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ORIGINAL PAPER

Ethnosciences—A step towards the integration of scientific and indigenous forms of knowledge in the management of natural resources for the future

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Abstract Integration of indigenous knowledge and ethnoscientific approaches into contemporary frameworks for conservation and sustainable management of natural resources will become increasingly important in policies on an international and national level, both in countries that are industrialised and those that have a developing status. We set the scene on how this can be done by exploring the key conditions and dimensions of a dialogue between 'ontologies' and the roles, which ethnosciences could play in this process. First, the roles of ethnosciences in the context of sustainable development were analysed, placing emphasis on the implications arising when western sciences aspire to relate to indigenous forms of knowledge. Secondly, the contributions of ethnosciences to such an 'inter-ontological dialogue' were explored, based on an ethnoecological study of the encounter of sciences and indigenous knowledge in the Andes of Bolivia, and reviewed experiences from mangrove systems in Kenya, India and Sri Lanka, and from case-studies in other ecosystems world-wide, incl. Australia, Burkina Faso, Ecuador, Ethiopia, Guatemala, Indonesia, Nepal, Niger, Philippines, Senegal, South-Africa and Tanzania.

Keywords Ethnobiology · Ethnoecology · Interdisciplinarity · Transdisciplinarity · Indigenous knowledge · Ontology · Epistemology · Latin-America · Africa · Asia · Oceania

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Introduction

By the end of the 1980s the World Commission on Environment and Development, (1987) defined sustainable development in terms of ''meeting the needs of the present without compromising the ability of future generations to meet their own needs''. It gave rise to the 'age of sustainable development', which in 1992 became a globally shared goal for development.

In 2002 at the World Summit on Sustainable Development (WSSD) held in Johannesburg the participants stated that progress made in sustainable development is rather ambiguous. On the one hand wider social consciousness of the need for sustainable development has proved to be a slow and time-consuming process, and main indicators for it show that the situation today is worse than it was 10 years ago, especially with regard to the pollution of air, water and soil, and resource consumption, as well as poverty and north–south income disparity. On the other hand some progress has been made with regard to the Agenda 21 issues; reduced population growth, slowed mortality rate, increased access to health and education and the role of women strengthened (Hens & Nath, 2003:12).

A major challenge for the implementation of the concept of sustainable development is its essentially normative character. It defines what to aim for without saying how to do it in specific social, ecological, economic, cultural or historical situations. In order to make the concept operative it must be translated into a set of new action-guiding ethical values by individuals and groups (Wiesmann, 1998). Through this, sustainable development brings into play a highly complex, broad range of often contradicting actors, structures, institutions, norms and values. They constitute the arena in which the normative principles of sustainable development have to be translated into new ways of producing and reproducing natural, material, human, social, and cultural resources. Such a broader view on sustainable development contributed to overcome the initially dominating emphasis on the protection of natural resources, mainly based on a specific combination of ethical values associated to the idea of intrinsic values of nature and the application of bio-ecological sciences and corresponding technologies. Although it is highly productive to organise sustainable development on the basis of the recognition of the intrinsic values of nature it does not guarantee that this concept finds societal consensus when concrete issues of development are at stake (Kellert, 1997). This means to accept that not all groups do share the intrinsic values of nature, which is especially true for those who have the interests, power and/or resources for acting against the corresponding principles.

As a consequence, overexploitation, conservation or sustainable use of natural resources have to be understood as ecological expressions of specific, socially and politically defined institutions, norms, values and structures (Pretty, 2003; Veeman & Politiylo, 2003). The evaluation of a certain system of natural resources e.g. the green revolution or a 'traditional' one cannot be based only on assessing their direct ecological, economic or social impacts, yet their real significance is based on conceptual and not merely technological foundations (Dove & Kammen, 1997).

This 'societal' interpretation led to an understanding of sustainable development as a result of social and political negotiation and learning processes between the main actors involved (Leeuwis, 2000). However, taking account of the central position of 'future generations' in the definition of sustainable development brings

into play a normative element, which is directly related to a specific concept of the 'nature' of humans and the relations through which they interact. This in turn leads to the nature of knowledge, its origin, foundations, limits and validity (=epistemology). Considering the needs of future generations is only meaningful when the conception of humans goes beyond a merely ego-centric and materialist understanding of life and living beings. This implies recognition that without a specific view on the world, which allows the establishment of a meaningful—and thus action guiding—relationship between humans, society and nature, sustainable development will remain literally without sense. This means social interaction cannot be understood only in terms of a negotiation-based and ego-centric optimisation of utilities. In such a view the questions on how to consider the widely unknown interest of physically and socially not yet present 'future generations' in a negotiation process of ego-centric oriented actors will be almost impossible to answer in a satisfactory manner. It is therefore not surprising that many initiatives in the field of sustainable development relate implicitly or explicitly to a concept of humans which—while not ignoring ego-centric or strategic action by principle—takes account also of the capabilities of humans for 'communicative' action (in the sense of Habermas' theory of communicative action) embracing an important resource for societal transformation beyond mere aggregation of individual preferences (Röling, 2002).

Relating the notion of sustainable development with 'future generations' does not only imply a certain understanding of social actors, and interaction, but also means to put forward the question of adequate understanding with regard to space, time and scales. Which are the adequate definitions of space, time and scales for assessing the impacts of the current forms of social and economic organisation and how many 'future generations' should be taken into account? Where will they live? These are becoming concrete questions, which have to be answered in order to operationalise the principles of sustainable development in concrete actions of today. In such a view the modernist, technocratic view of sustainable development has been replaced by a new vision of the world in which the authority of science and technology is increasingly questioned and more emphasis is placed on cultural diversity (Redclift, 1993).

Sustainable development therefore requires the definition of basic concepts on what humans, social relations, society, nature, space and time are, and the determination of the relations through which they are interrelated. Consequently, the discourse of sustainability is related to a specific, socially constructed and culturally shaped theory on the nature of basic subjects related to sustainable development. Considering the importance of cultural diversity in the definition of concrete actions aiming at the implementation of sustainable development means to recognise that this can only be achieved as far as it is based on a shared theory of 'how things are'. Such a 'theory on how things are' is considered an ontology referring to a theory of every type of objects, concrete and abstract, existent and non-existent, real and ideal, independent and dependent (Poli, 1996).

Linking the concept of ontology with the principles of sustainability means that the ontology of sustainable development must be conceived as a product of social negotiation and collective learning between the stakeholders involved. Although it might seem a rather ambitious undertaking to consider an ontology of sustainable development, it is necessary to consider that ... *our ontological choices are consequential, determining analytical points of entry, arenas of theory and praxis, and normative positioning.* (Goodman, 2001:182). The relevance of such a viewpoint

becomes evident when considering that the allegedly 'more practical' issues of 'green revolution' or 'traditional' management of natural resources e.g. by Dayak people in South East Asia are underpinned by specific ontological assumptions that are defining the specific contents of what humans, society and nature are. The theories of objects are thus involved in delimiting the scope, direction and rationality for defining what natural resources are and how they have to be used (Dove & Kammen, 1997; Yapa, 1993).

Although the importance of science in the pursuit of sustainable development is widely recognised, its role in and its relationship with society is currently undergoing a critical examination.

Many scientists are calling for a 'new social contract' between science and the public based on mutual commitments to jointly approach the most pressing problems of today. Thereby the need for finding a balance between social equity, poverty reduction and other societal and environmental challenges must be based on reciprocal participation in decision making of societal and scientific actors (Strigl, 2003: 269ff.). Instead of claiming independence from societal interests, research for sustainable development calls for a definition of its role, use and further development as part of societal and not scientific defined goals (Hirsch Hadorn, 2002). Although research for sustainable development makes clear differences in regard to other academia based approaches to investigation it is not aspiring to replace the latter. Discipline-orientated and specialised research has to fulfil a function within sustainable development. Nevertheless, the orientation and importance of disciplinary research in comparison to inter- or trans-disciplinary approaches must remain open to societal debate.

A clear expression of this attitude is Agenda 21 (1992). In this worldwide agreement on sustainable development in 1992, chapter 35 states that current research should be broadened to include, on the one hand, more involvement of the public in defining long-term societal goals and formulating sustainable development scenarios, and on the other hand to develop methods for linking the findings of established sciences with indigenous knowledge.

The principles of Agenda 21 reveal that sustainable development requires a conceptual differentiation that is able to meaningfully articulate scientific and indigenous forms of knowledge. Taking account of the need to define the ontological foundations of sustainable development based on social negotiation and collective learning processes this poses the question of how such an 'inter-ontological' dialogue could be operationalised in concrete interfaces of development.

The present paper's objective is therefore to explore the key conditions and dimensions of such a dialogue between 'ontologies' and the roles which ethnosciences could play in it. In a first step the role of ethnosciences in the context of sustainable development will be further analysed, placing emphasis on the implications arising when sciences aspire to relate to indigenous forms of knowledge. In a second step the contributions of ethnosciences to such an 'inter-ontological dialogue' will be explored, based on an ethnoecological study of the encounter of sciences and indigenous knowledge in the Andes of Bolivia. This will be complemented by other case-studies, among which are those in the current special issue on 'Bridging the gap between natural resources and their human management for the future using ethnosciences' (Dahdouh-Guebas, 2006).

Science, sustainable development and the role of ethnosciences

Sustainable development in general and sustainable management of natural resources in particular have to draw on a broad range of knowledge, which embraces 'western scientific knowledge' as well as 'traditional scientific knowledge', e.g. indigenous or local forms of knowledge. Unfortunately, traditional scientific knowledge is sometimes referred to as 'non-scientific knowledge', but throughout this paper we adopt the meaning as quoted above. However, for the sake of simplification we refer to 'scientific knowledge' and 'traditional knowledge' hereafter—each a form of knowledge which, in our opinion, can be scientific in nature. In contrast to scientific knowledge, indigenous knowledge is holistic, functional[1] and adaptive to changes in social and natural environment, and it has been transmitted for many thousands of generations. This challenges those forms of natural resource management, which are based on disaggregating knowledge into specialised disciplines and specialisations. However, it is not the mere fact of this integration of knowledge which is challenged; the critical aspects are related to the questions on who is setting the issues for a particular disciplinary research agenda and how the findings should be re-integrated in function of a societal process oriented in the principles of sustainable development. As a consequence, the roles of conventional scientific knowledge production in the context of societal processes are put under public scrutiny.

