and Development* **18**: 248-267.

Bebbington A. 1993. Modernisation from below: an alternative indigenous development? *Economic Geography* **69**: 274-292.

Berger P, Luckmann T. 1966. *The social construction of reality*. Penguin: Harmondsworth.

Berkes F. 2002. Cross-scale institutional linkages: Perspectives form the bottom up. In *The Drama of the Commons*. Ostrom E, Dietz T, Dolsak N, Stern PC, Stonich S, Weber EU (eds). Washington, D.C., National Academy Press; 293-322.

Berkes F. 2009. Evolution of co-management: Role of knowledge generation, bridging organizations and social learning. *Journal of Environmental Management* **90**: 1692-1702.

Blackmore C. 2007. What kinds of knowledge, knowing and learning are required for addressing resource dilemmas?: A theoretical overview. *Environmental Science & Policy* **10**: 512–525.

Brenner N. 2001. The limits to scale? Methodological reflections on scalar structuration. *Progress in Human Geography* **25**: 591-614.

Briggs J. 2005. The use of indigenous knowledge in development: problems and challenges. *Progress in Development Studies* **5**: 99-114.

Briggs J, Sharp J, Hamed N, Yacoub H. 2003. Changing gender relations, changing environmental knowledges and livestock management in Upper Egypt. *Geographical Journal* **169**: 313-325.

Briggs J, Sharp J. 2004. Indigenous knowledges and development: a postcolonial caution. *Third World Quarterly* **25**: 661-676.

Briggs J, Sharp J, Yacoub H, Hamed N, Roe A. 2007. The nature of indigenous knowledge production: evidence from Bedouin communities in southern Egypt. *Journal of International Development* **19**: 239-251.

Brokensha D, Warren D, Werner O (eds). 1980. *Indigenous Knowledge Systems and Development*. University Press of America: Lanham.

Bruckmeier K, Tovey H (eds). 2009. *Rural sustainable development in the knowledge society*. Ashgate, UK.

Burt RS. 1992. *Structural Holes: The Social Structure of Competition*. Harvard University Press: Cambridge, MA.

Campbell BM, Mandondo A, Nemarundwe N, Sithole B, De Jong W, Luckert M, Matose F. 2001. Challenges to proponents of Common Property Resource systems: Despairing voices from the social forests of Zimbabwe. *World Development* **29**: 589-600.

Campbell LM, Vainio-Mattila A. 2003. Participatory development and community-based conservation: Opportunities missed for lessons learned? *Human Ecology* **31**: 417-437.

Cash DW, Clark WC, Alcock F, Dickson NM, Eckley N, Guston DH, Jäger J, Mitchell RB. 2003. Knowledge systems for sustainable development. *Proceedings of the National Academy of Science* **100**: 8086–8091.

Chapman DS, Termansen M, Jin N, Quinn CH, Cornell SJ, Fraser EDG, Hubacek K, Kunin WE, Reed MS 2009. Modelling the coupled dynamics of moorland management and vegetation in the UK uplands. *Journal of Applied Ecology* **46**: 278–288

Chhartre A, Agrawal A. 2009. Trade-offs and synergies between carbon storage and livelihood benefits from forest commons. *Proceedings of the National Academy of Sciences of the USA* **106**: 17667–17670.

Cooke B, Kothari U (eds). 2001. *Participation: the New Tyranny?* Zed Books: London.

Cox KR. 1998. Spaces of dependence, spaces of engagement and the politics of scale, or: looking for local politics. *Political Geography* **17**:1-23.

Cundill G, Fabricius C. 2009. Monitoring in adaptive co-management: Toward a learning based approach. *Journal of Environmental Management* **90**: 3205-3211.

Curtin C, Western D. 2008. Grasslands, people, and conservation: over-the-horizon learning exchanges between African and American pastoralists. *Conservation Biology* **22**: 870–877.

Dietz T, Ostrom E, Stern PC. 2003. The struggle to govern the commons. *Science* **302**: 1907–12.

Diez, E. 2008. *An assessment of the use and usefulness of decision support tools in desertification policy and management*. PhD Thesis, Cranfield University, UK.

