11 Farmer Knowledge and Scientist Knowledge in Sustainable Agricultural Development: Ontology, Epistemology and Praxis

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Introduction

What comprises local scientific knowledge of traditional or indigenous farmers (FK) and formal global scientific knowledge (SK)? How similar are they? What is 'sustainable' agriculture and what roles should FK and SK play in sustainable agricultural development? Who determines these roles and what effect does the assignment of roles have on the success of development projects? These are some of the questions that we have been asking ourselves and others during our years spent working with farmers and scientists in applied research and development in many locations around the world.

Conventional agriculture is widely acknowledged to be unsustainable, and more sustainable ways of producing food are advocated both for industrial and traditionally based agriculture (Matson et al. 1997; Tilman et al. 2002; Boody et al. 2005). However, sustainable agricultural development is a goal, based on values (see Sillitoe, this volume). It increasingly involves participation of both farmers and scientists, and thus requires an understanding of FK and SK. To respond more effectively to the needs of small-scale farmers in the Third World, we need to discuss openly the values underlying different definitions of sustainability to reach consensus on goals of agricultural development, and the empirical basis of definitions of FK and SK to understand their potential roles in meeting these goals.

FK and SK about the biophysical world are often defined deductively, based on assumptions that follow from the definition of sustainability used in a given programme or project (see Rhoades and Nazarea, this volume). This conflates two realms that are ontologically and epistemologically distinct: (1) sustainable agriculture, which can only be defined as a subjective, value-based goal, and cannot, therefore be objectively verified (although sustainability under a given definition can be evaluated using objective indicators), and (2) FK and SK about the biophysical world, which are not goals, but are concepts about the world which can be objectively verified independently of any definition of sustainable agriculture by comparing them to exogenous systems of rationality (both farmers' and scientists') – descriptions of reality agreed on by farmers and scientists – and by measuring their efficacy in meeting goals (e.g. of 'sustainability') when translated into practice. While some argue that FK and SK cannot be usefully distinguished because together they constitute different aspects of a 'hybrid' knowledge (see Dove et al., and Smith, this volume), we believe that even if FK and SK are part of a larger knowledge system, it is useful to compare them analytically. In this way both similarities and differences can be compared in terms of reference to a common ontological model (Soleri and Cleveland 2005), and differences in knowledge among farmers (Soleri et al. 2002) and among scientists (Cleveland 2001) can be examined. The practical importance of this conflation is that roles of farmers and scientists in development are often determined by the deductive definitions of FK and SK deriving from value-based goals, and not by an understanding of FK and SK based on empirical research. When the roles of farmers and scientists are based on untested assumptions about the nature of FK and SK, the probability of attaining the goal of sustainability, under any given definition, may be significantly reduced. This is especially important because of the growing interest in the potential of FK to make a contribution to agricultural development, both to increase the effectiveness of scientist and farmer research and practice, and to empower farmers.

We focus on small-scale, Third World farmers cultivating in marginal environments, using minimal external inputs, most of whom are poor – hereafter simply 'farmers'. Food production by these farmers is important to meet the growing demand for food (Narayanan and Gulati 2002), even with the expected increase in production in large-scale agriculture in more optimal environments (Heisey and Edmeades 1999). It is estimated that by 2025 three billion people will depend on small-scale Third World agriculture production (Falkenmark 1994: cited in Evans, 1998 #2325; Goklany 2002).

There has been much written about the way in which the concepts and use of local indigenous knowledge and FK held by different people and groups – e.g. NGOs (non-governmental organisations), environmentalists, government organisations, scientists, the media, and indigenous farmers themselves – depend on their social and political positions, especially the misunderstanding of FK by scientists and Westerners in general (e.g., Ellen et al. 2000; Sillitoe 2000; Haverkort et al. 2003). Building on this discussion, we present arguments below that the dominant views of FK and SK, are based, at least in part, on different definitions of sustainable agriculture, and each implies different roles for farmers, natural scientists and social scientists involved in sustainable agricultural development.

