# Mobilising knowledge for ecosystem assessments

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## Abstract

In assessments such as the southern African Millennium Assessment or SAfMA, knowledge relevant to an issue of societal importance is collected, evaluated, organised and communicated in order to support decision-making. Formal assessments are, by nature, part of the 'scientific' world view. In order to retain their credibility and power, they have to conform to the norms of evidence, logical inference and trace-ability that apply in that domain. This type of formal knowledge is the conventional source of information for ecosystem assessments. But local resource users also constantly assess the condition of their ecosystems, albeit in an informal and tacit manner. This informs their decisions about short term ecosystem utilization and enables them to make longer term predictions. In the process, a knowledge system tacitly evolves through adaptive management and inter-generational learning, and transferred between ecosystem users. A great deal of relevant information is held in these less formal local, 'traditional' or 'indigenous' knowledge systems. This paper suggests approaches by which formal and local knowledge can, in complementary ways, be brought to bear on ecosystem assessments. It provides examples of the appropriate and inappropriate use of local and formal knowledge respectively and suggests rules for validating them. It further indicates how the procedures usually associated with formalising local knowledge can usefully be applied to tacit knowledge within the science domain as well. Local knowledge, embedded in local cultures and belief systems, is most useful for gathering localized and fine-grained information about ecosystem and social dynamics, ecosystem management practices, local belief systems, human behaviour, historical patterns of social and ecological change, and information about fine-grained key resource areas that make a disproportionate contribution to human well-being.

The assessment process added value to these different sources of knowledge through

- collation: making relevant information from diverse and dispersed sources available
- evaluation: comparison, checking and applying informed judgement to competing or absent information
- summarisation: approaches to reducing the complexity and detail of data, including indices, indicators and statistical analysis
- synthesis: recombination of primary information to provide novel insights, through simple or complex models
- promoting dialogue and debate between investigators with varying world views who work at different spatial scales, and amongst decision makers [and the public?]
- communication: translating from specialist/technical domain into a policy domain using maps, diagrams, pictures, tables and words, and its dissemination in printed and non-printed media.

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## Introduction

'The truth' is illusive when dealing with complex, dynamic systems (Kay et al. 1999). Scientists and practitioners face a number of challenges, e.g. how to deal with information 'fuzziness'; how to reconcile seemingly contradictory data; how to smooth over geographic and spatial variability or 'lumpiness'; and how to consolidate information gathered at different spatial scales. One of the solutions proposed has been to amalgamate different types of knowledge, e.g. by working across disciplines, combining qualitative and quantitative information, and linking formal and local knowledge in a complementary manner. But this approach is no panacea, and new challenges arise when knowledge is combined. The techniques to combine data from disparate sources collected at different spatial scales are neither well developed nor validated.

The southern African Millennium Assessment (SafMA) was undertaken at a variety of scales, from the regional (with sub-Saharan Africa is the assessment area) to the local (at the scale of a village, single protected area or micro watershed). Each of these scales had its own stakeholders, and thus key topics of concern. These in turn defined the information needs for the assessment at that scale. Our experience was that, as the scale of assessment moved from regional to local, so the balance of information availability shifted from formal, documented data, typically regarded as being in the 'scientific domain', towards informal, tacit information contained in the life experience of local residents and in folklore transmitted by oral tradition, or perhaps documented, but not in according to scientific standards. We contend that the distinction between 'formal' and ' informal' knowledge is not as absolute as is often thought, and that at the level of broad principles, similar rules of use and validation apply, although the procedures may differ. There are elements of both sorts of knowledge at all scales.

Knowledge can be classified and defined in a variety of ways. Here we use the phrase 'explicit' to mean knowledge which exists in a written (ie codified, including numeric or graphical) form. 'Tacit' knowledge, on the other hand, is held in people's memories. 'Formal' knowledge has passed through a strict and agreed set of universally accepted rules qualifying it for a particular use, whereas 'informal' knowledge has been subject to local rules of validity (Table 1). 'Local' knowledge has a fine-grained perspective and is highly context-specific, vs. 'universal' knowledge, which is more coarse-grained and which incorporates a variety of contexts. The application of different types of knowledge can be depicted in two dimensions, with the 'informal→formal', and 'local→universal' gradients on the respective axes (Figure 1). Local, informal knowledge is mostly reserved for customs, traditions and consumptive use of ecosystem services, whereas universal, formal knowledge often characterizes international conventions, global change models and space aviation programmes. A particular set of rules pertain to the scientific method; knowledge that satisfies these rules is 'scientific', and usually also explicit.