A first reaction to the societal demands for a disciplinary mode of scientific knowledge production is an interdisciplinary approach. Although still based on a disciplinary vision of knowledge it seeks to coordinate the objectives and methodologies in order to achieve a less fragmented view on environmental issues, e.g. as currently happening in research on climate change (Norgaard, 2004). Although interdisciplinarity allows the integration of natural and social sciences and humanities, the definition of the issues to be addressed and the corresponding 'theories of objects' or ontological foundations essentially remain within the academic community. Through this, the problems of a lack of societal participation in issue-setting and its application to concrete development goals are almost the same as in the case of disciplinary-based knowledge production.

The term 'interdisciplinarity' has often been abused by research groups or journal publishers who use the term as the combination of different sciences *within* a science field (particularly within the exact sciences), or to the compilation of different science disciplines without true interaction or integration. We would like to emphasize the need for interdisciplinarity between basic and applied sciences on the one hand, and social and human sciences on the other, which can be termed 'interscientific interdisciplinarity' (i.e. scientific interdisciplinarity that transcends the science fields). Sometimes it is referred to as '(scientific) transdisciplinarity', but may cause confusion with earlier definitions of this term.

In fact, the second more comprehensive reaction to the societal claims about a disciplinary based knowledge production is the 'transdisciplinary approach'. By increasing the scope and the number of interactions of knowledge production it

[1] 'functional classification' of organisms as opposed to the systematic Linnean classification in western biological science : e.g. to some indigenous communities it is more functional to closely relate edible and non-edible or venomous organisms (plants, fish, etc...) and therefore categorise and name them in a similar way, than to follow a classification based on Linnean taxa.

seeks to go beyond the boundaries of western scientific actors and has thus become a key feature of sustainability research (Hirsch Hadorn, 2002). Transdisciplinarity aims for a shift from disciplinary-based scientific to a more societal mode of knowledge production by integrating everything that is between, across and beyond disciplines (Nicolescu, 1996). Transdisciplinarity therefore includes 'interscientific interdisciplinarity' (its scientific branch), but also traditional forms of knowledge.

Transdisciplinary approaches to research are thus essentially based on a societal issue setting and the building of bridges between natural, social sciences and humanities as a basis for integrating scientific as well as traditional forms of knowledge and actors (Hurni & Wiesmann, 2004). This societal mode of knowledge production is the logical cementation of a fundamental fact not sufficiently taken into account by the scientific community for a long time. Western science came to be defined as a universal, autonomous, value-free knowledge system, but its imposition without proper attention to local knowledge and wisdom has led to considerable disappointment.

Indigenous knowledge has often been dismissed as unsystematic and incapable of meeting rapid economic growth needs of the modern world. Historically, modern societies have regarded indigenous people and traditions as less progressive, and as a result many groups of indigenous peoples, especially their younger generations, are influenced to devalue their native cultures and to adopt new lifestyles and technologies. Consequently, indigenous knowledge systems have not been captured and stored in a systematic way and are therefore facing extinction. The lust for modernity and new technologies are threatening the loss of a great store of knowledge held by native people. A good number of indigenous groups have suffered from long-term discrimination, inequity and exclusion from the planning and execution of development programmes and projects (Van Camp, pers. comm, International Conference on Indigenous Knowledge Systems, 21–23 November 2005, Brussels, Belgium).

Although science has been very successful, it has always been—and will always remain—part and parcel of the 'social processes' that bring actors, institutions and nature into specific, culturally shaped and historically evolving relations (Norgaard, 1994).

Transdisciplinarity takes into account that science is part of the processes it describes and is therefore focussing on a systemic view of social and 'natural' dynamics that are shaping the world. It also recognises the plurality of forms of knowledge, world views and the ethical values connected to them within different social and cultural groups (Scholz, Häberli, Bill, & Welti, 2000). A major challenge for transdisciplinarity therefore consists in finding ways of encouraging a dialogue and cooperation between heterogeneous groups of social actors with different forms of knowledge, instead of imposing a single, internally thoroughly coherent view of the world through a hegemonic discourse that silences all other discourses, by positioning itself 'outside' the issues to be addressed.

We believe that it is precisely in this regard where 'ethnosciences' could play an important role in advancing transdisciplinarity and sustainable development. By ethnoscience we understand according to Atran (1991: 650) a scientific realm which aims to understand how humans—in spite of their fragmented and limited interactions with the world—are developing different forms of knowledge and beliefs. This allows an understanding of how humans vary their knowledge and beliefs within different ecological and historical contexts in order to express the

manifold possibilities offered by human cultures. More concretely, ethnosciences are referring to the set of concepts, prepositions, and theories that are unique to each particular culture group in the world (Meehan, 1980). Ethnosciences are essentially cross-disciplinary, based on increased collaboration between social sciences and humanities (anthropology, sociology, history of science, psychology, philosophy) with natural sciences such as biology, ecology, agronomy, climatology, astronomy, or medicine. At the same time ethnosciences are increasingly transdisciplinary in their nature (Ingold, 2000). Integrating ethnosciences into societal modes of knowledge production allows to systematically take account of the cultural—and therefore also ontological—differences and similarities of the forms of knowledge of the actors involved in specific issues of sustainable development. Hence ethnosciences allow the exploration of the dimensions and boundaries of the arena in which an inter-ontological dialogue would be possible.

How to relate scientific and 'local' forms of knowledge?

As shown above a central issue related to science and sustainable development concerns the links between scientific, local or indigenous forms of knowledge. For a proper definition of such a relationship it is necessary to examine the corresponding choices. The debate in science about its relation to local knowledge is not new: since the beginning of the Enlightenment, the natural—and to a lesser extent—social sciences have always understood their 'mission' as a conscious and critical revision of 'local knowledge', often considered superstitious or romantic. It is therefore not surprising that the relationship between science and other forms of knowledge is often reduced to an evaluation of the coherence and consistency between the two forms of knowledge in question, with science making a hegemonic claim to truth. However, as Table 1 shows this is not the only possible relationship in the eyes of local communities.

The typology reveals that an intercultural perspective is the most adequate way of relating different forms of knowledge because it encompasses the highest potentials for cooperation based on mutual respect maintaining the autonomy of the different processes of knowledge production. Suggesting an intercultural relationship between different forms of knowledge raises three major issues that need to be addressed:

First, the comparison between the different attitudes reveals that the relation between science and local knowledge depends on specific ethical positions. No relation between science and local knowledge can thus be 'value-free' making it impossible to define something like an 'objective' or 'science-based' relationship.

Secondly, an intercultural perspective implies the establishment of the broadest possible field of interaction between different types of knowledge. This means that the interrelationship must be based on a process of deliberation that should at least involve the interrelated dimensions of practice, values and worldviews. Another necessary condition is the agreement on fundamental ethical principles before embarking on intercultural dialogue. The main one is the will to communicate, which can be formulated as: ''*I accept the possibility that the other may be right*''. An intercultural relation means to shift from competition and the imposition of uniformity to the search of complementarities and cooperation between different forms of cultural knowledge aiming for mutual learning and adaptation in the light of obtaining new insights rather than just confirming existing ones. The drawbacks of

Table 1 Typology of science's relations to local and indigenous forms of knowledge (based on Dahdouh-Guebas, Ahimbisibwe, Van Moll, & Koedam, 2003; Rist, Zimmermann, & Wiesmann, 2004)

Attitude of science towards local knowledge	Characteristics	Examples
Unacknowledging	Science simply ignores a practice based on local knowledge	Veterinary research does not investigate the effects of a ritual to prevent mouth and foot disease in the Andes
Utilitarian	Elements of local knowledge that can be scientifically understood or validated are accepted to increase the stock of scientific knowledge	Aspirin is based on a local practice developed in 'Antiquity' by the Egyptians (using dried myrtle leaves) and the Greeks (with willow bark), unaware of its active ingredient (salicylic acid)
Paternalistic	Traditional knowledge is conceived of as a starting point that requires 'updating' by science	Indigenous field crops are modified through genetic engineering and traditional livestock breeding is 'blended' with 'modern' technologies
Neo-colonial	Traditional knowledge and local data are taken from local people and research institutions	Scientific studies are carried out in developing countries by researchers from industrialised countries without collaboration at the publication level
Essentialist	Local knowledge is fundamentally better than science, it should not be influenced by Western technology and should have the right to remain as is	'Going native', rejection of potential contributions from science; focus on preserving local knowledge in its 'pure form'
Intercultural	Science is aware that it is only one type of knowledge among others, and that knowledge is always embedded in cultural and historical settings. Science and local knowledge can benefit from comprehensive interaction	Development of complementary medicine and health care systems; clarification of interactions that have not (yet) been explained by science (e.g. homeopathy, traditional healing)

non-acknowledgment, arbitrariness and paternalism presented in the typology can only be overcome by founding the relationship between different types of knowledge on an intercultural basis.

The third issue relates to the fact that real intercultural communication is more likely to happen when the parties involved do have shared questions on fundamental aspects related to the form of knowledge they represent. Consequently, the identification of such questions of common interest is turning out to be an important condition for the establishment of a dialogue between different forms of knowledge.

Ethnoecology and sustainable management of natural resources

A most prominent field of ethnosciences is the ethnobiology that is often almost identical with what is defined as ethnoecology. Benthall (1993) defines ethnobiology as a new branch of science which brings together two important areas of human

knowledge—ethnology, the study of cultures, and biology, the study of life. Gragson and Blount (1999) define ethnoecology quite similarly as the study of the interactions between organisms (plants, animals, biodiversity) and the physical, biological and human factors to which they are related. Although we are aware that some authors consider that ethnobiology comprises ethnoecology (just like ecology falls under biology), due to the similarities in the above definitions, for the purpose of the following discussion we consider ethnoecology and ethnobiology as interchangeable. We refer to Martin (2001) for a comprehensive overview of the history and definition of the above terms.

Ethnobiology is thus based on an interdisciplinary study of the relationships of plants and animals with human cultures, including past and present relationships between peoples and the environment. Ethnosciences encompass ethnobotany (Cunningham, 2001; Martin, 2004; Minnis, 2000), ethnozoology, palaeoethnobotany, zooethnoarchaeology, ethnoecology (Nazarea, 1999), ethnoagronomy (Altieri, 1993), ethnoforestry (Pandey, 1998), ethnopedology (WinklerPrins & Sandor, 2003), and other related areas such as ethnoclimatology (Orlove, Chiang, & Cane, 2002), ethnoastronomy (Fabianm, 2001), ethnomedicine (Nichter, 1992), or ethnopharmacology and nutrition (Pieroni & Price, 2005); also in mathematics (D'Ambrosio, 1999; Huylebrouck, 2005) or chemistry (Pedersen, 2000) 'ethno approaches' are becoming available.

