

Local ecological knowledge in natural resource management

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Abstract

Rural people's livelihoods depend on their knowledge to manage available natural resources. Their knowledge continues to evolve under changing circumstances, based on personal experience and observations and acquired from secondary sources. In contrast to the populist view of cultural embeddedness of local knowledge, we assert that farmers knowledge that have developed and used in their decision making have ecological rationality in most cases and can be differentiated from cultural and supernatural aspects. While local insights may be comparable with scientific understanding in some respects, it may also differ in its scope and structure.

Using case studies from Indonesia and Peru we illustrate the nature and scope of local ecological knowledge. In the Indonesia case, we investigated farmers' knowledge about soil erosion and associated natural processes both at a plot and landscape levels. While plot level knowledge was rich and diverse, landscape level knowledge was rather generic and was associated with implementation constraints on an individual basis. In Peru, we appraised local ecological knowledge about soils and other aspects of farming systems among the Shipibo communities with relatively new and general but evolving knowledge system. With these examples and other references, we discuss the nature and scope, limitations and usefulness of local knowledge in natural resource management. We advocate research and development based on local knowledge and innovations that are complemented with appropriate scientific investigation.

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Introduction

Rural people most often depend heavily upon natural resources for their livelihood. The long-term sustainable use of such resources, such as soils and forests, depend on local people's knowledge, management and local people's ability to maintain and utilize it. As in the case of soil management, it is reasonable to expect that such people will have observed soils and the processes surrounding their utilization very closely, so developing knowledge that they can use to predict the likely consequences of possible interventions. It is useful to distinguish such locally derived knowledge from formal 'soil science' because, while local insights and scientific understanding may be comparable in some respects, the former may also differ in their scope and structure.

Local knowledge represents the current position of a local community in terms of its land use. Since local conditions vary and people have different objectives and levels of dependence on soil resources, local ecological knowledge may vary from place to place. However, some commonality may exist when farmers have similar means of observation and farm in similar agroecological conditions. This makes documentation and analysis of local ecological knowledge a key task in the development process. Appreciation of local knowledge is of fundamental importance to professionals seeking to assist the local development of sustainable land-use practices, both because it is necessary for effective communication with local people and because it allows research and extension activities to be appropriately targeted at locally experienced constraints.

There are important differences in the emphasis of research on local knowledge following anthropological, as opposed to natural science, traditions. We advocate an interdisciplinary way forward that both distinguishes practical explanatory and predictive knowledge from cultural values and norms and seeks to use terminology that is as free as possible from associations with particular disciplinary traditions. While this remains a controversial distinction, it has been incorporated within a knowledge-based-systems methodology that has been used to acquire local ecological knowledge about natural resources in several long-term participatory development initiatives.

Local knowledge

The terminology surrounding the study of local knowledge is rich, although people's choice of language often reflects the disciplinary context within which their work is grounded. For present purposes, we view knowledge as:

an output of learning, reasoning and perception and a basis for predictions of future events; it is people's understanding and interpretation based on some explainable logic of supposedly general validity.

This does not necessarily imply any objective notion of absolute truth, but rather a particular interpretation of information and data. 'Knowledge' is a logical interpretation or explanation of data, acquired either personally or from external sources. We use the term 'understanding' to mean knowledge which is specific to the person who interprets it, regardless of whether they can articulate it or not, whilst 'knowledge' is used to mean understanding that can be articulated and so can be recorded independently of the interpreter, thus making its utility more general (Sinclair and Walker, 1998). The knowledge a specified group of people has about a specified domain constitutes a 'knowledge system'.

The distinction between local people's knowledge and practice has not always been recognized in the literature on this subject. This is most notable with respect to the body of

work on ITK (Indigenous Technical Knowledge), which often describes people's actions rather than the underlying rationale driving them (IDS, 1979). Knowledge alone does not lead to action; conditions and constraints due to cultural norms, religious obligations, and economic and policy circumstances can all influence farmers' decisions, forcing them to act in an ecologically irrational manner. Moreover, agricultural practice generally unfolds over time (during a season, or over several years in the case of perennial crops), so that farmers may make many separate decisions about the cultivation, tending and harvesting of crops, each of which would be contingent upon the circumstances extant at the time that it is made. These build up a complex agricultural practice, in which it is difficult to disentangle ecological knowledge from other social and economic constraints by simply observing the result (Richards, 1989).