Sustainable Agricultural Development: Ontology, Epistemology and Knowledge

Defining and Measuring Sustainable Agriculture

Many agricultural development policies and projects, from the World Bank and the FAO (Food and Agriculture Organization) to the smallest grassroots farmer organisation, are today labelled as 'sustainable'. All these definitions share a common desire for agriculture to 'develop' in a way that is sustainable in the basic sense of not self-destructing over the short term, but beyond this definitions can diverge radically. One inherent difficulty is that sustainability is a goal, a teleological concept that cannot be measured until a subjective, value-based definition has been agreed on (Costanza 2001). This is often not sufficiently recognised, resulting in discussions that do not deal with the basis of disagreement. All of the key components in any definition of sustainable agriculture, including the spatial and temporal boundaries of the system, and which are the 'good' aspects to be kept and the 'bad' to be eliminated, are subjective judgements (c.f. Thompson 1995).

Confusion about these basic ontological and epistemological aspects of sustainable agriculture abound. For example, an examination of sustainable agriculture in Zimbabwe asserted that a definition of sustainable agriculture was impossible, but then used objective indicators to measure sustainability (Campbell et al. 1997). However, the indicators chosen, including crop yield and soil organic matter, imply a definition of sustainability, and the authors' conclusion that indicators of sustainability are always inadequate may result in part from the failure to define sustainability in the first place. In addition, their claim that objective biophysical criteria for sustainable agriculture are impossible to define because they are overwhelmed by social and political changes external to them, could be addressed by including social and economic as well as environmental criteria in the definition.

Sustainable agriculture, and sustainable development in general, are often conceived of as having three main components: economic, environmental and social (e.g., Goodland 1995; Costanza 2001). However, one of these components is often emphasised over the other two, as illustrated in Table 11.1. Each of these emphases is based on contrasting underlying assumptions about the human carrying capacity of the Earth and the components of human impact (population size, consumption levels, and the technology used to produce what is consumed) (Daily and Ehrlich 1992). In addition, there are important assumptions about some of the major variables that affect the components of human impact: natural resources, human nature and markets (Costanza 2001).

Table 11.1 Definitions of sustainable agriculture with different emphases, and the assumptions they are based on.

	Environmental emphasis	Social emphasis	Economic emphasis
		Definitions of sustainability	
Sustainability components	*Conserving natural environment* (ecocentric), to provide resources for people (anthropocentric). Focus on natural capital.	*Social justice, empowerment of* indigenous peoples, women, minorities. Focus on social (moral) and human capital; fair distribution.	*Continuous growth of economy* to provide wealth for future generations. Focus on economic (human-made) capital; allocative efficiency.
		Assumptions	
Human carrying capacity	Surpassed (or will be soon)	Best dealt with later	No limit (in near future), can be increased for a very long time.
Human *population* size	Needs to be *controlled*	Not the *major problem*	*Not a problem*
Consumption	Depends on population size, must be reduced	Inequity is main problem	Must increase
Technology	Must be more efficient, less impact on environment	Must be more equity of access	Can be improved to increase human carrying capacity
Natural resources	Complementary; finite physical (*source and sink*) *limits to supply*.	Unequal distribution major problem	Substitutable; demand and technology drive supply
Human nature	Concern for environment	Concern for others	Concern for self
Markets	Can't value natural resources; destroy environment. Must define limits ecologically. Low discount rate on future value.	Can't value social good; destroy community. Need redistribution to address inequity. Low discount rate on future value.	Translate self-interest into social good. Trickle down to address inequity. High discount rate on future value.

When agreement on a subjective definition of sustainable agriculture is reached among a group of people (explicitly or implicitly), then indicators of sustainability can be generated, and the degree to which a given component of a specific agricultural system, including practices and knowledge (FK and SK), is sustainable can be objectively assessed. However, the choice of indicators will also necessarily be influenced by values, meaning that while measuring sustainability can be done more objectively than defining sustainability, measuring sustainability can never be completely objective, just as no knowledge of objective reality can ever be completely objective.

Knowledge and Sustainable Agriculture

The belief that indigenous knowledge is critical for sustainability has been spreading for more than two decades. An important milestone in this movement was the incorporation of this concept in the 1992 Convention on Biological Diversity. For example, Article 8(j) calls for signatories to 'respect, preserve and maintain knowledge, innovations and practices of indigenous and local communities embodying traditional lifestyles relevant for the conservation and sustainable use of biological diversity' and to 'encourage the equitable sharing of benefits' arising from the use of same.