Many ethnobiological researches are carried out in non-western countries and they are characterised by the adoption of an interdisciplinary starting point taking into account the social and cultural embeddedness of knowledge, technologies and practices inherent to natural resource management. Instead of disaggregating the practices found in the life worlds of farmers, traders, craftsmen or shamans and packing them into the highly specialised disciplines of ecology, agronomy, forestry, botany, medicine etc. the ethno-approaches are adopting a more comprehensive view focussing on social practices in order to reveal the underlying cultural dimensions (Atran, 1991; Nazarea, 1999; Posey & Plenderleith, 2002; WinklerPrins & Barrera-Bassols, 2004).

Ethnoecology allows the exploration ways to overcome disciplinary views on natural resources by building bridges between aspects normally studied separately by natural and social sciences or humanities. Gragson and Blount (1999) consider that a key difference between ecology and ethnoecology is the point of reference from which an explanation is derived. While in the first case the explanation is given by a scientifically informed analyst, in the case of ethnoecology the explanation derives from people belonging to diverse cultures, actively participating and intervening in relationships defining a particular system. Through this the ethno-approaches offer an interesting entry point to the study of the manifold human–nature relationships at the basis of many environmental conflicts. Ethnoecology also allows the unfolding of the 'theories of objects' or the ontological assumptions of scientific as well as traditional forms of knowledge. Through this, ethnoecology sheds light on the specific background against which 'nature' is perceived defining the ground of what is defined as 'natural resources' and the ways through which they have to be managed (Wiesmann, 1998). From this perspective ethnoecology permits to keep in touch with 'concrete' aspects of natural resource management without ignoring the related more general social, cultural and cognitive aspects. Ethnoecology provides a conceptual tool for a more comprehensive understanding of the arenas, actors, forms of knowledge and the corresponding ontological and eventually

existing epistemological foundations which have to be taken into account in the search for more sustainable management of natural resources.

Although the starting points of ethnosciences are at local to regional levels—due to the rapidly growing interdependencies with the factors of global change—they are also highly relevant for analysing global tendencies. Ethnoecology allows the demonstration of how new communication, transport or other technologies as well as unequal distribution of resources, power and opportunities affect the patterns of action, orientation and interpretation of local actors; furthermore it allows us to trace back to the norms, values and aspirations of indigenous and other marginalised people. Ethnoecology also gives evidence about 'local' counter-notions of globalisation which are derived from their own 'cosmocentric'—and therefore more than global views of life—allowing them to participate in the worldwide debates on the kind of globalisation which should be envisaged in view of sustainable development (Toledo, 2001). In light of this, ethnosciences are helping to correct the widely accepted but mainly unjustified assumption according to which indigenous knowledge represents a mere locally based collection of an empirically generated body of experiences impossible to relate to current tendencies of global change. In reality, the use of ethnosciences is invaluable in helping the understanding and explaining of past ecosystem processes and human–environment interactions for the natural scientists (e.g. Dahdouh-Guebas et al., 2005). However, ethnosciences show that rather than lacking a global dimension, local knowledge refers to a different ontological background against which global phenomena are interpreted.

It is important to underline that the claim for a better relationship between scientific and traditional 'local' knowledge is not only relevant for a sustainable resource management in southern or eastern societies where indigenous people represent an important share of the population. Also in northern or 'western' societies there is a growing acceptance that currently available alternatives for sustainable development are often based on 'local' forms of knowledge initially developed outside conventional sciences. Clear examples are organic and biodynamic farming (Conford, 2001; Kloppenburg, 1991) or the emerging field of agroastronomy (Vogt et al., 2002; Zürcher & Cantiani, 1998). These 'alternative' forms of knowledge are based on recently generated experiences, often linked to specific social movements searching to overcome the present limitations of science-based processes of knowledge production. The case of organic agriculture can be considered as an example on how scientific, expert and different forms of 'local' knowledge are interplaying in the sense of a societal process of knowledge production that today represents the most advanced translation of the principles of sustainability into the agri-food system (Rist, 2003).

At a global level the relevance of 'indigenous' and 'local' forms of knowledge for sustainable development has been widely demonstrated mainly in regard to natural resources management, e.g. biodiversity (Maffi, 2001), water (Cremers, Ooijevaar, & Boelens, 2005), soils (WinklerPrins, 1999) and retrospection and prediction on ecosystem changes (Dahdouh-Guebas, Mathenge, Kairo, & Koedam, 2000; Kovacs, 2000; Dahdouh-Guebas, Van Pottelbergh, Kairo, Cannicci, & Koedam, 2004; Dahdouh-Guebas et al., 2005). But it is important to emphasize that the practical relevance of ethnoecology for sustainable resource management also consists in pointing out specific forms of social organisation which are compatible with the social principles underlying sustainable development e.g. community-based regulations of access, distribution and use of natural resources, considering changing

contexts and needs in the perspective of adaptive and learning-oriented reasoning (Armitage, 2005; Rist, Delgado, & Wiesmann, 2003).

The manifold 'alternative' approaches to knowledge production aim at linking sciences with local communities of 'practitioners'. They seek to jointly develop alternative ways of farming, foresting or healing, based on empirical and theoretical knowledge, only partially recognised by main-stream sciences.

Against this background we identify four aspects justifying a particularly high importance of ethnoecology for the search for more sustainable management of natural resources:

First, ethnoecology gives concrete conceptual and methodological insights on how to envisage inter- and transdisciplinary research in the field of natural resources.

Secondly, ethnoecology makes explicit norms, values, experiences and associated specific competences of users of natural resources in 'traditional' (e.g. peasants) as well as in 'modern' (e.g. organic farmers) societies. By showing the dimensions of valuation of 'nature' ethnoecology shows how 'natural resources' are socially constructed and also allows the elucidation of the factors acting on this process. This allows a better grasp of the underlying principles of a steadily growing number of examples showing highly significant contributions of local and indigenous forms of knowledge to a more sustainable management of natural resources.

Thirdly, ethnoecology helps to make it clear that the knowledge of local people does have notions of 'globality' which are based on their own cultural background and that they expect to participate with them in current discourses on globalisation and sustainable development.

Fourthly, ethnoecology allows to creation of solid ground for better linking practices, orientations and patterns of interpretation in an intercultural perspective. Instead of competition and hegemony the relationship between different forms of knowledge is based on respect, complementarity and cooperation. Cultural diversity rather than being an obstacle becomes a fundamental resource for joint knowledge production, considering that the participants involved in the dialogue represent specific ontological foundations related to 'nature', humans and society and the relationships through which they are interacting.

Ethnoecology as a steppingstone for an ontological dialogue between natural science and Andean cosmovision

In this section we will explore how ethnoecology can help to identify continuities and discontinuities between natural science and indigenous knowledge. The following example is part of an initiative, carried out by the Agroecology Programme University of Cochabamba (AGRUCO), Bolivia and the Swiss Development Agency. The main objective is the establishment of an intercultural dialogue and the cooperation between a science-based academic institution and indigenous Aymara communities in order to identify elements for a theory and practice for jointly defining adequate levels of integration of scientific and indigenous forms of knowledge as a contribution to sustainable development (Rist, San Martín, & Tapia, 1999). In other words, ethnoecology served as a steppingstone for engaging in a societal mode of knowledge production based on the principles of transdisciplinarity and sustainable development.

Ethnoecology in Andean communities

Ethnoecological research helped to reveal how the specific ecological knowledge and practices of the indigenous people are underpinned and shaped by the specific forms through which they conceive nature, space, time, human and non-human (spiritual) beings and their mutual relationships (Delgado, 2002; Rist, 2002; San Martin, 1997). This Andean concept of the man–nature relationship becomes visible when considering the interpretations and actions taken in Aymara communities after having being affected by a hail fall. Hail is a quite common 'natural' event that can cause great damage in main food crops such as potatoes. Hail is understood as a 'sign' of 'Pachamama' (earth's mother) telling people that there was a violent shedding of blood in their community. For that reason the authorities in charge of maintaining the relationship between beings of the human and spiritual community are visiting every house in order to identify the persons responsible for it. Once identified the implicated persons they have to participate in a series of rituals aiming to appease the rage of 'Pachamama' (Van den Berg, 1990). The Andean point of view clearly expresses the idea that nature is an intelligible entity that is involved in relating human behaviour with 'natural' processes e.g. hail formation (see Table 2).

Andean people in the highlands of Bolivia perceive life as a continuously changing interplay of social, spiritual and natural-material aspects. Humans, on the basis of their social, cognitive and emotional capacities, are participating in a spiritual world that is directly linked to social life and natural-material processes. The spiritual sphere of life becomes the main connecting element of the other domains of the life. Through this the physical space transforms into a 'living landscape' in which human beings, animals, plants and spiritual beings coexist. Time has a cyclical notion, which maintains that life, seasons, stars and planets, historic periods or natural resources are constantly moving on their cyclical way between the different spheres of existence. Such a pattern of interpretation is based on the assumption that 'nature', in the shape of 'Pachamama', 'talks' to people related with her (Rist, 2002). Nature becomes thus meaningful and intelligible: Instead through 'words', the communication happens through 'signs of Pachamama'. This helps to assess the current state of the interplay between the three basic spheres of life, which are the material, the social, and the spiritual spheres. The relationship between humans and nature is thus showing a clear notion of co-evolution between the material, social and spiritual domains of life (Delgado & Ponce, 2003). It is noteworthy that the Andean worldview is not finalist nor deterministic yet there is no concept suggesting that 'Pachamama' obliges people to behave or evolve in a preconceived direction. Thus the relationship is based on communication rather than on determination. The search for protection from hail-storms is therefore seen as a moral challenge. This brings into play a theory referring to 'how things are', which can be considered as an 'Andean ontology'. Such an 'ethno-ontology' admits the possibility of a relationship between mind, man and matter (van den Berg & Schiffers, 1992).