A generic conception of local knowledge systems concerned with natural resource management can also usefully distinguish pragmatic knowledge about how the natural world works (predicting outcomes of management interventions) from cultural values that modify the desirability of various outcomes (Fig. 1). The latter distinction is controversial, particularly when viewed from the anthropological tradition, which sees all knowledge as being culturally embedded (Ellen, 1998). However, it has been found to be empirically useful in dialogue with farmers. Accepting these distinctions, knowledge of the natural world can be seen to comprise 'explanatory knowledge' (concerned with ecological processes) and 'descriptive knowledge' (concerned with the properties of the various components of agroecosystems, such as trees, crops and soils). This contrasts with 'supernatural knowledge', which consists of higher level, often spiritually based, explanations for the order of things. The latter may form the basis of the rules, norms and values assigned by culture, religion or other moral or social imperatives. This, in turn, often places constraints on people in terms of what they are prepared to do. For example, Muslims and Hindus do not eat pork or beef, respectively. Mayan farmers are reputed not to have sold maize, because they believed that maize was symbolically equivalent to human flesh (Asturias, 1949). The Hanunoo shifting cultivators in the Philippines use the interpretation of their dreams in their selection of cultivation sites (Conklin, 1957). In Zambia, in cases of a venomous snakebite, local people can readily articulate the mechanism by which a victim is affected; but, why that particular person met with the misfortune of being bitten requires a higher level, supernatural explanation involving malice and witchcraft (Sinclair and Joshi, 2000). In practice, however, farmers tend to reply to pragmatic questions about the ecology of their farming systems with answers based on natural rather than supernatural explanations. Hence, most of the time, it is not difficult to separate the natural aspects of knowledge from the supernatural.

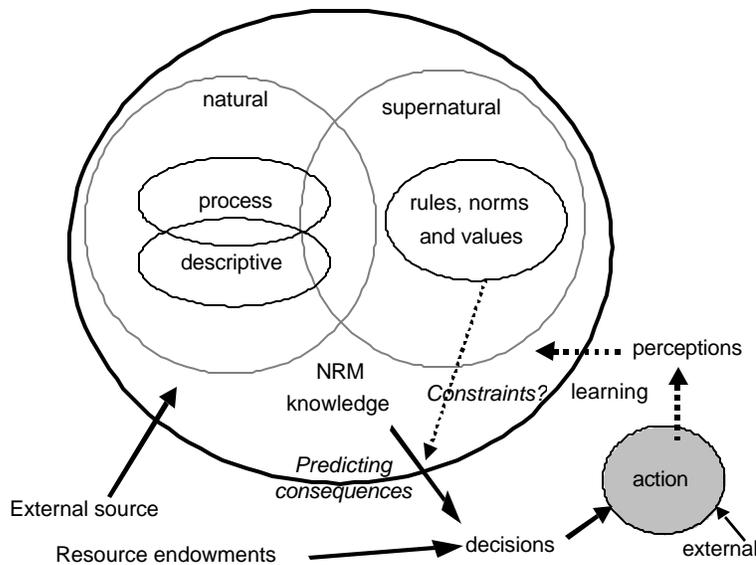


Figure 1. Conceptual diagram of various forms of knowledge influencing farmers' natural resource management (NRM) decisions and actions.

Local knowledge is dynamic and continuously evolving, in that farmers learn both by evaluating the outcomes of their previous actions and by observing the environment. Farmers also augment their knowledge by interacting with other people and the media. This view contrasts with the ubiquitous use of words such as 'traditional' (Ford and Martinez, 2000; Berkes *et al.*, 2000) or 'indigenous' (Sillitoe, 1998) to describe rural people's knowledge, since they imply old, pristine knowledge systems that are culturally specific. In reality farmers' knowledge is likely to be hybrid in nature, with bits of knowledge being drawn from multiple sources. Indeed, many of the crops now cultivated by smallholder farmers are exotic, and have been introduced, together with some knowledge regarding their cultivation, from other parts of the world. For example, in the jungle rubber system in Indonesia (Southeast Asia), smallholders now cultivate a South American tree introduced by colonial governments about a century ago (Gouyon *et al.*, 1993). Local smallholders use technology that is, in part, derived from colonial plantation management - e.g. tapping techniques - but also from smallholder innovation - e.g. high-density planting and allowing secondary forest to regenerate around the rubber trees instead of clean weeding (Dove, 2000).

There is a long and still active tradition of defining local knowledge systems in opposition to scientific knowledge (Levi-Strauss, 1966; Sillitoe, 1998; Berkes *et al.*, 2000). Various terms are encountered in the literature referring to this dichotomy - 'formal' vs. 'informal', 'western' vs. 'indigenous' and 'outsider' vs. 'insider'. However, the problem with this sort of frame of analysis is that, in most cases, the knowledge of local people is not some pristine indigenous perception of the world. It is more likely to have been interacting with external knowledge, at least to some extent, for the last 500 years or so (Agrawal, 1995).

It is very difficult, if not impossible in any meaningful way, to trace the origin of knowledge. Attempts to generalize about fundamental differences in local and scientific knowledge are fraught with difficulty. Assertions that local people's knowledge is heuristic (based on rules of thumb that may have no explanatory basis) have not been borne out by research. It has been shown, in a range of cultural and agroecological contexts, that some of the understanding that farmers have involves mechanistic explanation of natural processes comparable with, and often complementing, scientific knowledge (Richards, 1994; Sinclair and Walker, 1999; Ford and Martinez, 2000). For these reasons we prefer to use the term 'local ecological knowledge' to refer to knowledge about agroecology held by people living in

a particular locality. 'Locality', in this sense, may be defined socially as well as geographically. As shown in Fig. 1, such local ecological knowledge comprises both directly and indirectly acquired knowledge. Typically, it is the locally derived elements that differ from scientific knowledge in their level of aggregation (grouping according to perceived pertinence). Whereas science has emphasized reductive analysis, farmers tend to think more holistically, with limits imposed on their analysis by what they are able to observe and experience. This creates regularities in local knowledge of natural processes across cultures, as well as regularities in terms of how local knowledge contrasts with scientific understanding.