Sustainable agriculture is central to sustainable development, and there is much interest in the potential for synergy between SK and FK, one of the central components of the debate over global vs. local knowledge. Farmers whose well-being and way of life is threatened by modern technology opportunistically make use of possibilities offered by modern technology to improve their situation (Cleveland 1998) – or they will no longer be able to remain farmers (see Dove et al., this volume, on hybrid knowledge). They may define their agriculture in ways that include industrial agriculture technologies, in part because it serves their larger goal of maintaining their physical and cultural identity. For example, Zuni indigenous farmers have learned how to use global positioning system (GPS) technology to map their family farm fields, and this has become a powerful force in resolving land disputes that have impeded the revitalisation of their farming system (Cleveland et al. 1995). Farmers' advocates, including many local and international NGOs, are also promoting the inclusion of FK in agricultural development (e.g. Haverkort et al. 2003).

Scientists are also interested in using FK to increase the sustainability of agriculture. Many have suggested that some local lessons can be generalised to the global scale, for example in management of common pool resources such as irrigation water, over which global competition is rapidly increasing (Ostrom et al. 1999). Matson et al. (1997: 508) advocate 'the development of more ecologically designed agricultural systems that reintegrate features of traditional agricultural knowledge and add new ecological knowledge'.

The explicit inclusion of both FK and SK in agricultural development is usually initiated by scientists or development professionals, probably because they are the ones in power. The result is participatory research and development programmes, with the implication that farmers are participating in scientists' applied research and development (Soleri et al. 2002). Multilevel or multistage classifications of participation are common in this kind of research, and tend to emphasise the degree of social and institutional participation of farmers and scientists (e.g., Biggs 1989). Often, the roles of farmers, natural scientists and social scientists appear to be determined by implicit or explicit assumptions about what constitutes FK and SK that derive deductively from the definitions of sustainable agriculture employed, not from empirical understanding of the nature of FK and SK in the contexts involved.

Farmer and Scientist Knowledge in Sustainable Agriculture Development

The most prominent views of the nature of FK and SK and their roles in development reflect those of the wider discussion of local or indigenous knowledge and modern, global science. These views tend to be based on unexamined, often value-based assumptions about the nature of these knowledges. Most can be classified into three broad categories based on definition of FK (Table 11.2): the economically rational farmer, the socioculturally rational farmer, and the ecologically rational farmer. Blaikie et al. (1997) propose a classification of local knowledge in natural resource development in which their 'classical' corresponds roughly to our 'economically irrational' view of farmers (not included in our Table 11.2, but see brief discussion below), 'neoliberal' to our 'economically rational', and 'neopopulist' to our 'socioculturally rational' and 'ecologically rational'. A fourth view, held by a minority, is one which we term the complex farmer. In the following sections we briefly describe these views of FK and the correlated views of SK, suggesting how each is based at least in part on a different definition of sustainable agriculture, and how each implies different roles for farmers, natural scientists and social scientists involved in sustainable agricultural development (Table 11.2).

The Economically Rational Farmer

Until after the Second World War a view of farmers as economically irrational dominated Western ideas of Third World agricultural development. As research on farmers increased, in part in an effort to understand their 'irrational' response to development, this assumption was replaced by the view that farmers are economically rational, but limited environmentally socially, and economically. Today farmers' 'behaviour may often seem irrational to Western economists who have little comprehension of the precarious nature of subsistence living and the importance of avoiding risks' (Todaro 1994: 282). As a widely-used textbook on economic development states:

Table 11.2 Definitions of sustainable agriculture, farmer knowledge (FK), and scientist knowledge (SK) in relationship to the roles of actors in agricultural development.

View of farmer based on sustainable agriculture definitions	Definitions			Roles		
	Sustainable agriculture	**FK**	**SK**	**Farmers**	**Natural scientists**	**Social scientists**
1. Economically rational	Economic emphasis; monolithic model of unilineal progress towards modern agriculture; absorb FK into SK, local farmers into global economy	Economically rational but 'primitive', theoretically limited	More rational, theoretically more powerful	Integrate into modern agriculture (or eliminate)	Develop improved technologies	Convince farmers to adopt modern technologies; train and direct farmers to participate
2. Socioculturally rational	Sociocultural emphasis; farmers gain local autonomy to renaturalise nature	Natural, organic, contextual, a 'skill', atheoretical	Reductionist, destructive of nature, theoretically ignorant of FK	Continue indigenous farming	None	Help farmers in struggle against hegemony of SK
3. Ecologically rational	Ecological emphasis; environmental FK and/or SK can increase sustainability of agriculture	Ecologically rational, descriptive and discriminatory, codifiable, may be generalisable	(a) Ecologically less accurate, more destructive, or (b) Ecologically more accurate, less destructive	Develop more ecologically rational farming	(a) Learn ecological principles from farmers, or (b) Provide resources and expertise to improve farmer practice	Catalogue and disseminate FK
4. Complex	Holistic emphasis; new, syncretic forms of knowledge, collaboration in practice	Complex: intuitive, empirical, theoretical; more informal	Complex: intuitive, empirical, theoretical; more formal	Investigate and integrate scientists' approach	Investigate and integrate farmers' approach	Investigate farmer and natural scientist knowledge, facilitate communication