Although such an ethno-ontological interpretation of hail is helpful, it is necessary to be aware of its social constitution. While action-guiding values, and norms are quite present in the discourses of Aymara people the underlying theoretical knowledge—in the sense of explicitly elaborated concepts can be only partly perceived by the members of the communities. Nevertheless, it is important to highlight that there is growing evidence that people of Andean communities are engaged in elaborating something like elements for an 'Andean ontology'. An increasingly

Table 2 Ways of interpreting hail in the Andean and the natural science perspectives (adapted from van den Berg, 1990; Malberg, 2002)

Natural science based view	Andean view
Explanation: Hail is created in cumulonimbus cloud formations at 5000–7000 m asl. Precipitation particles of comparable weight are transported upwards, sometimes repeatedly, by updrafts. They collect super-cooled water in the process, freeze, and then fall from the clouds as hailstones. A hailstone 3 cm in diameter hits the ground with a speed of 100 km/hr and can cause great damage...	*Explanation:* ''Mother Earth produces as a function of how humans treat her. If we treat her well, there will be good harvests and protection for everyone. If we treat her badly, natural disasters will occur and the harvest will suffer or may even disappear...''
Hail seldom occurs over very widespread areas. It is a typically local event that is very difficult to predict	''Where blood is shed violently, there will be hail...Together with those responsible, we must perform rituals to appease Pachamama...''
Interpretation: Explanation is concerned above all with the question on how hail formation occurs*. Interpretation is reductionistically bound to a disciplinary view of natural processes, perceived to happen independently from human behaviour (unpredictability); explicitly empiricist-materialist explanation, non-intelligible from a man–nature relationship point of view	*Interpretation:* Explanation is concerned above all with the question why hail falls in a specific place and situation. Interpretation is holistic relating to an integrated whole including nature, human beings and society; explanation based on the assumption of a meaningful intelligible man–nature relationship

*'how' and 'why' may be synonyms to natural sciences communities

reflexive treatment of their own history, identity, religiosity, culture and the socio-economic and ecological context in which they evolve is playing a major role in it (Delgado, 2002; Loayza, 1996; Ticona, 2000; Wachtel, 1990). Among these components of an 'Andean ontology' the peasants are giving great attention to the relationship between mind, man and matter e.g. expressed as the inquiry on whether rituals, moral behaviour or other symbolic practices can directly influence natural and social processes (Rist, 2002).

Ethnoecology of sciences

The ethnoecological findings on hail were fed back to the communities as part of the intercultural dialogue they maintain since many years with the University of Cochabamba. This provided a space to ask the question on the ethnoecology of the scientific interpretation of hail. Hail is an issue for natural sciences and is explaining it as a climatologic phenomena based on causality (Malberg, 2002). It forms part of an ontology of 'modern sciences' which according to Guttenplan (1994: 76) refers to a *world [that] seems to consist of such things as particles, atoms and molecules governed by laws, and it is this orderly and increasingly complex arrangement of energetic matter that gives shape to the world we experience. One science – physics – studies the physics of energetic matter at the most basic level, and it is for this reason that the scientific worldview is often called 'physicalism'. Other sciences – from chemistry to biology – attempt to unravel the laws that govern more complex configurations up to, and including, the organisms that have populated this planet.* Such a view assumes independence of 'natural laws' from human behaviour (details see Table 2). Natural processes are conceived of as non-intelligible, meaning that they are based on causality and are thus independent from any human, social or spiritual

category of 'meaningfulness'. Consequently, besides referring to unpredictability, to the Andean communities natural science can give no further answer to the question on why hail might have fallen in a particular place, time and situation. To natural science communities, however, the 'why' is explained by a logical series of explanations from physical, chemical, and other disciplines. In the natural sciences view, protection against hail is understood as protecting human beings from the external forces of nature.

Taking a look at the ontological foundation of ethnoecology itself helps to further clarify the arena configured by the encounter of indigenous and scientific forms of knowledge. Ethnoecology, which forms part of cognitive anthropology, represents a 'dualist ontology' according to which ... *persons can neither know nor act upon their environment directly, but only indirectly through the medium of their cultural representations. This supposition rests upon a cognitivist account of perception whose roots lie deep in the western dualist world view* (Ingold. 1992:40).

The example of the encounter of natural science with the vision of Aymara communities revealed fundamental ontological similarities and differences. Both can agree on the existence of three main realms of life, which can be called a social, material and spiritual sphere of the world (see Fig. 1). The main differences are based on the basic assumptions about the ontological quality of, and the relationship between a material, social and spiritual domain of life. Such a point of view makes clear why it is so difficult or impossible to come to a consensus in concrete issues i.e. in regard to the exploitation or conservation of biodiversity, the use of renewable or non-renewable energies or the role of markets within the wider society: Finally the basic values leading to privilege a certain stance in regard to these questions are pointing to the underlying ontological assumptions.

The indigenous visions of the Aymara clearly suggest a direct relation between the spiritual domain of life with social and natural processes. Social and material life is perceived as a kind of 'materialisation' of spiritual phenomena—not necessarily based on causality—in the domains of social and material spheres. This view is also characteristic to many other indigenous cultures in Africa, East Asia and also in the case of biodynamic farmers in Western countries (see for other similar examples Haverkort, van 't Hooft, & Hiemstra, 2003) and can thus be considered as a more general feature of approaches for resource management organised on cognitive foundations beyond materialist or dualist understandings of life.

From the point of view of sciences the two most prominent stances are the materialist and dualist one. On the one hand a materialist ontology suggests that ultimately processes belonging to the material sphere of the world determine all phenomena related to the social and spiritual domains of life. On the other hand dualist views perceive social and cultural manifestations as unconnected from the 'laws of nature'. Mind is considered to belong to a subjective sphere of human existence rejecting the possibility of the human consciousness to know whether there is or not any direct connection between mind, body and matter. In regard to Fig. 1 this means to pose the question whether social or material life are perceived as closely related to the wider domain of spiritual life or whether the social and spiritual sphere are determined by the central domain of the material sphere.

Ethnoecology, although based on a specific—dualist—worldview, allows the description of the worldview of the Aymara Indians (or other indigenous groups) which is neither materialist nor dualist. However, ethnoecology leaves indigenous people alone when they start to ask themselves about the 'reality' of their own

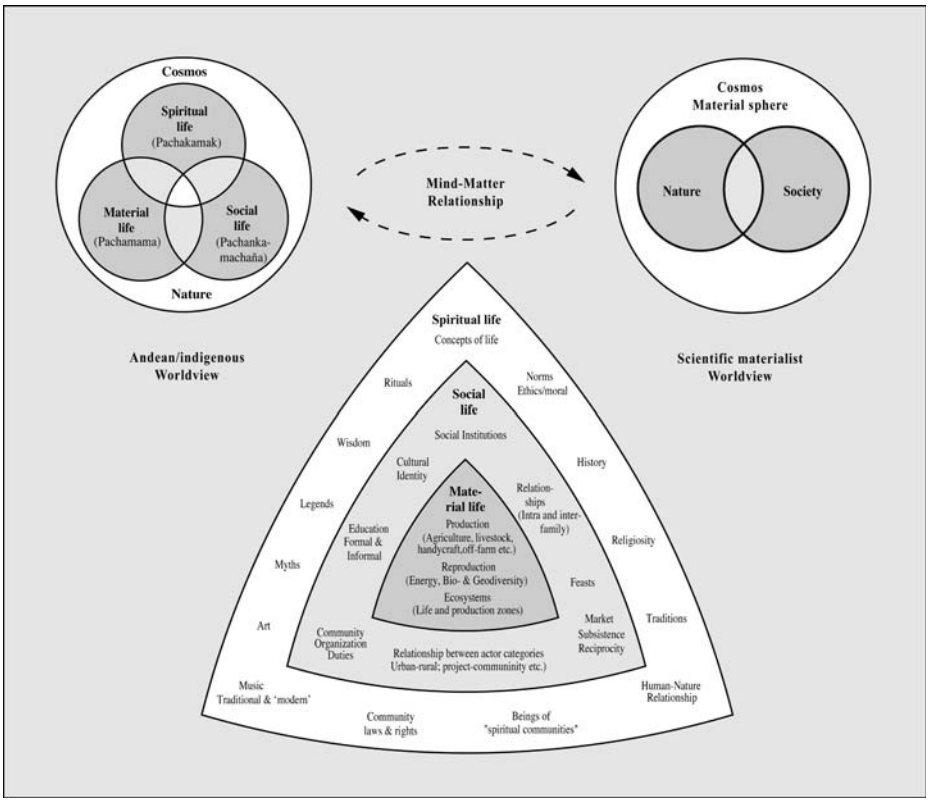

Fig. 1 Ethnoscientific comparison of key features of an indigenous (here Aymara) and scientific (natural science based) materialist 'theory of objects' (ontology). It shows that the most important difference relates to the 'ontological quality' of mind and matter: While the materialist position stands for a 'monism of matter', the indigenous position rather represents a 'monism of mind'. An intercultural dialogue between representatives of the scientific and indigenous community means therefore to engage in a dialogue between different 'ontological communities'. Exchanging knowledge and experiences rooted in different ontologies aiming for intersubjectively revise and further explore practical and theoretical aspects related to the mind–matter relationship is therefore a central element of the dialogue of ontological communities. This means that a dialogue on any aspect related to the material sphere of life (e.g. agriculture, ecology), social sphere of life (e.g. economic relations, social organisation) or spiritual sphere of life (e.g. concept of life, religiosity) must be carried out considering the close relationship—always more or less explicit—between the practical, moral, epistemological and ontological dimensions of knowledge

ontology on mind, body and matter: While the materialist and dualist points of view are basing their forms of knowledge in an ontological answer, the indigenous people seem to suggest to organise the dialogue between the three different 'ontological communities' involved, in a question about the relation between mind, body and matter.

In such a view it becomes evident that a dialogue between different ontological communities that takes the premises of interculturality seriously, should be based on re-formulating the materialist and dualist ontological answers in terms of possible stances in regard to a commonly shared, not yet definitively answered common question, which puts in the centre of the debates a hypothesis of a mind–matter

interrelationship. This would allow for all three parties to critically revise own and other experiences, views and taken-for-granted-knowledge in the perspective of joint and societal-based process of searching an answer to the hypothesis of a mind–matter relationship and the consequences rising from this for a concept of life and the implications this would have for the kind of development to be envisaged.

This means that the encounter of social and natural sciences with indigenous knowledge configures an interface of three different ontologies.

