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Ethnopedology: a worldwide view on the soil knowledge of local people

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Abstract

Ethnopedology, a hybrid discipline nurtured by natural as well as social sciences, encompasses the soil and land knowledge systems of rural populations, from the most traditional to the modern. Using this statement as a starting point, the first part of the paper defines ethnopedology in terms of conceptual scope, methodological approaches and dominant research themes. Initially, classic ethnographic studies focused on the linguistic analysis of local soil and land classification systems, while the comparative approach aimed at establishing similarities and differences between local knowledge and scientific information. More recently, interest has shifted towards a more integrated approach, which recognizes the relevance of the cultural context in local sustainable land management. Ethnopedological research covers a wide diversity of topics centered around four main issues: (1) the formalization of local soil and land knowledge into classification schemes, (2) the comparison of local and technical soil classifications, (3) the analysis of local land evaluation systems, and (4) the assessment of agro-ecological management practices. In the second part of the paper, the current status of ethnopedology in a worldwide perspective is assessed from a compilation of 895 references, with respect to the abundance, distribution and diversity of ethnopedological studies (EPS). These EPS are distributed over 61 countries, mainly in Africa, America and Asia, and cover 217 ethnic groups. The geographical density of EPS is positively correlated with linguistic and biological diversities. Most EPS have been carried out in fragile agro-ecological zones, where communities living with limited resources have developed efficient land and water management systems to compensate for resource scarcity. Of the three main components of ethnopedology—i.e. Corpus, Praxis and Kosmos—more attention has so far been given to local cognitive systems (Corpus) and local management systems (Praxis) than local belief and symbol systems

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(Kosmos). Shifting the research emphasis to the cosmovision of local peoples would improve the contribution of EPS to the formulation and implementation of rural development programmes.

Keywords: Ethnopedology; Local people; Local soil knowledge; Worldwide review

1. Introduction

Ethnopedology aims to document and understand the local approaches to soil perception, classification, appraisal, use and management (Furbee, 1989; Hecht, 1990; Tabor, 1990; Niemeijer, 1995; among others). Comparatively, more progress has been achieved in ethnobotanical and ethnozoological research than in ethnopedological research during the last 20 years (Berlin, 1992). Despite thousands of years of applied ethnopedology practiced by indigenous peoples, local soil knowledge has not been historically reflected in soil science research (Boulaine, 1989; Krupenikov, 1993; Yaalon and Berkowicz, 1997). Often, indigenous soil and land knowledge appears as an exotic corpus of primitive human experience and attitudes related to the soil resource. However, complex pedological wisdom developed more than 2000 years ago in China (Needham and Gwein-Djen, 1981; Chingkwei and Shenggeng, 1990), Egypt (Chadefaud, 1998), India (Abrol, 1990) and Mexico (Williams, 1975), in places intimately related to the major centers of plant domestication in the world (Vavilov, 1949–1950; Grigg, 1974). Over the last few decades, remarkable examples of soil knowledge from non-western civilizations living mainly in tropical and subtropical areas have been described, and their current strength has been assessed. To evaluate the growing importance of ethnopedology, an inventory of published ethnopedological studies (EPS) and related grey literature was carried out and compiled in an annotated bibliography, supported by an electronic database (Barrera-Bassols and Zinck, 2000). Analysis of this information source reveals that ethnopedology is consolidating its base as an innovative discipline by enlarging its conceptual scope and expanding its scientific production. As ethnopedology can be approached from different angles by different scientists with their own points of view, goals and motivations, the concept of local soil knowledge is gaining new dimensions. Therefore, in the first part of the paper, the definition of ethnopedology is reviewed in terms of conceptual scope, methodological approaches and dominant research themes. Simultaneously with its conceptual widening, ethnopedology has also developed quantitatively, with a substantial increase in EPS since the early 1990s. The abundance, distribution and diversity of EPS were assessed using the compiled database coupled with a geographical information system (GIS). The results of this analysis are presented in the second part of the paper.

2. Ethnopedology defined: a mutating discipline

2.1. Conceptual width: from descriptive to explanatory

Ethnopedology is a part of ethnoecology, the study of indigenous environmental knowledge (Toledo, 1992, 2000). It is a hybrid discipline structured from the combination of natural and social sciences, such as soil science and geopedological survey, social anthropology, rural geography, agronomy and agro-ecology (Barrera-Bassols and Zinck, 1998) (Fig. 1). Often, terms such as traditional, folk, local, indigenous, farmers' and peoples' soil knowledge systems are used interchangeably to refer to ethnopedology, although they are not strictly synonymous (Ettema, 1994; Sillitoe, 1998; Winkler-Prins, 1999; Talawar and Rhoades, 1998).