> in spite of the relative backwardness of production technologies ... the fact remains that given the static nature of the peasants' environment, the uncertainties that surround them, the need to meet minimum survival levels of output, and the rigid social institutions into which they are locked, most peasants behave in an economically rational manner when confronted with alternative opportunities. (Todaro 1994: 305)

The rational farmer viewpoint that dominates mainstream agricultural development today is based on a unilineal theory of development, the highest level of which is the modern industrial state which enjoys mass consumption and other 'blessings and choices opened up by the march of compound interest' (Rostow 1971: 6). Agriculture is specialised and totally commercial, 'no different in concept or operation from large industrial enterprises' (Todaro 1994: 310).

Definition of sustainable agriculture. The definition of sustainable agriculture that characterises this view of farmers emphasises economics, and modern, technologically complex, high-input agriculture. For example, a fundamental assumption often made by genetically engineered (GE) crop advocates is that Third World agriculture is 'primitive' and that the major goal of agricultural development is ultimately to replace it with modern industrial agriculture, including genetically engineered crop varieties, incorporating farmers into the global seed system dominated by private companies (DeVries and Toenniessen 2001; Conway 2003).

Economic growth is a key component of sustainable agriculture, and the emphasis is on increasing the slope of total factor productivity, or output through time (Lynam and Herdt 1992), often based on modern crop varieties that are highly responsive to increased inputs such as irrigation and manufactured fertilisers and pesticides (Cleveland 2001). For example, a report on a development project in Senegal concluded that, 'If farmers are given better access to information, rice technologies, inputs and decision making, rice production on irrigated land in West Africa may leap forward rapidly as potential production gains are still large' (Haefele et al. 2002).

Population growth is taken as exogenous, and since sustainable agriculture must feed a growing population, it equates with 'sustainable growth' (Lynam and Herdt 1992: 211). The time period for measuring sustainability must be short enough to make a projection with low probability of error, i.e. less than twenty years, and the spatial scale must be limited, i.e. the farming system in a specific location, since higher organisational levels cannot be adequately defined. Environmental sustainability is subordinate to economic growth, e.g. the adoption of agro-ecological technologies is seen as dependent on whether farmers view them as increasing profit or welfare, and therefore will only be useful if they 'complement the continued use of inputs in the intensification of farming systems' (Lynam and Herdt 1992: 215).

Definition of farmer and scientist knowledge. This view of the rational farmer developed within economics in the 1960s in reaction to the view that farmers are

'irrational' or 'primitive'. The economists Boserup (1965) and Schultz (1964) published important books citing evidence to support their claims that farmers are capable of responding in economically rational ways to forces generated by the market place and population pressure.

Even as definitions of farmers' economic rationality continue to be refined, the underlying assumption remains that farmers attempt to maximise their individual utilities, making decisions in the same way that any business person would, if they have the same information and opportunities (Hardaker et al. 1997). Thus, seemingly irrational behaviour can be understood as the result of the constraint of 'partial engagement in ... markets which are often imperfect or incomplete' (Ellis 1993: 13). Agricultural modernisation and development is cast in terms of improving markets, prices, technology or education to remove constraints on farmers' potentially economically rational behaviour that will lead them down the path to modern agriculture (Todaro 1994). It also focuses on replacing inferior FK with superior SK, as for example in a participatory plant-breeding project in Mexico, which attempted to teach farmers basic maize reproductive biology and selection techniques, assuming that in-field plant selection will be more efficient than the traditional method of selection of ears post-harvest (CIMMYT 2000). Often, the only FK considered worth researching is knowledge received from outsiders, as in an irrigation project in Senegal that documented farmers' knowledge of production practices recommended by the government irrigation and extension authority (Haefele et al. 2002).