Ethnosciences case-studies bridging the gap between natural resources and their human management for the future

In this Special Issue of *Environment, Development and Sustainability* Byg, Vormisto, and Balslev (2006) trace back how ecological and material characteristics are influencing local definitions of 'use' of palm species in indigenous and mixed groups of migrants in South-Eastern Ecuador. Their study shows that although the use of palms was strongly correlated to abundance, local perceptions of palm availability did not correspond to palm abundance as measured through science, nor did people's use of palms seem to be related to their notions of the abundance of different species. This puzzling finding points to culturally shaped differences in regard to space and scales used for assessing whether a resource is rare or abundant. This points to the importance of considering ontological dimensions—expressed in local perceptions of space and scales—before engaging in conservation or development projects. Only through this inter-ontological dialogue may unnecessary misunderstandings and conflicts based on different views and perceptions of environmental resources be avoided.

Price and Björensen Gurung (2006) present an interesting comparison of ethnoentomological knowledge as emerging within a 'modernised' green revolution based rice-farming systems in the Philippines and more subsistence oriented 'traditional' rice farming in Nepal. The work unfolds a panorama of different forms of local knowledge on insects on the part of farmers and scientists. While in both cases farmers showed to have difficulties in identifying the metamorphosis of insects, their understanding coincided with an inversion of the Linnaean system of insect classification. Instead of privileging morphology as the main taxonomic criterion, farmers from Nepal and the Philippines give priority to a taxonomy which described the impacts on crops and ecological interrelations (habitats/food sources). In the context of the farmer field schools these ontological differences can be brought into a fruitful dialogue, where science rather than being the provider of truth, contributes to a process of mutual learning in search for more sustainable use of natural resources.

The work of Cocks, Bangay, Wiersum, and Dold (2006) concentrates on the role of woody resources for household cultural artefacts in non-traditional communities of South Africa. It argues that the emphasis on the immediate utilitarian values of wild resources for rural livelihoods tends to overlook their cultural values. The work shows that culture and gender-specific cultural artefacts of *amaXhosa* people in South Africa are persisting in rapidly modernizing peri-urban communities. This points to the need to critically revise conventional theories of modernisation. Valuing biodiversity must therefore go beyond the evaluation of wild plant's market prices by taking account of the affective needs of the users such as belongingness and identity. This means that the persistence and revitalisation of 'traditional' practices

rather than being ''stagnation in the traditional past'', is part of a broader strategy aiming at the conservation of biocultural diversity in a dynamic sense.

The paper of German, Alemu, Kidane, and Shemdoe (2006) presents an overview of unanticipated spin-offs from the introduction of trees into existing smallholder farming systems in mountainous regions of Ethiopia and Tanzania. A participatory landscape assessment identifies the drying of water resources and decreased crop yields as negative impacts of expert-driven and indigenous agroforestry practices. The resulting dialogue between an ecological and indigenous ontology of trees and their specific uses gave place to an innovative methodology for identifying niche incompatibilities in agroforestry which takes into account the critical importance of local knowledge in forming solutions that are appropriate to contemporary realities.

The contribution of Wezel and Lykke (2006) demonstrates the 'living quality' of local knowledge on woody vegetation in Burkina Faso, Niger, and Senegal. Instead of being passed in an unreflected manner from one generation to another, local knowledge is constantly co-evolving with changing natural and socio-economic conditions. The consideration of local knowledge on woody vegetation from more than just a few villages, allowed the constructive re-addressing of the doubts regarding the reliability of local perceptions, sometimes associated with the integration of scientific and local knowledge in the sustainable use of natural resources. This permits the generation of crucial information for insightful priorities for assisted regeneration, reforestation and conservation strategies in Sahelian West Africa. In this view building development strategies on indigenous knowledge represents an incentive for local people for maintaining this knowledge alive. Additionally this provides an important source for the enhancement of mutual learning between representatives of scientific and local forms of knowledge.

Edwards and Heinrich (2006) focus on redressing cultural erosion and ecological decline in a far North Queensland Aboriginal community. A novel answer to invert the loss of traditional environmental knowledge, usually transmitted orally, is analysed. Instead of a conventional ethnoecological study, the researchers orientated their work towards the question of how the complexity of biological knowledge from within the scientific and the aboriginal ontologies can be represented and integrated in such a way that it can be of use to scientists *and* local people. As a consequence, learning and two-way exchange of knowledge are becoming central parts of interdisciplinary action research initiatives. The resulting process of co-production of knowledge replaces the search for hegemony of one knowledge system over the other for the benefit of a relationship that seeks to emphasis complementarities. Further more, the participatory construction of a computer-based database on the aboriginal ecological knowledge allowed a guarantee of the intellectual property rights of the communities involved.

The paper of Jayatissa, Hettiarachchi, and Dahdouh-Guebas (2006) analyses the importance of ethnobotanical knowledge in the search of alternative uses of the Mangrove apple, which had expanded due to the negative impacts of new irrigation systems in an important centre of lagoon fisheries. Based on ethnobotanical studies the researchers engaged in the development of ice cream and fruit drinks based on improved transformations of the pulp of Mangrove apple fruits. The collaborative approach between local people and researchers increased the economic interests in maintaining and protecting mangrove ecosystems. This contributes to making sustainable management of these ecosystems more profitable.

In many cases the link between scientists and local inhabitants is weak and policy decision-makers are biased to what field rangers or scientists claim. This has lead to socio-economic and ethical problems. There are other examples from mangrove areas that illustrate this. One case-study illustrated the consequences of imposing a ban on mangrove cutting without providing alternatives to the local people. Dahdouh-Guebas et al. (2000) illustrated how the stricter policy in Kenya aimed at forest regeneration drove the local inhabitants into hardship (Fig. 2). When such bans are put into place alternatives to mangrove cutting should be investigated by the government, but very often policy is restricted to what is not allowed. In the absence of alternatives provided by the government, Omodei Zorini, Contini, Jiddawi, Ochiewo, Shunula, and Cannicci (2004) investigated in the same area how desirable a series of alternatives (e.g. productive coconut, vegetable crops, dairy cows, etc...) would be in terms of relevant socio-economic and ecologic criteria (e.g. speed and variability of income and yield, work effort, environmental impact). Their multi-criteria analyses revealed plausible alternatives to mangrove cutting. The essence of this Kenyan case is that without taking into account local people's dependency on a natural resource that has become threatened, management of the resource (with as sole objective the conservation of the natural resource and

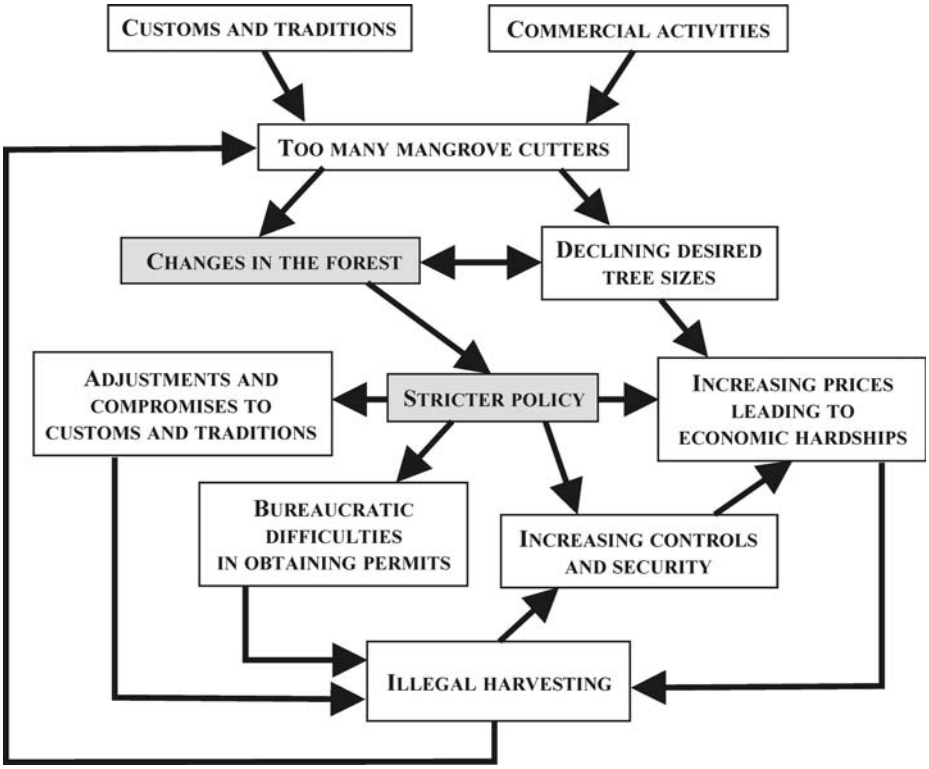

Fig. 2 Consequences of a ban on mangrove cutting that was put into place to preserve the mangrove in Kenya (adopted from Dahdouh-Guebas et al., 2000). Note the conflicts between management and subsistence users when insufficient attention is given to the consequences of the management towards the subsistence users (see text)

avoidance of further degradation) will fail. In some cases the threat results from the actions of commercial users, who are affecting the resource and the subsistence users (Dahdouh-Guebas et al., 2000). But in other cases the problem may evolve into a truly ethical crisis in which, for instance, population growth of the subsistence community itself threatens the natural resource. In this extreme situation the solution cannot do without a thorough ethnoscientific approach.

In an Indian case-study mangrove browsing by feral water buffaloes was deemed dangerous for the regeneration or productivity of mangroves in the East-Godavari Delta by the Forest Department (India). The Forest Department offered local herdsmen hybrid cows that needed not graze in the mangroves (Dahdouh-Guebas, Vrancken, Ravishankar, & Koedam, 2004). However, closer analysis of the conflict and of the alternative provided revealed, first, that scientists could not experimentally confirm that mangrove browsing by feral water buffaloes posed a threat, and secondly, that the hybrid cows had many shortcomings compared with feral water buffaloes (more expensive, more care, lower yields, less resistance to disease) (see Fig. 3).

The above mangrove case-studies illustrate how ethnoscientific (interscientific interdisciplinary) approaches obtained rigorous findings and resulted in more acceptable and sustainable outcomes than those from imposed law- and enforcement-based regulations.