In summary, recent research into locally derived ecological knowledge across a range of agroecological and cultural contexts indicates that it often:

1. has explanatory aspects, with a logical structure comparable to scientific understanding (Sinclair and Walker, 1999);
2. has regularity regionally (Sinclair and Joshi, 2000), and across similar agroecosystems, in contrasting cultural contexts (Thorne *et al.*, 1999; Roothaert and Franzel, 2002);
3. has some complementarity with scientific knowledge (Thapa *et al.*, 1995; Sinclair and Walker, 1999; Thorne *et al.*, 1999);
4. is holistic, but is also often agroecologically specific - being aggregated by the organisms and environmental context from which it was derived (Moss *et al.*, 2001);
5. can be readily articulated and recorded through structured discussions with local people (Sinclair and Walker, 1998).

Many proponents of the importance of local knowledge have promoted its use both in combination with scientific investigation and as a means of enhancing our overall ecological understanding. However, for some time, wide application of what local ecological knowledge had been acquired remained elusive, partly because of the difficulty associated with accessing much of the knowledge contained in reports, articles and theses. The development of formal methods for making explicit records of local ecological knowledge on computer (in a form that allows them to be flexibly accessed, evaluated and used), have made it easier to incorporate local knowledge in agricultural research and extension (Box 1; Walker *et al.*, 1997).

Box 1. Formal methods for knowledge acquisition

Much of the understanding about local ecological knowledge presented in this chapter has been developed through the use of a knowledge-based-systems methodology for acquiring and evaluating local knowledge (Walker *et al.*, 1995). This comprises two major phases: the first involves gathering knowledge from people and recording it in an easily accessible form; the second investigates how widely this acquired knowledge is held in the community of interest (Walker and Sinclair, 1998).

In the first phase, ecological knowledge is collected from a small sample of deliberately chosen individuals thought to be knowledgeable about the domain of interest and willing to co-operate. The knowledge is collected through repeated, focused interviews with these key informants. Between successive interviews, knowledge is abstracted from records of the discussions with key informants and expressed as a series of unitary statements (written in simple, formal grammar) and terms. These are stored on computer in the form of a knowledge base, so that the knowledge is accessible and can be evaluated using tools for handling qualitative data, including automated reasoning procedures. Contextual information about who articulated the knowledge and the conditions under which each statement is valid are also stored. A customizable software package (AKT5 - the Agroecological Knowledge

Toolkit, freely downloadable from www.bangor.ac.uk/afforum) provides the facilities necessary to explicitly record, access and evaluate local ecological knowledge. It has built-in features for representing hierarchical information, displaying synonyms and exploring cause-effect relationships.

In the latter phase, involving a test of generality (or distribution) of knowledge across multiple communities, a large randomized sample of people is drawn from the target community (as in Joshi and Sinclair, 1997) to explore how representative the knowledge base is. For details, including the rationale of the approach and a manual for the AKT5 software, see Dixon *et al.* (2001).

LEK about soil erosion in Sumberjaya, West Lampung, Sumatra (Indonesia)

The island of Sumatra is composed of a chain of (inactive) volcanoes and mountains running parallel to its west coast, and a vast lowland peneplain with generally acid sedimentary soils on its eastern side (van Noordwijk *et al.*, 1998). The richer soils are found in the mountains and foothills (piedmont): many of the valleys in the mountains have been used for agriculture for thousands of years, with pottery and other archaeological remains providing evidence of long-term external trade links via the rivers. Sumberjaya is one of these valleys, having an elevation between 500 and 800 m a.s.l. and rainfall averaging 2614 mm year¹ (Agus *et al.*, 2002). Until the middle of the 20th century, the valley remained relatively inaccessible by road and was sparsely populated. Population densities have now reached 147 per km² (BPS, 1999), as a result of immigrants flowing into the area either from traditional coffee growing areas to the north, or from the island of Java. Coffee (*Coffea robusta*) is the main component of the majority of gardens. A considerable part of the area has been designated 'protection forest', and hundreds of households have been evicted from the area in the name of 'watershed-protection functions'. Only after the political changes of the late 1990s have farmers resettled the area; and, they are currently negotiating tenurial rights in the context of 'community forest management' arrangements. Perceptions of watershed functions thus have a direct, political relevance in this area.