Dietz T, Ostrom E, Stern PC. 2002. The struggle to govern the commons. *Science* **302**:1907-1912.

Diouf A, Lambin EF. 2001. Monitoring land-cover changes in semi-arid regions: Remote sensing data and field observations in the Ferlo, Senegal. *Journal of Arid Environments* **48**: 129-148.

Dobbins M, Hanna SE, Ciliska D, Manske S, Cameron R, Mercer SL, O'Mara L, DeCorby K, Robeson P. 2009. A randomized controlled trial evaluating the impact of knowledge translation and exchange strategies. *Implementation Science* **4**: 61.

Dougill AJ, Fraser EDG, Reed MS. In press. Anticipating vulnerability in food systems to climate variability and change: challenges of using dynamic systems approaches and the case of pastoral systems in Botswana. *Ecology & Society.*

Engel-Di Mauro S. 2003. Disaggregating local knowledge: the effects of gendered farming practices on soil fertility and soil reaction in southwest Hungary. *Geoderma* **111**: 503-520.

Enting J, Huirne RBM, Dijkhuizen AA, Tielen MJM. 1999. A knowledge documentation methodology for knowledge-based system development: an example in animal health management. *Computers and Electronics in Agriculture* **22**: 117-129.

Failing L, Gregory R, Harstone M. 2007. Integrating science and local knowledge in environmental decisions: a decision-focused approach. *Ecological Economics* **64**: 47-60.

Fazey JA, Marton F. 2002. Understanding the space of experiential variation. *Active Learning in Higher Education* **3**: 234-250.

Fazey I, Fazey JA, Salisbury JG, Lindenmayer DB, Dovers S. 2006a. The nature and role of experiential knowledge for environmental conservation. *Environmental Conservation* **33**: 1-10.

Fazey I, Proust K, Newell B, Johnson B, Fazey JA. 2006b. Eliciting the implicit knowledge and perceptions of on-ground conservation managers of the Macquarie Marshes. *Ecoogy and Society* **11**: Art 25.

Fazey I, Gamarra JGP, Fischer J, Reed MS, Stringer L, Christie M, In Press. Adaptation strategies to reduce vulnerability to future environmental change. *Frontiers in Ecology and the Environment*

Fazey I, Evely AC, Latham I, Kesby M, Wagatora D, Hagasua JE, Christie M, Reed MS. In press. Reducing vulnerability: a three-tiered learning approach for collaborative research in the Solomon Islands. *Global Environmental Change*

Ferrarini A, Bodini A, Becchi M. 2001. Environmental quality and sustainability in the province of Reggio Emilia (Italy): using multi-criteria analysis to assess and compare municipal performance. *Journal of Environmental Management* **63**: 117–131.

Freeman LC. 1978. Centrality in social networks: conceptual clarification. *Social Networks* **1:** 215-239.

Gould RV, Fernandez RM. 1989. Structures of Mediation: A Formal Approach to Brokerage in Transaction Networks. *Sociological Methodology* **19:** 89-126.

Gould RV, Fernandez RM. 1994. A Dilemma of state power: Brokerage and influence in the National Health Policy Domain. *American Journal of Sociology* **99:** 1455-91.

Hargadon AB. 2002. Brokering Knowledge: Linking Learning and Innovation. *Research in Organizational Behaviour* **24**: 41-85.

Holland J, Campbell J. (eds) 2005. *Methods, Knowledge and Power: Combining qualitative and quantitative development research.* ITDG Publications.

Holling CS. 1992. Cross-scale morphology, geometry, and dynamics of ecosystems. *Ecological Monographs* **62**: 447-502.

Holecz F, Heimo C, Moreno J, Goussard JJ, Fernandez D, Rubio JL, Erxue C, Magsar E, Lo M, Chemini A, Stoessel F, Rosenqvist A. 2003. Desertification- a land degradation support service. *Proceedings at International Geoscience and Remote Sensing Symposium (IGARSS)*, 21-25 September 2003. Toulouse, France.

Howells J. 2006. Intermediation and the role of intermediaries in innovation. *Research Policy* **35**: 715-728.