Ideally, ethnopedology encompasses all empirical soil and land knowledge systems of rural populations, from the most traditional to the modern ones. It analyzes the role of soil and land in the natural resource management process, as part of ecological and economic rationale. Soil and land are explored as (1) polysemic cognitive domains, (2) multiple-use natural resources, and (3) objects of symbolic meanings and values. Symbolism (Kosmos), knowledge (Corpus) and management practices (Praxis)—the K–C–P complex—articulate the empirical wisdom of local people about the soil resource (Fig. 2). The interaction of the three domains of the K–C–P complex results in the merging of sacred and secular features, knowledge and experience, facts and values, and matter and mind. In practical terms, it allows peasant's risk aversion to be counteracted, enhances food self-sufficiency and agricultural sustainability, promotes low dependence on external inputs, makes maximum use of soil and landscape diversity, and secures survival under economic uncertainty. To reach these goals, a strict cultural control—selecting and monitoring land uses and management practices—is applied within each community.

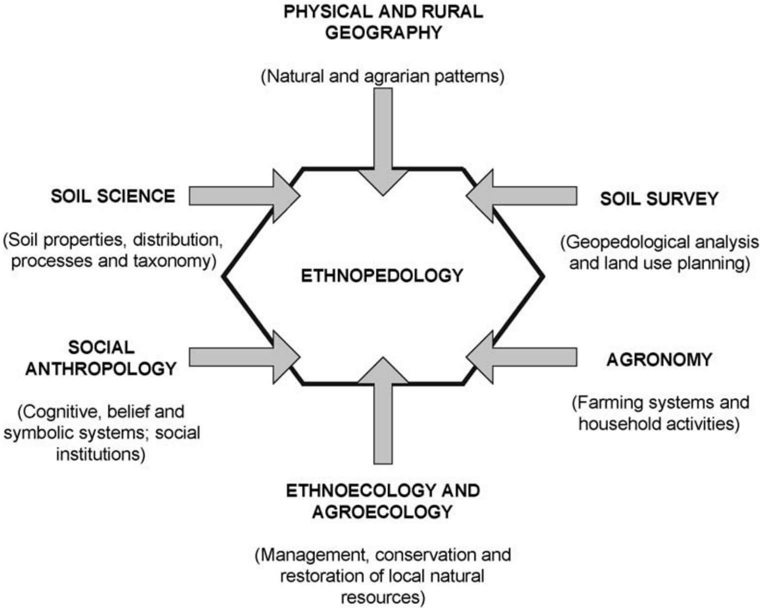

Fig. 1. Ethnopedology as a hybrid discipline.

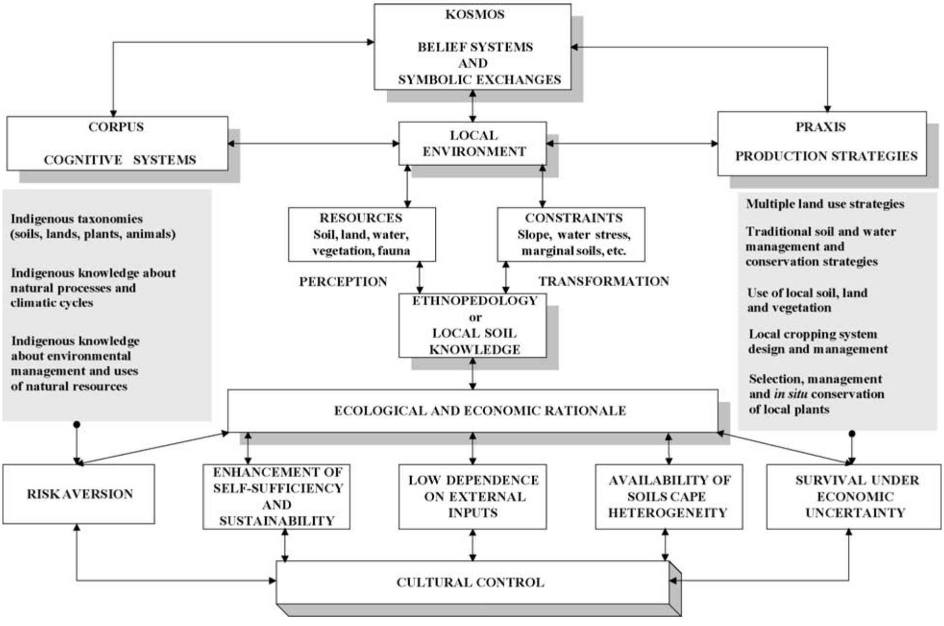

Fig. 2. The scope of ethnopedology (adapted from Altieri, 1993).

The main research fields of ethnopedology include:

- local classification nomenclatures, and soil and land taxonomies;
- local soil and land resources perception, and the explanation of the structure, distribution, properties, processes and dynamics of the soil mantle;
- local knowledge of soil and land relationships with other biophysical factors, elements and processes;
- beliefs, myths, rituals and other symbolic meanings, values and practices related to land management and soil quality evaluation;
- local land uses and soil management practices;
- local adaptation, renewal and transformation strategies of soil properties and land qualities;
- co-validation of ethnopedological knowledge, abilities and skills with modern soil science, geopedological survey, agro-ecological strategies, and agricultural and other rural practices, to promote participatory land evaluation and land use planning procedures for endogenous sustainable development.