Coffee cultivation methods and garden typology vary widely across the district (Verbist *et al.*, 2002). Gardens range from young monocultures of coffee, through simple shaded coffee to complex multi-strata agroforests. Increasing land scarcity has resulted in the cultivation of steeper land and the conversion of most primary and secondary forest to agriculture, except in the case of some of the steepest slopes and the top of a ridge which formally held the status 'protection forest'. Soil conservation in these erosion-susceptible areas is a priority, in order to sustain coffee yields in the short term and prevent a longer term decline in productivity. Consequently, various soil management strategies and garden typologies have developed to suit different locations. A variety of soil conservation measures are applied in coffee gardens – from physical barriers such as terraces, trenches, ridges and pits, to the choice, positioning and manipulation of the plant components within the garden. Soil conservation measures are also practiced, as is soil improvement through cultivation, and fertilizer and compost application. The effects of companion tree species in a mixed coffee system are well understood by farmers in Sumberjaya, where trees are classified based on their 'friendliness' to coffee (Chapman, 2002).

Farmers in Sumberjaya hold the view that a decline in forest cover affects uniformity of water flow in rivers, resulting in an increase in river flooding in the rainy season and greatly reducing the amount of water in rivers in the dry season. They also believe water turbidity increases with destruction of forest cover (Fig. 2).

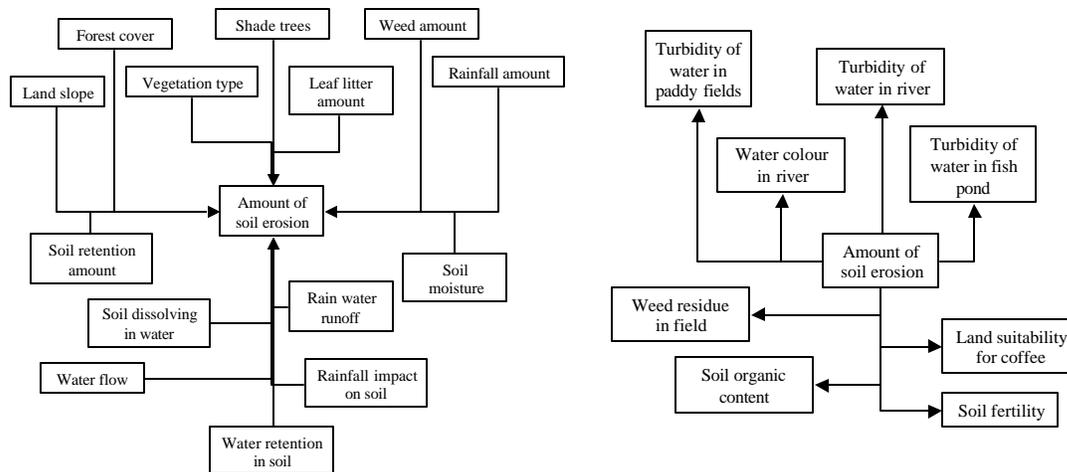


Figure 2. Sumberjaya farmers' understanding of the causes and consequences of soil erosion in coffee gardens and the surrounding landscape. Change in values (such as increase or decrease) for source nodes determines values

Cultivation methods strongly influence the efficiency with which coffee gardens maintain watershed functions. Earthen constructions (such as terraces, furrows and composting holes) can help reduce erosion. On the other hand, weeds and weeding techniques also affect soil erosion, as intensive weeding increases erosion whilst the presence of weeds can be used to reduce erosion, as can weed strips, ring weeding and mulching.

Riverside vegetation is believed to be crucial to watershed function at a landscape level, significantly influencing flooding, landslides, bank erosion and changes in the courses of rivers. There was no consistency amongst the farmers with regard to how wide this vegetation should be: estimates ranged from 50 to 500 m. Trees along river banks, even if they occur only in thin strips a few metres wide, are considered to be effective filters by farmers. Additionally, the root systems of vegetation are believed to hold soil, thereby reducing the occurrence of landslides and soil loss. Shrubs and bushes along riverbanks also believed to have similar functions. Bamboo, which has many fine and intricate roots, is considered a very efficient plant for planting along riverbanks.

Farmers see turbid water flowing down from up-slope coffee gardens and forests as something, which contributes to soil fertility in paddy fields (represented in the second diagram in Fig. 2), even though excessive water flow and sedimentation are physically detrimental to paddy plants. By carefully monitoring and regulating water flow in and out of paddy fields, farmers control water speed and the duration for which that water remains in paddy fields, and hence the deposition of soil particles. It is common knowledge amongst farmers that, if water flow is properly regulated, such sedimentation leads to a reduction in the turbidity of the water flowing out of the fields. Cultivation practices that disturb soil (installing paddy fields, building terraces, hoeing and even planting rice), however, increase water turbidity.