Roles in agricultural development. Farmers' roles are passive – they are expected to give up their primitive ideas and methods and to adopt modern farming methods, or to get out of farming altogether. However, farmers may be considered to be 'only dimly aware of the potential benefits of improved germplasm and crop management practices', and lack the education and skills needed to manage modern crop varieties 'properly' (Aquino 1998: 249). Outsiders facilitate the replacement or modernisation of small-scale farmers, including replacement of their crop varieties with modern ones (Srivastava and Jaffee 1993). This is the dominant theme, for example, among both private companies and international agencies promoting GE crop varieties for Third World farmers, such as the Rockefeller Foundation policy for GE crops, which is similar to its policy for the Green Revolution (Conway 2003). Small-scale farms in the Third World are considered inferior and transitory, but requiring modernisation in the short run to keep people from migrating to cities (Hazell 2004). They need time to become educated enough to leave 'unproductive' farming behind.

The Socioculturally Rational Farmer

In part a response to the economic rationality viewpoint, the 'socioculturally rational farmer' perspective rejects the assumption that SK is always superior to FK, and that unilineal, market-driven agriculture development can be sustainable. Instead it emphasises the social and political relations believed to be implicit in conventional agricultural development, and proposes alternatives based on what proponents perceive to be the social and cultural perspectives of the farmers themselves.

Definition of sustainable agriculture. Definitions of sustainable agriculture emphasising social aspects and equity are often associated with a view of farmer knowledge as natural, organic, contextual, and skill rather than theory. These definitions often include the assumption that modern agriculture is inherently unsustainable, and indigenous agriculture inherently sustainable. Like the economically rational view, and in contrast to the ecologically rational view, this view does not emphasise environmental limits and the need to limit human impact.

Definition of farmer and scientist knowledge. This viewpoint proposes that FK and SK are – often fundamentally – different, and that FK is more sustainable because it is more 'natural', 'organic' and 'holistic' than SK, and farmers may be considered to be inherently conservators of their environment and their crop production resources (e.g., Escobar 1999). The difference in knowledge is based on an 'enormous epistemological difference' between 'peasants' whose thought is 'inherently holistic and dependent on identifying things in terms of their relationships to larger wholes' and that of the modern Western world which is 'inherently atomistic and reductionist, defining identity in terms of the thing itself and not in relation to the context of which the thing is part'(Taussig 1977: 150). Much of the discussion of knowledge systems and development is cast in modern vs. postmodern/premodern terms, emphasising FK and SK as fundamentally different, which often means that there can be no constructive combination of the two, and we are forced to choose between them.

There is often an assumption that knowledge is more socially than environmentally constructed, and the unique localness of FK is emphasised. For example, 'All traditional knowledge systems use different paradigms, which manifest themselves in the knowledge of everyday life ...' (Haverkort et al. 2003: 36). Fairhead and Leach's study of West African farmers' management of their forest-savannah vegetation and soils concludes that they 'enrich' the landscape by converting savannah into 'forest islands', while providing themselves a relatively good living, and that local 'specificities' are most important (1996). They see this as a stark contrast to the 'reading' of development professionals who are allied with existing power structures, and see the landscape as degraded into patchy savannah from a pre-existing pristine forest by destructive land use. Fairhead and Leach link this 'reading' with functionalist equilibrium 'cultural ecology' models that they say are based on inadequate and outdated ecological theory and embedded in a Western science epistemology that decouples 'natural and social phenomena'.

One prominent approach that supports the socioculturally rational farmer view is the relativist, utilitarian tradition of ethnobiology or folk biology, proposing that local knowledge is unique and depends on the goals, theories and beliefs of the local people (Medin and Atran 1999: 6). As Berlin notes, the utilitarian tradition is often dominated by economic concerns, or descriptions of uses, and this continues to be a strong tradition in economic botany and zoology (Berlin 1992).