**[Insert Table 1]**

**[Insert Figure 1]**

The SAfMA team faced a number of challenges when attempting to amalgamate these different types of knowledge across spatial scales. We confronted these potential challenges from the outset, and proactively, and sometimes reactively, devised strategies for dealing with them. In the process we learnt a number of lessons about knowledge amalgamation and sense-making in complex assessments. This paper shares the experience in SAfMA of soliciting (making explicit) and assessing (formalising) traditional knowledge at the local scale, and at the regional scale making explicit the tacit knowledge from 'scientific' sources. It then discusses the processes by which the assessment adds value to this input data, from whatever source it is derived.

**Incorporating informal, local knowledge systems**

Local ecological knowledge, also sometimes called 'local knowledge', 'informal knowledge' or 'traditional ecological knowledge', is embedded in local customs, belief systems and learning. Local knowledge is particularly relevant in ecosystem management, and its integrity is acknowledged in the Convention on Biological Diversity (Article 8j). The characteristics of local knowledge are:

- Like all types of knowledge, it constantly evolves, through generations of hands-on experimentation, and is carried over from one generation to the next in their folklore, societal norms, management systems and social memory (Berkes and Folke, 1998). This adaptive process more often than not acts as a filter on the quality and validity of knowledge that is transferred.
- Local knowledge is very seldom documented (except through intermediaries such as researchers, writers and journalists), and is mostly tacit.
- Local knowledge is used in everyday situations. Its main value lies in helping local people to cope with day-to day-challenges, detecting early warning systems of change, and in knowing how to respond to challenges. It is extensively used by local practitioners to develop natural resource management strategies, set rules that govern the use of ecosystem services, and in day to day decisions such as knowing which medicines to use, knowing where to find food or water in times of crisis, and knowing which plants and animals are best avoided and which not.
- Knowledge is the 'backbone' of local social institutions, which act as knowledge banks and mechanisms for knowledge transfer between individuals and over time. Social institutions convert knowledge into sets of rules, norms and social behaviours, which then become local management systems (Folke, Berkes and Colding, 1998). Institutions are therefore the conduit, which converts knowledge into management systems, strategies and policies.

Local knowledge, and especially traditional knowledge, is mostly tacit and seldom documented or 'refereed' [Examples and references]. Traditional knowledge is jealously guarded, and for good reason: violations of intellectual property rights occur regularly and are so common that they are even entrenched in the text of international Conventions such as the Indigenous Peoples Convention in the Convention on Biological Diversity. [Examples and references]. Many scientists are sceptical of the validity of informal knowledge, because of the lack of rigour, while unsophisticated practitioners are sceptical about science because they often do not understand it, or because science has on some occasions been used to mask realities or manipulate the truth [Examples and references]. Concerns about data uncertainties can mar the confidence in results based on knowledge amalgamation [Examples and references].

*Why include local knowledge in an ecosystem assessment?*

Local and indigenous knowledge can contribute toward the conservation of biodiversity and to natural resource use in general (Gadgil *et al*., 1993; Colding, 1998; Johannes, 1998;

Alcorn, 1989). Conventional approaches to understanding and managing the environment have come under increasing scrutiny over the past two decades. The result has been growing calls from various disciplines and institutions for broader approaches and solutions to environmental and societal problems as a whole (Berkes *et al,* 2003), emphasising, amongst other things, decentralisation and integrated conservation and planning that is sensitive to local cultural values and institutions (Mauro and Hardison, 2000).

This has meant that the value and importance of "indigenous knowledge" is now increasingly being recognized (Martello, 2001). Local knowledge also holds lessons for adaptive managers; Berkes *et al.* (2000), for example, suggest that traditional knowledge can be described as adaptive because it acknowledges that environmental conditions will always change, assumes in many instances that nature cannot be controlled, and that yields cannot be predicted. Adaptive management is designed to improve on a trial and error basis, an attribute inherent in the social learning process, where learning occurs at the level of the group, rather than the individual.