All farmers interviewed are aware of deforestation, erosion and water problems: their knowledge was detailed and commonly shared. Farmers also know about the processes and reasons behind these problems and possess a substantial range of possible technical solutions. However, in reality, not all farmers practice soil and water conservation measures when cultivating steep slopes. Schalenbourg (2002) identified the following common constraints faced by farmers in translating their knowledge into practice:

1. Lack of capital investment (money, labour and time). Most soil conservation practices require time, money and labour, and often involve construction work and maintenance and most farmers cannot not invest substantially to soil conservation innovations.
2. Lack of enthusiasm ('laziness') or lack of the necessary incentives. Many farmers admitted that they are too *malas* or 'lazy'. The farmers probably meant to imply that soil conservation is not their priority or that implementing soil conservation practices does not yield sufficient benefits to make it worthwhile.
3. Uncertain land tenure. Many farmers cultivate coffee on government designated 'forest land', and the region has seen numerous evictions (by the government). Land tenure largely remains uncertain, and this has been an important factor with regard to influencing farmers' decisions not to spend their resources on long-term soil conservation methods.
4. Low returns to labour, or a low price for coffee, result in emphasis being placed on short-term cash gains (including alternative annual cash crops) rather than on long-term productivity and sustainability. Due to very low price of coffee many farmers have converted their fields to the production of other cash crops, and thus are involved in vegetable production and fish farming. Again, farmers are not prepared to invest in any soil conservation activity that requires additional resources, especially if that activity only facilitates long-term coffee production.
5. Isolated efforts with regard to soil conservation are ineffective. Only a concerted effort can yield tangible results, which perhaps to a great extent explains why farmers do not practice soil conservation practices.

LEK about resource management among Shipibo Conibo community in Pucalpa, Peru

Belonging to the Pano Linguistic group, the Shipibo Conibo ethnic people form the majority among the inhabitants of the Ucayali Region. The main activities of these people are fishing, hunting wild animals and gathering fruits and medicinal plants as well as some subsistence farming of yucca (cassava) and bananas in small plots. Crop diversification both for subsistence and semi-commercial purposes is gaining momentum in the recent years. The farming practices are based on cultivating the alluvial soils that are flooded annually for two to three months when the people resort to hunting and fishing. After the floods have receded, the local people plant crops in the nutrient-rich soils.

Using the formal knowledge acquisition methodology (Box 1), 24 local people from seven communities (Limóngema, Santa Isabel de Bahuanisho, Palestina and Puerto Bethel, Palaillo, Patria Nueva and Saposoa) were interviewed at various stages to articulate their knowledge about their farming practices and annual and tree species.

The local Shipibo people attribute high soil fertility to dark non-clayey property, soil humidity and its organic content (Fig 3). The effect of flooding is an increase in the nutrient contents of soil. Likewise, decomposition of leaves and the time for soils to 'rest' after cultivation also contribute to soil fertility. Cultivation of crops (such as Indian corn, yucca or cassava and bananas) is known to reduce soil fertility.

The presence of a local weeds shuashui (scientific name not identified), *arrocillo* (*Rottboellia exaltata*) and gramalote (*Brachiaria mutica*) are known as indicators of poor soils such as *Mapu Mai* (hard soil) and *Mai Joshin* (red soil) where although crops can grow but unlikely to flower or yield fruits. In such soils corn stalks are small, plants are stunted, banana bunches are much smaller than normal and overall production is low.