While the utilitarian approach in ethnobiology often emphasises the usefulness of SK as an aid in describing FK, a more extreme version of the socioculturally rational view sees attempts to explain farmers' knowledge and practice in scientific terms as impeding true appreciation of their knowledge (see Selener 1997: 175–76), with the implication that there is no ontological basis for comparison. Therefore, FK is relegated to a black box that can only be described by outside ethnographers, and it is not considered valid to investigate the relationship of FK to external reality or to SK, or the way it is generated. 'Culture' becomes an entity that is 'assimilated in something of the same way a body warms to the sun' (Medin and Atran 1999: 6). For example, Ingold rejects knowledge as economic rationality (embodied for him in evolutionary psychology) and knowledge as ecological rationality (embodied for him in evolutionary ecology) and advocates knowledge as acquired through performance, or 'enskillment', which seems to imply that farmers acquire knowledge through direct experience and contact with nature, rather than explicitly (e.g., Ingold 1996). Richards applies these assumptions to farmers' cropping patterns and sees each farmer's crop mixture as a 'completed performance' which can only be interpreted by 'reconstructing the sequence of events in time', because he declares that it is 'not the outcome of a prior body of "indigenous technical knowledge"' and 'much of it should be judged and valued not by the standards of scientific analysis, but as self-help therapy' (Richards 1993: 67, 70).

Roles in agricultural development. The farmers' role in sustainable agriculture in this view is often to continue their practices based on their traditional or indigenous knowledge. The 'proper' role for outsiders is empowerment of local people, and they 'must choose between being facilitators for local autonomy ... by brokering the preservation and application of knowledge systems that contribute to rehumanization and re-naturalization of nature ..., or be agents of hegemonic "progress"' (Purcell 1998: 267). Yet some who see universal, reductionist SK and local, holistic indigenous knowledge as fundamentally different, do see them sharing analogous processes and practices at a deeper level, and advocate debate between the two (e.g., Watson-Verran and Turnbull 1995).

The Ecologically Rational Farmer

The ecologically rational farmer view sees FK as ecologically rational, emphasising its descriptive and discriminatory value. However, while FK is often considered codifiable, and, therefore, to some extent generalisable, it is not generally regarded as theoretical.

Definition of sustainable agriculture. The ecologically rational farmer view gives the definition of sustainable agriculture an environmental emphasis. Like the socioculturally rational farmer viewpoint, it rejects the assumption that unilineal, market-driven agriculture development can be sustainable. This view, in contrast to the previous ones, often emphasises natural limits to growth, and the need to limit human impact through greater understanding of ecological principles to improve management.

Definition of farmer and scientist knowledge. In contrast to the socioculturally rational farmer viewpoint, and similar to the economic rationality viewpoint, the ecologically rational viewpoint sees no fundamental differences in FK and SK, because the 'subject matter' of agriculture is common to them both, and 'may be of much more importance than are the social and cultural contexts' (Sumberg and Okali 1997: 150). Sometimes this view explicitly contrasts farmers' ecological rationality with ecological irrationality engendered by conventional 'rational choice' economics (Chambers et al. 1989). This view emphasises farmers' accurate and sustainable ecological knowledge of their environments. There are two main variants of the ecologically rational farmer viewpoint. The first assumes that FK is usually superior to SK because farmers have an intimate knowledge of their environments, and seek out and emphasise areas of empirical and epistemological overlap between indigenous farmers and modern agricultural science. This has been critiqued as a 'populist' assumption that ignores the role of experience and intuition in local knowledge (Scoones and Thompson 1993). The second assumes that SK is usually superior to FK because of the greater explanatory power of modern science. It often sees farmers as 'barefoot scientists', whose knowledge needs to be vetted in comparison to the more accurate SK. (See (a) and (b) in row 3 in Table 11.2.)

The first version often sees SK as inferior because it is inextricably associated with capitalist economic assumptions (see Sillitoe, this volume). For example, a study of Zapotec farmers in Mexico suggests they are scientists because they 'hypothesize, they model problems, they experiment, they measure results, and they distribute knowledge ...', even though they 'typically proceed from markedly different premises – that is, from a different conceptual basis', one that is 'culturally incommensurable with those predominating in industrialized societies' (González 2001: 3) (see Smith, this volume, on incommensurability).

The second version suggests to some that the similarity of local and scientific knowledge is due to cognitive human universals as well as predictable regularities in the natural world (Boster 1996). The intellectualist or comparativist tradition in ethnobiology takes this view. It sees categories as recognised rather than culturally constructed because nature herself comprises an independent organised pattern, and there are universals in human cognition, resulting in cross-cultural similarities in the ways in which humans conceive biological organisms (Medin and Atran 1999: 8). It is sometimes assumed that SK can serve as the ontological comparator, or the 'metalanguage in terms of which the folk system can be understood' (Berlin 1992: 201). Some behaviour is seen as influenced by group dynamics at a level at which farmers may not be cognizant, for example in the management of large-scale irrigation systems (Lansing et al. 1998).