Local knowledge can fill knowledge gaps. It is an invaluable source of fine-grained, detailed information about local ecosystem services, especially (but not exclusively) in areas where little formal knowledge exists. Local geographic knowledge can, for example, be converted to formal maps with the aid of GIS, and knowledge about patterns of ecosystem change can be used to inductively develop and test models of ecosystem dynamics. Resource users have detailed knowledge of fine-grained resource patches such as fountains, caves, patches of richer vegetation, and areas where wildlife congregate during certain periods.

Local knowledge is often the only source of information about past patterns of ecosystem use, past land use, traditional customs and the history of local politics. Changes occurring at shorter intervals than those formally recorded by historians, and a more nuanced understanding of the underlying causes of social-ecological change is captured in local memory.

Local people routinely adopt an integrated, systems approach when assessing and managing ecosystems. Culture, natural resources, livelihoods and management practices are viewed as part of the same integrated system. Economic, political and climatic drivers of change are assimilated in local knowledge systems, and the links between these causal factors are obvious to local resource users.

Local knowledge has, in many instances, co-evolved with ecosystems. The feedbacks between ecosystem change and knowledge is evident in local customs, belief systems and day-to-day adaptive management practices. Many of the flexible livelihood strategies that are observed in local societies are a response to reduce people's vulnerability to sudden change.

Local knowledge involves local resource users, and they gain a sense of ownership of the information that is generated. The most important reason for using local knowledge is that it has evolved with the local context. It is context-specific, having co-evolved with local conditions. It is often the only source of local management information about an area. Local knowledge is highly integrated and truly multi-disciplinary. Local people have to adopt a systems approach in their views about ecosystems.

*The shortcomings of local knowledge*

Local knowledge falls short where the rate of change in social-ecological systems is faster than the rate of knowledge evolution. Consistently high livestock densities in the Great Fish River, for example, is a recent phenomenon precipitated by elevated human population densities as a result of social engineering during a previous political dispensation. This has resulted in an ecological 'flip' due to the invasion of unpalatable shrubs (notably *Euryops* and ?? species), which outcompete other plants for moisture and end up homogenizing the landscape. The appropriate response is to mechanically remove these indigenous invaders and re-seed the area with a range of shrubs. But local people have never experienced these invasions until recently and have not evolved local knowledge to cope with it. The same applies to alien invaders, although in that case the coping strategy is to 'switch' to invasive aliens as sources of fuel and building materials. The rate of use is, however, in most cases lower than the rate of increase of invaders. When sacred pools in the Kat River Valley became surrounded by the invasive Australian *Acacia mearnsii*, this species was afforded the same local protection as the valuable indigenous species that are naturally associated with such pools.

Local knowledge sometimes evolves inappropriately, due to powerful external influences that over-ride sensible local adaptations. In Richtersveld National Park, for example, Nama pastoralists believe that donkeys may not be harmed because of their biblical significance, and that killing a feral donkey will lead to prolonged drought (Hendricks 2003). Local people have no use for feral donkeys, which compete with their goats and sheep and have harmful effects on biodiversity and productivity, but the custom is religiously applied.

Local knowledge is often too fine-grained and context-specific, and does not respond to events and processes that do not have direct local repercussions. Local collectors of rare succulents in Lesotho and Richtersveld are unaware of the global conservation significance of the plants they illegally trade in (Hendricks pers. comm.). Local knowledge also rarely responds to slow processes such as gradual soil erosion, changes in the composition of palatable rangelands, siltation of water bodies, invasive plants, encroachments of mines on rangelands, and slow changes in ground water quality due to cattle dips. Often local people's explanations for the causes of these slow changes are flawed, especially when they make spurious links between cause and effect. People at Machibi village in the Eastern Cape, for example, observed an increase in spider webs on unpalatable invasive shrubs. This was mainly because the webs, which were always there, became more visible in the structurally altered shrubland. People started believing that a linked drop in livestock fecundity was caused by spiders, rather than the reduced productivity and palatability of the vegetation (C. Fabricius, pers. obs.).