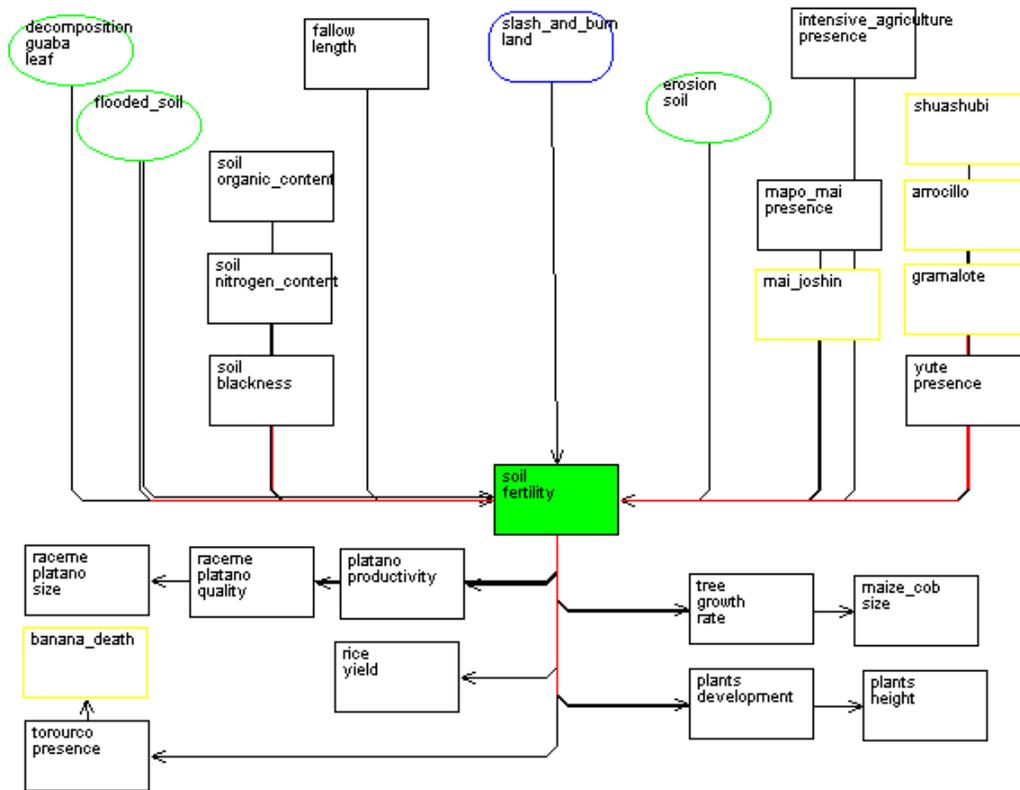


Figure 3. Ucayali farmers’ knowledge about cause-effect relationship in soil fertility maintenance. This is an output the AKT5 software. The node borders are colour coded to represent different types (yellow – process; green – process; blue– human action; black– attribute). Arrows imply a change in target nodes due to source nodes.

Table 1. Shipibo typology for local soils

Shipibo term	Location/type
Camantin	Non floodable land
Maicon	Floodable land good for crops
Tasba Canin	Floodable land, floodplains
Mai huiso	Black soil
Mai joshin	Red soil
Mana mai	High non-floodable land
Naco	Mud
Mapo mai	Clayey soil
Mashi mai	Sandy soil

Planting of annual crops - Indian corn (*Zea maiz*), rice (*Oryza sativa*), cow pea (*Vigna unguiculata*) and peanuts (*Arachis ipogea*) is done after the floods have receded leaving behind nutrient rich sediment. The overall effect of floods on soil fertility is perceived by the Shipibo people to be good for farming (Fig. 4).

Flood tolerance of crops is often related to their root system. The common varieties of bananas, for example, do not tolerate flooding because of their surface root system that tends to rot easily under water logging. The varieties such as *sepucho* and *campeón* with

deeper root systems are however are more tolerant to floods. Likewise, a six-month variety of cassava or yucca (*Manihot esculanta*) is preferred to avoid flood damage.

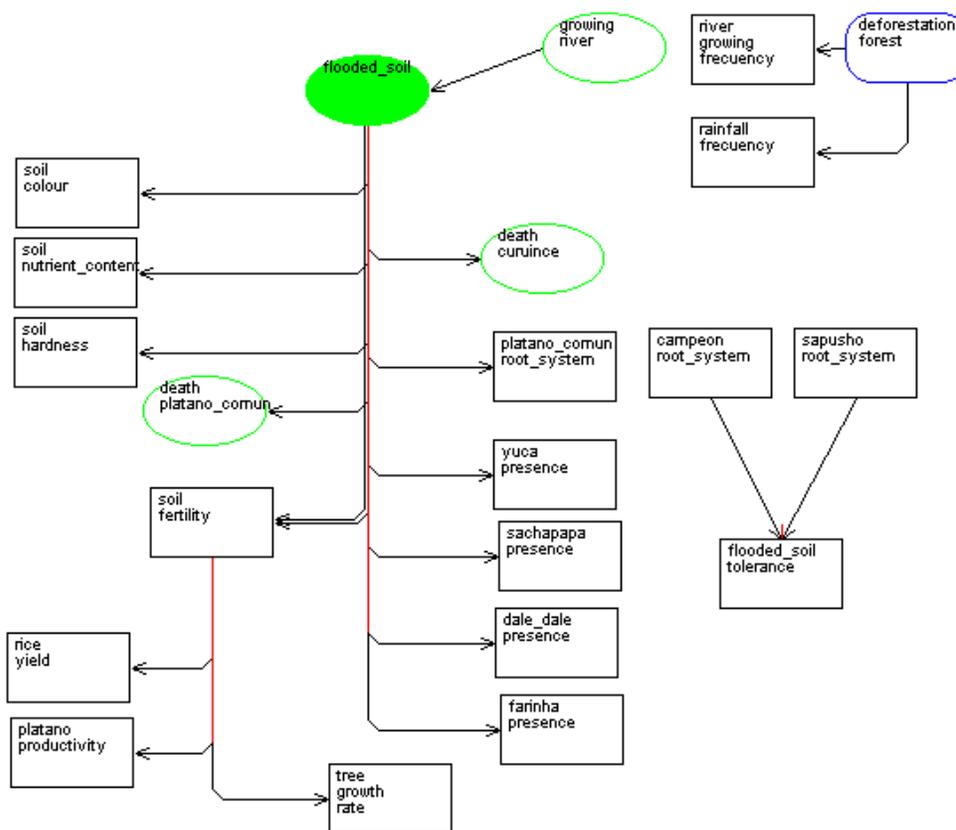


Figure 4. Shipibo farmers’ knowledge about effects of river flooding on crop cultivation.