Roles in agricultural development. In the first version of this view, the role of outsiders is to understand the extent that FK is compatible with SK, and to support and learn from farmers. For example, participatory plant-breeding projects may focus on improvements based on farmers' crop varieties, with the implicit or explicit assumption that these varieties and FK are locally adapted (Soleri et al. 2002).

In the second version, the role of outsiders is to figure out inadequacies in FK and to remedy them with the application of SK. For example, participatory plant-breeding projects may focus on improvements based on plant breeders' modern crop varieties, with the implicit or explicit assumption that these varieties and SK can be locally adapted and will, therefore, result in more ecologically sustainable development (Soleri et al. 2002). Often outsiders use SK to evaluate FK, as in a study of soil erosion in Burkina Faso, which concluded that farmers have a good knowledge of wind erosion processes, but not of water erosion processes, and are willing to apply new techniques to control erosion, but the main constraints to apply these measures are insufficient knowledge and lack of labour (Visser et al. 2003).

The Complex Farmer

This is the viewpoint we believe is most consistent with the available information on FK and SK. The main difference between the complex farmer viewpoint and the three just described is that it emphasises distinguishing as much as possible value-based from empirically based knowledge, and an inductive approach to understanding FK and SK. This opens up the possibility that FK and SK can be both similar and different, and that either one can be 'better' than the other, depending on the situation and definition of sustainable agriculture.

Definition of sustainable agriculture. Definitions of sustainable agriculture are holistic, including sociocultural, environmental and economic sustainability, and explicitly discuss the empirical and value-based assumptions underpinning the definition.

Definition of farmer and scientist knowledge. An important goal is to understand similarities and differences between local and global scientific knowledges in a practical way. The interest is not only in the extent to which local and global scientific knowledges are similar or different, but also whether one is *better* than the other, not in a metaphysical sense, but in an empirical and practical one – that is, for any specific situation we need to ask 'Which knowledge, SK, FK or a combination of SK and FK, produces the most sustainable agriculture given our definition?' (c.f. Medin and Atran 1999: 12). As Sillitoe states, 'The objective is not to assess the veracity of local ideas against scientific ones, both are relative, but to enrich our overall understanding of environmental interactions within cultural contexts' (Sillitoe 1996: 11).The outcomes can be measured in terms of both farmers' and scientists' goals.

Based on our review of existing research, the general hypothesis on which this view is based is that both FK and SK (1) include knowledge about how reality *ought to be*, based on individual values and goals, and knowledge about how reality *is*, based on observations of external social and biophysical reality; (2) contain knowledge about how reality is that is *localised* and empirical because based on unique local contexts, and *generalised* and theoretical because based on widespread patterns (e.g. due to biological evolution); and (3) are *conscious* and *unconscious*. For example, rather than assuming that FK is tacit and embodied in contrast to SK which is conscious and explicit, the complex farmer view interprets research on FK and SK as showing that both are in important ways both tacit and explicit (Sillitoe, this volume, Chapter 1). As Scoones and Thompson stated it, FK and SK 'are both general and specific, theoretical and practical. Both are value-laden, context-specific and influenced by social relations of power' (1994: 29).

Similarities between SK and FK result from the common biophysical environment experienced by both scientists and farmers, and the biological similarities in physical perception and cognitive function shared by all humans. Differences between SK and FK result from the many unique characteristics of farmers' situations compared with those of scientists, including different growing environments, crop genotypes, cultural values and social organisation. A number of examples of this approach exist, although not necessarily identified explicitly in the terms we use here. They demonstrate a high degree of variability in and between FK and SK, underlain by consistent patterns, providing the basis for complementarity and collaboration.

In northwest Syria, FK and SK of soils and land use potential was compared and found to be complementary, with FK more local and emphasising sociocultural variables, whereas SK was more general and emphasised biophysical variables (Cools et al. 2003). Research on farmers' weather prediction and their use of scientific meteorological information in Burkina Faso found that farmers operate in multiple cognitive frameworks, and are interested in receiving scientific information because they perceive local forecasting methods as becoming less reliable as a result of increasing climate variability. However, there are significant differences between scientific and local forecasts: the former predict total rainfall quantity at a regional scale, whereas the latter stress rainfall duration and distribution and are more attuned to crop–weather interactions and stress the relationship between knowledge and social responsibility (Roncoli et al. 2002). Malawian farmers' taxonomy of cassava varieties based on plant morphology distinguished varieties with no morphological differences between them perceptible to scientists, but whose distinctness was supported by molecular analyses for cyanogenic glucoside levels, and by fine-grained genetic analysis (Mkumbira et al. 2003). It appears that their extensive experience and observations have resulted in FK of cassava plant morphology being more extensive and capable of discriminating at a more subtle level than SK.