In general, individual EPS concentrate their investigation in one single research field, and there are few examples attempting to cover more than one field at the same time. To become more integrated, ethnopedological research would have to combine spatial and temporal scales (climatic, eco-geographical, agro-ecological and biophysical) with operational dimensions (structural, dynamic, relational, utilitarian

Table 1
Systemic approach to ethnopedological research

Operational dimensions	Spatial and temporal scales			
	Climatic	Eco-geographic	Agro-ecological	Biophysical
Structural	bioclimatic zoning landscape soilscape vegetation cover	agroclimatic zoning relief patterns soil patterns vegetation types	mesoclimatic zoning relief types soil associations biological associations	microclimatic zoning landforms soil types biological species
Dynamic	climatic seasonality	soil performance variability	soil nutrient variability and cycle	soil fertility renewal/ resilience
	hydrological cycle	soil erosion and deposition	soil quality variability	crop phenology
	soil drainage	land productivity cycle	ecological cycle and variability	biological cycles
Relational	climate–land relationships	soil–relief relationships soil–water relationships	soil–agro-ecology relationships	soil–crop relationships
Utilitarian	multiple land use and management strategies	agricultural and forestry management strategies	agrohabitats agroforestry	agricultural plots home gardens forest plots
Symbolic	religious calendar	agricultural and religious calendars	agricultural and religious calendars	agricultural and religious calendars

and symbolic) in order to understand local soil and land knowledge systems (Table 1). Research items would include (1) local cognition, (2) local management and conservation, and (3) local perceptions and beliefs about soil and land spatial heterogeneity, temporal variability, natural dynamics and processes, and interrelationships with other biophysical factors. The interrelationship between the spatial and temporal scales and the operational dimensions would allow a systemic approach to interpreting local soil and land theories and practices (Barrera-Bassols and Zinck, 2000).

2.2. Methodological approaches: from mono-disciplinary to integrated

A review of ethnopedological information sources reveals three main research approaches: ethnographic, comparative and integrated (Barrera-Bassols and Zinck, 1998; WinklerPrins, 1999). It also shows a shift from early mono-disciplinary research towards studies that combine a variety of methods and techniques, in accordance with the broad nature of the traditional soil knowledge.

2.2.1. Ethnographic approach

In the ethnographic approach, field data analysis and ethnopedological knowledge acquisition are the main objectives in recognizing farmers' environmental rationality from a cultural perspective (Malinowski, 1935; West, 1947; Conklin, 1957). In this type of study, the ethnopedological information is not compared with scientific soil information. In most cases, the empirical soil information does not substantially contribute to integrated analysis of the local natural resource management.

Classical ethnographies usually contain a few descriptive sections devoted to ethnopedology. Linguistic criteria referring to soil attributes and land management strategies are often listed. Earlier ethnopedological attempts were based on the linguistic analysis of local soil and land classification systems, similar to earlier studies on ethnobiology (Talawar and Rhoades, 1998).

2.2.2. Comparative approach

The comparative approach aims to establish similarities and differences between local knowledge and scientific information. This type of study intends to identify possible correlations between different soil and land classifications and management systems. The analysis does not take into consideration the socio-cultural contexts from which perception, beliefs, cognition and practices are derived.

Two main research trends have influenced these studies. One approach, related to the 'cognitive universalistic school', has been formalized by Berlin (1992) with his theory of universal principles of 'folk' biological classification systems. Much of this kind of research seeks to correlate local soil classification systems with the universal folk biological classification or with scientific soil taxonomies such as the USDA soil taxonomy (Soil Survey Staff, 1998) or the FAO soil legend (FAO/UNESCO, 1988). The other approach is rooted in modern soil science and focuses mainly on developing 'natural' or 'objective' universal soil taxonomies (Queiroz Neto, 1998). It is also concerned with the spatial and temporal patterns and genetic processes of the soil resource (Buol et al., 1997).

Most EPS have followed the comparative approach. As in conventional ethnobiology, the analysis and correlation of soil and land classification systems form the main objective of the research, thus excluding other fundamental elements belonging to the local environmental knowledge systems, such as the symbolic meanings and values, as well as farmers' expertise. Although some studies demonstrate the scientific validity of local soil and land resources cognition, in most cases it is assumed that soil science is superior to local soil knowledge, so that the latter needs to be proven and formalized to be scientifically tapped (Thrupp, 1989; Sillitoe, 1998). The application of local soil and land resources knowledge during the production process is left out; thus the practical consequences of cognition systems and the analysis of local ecological and economic rationale are not covered by these studies.

2.2.3. Integrated approach

The integrated approach identifies and mobilizes the relationship between cultural and scientific information in order to elaborate natural resource management schemes according to local social, cultural, economic and ecological contexts. Together with off-community agents (e.g. soil scientists, agronomists, social scientists, planners, among others), farmers participate in validating and integrating information into the local decision-making and planning procedures. Designing sustainable natural resource management models is promoted.