Table 2. Flood tolerant trees as reported by the Shipibo people:

Fruit trees	Wood trees
Bread Tree (<i>Artcarpus sp.</i>)	Bolaina (<i>Guazuma crinita</i>)
Champion banana (<i>Musa sp.</i>)	Capirona (<i>Capirona decorficans</i>)
Sapucho banana (<i>Musa sp.</i>)	Quinilla (<i>Manikara bidenta</i>)
Mango (<i>Manguifera Indica</i>)	Lupuna (<i>Chorisia sp.</i>)
Camu Camu (<i>Myrccciaria sp.</i>)	Caoba or Mahogany (<i>Swithenia macrophila</i>)
Coco (<i>Cocos nucifera</i>)	Moena (<i>Ocotea sp.</i>)
Poma Rosa (<i>Sysigium jambos</i>)	Cedro or Cedar (<i>Cedrella spp</i>)
	Catahua (<i>Hura crepitans</i>)

However, there was disagreement among local people’s knowledge regarding the the flood tolerance of two fruit species - Caimito (*Pouteria caimito*) and Shimbillo (*Inga sp.*). Literature suggests that only Caimito is tolerant to flooding.

Slashing and burning of existing vegetation is carried out by the Shipibo Conibo people and this was based on the trees and other vegetation in the plots. The ashes from burning are known to enhance soil fertility by adding nutrients. Burning fields also help reduce ant and termite infestation (Fig. 4). The curuince (*Atta cephalotes*), an ant, is a serious pest that defoliates cassava plants and fruit trees only in areas without flooding.

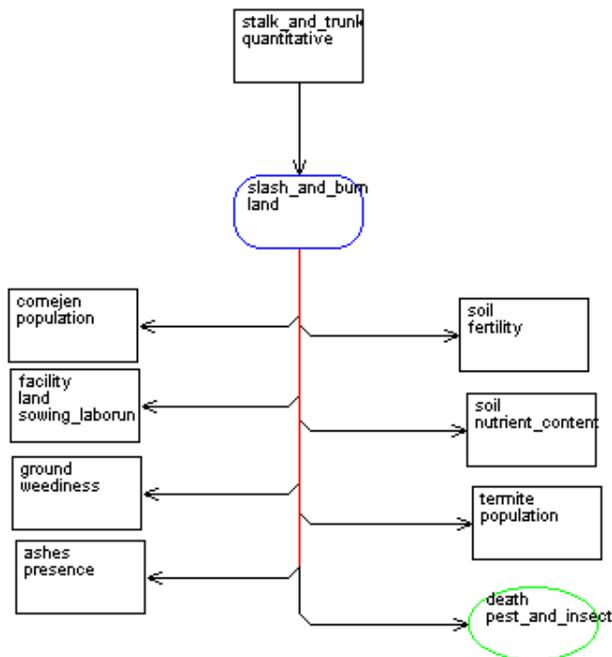


Figure 4. Shipibo people's knowledge about slashing and burning activity and its effects.

Discussion

With the preceding examples about LEK regarding soil erosion and conservation among farmers in south Sumatra and LEK about soil and plant management among Shipibo people in Ucayali in Peru farmers, the nature and type of LEK among rural people become clear. These confirm observations from elsewhere that local people often have a sophisticated understanding of such natural resource management issues, based largely upon their own observations. While notions of the description, classification and fertility of soils are heavily localized, underlying explanations of interactive processes can be generalized - although local knowledge tends to be both aggregated and limited by the methods of observation available to farmers. This implies that although LEK may be specific to the soil and crop types within a locality, the underlying explanatory knowledge and the underlying principles may be open to wider extrapolation.

Whilst studying local knowledge may be interesting in itself, the LEK research reported here and others at ICRAF have been driven by development imperatives. A key criticism, from anthropological quarters, of the knowledge-based-systems approach advocated here is that it seeks local knowledge on a utilitarian basis (Sinclair and Walker, 1999). Indeed, a key criterion for the inclusion of items in a knowledge base is that they are useful, in as much as they could conceivably be used, in some form of reasoning process, to answer a question about the subject of the knowledge base. The usefulness of local knowledge in natural resource management can be viewed from three aspects: building on local practice, recognizing the sophistication of local knowledge and realizing its limitations.

In some circumstances, interventions that build on local practice to improve soil management will stand a far higher chance of adoption by local farmers than entirely new technologies. Local solutions also tend to be far less costly and risky than external introductions. Indeed, it is often through understanding why farmers are not already employing locally known techniques for more sustainable soil use that we are able to identify

key constraints within the system. In the case study from Indonesia, it is obvious that non-technical issues, such as land tenure and market price of commodities, play a key role in adoption of soil conservation measures by farmers. Farmers often take actions that they know compromise sustainability, because they trade the negative impacts off against either the positive gains from the practice or the costs of taking alternative courses of action.