Ingram J. 2008. Are farmers in England equipped to meet the knowledge challenge of sustainable soil management? An analysis of farmer and advisor views. *Journal of Environmental Management* **86**: 214–228.

Jessop B, Brenner N, Jones M. 2008. Theorizing sociospatial relations. *Environment and Planning D: Society and Space* **26**: 389-401.

Jordan J, Jones P. 1997. Assessing Your Company's Knowledge Management Style. *Long Range Planning* **30**: 392-398.

Juma C. 1989. *The gene Hunters*. Zed: London.

Kalland A. 2000. Indigenous knowledge: prospects and limitations. In *Indigenous environmental knowledge and its transformations*, Ellen R, Parkes P, Bicker A. (eds), Harwood Academic Publishers: Amsterdam; 1-33.

Kapoor I. 2002. The devil's in the theory: a critical assessment of Robert Chambers' work on participatory development. *Third World Quarterly* **23**: 101-117.

Katz EG. 2000. Social capital and natural capital: a comparative analysis of land tenure and natural resource management in Guatemala. *Land Economics* **76**: 114-132.

Kellner K, Moussa AS. 2009. A conceptual tool for improving rangeland management decision at grassroots level: the local level monitoring approach. *African Journal of Range and Forage Science* **26**: 139-147.

Kipuri N. 1996. Pastoral Maasai grassroots indicators for sustainable resource management. In *Grassroots indicators for desertification experience and perspectives from Eastern and Southern Africa,* Hambly H, Angura TO (eds). International Development Research Centre: Ottawa, Ontario, Canada; 110-119.

Klerkx L, Leeuwis C. 2008. Balancing multiple interests: Embedding innovation intermediation in the agricultural knowledge infrastructure. *Technocation* **28**: 364-378.

Klerkx L, Hall AJ, Leeuwis C. 2009. *Strengthening Agricultural Innovation Capacity: Are Innovation Brokers the Answer?* No 19, UNU-MERIT Working Paper Series, United Nations University, Maastricht Economic and social Research and training centre on Innovation and Technology.

Klintenberg P, Kruger AS, Seely MK. 2008. Local level monitoring for improved farming management. In *Land and Water Management in Southern Africa: Towards sustainable agriculture,* Nhira C, Mapiki A, Rankhumise P (eds). The Africa Institute of South Africa: Pretoria, South Africa; 463-473.

Lane SN 2001. Constructive comments on D. Massey 'Space-time, "science" and the relationship between physical geography and human geography'. *Transactions of the Institute of British Geographers* 26: 243–256.

Lebel L. 2006. The Politics of Scale in Environmental Assessments. In *Bridging Scales and Knowledge Systems: Concepts and Applications in Ecosystem Assessment*, Reid WV, Berkes F, Wilbanks T, Capistrano D (eds). Island Press: Washington; 37-57.

Long Martello M. 2004. Expert Advice and Desertification Policy: Past Experience and Current Challenges. *Global Environmental Politics* **4**: 85-106.

Lundvall BA, Johnson B. 1994. The learning economy. *Journal of Industry Studies* **1**: 23-42.

MA (Millennium Ecosystem Assessment) 2005. *Ecosystems and Human Well-being Synthesis*. Island Press: Washington D.C.

Mackinson S, Nottestad L. 1998. Combining local and scientific knowledge. *Reviews in Fish Biology and Fisheries* **8**: 481-490.

Maddox G, Giblin J, Kimambo IN (eds.) 1996. *Custodians of the land: ecology and culture in the history of Tanzania.* James Currey: London.

Martin A, Sherington J. 1997. Participatory research methods: Implementation, effectiveness and institutional context. *Agricultural Systems* **55**: 195-216.

Meadowcroft J. 2002. Politics and scale: Some implications for environmental governance. *Landscape and Urban Planning* **61**:169-179.

Morgan DL. 2007. Paradigms Lost and Pragmatism Regained: Methodological Implications of Combining Qualitative and Quantitative Methods. *Journal of Mixed Methods Research* **1**: 48-76.

Moyo B. 2009. Indigenous knowledge-based farming practices: a setting for the contestation of modernity, development and progress. *Scottish Geographical Journal* **125**: 353-360.