This ethnopedological approach is still in its early days (Östberg and Reij, 1998; WinklerPrins, 1999). Its main goal is to link soil and land wisdom and knowledge in order to promote feasible and sustained local endogenous development in an interdisciplinary perspective. By analyzing historical, ecological, economic and political factors and changes at the local level, and with the full participation of the local actors, this contextual approach could gain strength through co-validating and implementing in a creative way both the scientific and the empirical sources of information.

What constitutes the most important aspect of these EPS is the analysis of the management process related to the soil and land resources dynamics. Central to this approach is understanding the multifaceted role played in the production process by people's knowledge of soil and land. By taking into account local values and symbolic meanings rather than distorting indigenous knowledge by imposing a western scientific model on it, the limits of both epistemologies are accepted and their synergies enhanced (Weinstock, 1984). Local peoples are knowledgeable about their soils, lands, plants and environment and well qualified to define their own problems. Sometimes, modern soil science may not be of particular relevance, or might not be attuned to local pedological and land use aspects (Bocco, 1991; Pawluk et al., 1992; Niemeijer, 1995). Mutual exchange of information could make soil surveyors and scientists more familiar with local soil and land knowledge systems, which is important if they want their work to be more effective and less exposed to political manipulation (Birmingham, 1996; Chambers, 1997; Sillitoe, 1998).

Recently, the need to develop a more integrated methodological approach to ethnopedology has been discussed among anthropologists, geographers, agronomists and soil scientists (Weinstock, 1984; Niemeijer, 1995; Sillitoe, 1998; Barrera-Bassols and Zinck, 1998; Östberg and Reij, 1998; Talawar and Rhoades, 1998; WinklerPrins, 1999). The traditional controversy between utilitarian and scientific, or between relativist and universalistic, is being overcome to the benefit of incorporating ethnopedological information into local sustainable land management models.

Some relevant issues still hamper reaching methodological integration:

- There is a need to go beyond the classificatory approach as the main or only ethnopedological research aim. More important than classifying is focusing on the management of soil and land resources.
- There is a need for an interdisciplinary integration of natural and social sciences that surpasses the cognitive studies of soil and land as 'perceived natural objects' and focuses on the different ways social subjects engage symbolically, cognitively and practically with soil and land resources. In this sense, the narrow notion of 'indigenous technical knowledge' cannot be abstracted from its cultural context.
- There is a need to fully understand the local context as a complex, dynamic and open system, where soil and land knowledge is applied in diverse ways according to ever-changing individual and social realities.
- There is a need to establish a participatory appraisal aimed at linking local actors and researchers in a mutual exchange, negotiation and continuing learning process.

2.3. Dominant research themes: from soil classification to land management practices

Ethnopedological research covers a wide topical array centered around four main subjects: (1) the formalization of local soil and land knowledge into classification schemes,

(2) the comparison of local and technical soil classifications, (3) the analysis of local land evaluation systems, and (4) the assessment of local agro-ecological management practices.

2.3.1. Classification principles, categories and classes

Major approaches to soil and land classification by indigenous peoples were derived from the comparative analysis of a set of EPS that record traditional taxonomic systems implemented by 62 ethnic groups located in 25 countries in Africa, America and Asia (Barrera-Bassols and Zinck, 1998). In spite of methodological inconsistency among the studies, making the comparative analysis cumbersome, some general principles can be identified, including: (1) the existence of complex systems of indigenous knowledge about the hierarchical organization of the soil mantle; (2) the recognition and implementation of morphological attributes for soil classification, which are at the same time dynamic, utilitarian and symbolic; (3) the use of similarities and differences between soil bodies for constructing multi-categorical classification systems; (4) the existence of universal criteria in all ethnopedological classification systems. More specifically, the following conclusions can be drawn from the comparative analysis:

- Although indigenous knowledge about soil and land resources is widely shared by all members of a community, there are differences in wisdom among people according to age, gender, social status and experience. Local people might give different answers to the same questions about the soil system, which together constitute the ethnopedological knowledge of a community and its social theory of the soil system.
- The multipurpose character of the ethnopedological classifications implies various ways of organizing and distributing the soil classes within a multilevel system. The inclusion or exclusion of given soil classes, their variable positioning in the categories of the system, all depend on the classification criteria assigned, which might be ecological, morphological, productive or symbolic, among others.
- Four sets of classification criteria are used by the sampled ethnic groups. The proportion of the groups implementing a given criterion is indicated as a percentage of the total number of groups. The four sets are: (1) color (100%) and texture (98%); (2) consistence (56%) and soil moisture (55%); (3) organic matter, stoniness, topography, land use and drainage (between 34% and 48%); and (4) fertility, productivity, workability, structure, depth and soil temperature (between 2% and 26%) (Fig. 3).
- The diagnostic attributes most frequently used to label soil classes are morphological ones. Of these, color and texture are the most representative. More comprehensive attributes, such as fertility or workability, which are in fact land qualities, are less commonly used. It is notable that there is no clear-cut distinction between soil and land characteristics.
- Unlike the ethnobotanical and ethnozoological classifications (Berlin, 1992), the ethnopedological classifications generally start, at the higher level of the system, with a comprehensive realm concept including all ‘soils’, the equivalent of Plantae or Animalae in the other natural realms.
- Unlike the ethnobiological taxonomic systems, which cluster only selected species occurring locally (Berlin, 1992), the ethnopedological classifications generally include all or most of the soil classes encountered locally.