*Concerns and challenges when collecting local knowledge*

The recognition of the potential role of in ecosystem management local knowledge has been challenged from various corners. A major, and growing challenge facing ecosystem assessments is the issue of relevance. Analysts have warned that local knowledge may not be relevant outside of the local context (du Toit *et al*, 2004), and there is concern about the ability, and also the impact, of scaling local knowledge up to broader spatial scales (Lovell *et al*, 2002). Other analysts warn of a downplaying of environmental problems when local knowledge is over-emphasized, and are concerned about politicians using flawed local knowledge as a reason for ignoring environmental challenges (Burningham and Cooper, 1999).

Some also argue that integration with more dominant formal knowledge systems can marginalize local knowledge systems. By providing an avenue for the extension of the social and conceptual networks of scientific assessment (Latour, 1987; Nadasdy 1999), integration can lead to the concentration of power in the hands of western science, rather than the intended outcome of empowerment of local people. For example, efforts to integrate or bridge different knowledge systems can lead to the translation of local knowledge into a form that is understandable and usable by scientists and formally trained resource managers alone (Nadasdy, 1999).

*Techniques used to collect, assimilate local knowledge*

A wide range of participatory research techniques was used to collect and integrate local knowledge into the assessment process (Babbie et al, 2001). Among the techniques used to collect local knowledge were; focus group workshops and interviews (Borrini-Feyerabend et al, 1997), semi-structured interviews with key informants (Pretty et al, 1995), a range of Participatory Rural Appraisal (PRA) techniques (Chambers, 1994; Borrini-Feyerabend, 1997, Campbell, 2002), and forum theatre. The range of PRA, also called Participatory Learning and Action (PLA) techniques (see http://www.iied.org/sarl/pla_notes/) included; matrixes, free hand and GIS mapping, pie charts, trendlines, timelines, ranking, venn diagrams, problem trees, pyramids, role-playing and seasonal calendars (Borrini-Feyerabend, 1997; Jordan and Shrestha, 1998; Jordan 1998; Department for International Development, 2000; Motteux, 2001).

However, these techniques proved useful only in collecting information; a larger challenge was posed by the need to integrate this information into the assessment findings. This was achieved in a number of ways. For example, data thus collected was converted into digitally enhanced charts, graphs, and reports by the specific researchers involved. In this way, tacit knowledge was made accessible to other scientists. However, in order to prevent an extractive process with a one-way transfer of knowledge (ie solely from local people to scientists) scientific knowledge was equally translated into a form that local participants could relate to. Story-lines and drama, for example, were used to translate complex issues such as future scenarios developed at the national level to local participants. Reactions were then recorded and delivered to scientists working at coarser spatial scales.

*Approaches to validating knowledge*

Combing formal and local knowledge can lead to a great deal of uncertainty. It is therefore essential to validate both formal and informal knowledge. Validation can be achieved through the cross-validation of both formal and informal knowledge. In other words, local experts validate scientific knowledge, and scientists validate informal knowledge. A combination of various participatory research techniques can be used to achieve this, including forum theatre, focus group workshops and interviews (Borrini-Feyerabend et al, 1997), semi-structured interviews with key informants (Pretty et al, 1995), as well as a range of Participatory Rural Appraisal (PRA) techniques (Chambers, 1994). In order to improve confidence in the data thus generated, qualitative findings should be validated through social and biophysical surveys, histiography, and GIS mapping.

Another approach to validate informal knowledge is 'triangulation', whereby different sources of knowledge (e.g. maps, transect walks and semi-structured interviews) are used to assess the validity of a data set. The validity of participatory methods is enhanced when groups, rather than individuals, provide information. A facilitator is crucial in the validation process, by e.g. guarding against the domination of individual views, and encouraging debate and discussion amongst participants before the final information is documented. Report-back meetings, where participants in the PRA process report their findings to other local people in an open forum, is another validation technique that was used in conjunction with the other approaches. The integrity of local knowledge can never by guaranteed, but by using the various techniques in a complementary way a form of 'local peer review' is introduced which greatly enhances the credibility of informal knowledge.

**Incorporating formal, but tacit, knowledge**

Formal knowledge can also be tacit, and formally trained scientists and managers have accumulated a large body of knowledge that is undocumented. 'Expert opinion'-based processes are not uncommon in scientific assessments. For instance, uncertainty statements, a key feature of the Intergovernmental Panel on Climate Change Third Assessment Report, are virtually impossible to derive given current information sources and technology by formal statistical procedures. They are expert opinions, but nevertheless extremely valuable. An attempt is made to calibrate them and make them internally consistent by defining a shared vocabulary (Moss and Schneider 2000). Some formal processes, such as 'the Delphi Method' exist for formalising and making explicit such tacit knowledge in a transparent way.