Ngugi MK, Conant RT. 2008. Ecological and social characterization of key resource areas in Kenyan rangelands. *Journal of Arid Environments* **72**: 820-835.

Niamir-Fuller M. 1998. The resilience of pastoral herding in Sahelian Africa. In *Linking social and ecological systems: management practices and social mechanisms for building resilience,* Berkes F, Folke C (eds), Cambridge University Press: Cambridge, UK; 250-284.

Nissen ME, Levitt RE. 2004. Agent-based modeling of knowledge dynamics. *Knowledge Management Research & Practice* **2**: 169–183.

Nonaka I. 1994. A Dynamic Theory of Organizational Knowledge Creation. *Organization Science* **5**: 14-37.

Norgaard R. 1984. Traditional agricultural knowledge: past performance, future prospects and institutional implications. *American Agricultural Economics Association* **66**: 874–878.

Nowotny H. 2003. Dilemma of expertise: democratizing expertise and socially robust knowledge. *Science and Public Policy* **30**: 151-156.

Oba G, Kaitira LM. 2006. Herder knowledge of landscape assessments in arid rangelands in northern Tanzania. *Journal of Arid Environments* **66**: 168-186.

Ochola WO, Kerkides P. 2004. An integrated indicator-based spatial decision support system for land quality assessment in Kenya. *Computers and electronics in agriculture* **45**: 1-3 3-26.

Olsson P, Folke C, Berkes F. 2004. Adaptive co-management for building. resilience in social-ecological systems. *Environmental Management* **34**: 75-90.

Ostrom E. 1990. *Governing the Commons: The Evoluation of Institutions for Collective Action*. Cambridge University Press: New York.

Ostrom E. 2005. *Understanding Institutional Diversity.* Princeton University Press: New Jersey

Pahl-Wostl C, Hare M. 2004. Processes of social learning in integrated resources management. *Journal of Community and Applied Social Psychology* **14**: 193–206.

Pahl-Wostl C. 2009. A conceptual framework for analysing adaptive capacity and multi-level learning processes in resource governance regimes. *Global Environmental Change-Human and Policy Dimensions* **19**: 354-365.

Phillipson J, Liddon A. 2007. *Common knowledge? An exploration of knowledge transfer*. Rural Economy and Land Use Programme Briefing Series No 6. Available at: http://www.relu.ac.uk/news/briefings/RELUBrief6%20Common%20Knowledge.pdf.

Polanyi M. 1962. *Personal Knowledge: Toward a Post-Critical Philosophy*. Harper Torchbooks: New York.

Polanyi M. 1967. *The Tacit Dimension*. Routledge and Keoan Paul: London.

Polanyi M. 1997. Tacit knowledge. In *Knowledge in Organisations*, Prusak L (ed). Butterworth-Heinemann: Boston, USA.

Pottier J 2003. Negotiating local knowledge: an introduction. In *Negotiating local knowledge: power and identity in development,* Pottier J, Bicker A, Sillitoe P (eds), Pluto Press: London; 1-29.

Prell C, Hubacek K, Reed MS, Burt TP, Holden J, Jin N, Quinn H, Sendzimir J, Termansen M. 2007. If you have a hammer everything looks like a nail: 'traditional' versus participatory model building. *Interdisciplinary Science Reviews* **32**: 1-20.

Prell C, Hubacek K, Quinn CH, Reed MS. 2008. 'Who's in the network?' When stakeholders influence data analysis. *Systemic Practice and Action Research* **21**: 443-458.

Prell C, Hubacek K, Reed MS 2009. Social network analysis and stakeholder analysis for natural resource management. *Society & Natural Resources* **22**: 501–518.

Prell P, Hubacek K, Reed MS, Liat R In press. Competing structures, competing views: the role of formal and informal social structures in shaping stakeholder perceptions. *Ecology & Society*

Quinn CH, Huby M, Kiwasila H, Lovett JC. 2007. Design principles and common pool resource management: An institutional approach to evaluating community management in semi-arid Tanzania. *Journal of Environmental Management* **84**: 100-113.