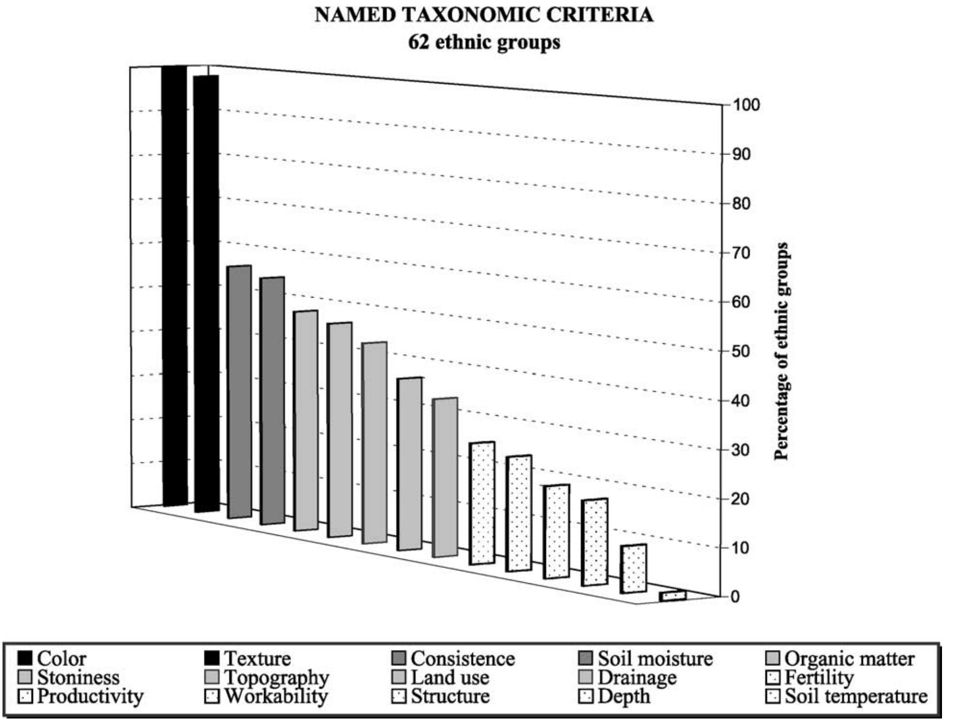

Fig. 3. Characteristics and qualities used by local peoples to classify soils.

- Considering all studies included in the inventory, the number of taxa (soil classes) belonging to the different systems recorded varies from 3 to 24. The average number of taxa recognized per ethnic group is 12. More than half (56%) of the sampled groups work with 8–14 taxa.

2.3.2. Comparison of local and technical soil classifications

There are some significant similarities and complementarities between indigenous and scientific soil taxonomic systems, showing potential synergism, especially for solving problems related to soil and land management. A few examples are provided to illustrate this potentially fertile research area.

A cluster analysis of related soil morphological attributes highlights a close correspondence with an indigenous soil classification system from northeastern Brazil. Thus, the empirical soil classification could be a useful framework for objectively grouping morphologically similar soils. The clustering of non-morphological attributes around key parameters, such as moisture and pH, and the comparison with main indigenous soil classes also show that indigenous soil taxonomy provides a reasonable framework for the preliminary stratification of soils for management purposes (Stacishin de Queiroz and Norton, 1992).

Ten years of ethnopedological research findings in the Himalayas demonstrate a close correlation between indigenous and conventional soil taxonomies (Tamang, 1993). Most of the indigenous classes can be readily converted into commonly used scientific classification schemes. Also, a close correlation between indigenous soil color classes and soil chemical conditions reveals that farmers are well aware of the unique differences between soil color and associated properties. Furthermore, there is a strong correlation between indigenous land classes and soil fertility. Local land quality classes for agricultural purposes correlate well with selected chemical properties (e.g. levels of cation exchange capacity and exchangeable cations), particularly in those soils that have not been altered by chemical fertilizers (Shah, 1995).

Indigenous and conventional knowledge systems are equally limited in their abilities to mitigate and prevent actual soil erosion hazards in the Himalayas. Both, however, have also extensive complementarities, considering the time frame and spatial scale of the responses provided by each system. Indigenous knowledge responds primarily over the long-term and takes into account off-site effects of soil loss. Complex soil landscape management and land use planning strategies constitute local responses to each specific erosion event over a decadal perspective. In contrast, conventional science primarily formulates general responses to individual erosion events and operates fundamentally on the site and over the short-term. Structural and vegetative techniques are implemented to reduce downstream sedimentation. The complementation of local and conventional approaches and techniques in the Shivalik Himalayas in India promotes increased productivity and drastically reduces sedimentation in eroded agricultural lands (Scott and Walter, 1993).