SAfMA, at the regional scale, faced a problem in synthesising the vast amount of data relating to biodiversity. Technical experts have been studying mammals, birds, reptiles, amphibia and plants in the region for hundreds of years, and have very good feeling for the trends in their populations throughout the region based on their accumulated experience, but are extremely reluctant to commit this information to paper. What was needed was an organising framework and process to do so. Biggs, Scholes and Reyers (2004) defined a 'Biodiversity Intactness Index' as a synthesising framework for the information, and then conducted 16 independent interviews, each lasting 3 to 5 hours, with technical experts in order to solicit the information. The process was greatly facilitated by first carefully defining the purpose, the metric, a reference point (large protected areas), and the nature of the land use activities. The borad taxa were further subdivided into functional groups, in collaboration with the experts, and the total study region was divided into ecosystem types. The mean and range of the expert estimates of the effect of different land use practices on biotic populations in each ecosystem type were then used in calculating an aggregate impact. The convergence in estimates between experts was remarkable, allowing the uncertainty range on the aggregate index to be estimated as $\pm$ 7% around a mean of 84 %.

**Adding value through the assessment process**

If assessments work on existing data, as they claim to do, where does the added value come from that could justify the expense of undertaking the assessment? We are convinced that well-conducted assessments are enormously valuable, and the source of this value is the assessment process itself. Assessment moves data up the value chain, to information, then knowledge, and in some cases, perhaps even wisdom. There are five basic processes by which it achieves this:

***Collation***. This consists of making relevant information easily available, in one location. It is the most basic function of an assessment. The information is typically obtained from diverse, and often hard-to-access sources, such as unpublished reports or 'grey literature'. For many policymakers in Africa, even the technically 'open' literature, such as international scientific journals and books, is either inaccessible or incomprehensible. Policymakers everywhere are typically overworked and overwhelmed by information, so collated, well-organised, source-attributed information on a particular topic, all in one place is a significant benefit. There are many examples of this kind of activity in SAfMA; for example the Zambezi Basin study brought together rainfall, evapotranspiration and river flow data for all the subcatchments by combining climate databases with model outputs and GIS analysis (Desanker and Kwesha 2004)

***Evaluation***. This process involves comparing, checking and applying informed judgement to information. In this an assessment differs fundamentally from a review. Scientific reviewers are expected to be 'neutral', and simply present all the sources of information, and be reticent in providing an opinion. Their target audience is assumed to be in the position to draw their own opinions. Assessments, on the other hand, *are* expected to express an opinion on the validity and meaning of data, especially if there are more than one competing or confliction data sources. If they fail to do so, the decision-makers who are the assessment audience are forced to come to their own conclusions, and are often not equipped to do so. The opinion must be clearly marked as such, so that decision-makers are free to take it or leave it. It should also include a statement of uncertainty, which can be formal ('the protein supply is 45 $\pm$ 5 g/person/day') or informal ('it can be cncluded with high certainty that …'). This process is central to assessments, since their purpose is to act as a translator between the domains of technical knowledge and decision-making. It is also the area where most classically-trained scientists feel least comfortable.; they like to be near-certain before venturing an opinion. An example of this kind of process in SAfMA is the comparison of four different forest cover products at the regional scale, leading to the opinion that there is 4.5 $\pm$ 0.5 million $km^2$ of forest in southern Africa (Scholes and Biggs 2004).

***Summarisation***. This process includes all approaches that help to reduce the complexity and detail of data. Even in data-poor areas, there is usually more data on hand than a decision-maker can usefully assimilate. The volume needs to be reduced until each decision is only informed by one to five variables. It is virtually impossible for any human brain, no matter how intelligent, to juggle the tradeoffs between more than this number of factors. Statistical summaries (means, medians, modes, standard deviations, ranges) all fall into this category. Great care must be taken to perform the statistical summarisation appropriately. For instance, there are important scaling considerations when accumulating averages from different-sized poulations. Indices and indicators also fall into this category. Indices are mathematical compilations of different types of data, forming a composite measure. Indicators are typically proxy data, which suggest a trend in some other, more fundamental, assessment variable. Indicators are a feature of State of the Environment reporting, but run the risk of becoming so numerous that they fail to achieve the objective of simplification. An example of summarisation in SAfMA is the Biodiversity Intactness Index (Biggs et al 2004). This combines thousands of observations at species level, with land cover and ecosystem maps, into a single score for biodiversity performance, with a confidence interval. The index can be progressively 'unpacked' at different scales or for different taxa or land cover types.