Raymond CM, Brown G. 2006. A method for assessing protected area allocations using a typology of landscape values. *Journal of Environmental Planning and Management* **49**: 797-812.

Raymond CM. 2008. *Mapping landscape values and perceived climate change risks for natural resources management: A study of the Southern Fleurieu Peninsula region, SA*, DWLBC Report 2008/07. Government of South Australia, through Department of Water, Land and Biodiversity Conservation, Adelaide.

Raymond CM, Bryan BA, Hatton MacDonald D, Cast A, Strathearn S, Grandgirard A, Kalivas T. 2009. Mapping community values for natural capital and ecosystem services. *Ecological Economics* **68**: 1301-1315.

Raymond CM, Fazey I, Reed MS, Stringer LC, Robinson GM, Evely AC. In press. Integrating local and scientific knowledge for environmental management: From products to processes. *Journal of Environmental Management*

Reed MS, Dougill AJ. 2002. Participatory selection process for indicators of rangeland condition in the Kalahari. *The Geographical Journal* **168**: 224-234.

Reed MS, Fraser EDG, Dougill AJ, 2006. An adaptive learning process for developing and applying sustainability indicators with local communities. *Ecological Economics* **59**: 406-418.

Reed MS, Dougill AJ, Baker T. 2008. Participatory indicator development: what can ecologists and local communities learn from each other? *Ecological Applications* **18**: 1253-1269.

Reed MS, Dougill AJ. 2009. Linking Degradation Assessment to Sustainable Land Management: a decision support system for Kalahari pastoralists. *Journal of Arid Environments* **74**: 149–155.

Reid WV, Berkes F, Wilbanks TJ, Capistrano D. 2006. Introduction. In *Bridging Scales and Knowledge Systems: Concepts and Applications in Ecosystem Assessment,* Reid WV, Berkes F, Wilbanks T, Capistrano D. (eds), Island Press, Washington; 1-20.

Reynolds JF, Stafford Smith DK, Lambin EF, Turner II BL, Mortimore M, Batterbury SPJ, Dowing Th. E, Dowlatabadi H, Fernández RJ, Herrick JE, Huber Sannwald E, Jiang H, Leemans R, Lynam T, Maestre FT, Ayarza M, Walker B. 2007. Global desertification: Building a science for dryland development. *Science* **316**: 847-851.

Schmiedel U. 2006. *Capacity development and scientist-land user collaboration towards sustainable management of Communal Lands in southern Africa - creating initial structures*. CD publication, Soil and Desertification - Integrated Research for the Sustainable Management of Soils in Drylands, Hamburg, Germany.

Schroeder RA. 1999. Community, forestry and conditionality in the Gambia. *Africa* **69**: 1-21.

Sharp J, Briggs J, Yacoub H, Hamed N. 2003. Doing gender and development: understanding empowerment and local gender relations. *Transactions, Institute of British Geographers* **28**: 281-295.

Sillitoe P. 1998. Knowing the land: soil and land resource evaluation and indigenous knowledge. *Soil Use and Management* **14**: 188-193.

Stringer LC, Reed MS, Dougill AJ, Seely MK, Rokitzki M. 2007a. Implementing the UNCCD: Participatory challenges. *Natural Resources Forum* **31**: 198-211.

Stringer LC, Twyman C, Thomas DSG. 2007b. Combating land degradation through participatory means: the case of Swaziland. *Ambio* **36**: 387-393.

Stringer LC, Reed MS. 2007. Land degradation assessment in southern Africa: integrating local and scientific knowledge bases. *Land Degradation and Development* **18**: 99-116.

Stringer LC, Twyman C, Gibbs LM. 2008. Learning from the South: common challenges and solutions for small-scale farming. *The Geographical Journal* **174**: 235-250.

Tahoun SA. 2003. Traditional Knowledge in the context of the UN Convention to Combat desertification. In *Sustainbale management of marginal drylands*, Adeel Z (ed), UNU Desertification Series no. 5,UNU: Tokyo.

Tlhalerwa N. 2008. *Gendered Indigenous Traditional Knowledge (ITK) System: Towards Sustainable Access and Management of Natural Resources in Khawa Village, Kgalagadi South Sub-District, Botswana*. MSc dissertation, Department of Environmental Science, University of Botswana, Gaborone.