Kufer, Grube, and Heinrich (2006) presents an ethnobotanical study of cacao (*Theobroma cacao* L.) in Eastern Guatemala. The central role of cacao in the celebration of the Ch'orti' Mayan rain ceremonies is highlighted. The cultural significance of cacao is only partly shared by the non-indigenous Ladinos of the area, who use cacao for culinary purposes on ceremonial occasions and Catholic holidays such as Christmas, but do not make ritual food offerings. The agrarian rituals are representing a cultural-symbolic gravitation field in which the ontological and epistemological foundations of the Mayan cosmovision are constantly created and recreated. This allows local forms of environmental knowledge to be kept alive, which can be showed to play an important role in keeping slash-and-burn maize agriculture within the limits of ecological sustainability. We agree with the authors' conclusion that the links of ecological knowledge with religious or spiritual practices deserve more recognition and should be integrated into local programs for environmental conservation. We would like to add only that this could be achieved through the establishment of time-spaces in which scientists and local actors could engage in mutual learning processes on the role of religiosity or spirituality in the shaping of knowledge among researchers, as well as Maya and Ladino people.

The work of Pfeiffer, Dun, Mulawaran, and Rice (2006) addresses the foundations of biocultural diversity regarding upland rice landraces in eastern Indonesia. Conservation and innovation of traditional rice landraces are closely related to indigenous rice based customs. The choices of certain rice varieties and the corresponding practices to produce and conserve them are expressions of a living culture. The close link between genetic and cultural diversity calls for a collaborative approach to shared knowledge production between scientists and farmers. A long-term conservation strategy of biological diversity is therefore dependent not only on a comprehensive understanding of the cultural practices related to local crops, but on enhancing the capacities of farmers to maintain and revive their cultural heritage through processes of cultural revitalisation and innovation. The work provides insights on the potential benefits and limitations of a new mode of collaborative

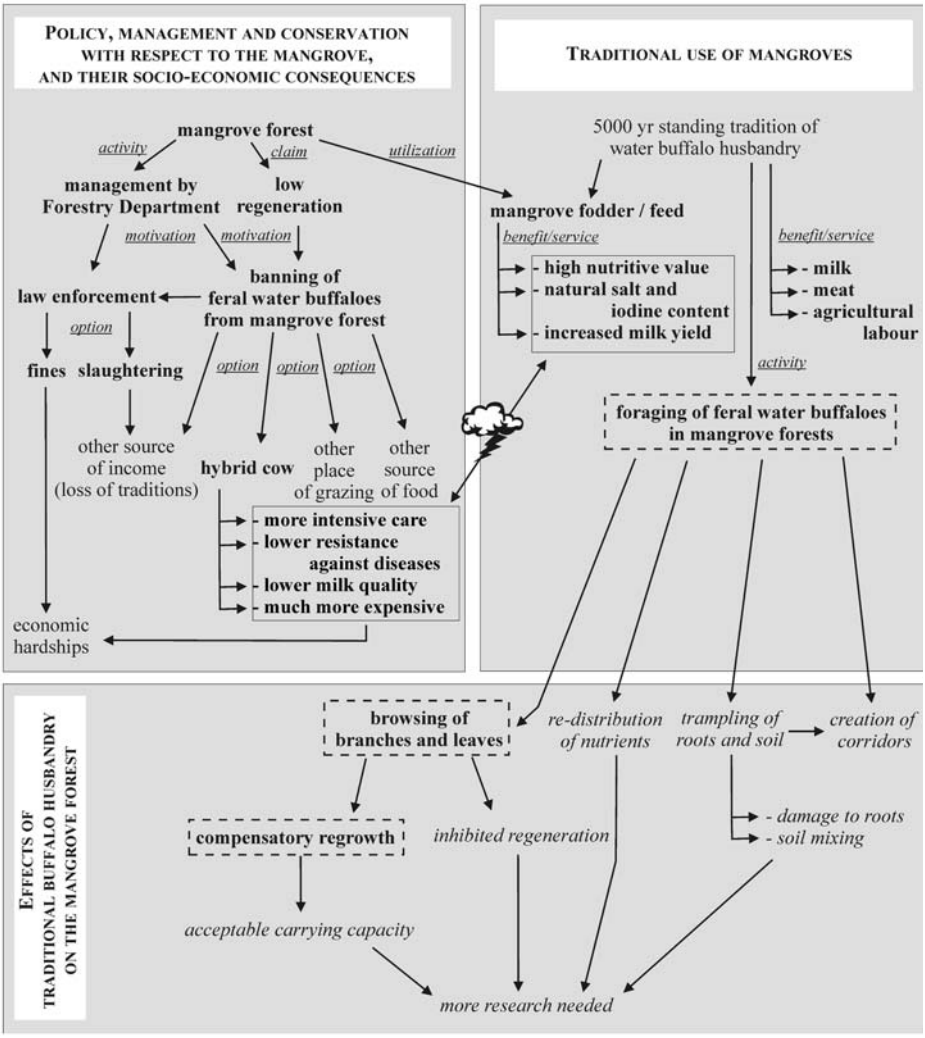

Fig. 3 Schematic illustrating the wider legal and societal framework in which the potential impact of feral water buffaloes on the East-Godavari mangroves (India) were investigated (based on Dahdouh-Guebas et al., 2004). The possible forestry and management policies and the consequences for local herdsmen are included. Arrows represent consequences, unless indicated otherwise (*underlined italic*). The major research focus and outcomes are in the dashed rectangles. Elements in bold are primary or secondary facts resulting from scientific investigation, whereas elements in italic are alleged based on statements made by local herdsmen during interviews and on international literature. Note that the claims made by the Forestry Department could not be confirmed by scientific research, and that the alternatives provided by the management were not satisfactory in the eyes of the subsistence herdsmen

co-production of knowledge between indigenous people and academics; and demonstrates how ethnographic and agronomic research can initiate a meaningful dialogue to further refine scientific and indigenous ontologies.

Finally, the article of Vermonden (2006) presents the main features of the transformations of the fishing activities in a village of Southeast Sulawesi province of Indonesia throughout the last 75 years. The gradual shift from a formerly subsistence oriented use of marine resources to a heavily commoditised exploitation shows many signs of a 'tragedy of the commons'. But interestingly, the tragedy is not fully consuming due to the interference of the traditional institution known as *sara.* The high legitimacy of community organisations allowed to give a more significant answer to be given to the negative impacts of commercialised blast fishing than the ban imposed by the government. By bringing back the ancestors into the arena of social negotiation, the economistic ontology of natural resources and development is challenged through the mobilisation of cultural capital.

Dialogue between 'ontological communities' in view of sustainable development

The above sections are giving good evidence for stating that the vagueness, arbitrariness and intentional or unintentional misinterpretations of sustainable development could be overcome by defining a corresponding ontology. This should go beyond the highly abstract call for considering 'the needs of present and future generations' by conceptually differentiating what it means with regard to specific notions on humans, society, social interaction, nature, space and time. In order to make more explicit what this means it is useful to consider the following four basic features which are related to what Poli called an 'ontology for knowledge organisation' (1996): First, *An ontology is not a catalogue of the world, a taxonomy... an ontology is the general framework (=structure) within which catalogues, taxonomies, terminologies may be given suitable organization* (ibid.:313). Secondly, *An ontology is not reducible to pure cognitive analysis (in philosophical terms, it is not an epistemology or a theory of knowledge).* (ibid.;313). Thirdly, *There is nothing to prevent the existence of several ontologies, in the plural. In this case too, ontological study is useful because, at the very least, it renders the top categories explicit and therefore enables verification of whether there are reasonable translation strategies and of which categorization can serve best to achieve certain objectives* (ibid.:314). Finally, *Reality is organized into diverse levels and there are highly sophisticated interdependencies among these levels and within them.* (ibid.:314)

Understanding an ontology as a general framework within which the basic items of sustainable development may be given suitable organisation and taking account of the existence of actor specific ontologies which could be representing diverse, but interrelated levels of reality sets the stage as a dialogue between 'ontological communities'. Meenaghan and Gibbons (2000) describe ontological communities as groups of people who have a common heritage, such as religion, language, ethnicity, or culture and affirm their own strong identity within the context of larger, more complex modern communities.

Regarding the conditions and features of an ontology of sustainable development the findings presented in this paper allow to identify the following, indeed preliminary, items. A first fundamental feature is the societal and process-related character of an ontology of sustainable development. The definition of the key concepts of an ontology for sustainable development cannot be left to one or several scientific disciplines alone. The generally well developed theories of objects of the different scientific disciplines constitute a necessary, but insufficient condition for the

development of an ontology of sustainable development. Understanding the construction of a theory of objects for sustainable development as part of a dialogue between different ontological communities means to integrate traditional (''non-scientific'') actors into the corresponding process. As the examination of the interaction between University and Aymara communities has demonstrated, ethnosciences represent especially appropriate means for such a purpose yet they allow ontological commonalities and differences between the different communities involved to be revealed.

As the example of the different patterns of interpretation of hail clearly shows the definition of an adequate relation between indigenous and scientific knowledge cannot be limited only to an *inter*cultural dimension: Without an *intra*cultural effort of the parties involved aiming at coming to higher levels of reflexivity leading to more clarity about the ontological foundations of their own forms of knowledge, a dialogue in equal conditions would be difficult to achieve. Through this the ontological communities allow themselves to make more explicit the lines of interdependencies, which are drawing the different types of knowledge related to the patterns of action (practice) together, of orientation (norms and values) and of interpretation (worldviews). As a consequence, the intercultural dialogue is more likely to become productive, because it embraces the three fundamental types of knowledge that are characteristic for the different ontological communities, avoiding through this the biases resulting from fragmented and partially unreflecting communication.

Ethnosciences can play a triple role in the establishment of a dialogue between different 'ontological communities' oriented in sustainable development. First, they help to create awareness within the scientific community of the importance of the ontological aspects, permitting to visualise how they are related to the actor-specific patterns of interpretation, orientation and action of scientific as well as indigenous stakeholders. Secondly, through this, ethnosciences contribute to the preparation of the ground to show to what extent the supposedly more 'concrete' issues related to agriculture, livestock-keeping or forestry, for instance, are interdependent on the underlying ontological foundations. This means that ethnosciences can thirdly, serve as a steppingstone to engage in broader societal processes concerning the definition of an ontology of sustainable development which is acceptable for at least the majority of the actors concerned allowing for better guidance of the processes of policy making and implementation.

Moreover, striving to define elements for an ontology of sustainable development as a result of intercultural dialogue means to accept that, instead of a generalised 'objective' truth claim, the ontological communities have to interact on the basis of intersubjective validation. In terms of social interaction this implies a shift from strategic to communicative action as a more adequate form of interaction for jointly defining aspects of an ontology of sustainable development. This means that scientific work has to adopt a multicultural perspective, which implies making an effort towards understanding the 'others' in order to *open up the possibility of learning about others and ourselves, of questioning and borrowing, of connecting with them, all to the end of altering and enlarging ourselves and them* (Fay, 1996: 245).