***Synthesis*** consists of combining primary information in ways that provide novel insights. The simplest syntheses may be ratios. For instance, when yield data are divided by population data, the result is the average food supply per person. If this is then compared with a threshold (eg 2000 cal/person/day), the result is information on food security that is not present in any one of the input variables alone, but is a result of their combination through synthesis. Synthesis can also take place through the application of much more complex models. An example from SAfMA is the regional scale analysis of the grazing service. Data from subnational livestock databases were converted, through metabolic models, into forage demand values. Climate, soil, topography and vegetation databases were the input to grass production  models that calculated forage supply. The difference between supply and demand provided a synthesised, spatial assessment of the pressure on the service, that could be related to independently-derived satellite observations on land degradation. (Scholes and Biggs 2004) Synthesis represents perhaps the most intellectually challenging aspect of assessment, but also the process by which the greatest value addition can take place.

***Dialectic.*** A very valuable assessment process is the dialogue and debate that occurs when investigators with different analytical models apply themselves to the same problem. One example is the interaction between social scientists and biophysical scientists. Another is between researches looking at the same issue at different scales. A third is the interaction between 'western' world views and 'African' world views. Finally, even within one discipline (eg ecology, economics or political science) there are usually different schools of thought. The assessment can be greatly enriched if these 'conflicts' are not excluded or papered over, but are actively encouraged as a source of constructive dialog and critique. If convergence can be achieved, then confidence in the robustness and wide acceptability of the finding is assured. Failure to converge, on the other hand, does not mean a failed process. It clearly establishes the uncertainty range of the issue. Successful use of dialectic requires a high level of self-confidence and mutual trust between the participants. Pre-judgement must be suspended, and intellectual differences must not be allowed to be expressed as personal animosities. These conditions are engendered by relatively frequent meetings, each with sufficient time to allow extended debate, and 'power balance' within the team.   SAfMA was characterised by a high level of  dialectical debate, quite un-nerving to new observers. The different approaches to scenario construction that were applied by the different sub-projects are an example (compare Lynam et al 2004 , Scholes and Biggs 2004, Bohensky et al 2004 and Fabricius  2004). The coherence of the entire enterprise was built on the *a priori* agreement to use the MA conceptual framework as the meeting point (Millennium Ecosystem Assessment 2003).

***Communication***. This is the process that transfers knowledge from the from the specialist/technical domain into a policy domain. It involves as much listening as speaking, remembering that communication is the message received, not the message transmitted. Assessment can be thought of as a translation device. It needs to render a signal intelligible, and deliver it to where it is needed. The jargon-ridden, extremely detailed scientific discourse often needs to be simplified (think of this as taking out the noise, and leaving the main signal), but should not as a result be distorted. The classical medium is the written report, because of its archival value and ease of use, but this is increasingly supplemented by electronic dissemination (web pages, CD-ROMs), video productions, radio broadcasts, posters and brochures. Face-to-face communication with the chosen target audience is an invaluable complement to the report. Assessment reports typically have a high content of graphical communication devices such as maps, graphs, diagrams, photographs and tables. Assessments often underestimate the time and resources needed for this process, without which the effort put into the preceding processes is useless.  Communication should begin with stakeholder involvement right at the beginning, and not be left as an afterthought. As a rough guideline, about a fifth of the total resources need to be dedicated to communication.

We suggest that the degree of expression of the above processes can be used as a yardstick for 'assessing assessments'. An assessment that applies them all, to a high degree, is likely to yield a worthwhile outcome.

## Conclusions

Ecosystem assessments represent formalised, explicit knowledge. There are ways of bringing informal and/or tacit knowledge into this domain, and doing so can significantly improve the robustness and coverage of the assessment.