Twyman C. 2000. Participatory conservation? Community-based natural resource management in Botswana. *Geographical Journal* **166**: 323-335.

Twyman C, Dougill AJ, Sporton D, Thomas DSG. 2001. A case of community self empowerment, Okonyoka, Eastern Namibia: environmental and policy implications. *Review of African Political Economy* **28**: 9-26.

UNCCD, 1994. *United Nations Convention to Combat Desertification in Those Countries Experiencing Serious Drought and/or Desertification Particularly in Africa: Text with Annexes*. UNEP, Nairobi.

van den Belt M. 2004. *Mediated Modeling: a systems dynamics approach to environmental consensus building*. Island Press: Washington, Covelo, London.

Vergunst P. 2008. Social integration: re-socialisation and symbolic boundaries in Dutch rural neighbourhoods. *Journal of Ethnic and Migration Studies* **34**: 917-934.

Vergunst PJB. 2009. Whose socialisation? Exploring the social interaction between migrants and communities-of-place in rural areas. *Population, Space and Place* **15**: 253-266.

von Krogh M. 1998. Care in knowledge creation. *California Management Review* **40**: 133-154.

Wilbanks TJ. 2006. How Scale Matters: Some Concepts and Findings. In *Bridging Scales and Knowledge Systems: Concepts and Applications in Ecosystem Assessment*, Reid WV, Berkes F, Wilbanks T, Capistrano D (eds). Island Press: Washington; 37-57.

WOCAT. 2007. *Where the land is greener: Case studies and analysis of soil and water conservation initiatives worldwide*. Hanspeter Liniger and William Critchley (eds). WOCAT.

World Bank. 1998. *Indigenous knowledge for development: a framework for development*. Knowledge and Learning Centre, Africa Region, World Bank. Available on the World Wide Web at: http://www.worldbank.org/afr/ik/ikrept.pdf.

Zermoglio MF, van Jaarsveld A, Reid W, Romm J, Biggs O, Yue TX, Vicente L. 2005. The multiscale approach. In *Millennium Ecosystem Assessment*, *Ecosystems and human well-being: Multiscale assessment,* Vol. 4, Island Press: Washington, DC; 61–84.

Figure 1: Thorny bush encroachment in Boteti, Botswana: a resource for browsers (Photo: R. Chanda, 2009)

Dimensions	Knowledge Type		
Local vs Generalised	Local ⟷		Generalised
Level of formal processes used to generate knowledge	Informal ⟷		Formal
Extent of expertise	Novice ⟷		Expert
Extent to which knowledge is articulated or accessible to others	Tacit (cannot be articulated) ⟷	Implicit (not yet articulated) ⟷	Explicit (articulated)
Extent to which knowledge is embedded in and reflects traditional cultural rules and norms that are derived from many generations of past human-environment relationships	Traditional Ecological ⟷	Local Ecological ⟷	Scientific

Figure 2: Different types of knowledge, showing a series of overlapping continua that exist in the literature (from Raymond *et al.*, under review)