One of the main issues mentioned in several ethnopedological reports is the inconsistency of indigenous soil knowledge at the regional scale. Indigenous soil and land classes are often named and characterized differently by members of the same ethnic group but from different villages, while technical soil surveys indicate a regional distribution of the same soil classes. This could result from the application of unsuitable research techniques or from real historical or cultural differences. Indeed, examples of ethnopedological research in Mexico reveal the existence of a region-wide soil knowledge among the Maya, Nahua, Otomi and Purhépecha peoples. The naming and characterization of soil and land classes are relatively homogeneous over thousands of square kilometers, forming a regional 'folk soil culture' (Barrera-Bassols, 1988). Over the last 15 years, a methodological approach has been developed in Mexico to map indigenous soil units at plot, local and regional scales; this has contributed to strengthening ethnopedological survey and rural land use planning (Ortíz-Solorio et al., 1989). The combination of photo-interpretation and ethnopedological survey has revealed, in some cases, close correspondence between conventional soil map units and ethnopedological map units (Licona et al., 1992).

2.3.3. Local land evaluation systems

Many ethnic groups have created their own land evaluation systems for agricultural purposes. Assessment criteria requiring a sophisticated microenvironmental knowledge are used to establish multiple cropping systems (Osunade, 1992; Gonzalez, 1994; Mafalacusser, 1995; Lawas and Luning, 1996). In general, land use decisions made by local people are more accurate and better adapted than the technical recommendations forwarded by extensionists. The integration of both knowledge sources, using GIS (Chase, 1995; Gonzalez, 1995; Jarvis and MacLean, 1995; Weiner et al., 1995; Wilcox and Duin, 1995; Lawas and Luning, 1997; Harmsworth, 1998; Gonzalez, 2000; Brodnig and Mayer-Schönberger, 2000) and knowledge-based systems (KBS) (Furbee, 1989; Guillet, 1989, 1992; Balachandran, 1995) for land evaluation and land use planning, is a promising new stream of research and application.

2.3.4. Agro-ecological management practices

Land and water management by indigenous groups varies in accordance with the conditions prevailing in each ecological zone. In the warm and moist lowlands, the indigenous perception, knowledge and management of land center on fertility conservation or restoration were formed using complex agro-ecological systems. Farming strategies mobilize an accurate knowledge of the micro-local soil conditions to select a variety of adapted crop associations (Fujisaka et al., 1996). Usually, agricultural fields are densely covered with plants to maintain soil productivity. Color changes in the topsoil are used to monitor the fertility status and for early identification of potential productivity decline.

In the warm and dry lowlands, the main issue of crop production is the scarcity and irregularity of rainwater supply. Local techniques have been developed for water harvesting and soil moisture conservation, particularly in Africa (Critchley et al., 1994; Reij et al., 1996). Common indigenous land management strategies include soil protection from erosion, salinization control, moisture maintenance in the arable layer, and disposal of sediments carried by intermittent streams.

In the cold and dry highlands, indigenous wisdom concentrates on protecting the soil from erosion and mitigating the effect of natural hazards on soil fertility. A variety of EPS has been carried out in the Andes (Sandor and Eash, 1995; PRATEC, 1996) and in the Himalayas (Tamang, 1993) to investigate the local techniques used for terrace and bench construction.

3. Ethnopedology assessed: a growing discipline

Since the 16th century, foreign travellers, missioners and explorers have accounted for the vast, complex and sophisticated perceptions of nature, pedological wisdom and land management systems possessed by the colonized 'noble savage' societies of Africa, America, Asia and Australia. But it was only recently that ethnopedology was recognized as a comprehensive discipline. The first structured attempts to acquire soil and land information from indigenous peoples came from social and cultural anthropologists. Cultural and environmental geographers, a few agronomists and some soil scientists have also contributed to the rapidly increasing collection of EPS in diverse geographical entities, agro-ecological zones and ethnic territories of the world (e.g. Sillitoe, 1998; Barrera-Bassols and Zinck, 1998; Talawar and Rhoades, 1998; Niles, 1999; WinklerPrins, 1999).

To assess the current status of ethnopedology in a worldwide perspective, published papers and grey documents were compiled in a large database of 895 references (Barrera-Bassols and Zinck, 2000). Of the reviewed references, 432 (48%) correspond to EPS proper, which specifically focus on the analysis of local soil perception, knowledge and management as the core subject; the other references correspond to studies of broader interest, which provide ethnopedological data within a wider research context. The following conclusions can be drawn from this collection of references with respect to the abundance, distribution and diversity of EPS.

3.1. Rapid expansion of ethnopedology

During the last two decades, the number of EPS has considerably increased. Since 1989, the average production has been 33 studies per year (Fig. 4). Some specific cultural areas already have an extensive literature on indigenous soil and land knowledge. Middle America (Guatemala and Mexico) and the Andean region (Bolivia, Colombia, Ecuador and Peru) are the most important of such areas in America. West sub-Sahelian Africa, West Africa, East Africa, the Himalayas, India and Southeast Asia also have plentiful EPS. The studied cultural cores cover seven of the major areas of plant domestication and several countries with a biological and/or cultural diversity among the highest in the world. They have a set of relevant features in common: (1) they form an important part of the major food-producing regions of the world, (2) they are among the major rural regions of the world, (3) they form part of the areas with the highest demographic growth rates, and (4) they are facing increasing human-induced soil degradation.