Research also shows FK, like SK, to include theory. In reviewing the results of research on subsistence of rainforest peoples, including his own with the Nuaulu of Seram, eastern Indonesia, in terms of their knowledge of nature, Ellen concludes that observations of 'particular instances' (substantive knowledge of many individual species) leads inductively to 'knowledge of general principles', and in knowledge transmission these 'overarching deductive models of how the natural world works are privileged over accumulated inductive knowledge'(Ellen 1999: 106). These models function at a macro-scale as a 'folk synecology', for example in connecting observations at the species level with forest structure and dynamics (Ellen 1999: 107). Wola farmers of New Guinea are aware of the geomorphological forces that both destroy and renew their soil resources, and can use their knowledge of processes to explain future aspects of soil formation (Sillitoe 1996: 135–36). However, unlike scientists, they do not appear to be aware of processes on a geological time scale. There are also similarities and differences between the taxonomic classification of animals by the Wola of New Guinea and Western science (Sillitoe 2003: 62–71). While Sillitoe states that 'identification depends on a fundamentally different approach to classification' (2003: 71), his data suggest that there are also fundamentally similar aspects.

In our recent research we have used scenarios based on basic biological principles to elicit FK (Soleri and Cleveland 2005) of genotype-by-environment interaction, heritability and genetically engineered crops varieties (e.g. Soleri et al. 2002; Soleri et al. 2005). While no truly neutral ontological comparator exists, we chose the basic biological model of genotype–environment relationships, which is universally accepted by biologists, including plant breeders, although they disagree among themselves about its *interpretation* at higher levels of generalisation, for example whether selection in optimal or marginal environments leads to genotypes that are better adapted to marginal environments (Cleveland 2001; Ceccarelli and Grando 2002). This variation in scientists' interpretations suggests that, when farmers do in fact think in terms of the basic model, it can be a valuable comparator, facilitating the consideration of FK and SK on equal grounds.

Overall our results are consistent with the complex farmer view – there are patterns in FK across different crops and countries, and between FK and SK that support the hypothesis that empirical and theoretical FK and SK consistently reflect similar patterns and relationships in reality; but there are also differences among farmers, among scientists, and between FK and SK, and these can often be explained in terms of differences in reality, e.g., in crop varieties, or in cultural values.

Roles in agricultural development. The challenge for scientists and development professionals changes in the complex farmer viewpoint from emphasising a deductive definition of knowledge, to emphasising inductive empirical research to understand the complexities that determine knowledge and practice in a particular situation, in order to promote sustainable agriculture as defined. The role of farmers will then depend on the extent of similarities and differences in FK and SK and the particular problem being addressed (Cleveland and Soleri 2002).

For example, goals in our research are to learn (1) how farmers understand the basic biological model of relationships between plant genotypes and growing environments that determine plant phenotypes including the results of seed selection; (2) how this understanding affects farmers' practices and expectations; (3) how FK of the basic biological model is similar to or different from SK of this model, and (4) how to contribute to collaboration between scientists and farmers to find ways to improve the results of plant breeding in farmers' own terms.

Can a Better Empirical Understanding of Knowledges Enhance Sustainable Agriculture?

If achieving a more sustainable agriculture requires that we develop new, syncretic forms of knowledge and practice, ones based on both modern agricultural SK, as well as the traditionally based FK, then we need to understand more about the nature and functioning of both FK and SK.

Real-world decisions are always based on incomplete knowledge, i.e., they are risky decisions (Hardaker et al. 1997). But decisions have to be made – and we should try to improve the likelihood that we are making the 'right' decisions by distinguishing between goals about the way things ought to be, in the form of definitions of sustainable agriculture, and empirical understanding of the way things are, in the form of increased understanding of FK and SK. We propose that distinguishing the different ontological natures of sustainability and knowledge could increase our ability to debate explicitly stated definitions of sustainable agriculture in terms of values, and the empirical nature of SK and FK in terms of data and hypothesis testing. In this way SK and FK are more likely to be successful tools for achieving whatever vision of sustainable agriculture we may agree on.

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