The findings of the reflections presented so far, allow us to state that the crucial contents of an ontology of sustainable development are related to the concepts of nature, humans, society, social interaction, space and time. The comparison of the three ontologies meeting at the interface of natural and social science and

indigenous knowledge showed that the specific differences between the notions of humans, society, social interaction, nature, space and time are closely related to different positions with regard to the underlying understandings of mind, body and matter and the ways through which they are interrelating. The current ontological incompatibilities between materialist, dualist and indigenous views could be overcome when they relate in more equal conditions. This could be achieved on the basis of a jointly shared question, which takes account of the whole range of ontological positions. A question, which could be shared, at least by the three ontological positions presented here, would be the one addressing the relation between mind and matter. If such a question were considered as a common issue of the different ontological communities, the materialist, dualist and indigenous views, instead of contradicting each other, could agree on hypotheses which reflect different levels of 'reality' and experiences and which are related to a jointly shared and indeed not yet fully answered question. Organising such a multi-ontological process of communication around a commonly shared question would prevent the different ontological communities from falling into the trap of fundamentalism because, even if they are different, they further develop their thinking in a process of permanent interaction with other ontological communities which strengthens attitudes of openness, dialogue and joint learning.

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References

Agenda 21. (1992). *The global partnership for environment and development: a guide to Agenda 21*, Geneva. http://www.un.org/esa/sustdev/documents/agenda21/english/agenda21chapter35.htm (accessed 12.4.05).

Altieri, M. A. (1993). Ethnoscience and biodiversity – key elements in the design of sustainable pest-management systems for small farmers in developing-countries. *Agriculture Ecosystems & Environment, 46*(1–4), 257–272.

Armitage, D. (2005). Adaptive capacity and community-based natural resource management. *Environmental Management, 35*(6), 703–715.

Atran, S. (1991). Ethnoscience today. *Social Science Information Sur Les Sciences Sociales, 30*(4), 595–662.

Benthall, J. (1993). Rights to ethnobiology. *Anthropology Today, 9*(3), 1–2.

Byg, A., Vormisto, J., & Balslev, H. (2006). Using the useful: Characteristics of used palms in south-eastern Ecuador. In F. Dahdouh-Guebas (Ed.), *Bridging the gap between natural resources and their human management for the future using ethnosciences*, *Environment, Development and Sustainability,* this issue.

Cocks M. L., Bangay, L., Wiersum, K. F., & Dold, A. P. (2006). Seeing the wood for the trees: The role of woody resources for the construction of gender specific household cultural artefacts in non-traditional communities in the Eastern Cape, South Africa. In: F. Dahdouh-Guebas (Ed.), *Bridging the gap between natural resources and their human management for the future using ethnosciences*, *Environment, Development and Sustainability,* this issue.

Conford, P. (2001). *The origins of the organic movement*. Edinburgh: Floris Books.
Cremers, L., Ooijevaar, M., & Boelens, R. (2005). Institutional reform in the Andean irrigation sector: Enabling policies for strengthening local rights and water management. *Natural Resources Forum, 29*(1), 37–50.
Cunningham, A. B. (2001). *Applied ethnobotany: People, wild plant use and conservation*. London, UK: Earthscan Publications Ltd., 300 pp .
D'Ambrosio, U. (1999). *Ethnomathematics: The art or thechnique of explaining and knowing; History of mathematics in the periphery: The basin metaphor: As illustrated by Latin America*. Berlin, Germany: Max-Planck-Institut für Wissenschaftsgeschichte, 116 pp.
Dahdouh-Guebas, F. (Ed.). (2006). *Bridging the gap between natural resources and their human management for the future using ethnosciences, Environment, Development and Sustainability Special Issue*. Dordrecht, The Netherlands: Springer Publishers.
Dahdouh-Guebas, F., Ahimbisibwe, J., Van Moll, R., & Koedam, N. (2003). Neo-colonial science by the most industrialised upon the least developed countries in peer-reviewed publishing. *Scientometrics, 56*(3), 329–343.
Dahdouh-Guebas, F., Hettiarachchi, S., Lo Seen, D., Batelaan, O., Sooriyarachchi, S., Jayatissa, L. P., & Koedam, N. (2005). Transitions in ancient inland freshwater resource management in Sri Lanka affect biota and human populations in and around coastal lagoons. *Current Biology, 15*(6), 579–586.
Dahdouh-Guebas, F., Mathenge, C., Kairo, J. G., & Koedam, N. (2000). Utilization of mangrove wood products around Mida Creek (Kenya) amongst subsistence and commercial users. *Economic Botany, 54*(4), 513–527.
Dahdouh-Guebas, F., Van Pottelbergh, I., Kairo, J. G., Cannicci, S., & Koedam, N. (2004). Human-impacted mangroves in Gazi (Kenya): Predicting future vegetation based on retrospective remote sensing, social surveys, and distribution of trees. *Marine Ecology Progress Series, 272*, 77–92.
Dahdouh-Guebas, F., Vrancken, D., Ravishankar, T., & Koedam, N. (2004). Short-term mangrove browsing by feral water buffaloes: Conflict between natural resources, wildlife and subsistence interests? *Environmental Conservation*, *33* (3)
Delgado F. (2002). *Estrategias de autodesarrollo y gestión sostenible del territorio en ecosistemas de montaña – Compelmentariedad ecosimbiótica en el ayllu Majasaya Mujlli, departamento de Cochabamba*. La Paz, Bolivia: Ediciones PLURAL – AGRUCO, 351 pp.
Delgado, F., & Ponce, D., (2003). Endogenous development and university education. In B. Haverkort, K. van 't Hooft, & W. Hiemstra (Eds.), *Ancient roots, new shoots: Endogenous development in practice* (pp. 192–203). London: Zed Books.
Dove, M. R., & Kammen, D. M. (1997). The epistemology of sustainable resource use: Managing forest products, swiddens, and high-yielding variety crops. *Human Organization, 56*(1), 91–101.
Edwards, S. E., & Heinrich, M. (2006). Redressing cultural erosion and ecological decline in a far North Queensland Aboriginal community (Australia): The Aurukun Ethnobiology Database Project. In F. Dahdouh-Guebas (Ed.), *Bridging the gap between natural resources and their human management for the future using ethnosciences*, *Environment, Development and Sustainability,* this issue.
Fabian, S. M. (2001). *Patterns in the sky an introduction to ethnoastronomy*. Illinois, USA: Waveland Press, Prospect Heights, 125 pp.
Fay, B. (1996). *Contemporary philosophy of social science: A multicultural approach*. Oxford, UK: Blackwell Publishers, 266 pp.
German, L. A., Alemu, G., Kidane, B., & Shemdoe, R. (2006). Social and environmental trade-offs in tree species selection: A methodology for identifying niche incompatibilities in agroforestry. In F. Dahdouh-Guebas (Ed.), *Bridging the gap between natural resources and their human management for the future using ethnosciences*, *Environment, Development and Sustainability,* this issue.
Goodman, D. (2001). Ontology matters: The relational materiality of nature and agro-food studies. *Sociologia Ruralis, 41*(2), 182–200.
Gragson, T., & Blount, B. G. (Eds.). (1999). *Ethnoecology – knowledge*, *Ressources and rights*. Athens, Georgia, USA: The University of Georgia Press, 184 pp.
Guttenplan, S. (1994). *A companion to the philosophy of mind*. Oxford, UK: Blackwell, 622 pp.
Haverkort, B., van 't Hooft, K., & Hiemstra, W. (Eds.). (2003). *Ancient roots, new shoots: Endogenous development in practice*. London: Zed Books, 264 pp.
Hens, L., & Nath, B. (2003). The Johannesburg conference. *Environment, Development and Sustainability, 5*(1–2), 7–39.