Assessments apply five broad processes to the knowledge they mobilise, and in doing so produce new knowledge, or put existing knowledge to work. In a world characterised by a wide gap between what is known in the technical domain, and what is applied in the decision-making domain, the complementary use of formal and informal knowledge represents a valuable tool.

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**Table 1.** The characteristics of knowledge along an formal-informal, and tacit-explicit gradients

| | **Formal** | **Informal** |
|---|---|---|
| **Explicit** | Most, but not all 'scientific' knowledge is in this quadrant. The typical outputs of a conventional assessment are also here | Codified, but neither collected nor tested in accordance with conventional scientific rules |
| **Tacit** | Scientifically-trained people have formal knowledge that is uncodified | Embedded in local customs, traditions and memory, transferred through oral history |

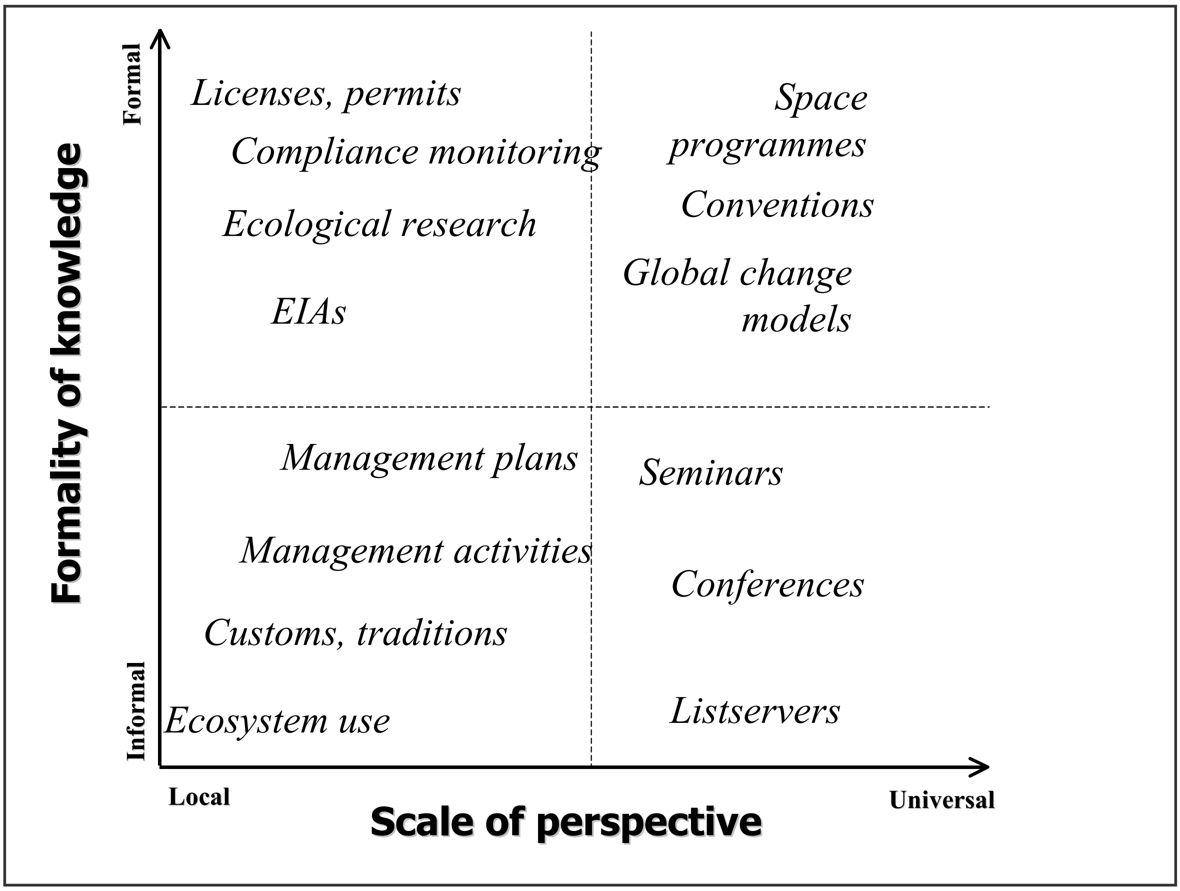


**Figure 1**. The most common uses of different types of knowledge, depending on perspective and formality