There are several reasons that explain the increase in EPS during the last 20 years, paralleling a general increase in interest for social sciences, as highlighted by Wallerstein (1996). (1) Since the beginning of the 1980s, social scientists have shown more interest in understanding non-western societies as emerging subjects facing specific and multifaceted ecological, cultural and political challenges after the deepening of their economic crisis and the resulting poverty. The weakening of the national states due to the globalization process has increased ethnic autonomy claims, national minority violence, and the reappearance of racism and cultural conflicts (Appadurai, 1996). (2) There is a growing

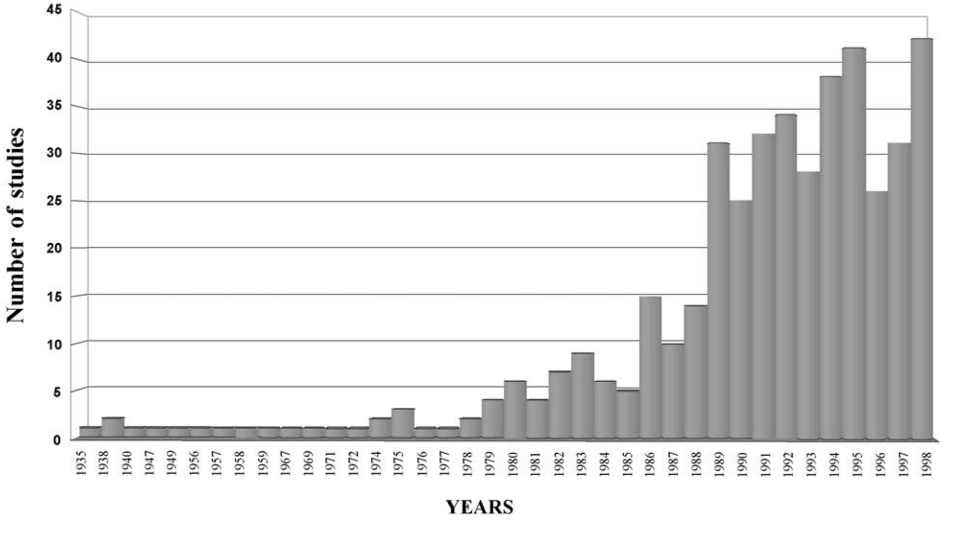

Fig. 4. Abundance of ethnopedological studies: 1935–1998.

concern to capture, formalize and preserve local soil knowledge before it becomes fragmented or even completely lost, as indigenous communities are increasingly facing cultural changes and social disintegration. (3) There is also a need to better understand local communities, because rural development as the paradigm of modernization has failed in many parts of the underdeveloped world—note the collapse of the Green Revolution and the resulting environmental degradation and uncertain food security in the coming future (Pretty, 1995). To enhance the social acceptability and chance of success of development programmes, local soil knowledge is increasingly incorporated in their formulation. (4) Local studies from the natural and social sciences focus on the political and ecological consequences of globalization and support the local sustainable production systems in traditional rural cultures. However, compared with the abundant biotechnological and crop-transgenic research—the new agricultural paradigm—the lack of interest in exploring contextual solutions to pressing food production and distribution issues still reflects the mechanistic agronomic misconceptions of the rural world (Kloppenburg, 1991; Cleveland, 1998).

3.2. Distribution of EPS by geographical entity

The 432 EPS of the references database are distributed over 61 countries, of which 35% are in Africa, 34% in America, 26% in Asia, 4% in Europe and 1% in the Pacific area. Africa has the highest number of EPS (41%), followed by America (23%), Asia (23%), Europe (8%) and the Pacific (5%) (Fig. 5). However, as the continents have different numbers of countries, in fact Africa, America and Asia have been equally addressed by ethnopedological research, with about 50% of the countries in each continent having one

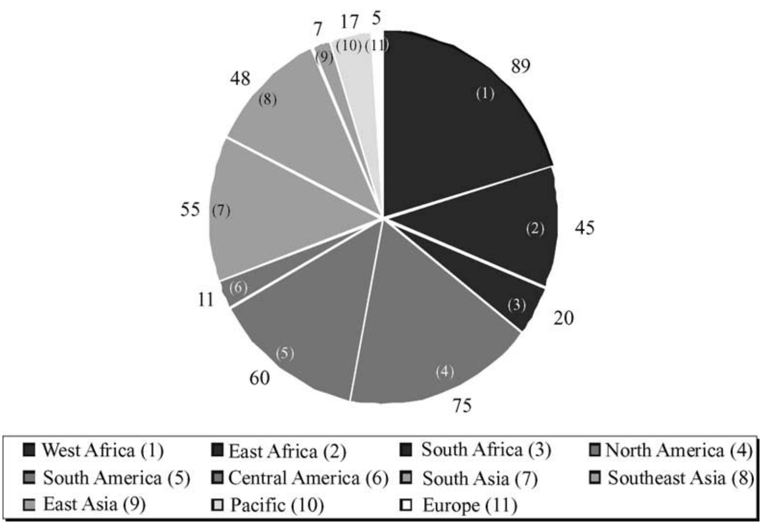

Fig. 5. Distribution of ethnopedological studies (EPS) according to continents and sub-continental areas. From (1) to (11): geographical regions showing relative abundance of EPS. From 5 to 89: numbers of EPS per geographical region.