Hirsch Hadorn, G. (Ed.). (2002). *Unity of knowledge in transdisciplinary research for sustainability. Hirsch Hadorn G, Unity of knowledge in transdisciplinary research for sustainability, Encyclopedia of Life Support Systems (EOLSS)*. Oxford, UK: Eolss Publishers, <www.eolss.net>.
Hurni, H., & Wiesmann, U. (2004). Towards transdisciplinarity in sustainability-oriented research for development. In H. Hurni, U. Wiesmann, & R. Schertenleib (Eds.), *Research for mitigating syndromes of global change* (pp. 31–42). Bern: University of Bern, Geographica Bernensia.
Huylebrouck, D. (2005). *Afrika en Wiskunde*. Brussels, Belgium: VUB Press, 304 pp.
Ingold, T. (1992). Culture and the perception of the environment. In E. Croll & D. Parkin (Eds.), *Bush base: Forest farm* (pp. 39–56). London, UK: Routledge.
Ingold, T. (2000). *The perception of the environment: Essays on livelihood, dwelling and skill*. London, UK: Routledge, 465 pp.
Jayatissa, L. P., Hettiarachchi, S., & Dahdouh-Guebas, F. (2006). An attempt to recover economic losses from decadal changes in two lagoon systems of Sri Lanka through a newly patented mangrove product. In F. Dahdouh-Guebas (Ed.), *Bridging the gap between natural resources and their human management for the future using ethnosciences*, *Environment, Development and Sustainability,* this issue.
Kellert, S. R. (1997). *The value of life: Biological diversity and human society*. Washington-Covelo, USA: Island Press; Shearwater Books, 263 pp.
Kovacs, J. M. (2000). Perceptions of environmental change in a tropical coastal wetland. *Land Degradation & Development, 11*, 209–220.
Kloppenburg, J. (1991). Social theory and the de/reconstruction of agricultural science: Local knowledge for an alternative agriculture. *Rural Sociology, 56*(4), 519–548.
Kufer, J., Grube, N., & Heinrich, M. (2006). Cacao in Eastern Guatemala – a sacred tree with ecological significance. In F. Dahdouh-Guebas (Ed.), *Bridging the gap between natural resources and their human management for the future using ethnosciences*, *Environment, Development and Sustainability,* this issue.
Leeuwis, C. (2000). Reconceptualising participation for sustainable rural development: Towards a negotiation approach. *Development and Change, 31*, 931–959.
Loayza, R. (1996). Mirando el futuro con los pies en el pasado. In Ministerio de Desarrollo Sostenible y Medio Ambiente, PNUD, COSUDE (Ed.), *Construyendo el Futuro. 25 opiniones sobre Desarrollo Sostenible en Bolivia. La visión de: el Gobierno, la Sociedad Civil, los Partidos Políticos* (pp. 55–60). Bolivia: La Paz.
Maffi, L. (2001). *On biocultural diversity: Linking language, knowledge, and the environment*. Washington, D.C., USA: Smithsonian Institution Press, 578 pp.
Malberg, H. (2002). *Meteorologie und Klimatologie. Eine Einführung*. Berlin, Germany: Springer, 364 pp.
Martin, G. (2001). Ethnobiology and ethnoecology. In *Encyclopedia of biodiversity*. (Vol. 2, pp. 609–621). New York, USA: Academic Press.
Martin, G. J. (2004). *Ethnobotany: A methods manual*. London, UK: Earthscan Publications Ltd., 268 pp.
Meehan, P. (1980). Science, enthnoscience, and agricultural knowledge utilization. In D. M Warren, D. Brokensha, & O. Werner (Eds), *Indigenous knowledge systems and development* (pp. 383–391). Lanham, MD, USA: University Press of America.
Meenaghan, T., & Gibons, W. E. (2000). *Generalist practice in larger settings: Knowledge and skill concepts*. Chicago, USA: Lyceum Books, 230 pp.
Minnis, P. E. (2000). *Ethnobotany – A reader*. Oklahoma, USA: University of Oklahoma Press, 327 pp.
Nazarea, V. D. (1999). *Ethnoecology: Situated knowledge/located lives*. Tucson, USA: University of Arizona Press, 299 pp.
Nichter, M. (1992). *Anthropological approaches to the study of ethnomedicine*. Amsterdam: OPA.
Nicolescu, B. (1996). *La transdisciplinarité – Manifeste*. Monaco: Editions du Rocher, 231 pp.
Norgaard, R. B. (1994). *Development betrayed the end of progress and a coevolutionary revisioning of the future*. London, UK: Routledge, 280 pp.
Norgaard, R. B. (2004). Learning and knowing collectively. *Ecological Economics, 49*(2), 231–241.
Omodei Zorini, L., Contini, C., Jiddawi, N., Ochiewo, J., Shunula, J., & Cannicci, S. (2004). Participatory appraisal for potential community-based mangrove management in East Africa. *Wetlands Ecology and Management, 12*, 87–102.
Orlove, B. S., Chiang, J. C. H., & Cane, M. A. (2002). Ethnoclimatology in the Andes. A cross-disciplinary study uncovers a scientific basis for the scheme Andean potato farmers traditionally use to predict the coming rains. *American Scientist, 90*(5), 428–435.

Pandey, D. N. (1998). *Ethnoforestry: Local knowledge for sustainable forestry and livelihood security*. Udaipur, India: Himanshu Publications, 91 pp.
Pedersen, L. D. (2000). Ethnochemistry. *Abstracts of Papers of the American Chemical Society, 219*, U304–U304.
Pfeiffer, J. M., Dun, S., Mulawaran, B., & Rice, K. J. (2006). Biocultural diversity in traditional rice-based agroecosystems: Indigenous research and conservation of *mavo* (*Oryza sativa* L.) upland rice landraces of eastern Indonesia. In F. Dahdouh-Guebas (Ed.), *Bridging the gap between natural resources and their human management for the future using ethnosciences*, *Environment, Development and Sustainability,* this issue.
Pieroni, A., & Price, L. L. (2005). *Eating and healing: Traditional food as medicine*. New York: Food Products Press, 361 pp.
Poli, R. (1996). Ontology for knowledge organization. In R. Green (Ed.), *Knowledge organization and change: Proceedings of the fourth international ISKO conference, 15–18 July 1996* (pp. 313–319). Washington, DC, USA: Indeks Verlag, Frankfurt/Main, Germany.
Posey, D. A., & Plenderleith, K. (2002). *Kayapâo ethnoecology and culture*. London; New York: Routledge.
Pretty, J. (2003). Social capital and the collective management of resources. *Science, 302*(5652), 1912–1914.
Price, L. L., & Björensen Gurung, A. (2006). Describing and measuring ethnoentomological knowledge of rice pests: Tradition and change among Asian rice farmers. In F. Dahdouh-Guebas (Ed.), *Bridging the gap between natural resources and their human management for the future using ethnosciences*, *Environment, Development and Sustainability,* this issue.
Redclift, M. (1993). Sustainable Development: Needs, Values, Rights. *Environmental Values, 2*(1), 3–20.
Rist, S. (2002). *Si estamos de buen corazón, siempre hay producción – Caminos en la revalorización de formas de producción y de vida tradicional y su importancia para el desarrollo sostenible*. La Paz, Bolivia: Ediciones PLURAL – AGRUCO – CDE, 502 pp.
Rist, S. (2003). Organic agriculture as social movement. Re-thinking sustainable agriculture in developing countries. In R. Lahmar, M. Held, & L. Montanarella (Eds.), *Food matter: Food security and soils* (pp. 108–114). Montpellier, France: Torba Soil & Society.
Rist, S., Delgado, F., & Wiesmann, U. (2003). The role of social learning processes in the emergence and development of Aymara land use systems. *Mountain Research and Development, 23*(3), 263–270.
Rist, S., San Martín, J., & Tapia, N. (1999). Andean cosmovision and self-sustained development. In W. Hiemstra (Ed.), *Food for thought - Ancient visions and new experiments of rural people – COMPAS* (pp. 177–190). London: Zed Books.
Rist, S., Zimmermann, A., & Wiesmann, U. (2004). From epistemic monoculture to cooperation between epistemic communities – Development research and sustainability. In *Proceedings of the international conference on ''Bridging Scales & Epistemologies'' Millennium Assessment*, Alexandria, Egypt, 17–20 March, 21 pp.
Röling, N. (2002). Beyond the aggregation of individual preferences. Moving from multiple to distributed cognition in resource dilemmas. In C. Leeuwis, R. Pyburn (Eds.), *Wheelbarrows full of frogs – Social learning in rural resource management* (pp. 25–47). Assen: Van Gorcum.
San Martin, J. (1997). *En la búsqueda del enfoque para el desarrollo rural autosostenible – Ukamäpi. Así nomás es pues*. La Paz, Bolivia: AGRUCO – UMSS – CSUDE / IC & PLURAL editores, 199 pp.
Scholz, R. W., Häberli, R., Bill, A., & Welti, M. (Eds.). (2000) *Transdisciplinarity: Joint problem-solving among science, technology and society*. Zürich: Haffmanns Verlag, 405 pp.
Strigl, A. (2003). Scinece, research, knowledge and capacity building. *Environment, Development and Sustainability, 5*, 255–273.
Ticona E. (2000). *Organización y liderazgo Aymara – La experiencia indígena en la política boliviana1979–1996*. La Paz: AGRUCO, Universidad Mayor de San Simón (UMSS) y Universidad de la Cordillera, 213 pp.
Toledo, V. (2001). Biocultural diversity and local power in Mexico: Challenging globalisation. In L. Maffi (Ed.), *On biocultural diversity: Linking language, knowledge, and the environment* (pp. 472–488). Washington D.C.: Smithsonian Institution Press.
van den Berg, H. (1990). *Latierra no da así nomás. Losritos agrícolas en la religión de los aymaras-cristianos.* Bolivia: Hisbol, La Paz, 352 pp.
van den Berg, H., & Schiffers, N. (1992). *La Cosmovisión Aymara,* Bolivia: Hisbol – UCB, La Paz, 383 pp.

Vayda, A. P., Walters, B. B., & Setyawati, I. (2004). Doing and knowing : Questions about studies of local knowledge. In A. Bicker, P. Sillitoe, & J. Pottier (Eds.), *Investigating local knowledge : New directions, new approaches* (pp. 35–58). London, UK: Ashgate Publishers.

Veeman, T. S., & Politiylo, J. (2003). The role of institutions and policy in enhancing sustainable development and conserving natural capital. *Environment, Development and Sustainability, 5*, 317–332.

Vermonden, D. (2006). Making a living from the sea: Fishery activities development and local perspective on sustainability in Bahari village (Buton island, Southeast Sulawesi, Indonesia). In F. Dahdouh-Guebas (Ed.), *Bridging the gap between natural resources and their human management for the future using ethnosciences*, *Environment, Development and Sustainability,* this issue.

Vogt, K., Beard, K., Hammann, S., O'Hara Palmiotto, J., Vogt, D., Scatena, F., & Hecht, B. (2002). Indigenous knowledge informing management of tropical forests: The link between rhythms in plant secondary chemistry and lunar cycles. *Ambio, 31*(6), 485–490.

Wachtel, N. (1990). *Le retour des ancêtres: les indiens Urus de Bolivie XXe–XVIe siècle: essai d'histoire régressive.* Paris: Gallimard, 689 pp.

Walters, B. B. (2003). People and mangroves in the Philippines : Fifty years of coastal environmental change. *Environmental Conservation, 30*(2), 293–303.

Wezel, A., & Lykke, A. M. (2006). Woody vegetation change in Sahelian West Africa: Evidence from local knowledge. In F. Dahdouh-Guebas (Ed.), *Bridging the gap between natural resources and their human management for the future using ethnosciences*, *Environment, Development and Sustainability,* this issue.

Wiesmann, U. (1998). Sustainable regional development in rural Africa: conceptual framework and case studies from Kenya. *Gegraphica Bernensia African Studies - A14.*

WinklerPrins, A. M. G. A., & Sandor, J. A. (Eds.). (2003) *Ethnopedology, Geoderma* Special Issue 111. Amsterdam, The Netherlands: Elsevier Inc., 374 pp.

WinklerPrins, A., & Barrera-Bassols, N. (2004). Latin American ethnopedology: A vision of its past, present, and future. *Agriculture and Human Values, 21*, 139–156.

WinklerPrins, A. (1999). Local soil knowledge: A tool for sustainable land management. *Society & Natural Resources, 12*(2), 151–161.

World Commission on Environment and Development (1987). *Our common future*. Oxford, UK: Oxford University Press, 400 pp.

Yapa, L. (1993). What are improved seeds? An epistemology of the green revolution. *Economic Geography, 69*(3), 254–273.

Zürcher, E., & Cantiani M.-G. (1998). Tree stem diameters fluctuate with tide. *Nature, 392*, 665.