It is also possible that local practices exist that can be built upon to address farmers' needs. For example, jungle rubber research in Indonesia identified the local practice known as *sisipan*, which involves rejuvenating rubber plots by gap replanting, instead of by slashing, burning and replanting at the whole-field level (Joshi *et al.*, 2003). Encouraging this practice could have important impacts on sustainability, with respect to the maintenance of soil fertility, biodiversity and watershed functions over the extensive area (in Sumatra and northern Borneo) covered by jungle rubber - estimated to be around 3 million ha (Gouyon *et al.*, 1993). It was evident that, as with many smallholder farming practices, use of *sisipan* was a response contingent upon specific circumstances (such as a lack of capital and the risk posed by vertebrate pests in new plantations) rather than a one-off decision. So, a farmer might interplant new rubber seedlings in a mature jungle rubber stand for some years (*sisipan*) until he or she has sufficient resources to opt for the slash-and-burn technique. The key to making gap-replanting a more attractive option to farmers than slash and burn lies in improving the productivity of the gap-rejuvenated rubber. This requires a method for establishing high-yielding rubber clones in the shaded and competitive environment of a gap in a mature jungle rubber stand. The initiative of ICRAF is an example of how local knowledge systems can be explored and then combined with scientific research to generate a sustainable technology built on local practice (Joshi *et al.*, 2003).

The existence of reasonably sophisticated local explanations about ecological processes also has profound implications for what research should be considered relevant to farmers. Where farmers have a detailed understanding of soil erosion and fertility increasing or reducing processes, fundamental research undertaken on mechanisms of interaction will clearly be perceived as relevant by farmers and thus will be easier to communicate to them. A common but pertinent observation in a number of soil related investigation about local knowledge number of studies is the local peoples' relatively poor knowledge about belowground interactions.

There is an erroneous assumption that adaptive research is more relevant to farmers than more fundamental research. That the opposite may be true is suggested by mounting evidence of both a high degree of sophistication in the local understanding of interactions and farmer experimentation. Farmers are probably better able than researchers to conduct adaptive research. However, it is difficult for them to tackle more fundamental research issues, because of limits imposed both by the observational techniques available to them and the extent to which they can vary the environment - not least because they have to obtain a living from that environment whilst, at the same time, conducting their research. This realization affects both what type of research is considered useful in support of farmer innovation and the form in which research results are communicated to farmers. Adaptive research tends to lead to prescriptive technology packages, whereas farmers may actually want flexible new knowledge and components that they can adapt to their needs. This requires a shift away from 'extension of prescriptions' towards 'extension of principles'. Enhancing the local knowledge system, through new research identified via analyses of the local knowledge initially held, may build capacity more generally. A richer knowledge system may reduce vulnerability, by ensuring that local communities are better able to cope with any new stresses and problems - including ones that have not been specifically anticipated.

Despite growing interest in, and recognition of, local knowledge in research and development initiatives, it is, however, important not to romanticize it. This is particularly true with respect to soil processes, since it is evident that the observational limits imposed by the

nature of the soil medium results in severe restrictions in terms of what farmers can see and hence understand from their own experience. As in the case of Shipibo communities, their knowledge was less developed, partly because of their very short history of permanent agriculture. This makes scientific knowledge and the research that generates it, a potentially powerful tool for use in assisting farmers to manage natural resources in a sustainable manner. It is clear that there is much that farmers still need to know to improve their livelihoods and that there are significant contributions that science can make.

Effective communication is a prerequisite for effective research and extension of innovations in natural resource management. Observations in many agroecosystems indicate that farmers' knowledge about soils is often localized, in terms of being aggregated, with regard to the soil and crop types found in their vicinity or of particular importance to them. This makes effective communication a far from trivial need, since a one-to-one correspondence is unlikely to exist between scientific terms and the terms used by farmers. Conventionally, rather than learning and using local terminology when communicating with farmers, researchers and extension staff have expected farmers to learn the scientific nomenclature and concepts encapsulated in the recommendations and technology packages extended to them. Respecting local knowledge by taking the trouble to learn about it, can be an important part of developing a productive participatory relationship with a local community, and may help to empower local articulation of research and extension needs, as well as providing the 'tools' for understanding what has been articulated. The recent identification of concepts that are common across large regional domains (such as hot and cool soil concepts) and the existence of similar knowledge in culturally and geographically different places that share agroecological circumstances suggests that learning and using farmer concepts may not be as daunting as it might first appear. The existence of some degree of regularity in farmer knowledge across cultures allows the use of frameworks for knowledge acquisition, thus speeding up the process of gaining familiarity with the knowledge system in new localities.

Research on local ecological knowledge is in an active phase: a key area for investigation is the need to explore how universal farmer knowledge is. A number of studies point to regularities in knowledge across cultures, as in the 'local theories' of soils (Niemeijera and Mazzucato, 2003) and tree fodder evaluation in Nepal and Kenya (Thorne *et al.*, 1999; Roothaert and Franzel, 2001). A more extensive test of the hypothesis that farmers in similar agroecological circumstances develop similar knowledge is required and, if proven, should pave the way for the more general use of local knowledge in developing the research and extension agenda and in communicating with rural people.

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