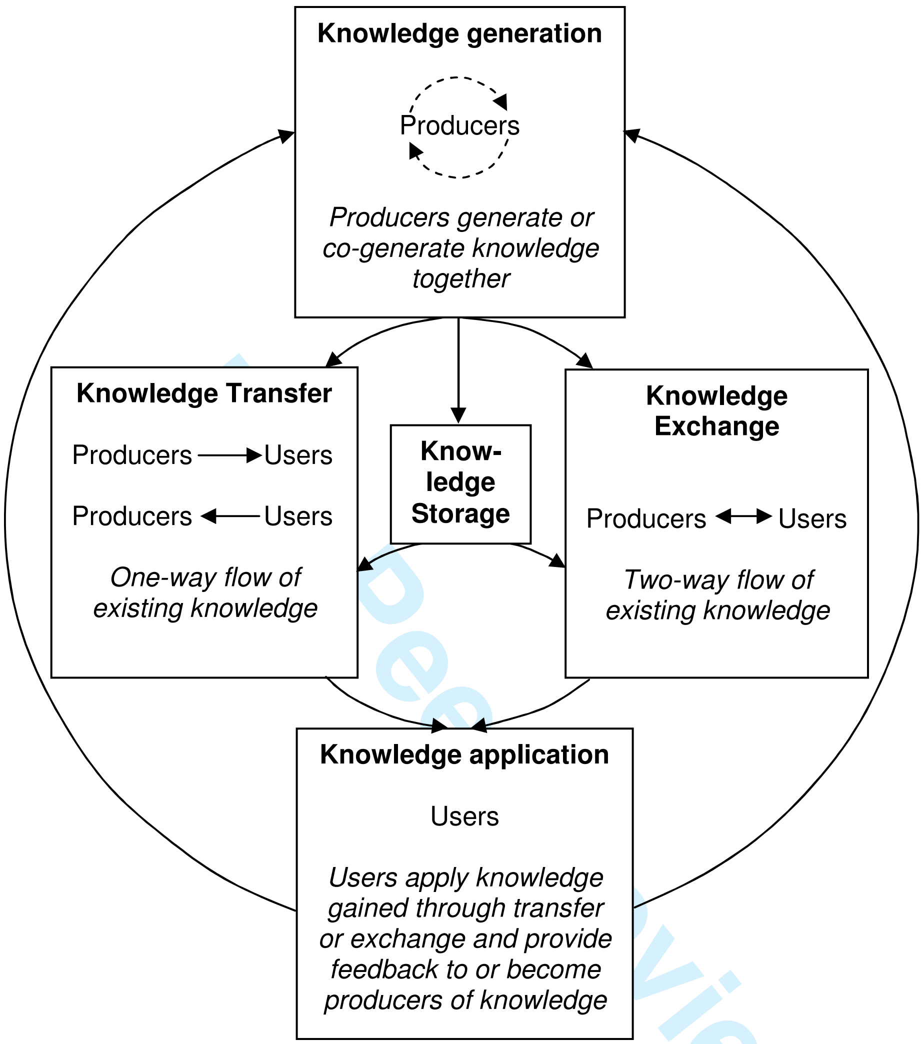

Figure 3: Modes of knowledge management, showing how knowledge is generated, with the potential to store, transfer or exchange knowledge between producers and users of knowledge before it is applied. People and organisations (e.g. scientists and members of policy and wider stakeholder community) may take on different roles in different parts of the knowledge management cycle. Hence knowledge producers can become users of knowledge, and users can become producers of knowledge, providing the potential for different actors to co-generate knowledge together. A key challenge is therefore to find mechanisms that break down traditional linear modes of knowledge production, dissemination, and implementation, and see all stages as processes for mutual learning, dialogue and providing motivation for real and sustained action.

Box 1: Horizontal knowledge management success stories from Drynet

Rather than dissect our failures, by looking for and learning from success stories, it may be possible to spread knowledge more widely. However, the context-specific nature of case studies means that we cannot just identify success stories with the assumption that knowledge will indeed spread to those who need it. Several other factors play a role in whether a particular local technique or approach spreads or not, for example: i) the extent to which the knowledge is context specific or more widely generalisable; ii) the extent to which the knowledge provides a good return on investment within a reasonable time frame for others to adopt it; iii) a technique or innovation should not demand a large amount of labour or capital; iv) the presence of institutional collaboration, existing networks or non-state agencies that can provide extension services and facilitate exchange of knowledge. Therefore, before success stories can become a vehicle for knowledge exchange, a close look is needed on why something is a success, and what elements are transferrable to other contexts. The way in which these stories are conveyed is also important. For example, a field visit may be far more effective than written documentation.

Drynet (www.dry-net.org) is a networking and capacity building effort of 14 CSO partners from around the world. Within the Drynet project, success stories (called “inspiring initiatives”) are documented and made public. The stories describe initiatives of various actors such as local soil and water conservation techniques, innovative ways to share information at local or national level, or successes in influencing national policy. They serve to inspire policy-makers as well as fellow practitioners. To ensure successes are spread effectively, additional activities are planned, such as selected exchange visits between practitioners within a country (horizontal knowledge exchange) and for national decision-makers to visit local projects (vertical knowledge exchange).

Another important lesson is to distinguish between the spontaneous spread of successful strategies and practices at grass roots level, and the role of external agents such as donors and development agencies in actively promoting this diffusion. The experience of the Drynet partners is that such external organisations can and should play an active but background role in the process. They should help to identify success, and facilitate their spread, including the provision of the necessary enabling conditions. But the lead role in the process should be taken by resource users and their local organisations. This means that there should be enough incentives for local land users to share their knowledge, for example by ensuring they learn something from others in return that they can use, by compensating them, or by ensuring somehow that they contribute to a process of change relevant for them in the future.

A participatory mapping exercise carried out as part of the Birjand Carbon Sequestration Project which is part of Drynet, finding cost-effective ways to rehabilitate degraded rangeland

Box 2: Forum for Integrated Resource Management (FIRM), Namibia

In Namibia a local monitoring system involving local community members was first developed for monitoring of wildlife in the Grootberg conservancy in north-western Namibia (Stuart-Hill *et al.*, 2005). This approach was adopted and further developed into a tool that can provide local farmers with relevant information (Klintenberg *et al.* 2003, 2008). The methods developed are specifically designed for communal farmers and their unique requirements in mind based on indicators identified by the farmers themselves. The LLM system provides detailed, relatively immediate and useful information needed for improved management of rangelands (Klintenberg *et al.*, 2008).

Recording of observations made by the farmers is an important part of the system. Most farmers, as part of their normal procedures, make decisions based on one or several environmental (or social) indicators. However, observations are seldom systematic or recorded. Information is often lost, as the memories fade and get mixed up between years. By recording his/her observations the farmer obtains a better understanding of how variable environmental conditions, e.g. amount and seasonality of rainfall, influence the state of the environment and his/her agricultural production. Secondly, by recording each observation in the prepared field guide, a historical record is created, which allows the farmer to compare conditions over the years and also to compare with fellow farmers in community Forums for Integrated Resource Management (FIRM) or comparable CBO (Kambatuku, 2003b; Klintenberg *et al.*, 2008; Kroll and Kruger, 1998).

FIRM is an approach designed to put rural communities in the driver's seat in terms of their own development. It involves a Community Based Organisation (CBO) of rural farmers taking the lead in organising, planning and monitoring their own development while coordinating the interventions of their service providers (Kruger *et al.*, 2003; Kruger *et al.*, 2008; Stringer *et al.*, 2007).

The joint discussion of results amongst farmers in a community FIRM is one of the key features of the LLM system, providing an information base for joint planning and decision making. Information generated through this farmer driven monitoring is ideally forming a central part in planning and decision making done by FIRM groups (Kruger *et al.*, 2008). At the same time, having a record supports the farmers in their communication with service providers, other natural resource managers and policy makers.

Research combining scientific observations and traditional knowledge held by local farmers has been carried out in central northern Namibia by various 'boundary organisations' (Klintenberg *et al.*, 2008; Klintenberg and Verlinden, 2008; Verlinden and Dayot, 2005; Verlinden and Kruger, 2007). By comparing results from a national land degradation monitoring system (Klintenberg and Seely, 2004) with local perceptions of environmental change, Klintenberg *et al.* (2008) could show that local perceptions corresponded with environmental changes identified by national monitoring. However, it was also shown that information given by local farmers revealed a more complex picture of causes and effects of environmental changes compared to the variables used for national level monitoring. It was therefore concluded that traditional knowledge held by local farmers could contribute meaningfully to improving national indicators when communicated through inter-level linkages.

This example illustrates the value of integrating traditional knowledge into scientific investigations of environmental change and land degradation based on an inter-level exchange of information. Integration of traditional knowledge improved the understanding, by scientists and the local community, of the complex systems being investigated. By involving the local equivalent of a FIRM and ensuring information flow between community members and scientists, results can be used by all participants, e.g. (Seely, 1998; Seely *et al.*, 2006, 2008). Moreover, as the research results are conveyed to different levels, communication pathways remain open by involving the FIRM and its members and service providers as possible.