or more EPS. In contrast, Europe and the Pacific area have been less studied. Of all tropical areas, the Pacific is the most neglected, although it has an important rural population, many ethnic groups and the highest linguistic diversity. From a worldwide total of 5000 endemic languages, 1600 are spoken in the Pacific islands (Harmon, 1996). Linguistic diversity parallels ethnopedological richness, since oral tradition conveys the local wisdom and know-how from generation to generation (UNESCO, 1997). As many endemic languages are threatened with disappearance, ethnopedological knowledge will also become lost.

Among individual countries, Mexico, Nepal, Peru, Nigeria and India are the most studied, having more than 20 EPS each and representing 41% of all EPS recorded in the collection (Fig. 6). With 71 EPS, Mexico dominates. The current EPS abundance figures do not necessarily reflect intrinsic differences in ethnopedological richness between countries, as other factors such as access to grey literature and NGOs promoting EPS in certain privileged countries play a role as well.

3.3. Peoples and ethnopedological diversity

3.3.1. Linguistic diversity and EPS

In total, 217 ethnic groups have one or more EPS: 35% in America, 33% in Africa, 28% in Asia and 4% in the Pacific area. Mexico and India together account for 18% of all ethnic groups having ethnopedological information. In Mexico alone, 41% of the country's ethnic groups (56 in total) have been studied from an ethnopedological point of view. Taking into account the existence of about 5000 endemic languages (Harmon, 1996; Maffi, 1998), barely 5% of global ethnopedological knowledge has been addressed.

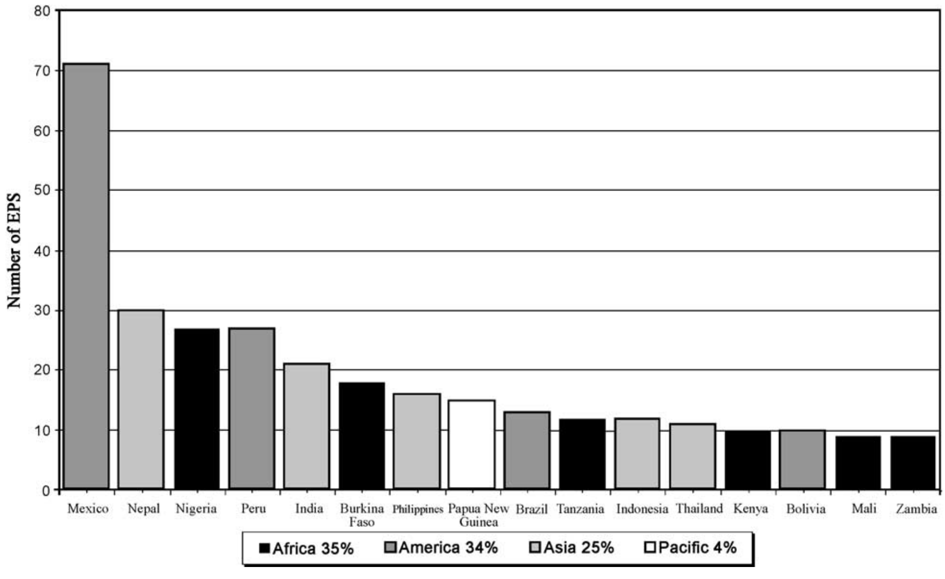

Fig. 6. Countries with high numbers of ethnopedological studies (EPS).

About 90% of local languages now used by small ethnic groups are likely to vanish during the twenty-first century (Maffi, 1999). This highlights the magnitude of the effort needed to make an inventory of and analyze the peculiar forms of indigenous perception, knowledge and management of the soil and land resources before they disappear altogether. It is expected that the loss of linguistic diversity will be 500 times larger than that of biological diversity (Krauss, 1992). This means that the loss of ethnopedological knowledge might be of considerable proportions, qualitatively as well as quantitatively.

Eight of the fifteen countries with the highest numbers of EPS (from 9 to 71) belong to the 19 countries with the largest linguistic diversity (Grimes, 1996). Linguistic diversity is extremely high (megadiversity) in Indonesia and Papua New Guinea, very high in India and Mexico, and high in Brazil, the Philippines, Tanzania and Nepal (Fig. 7). There is thus a clear relationship between linguistic and ethnopedological diversities.

3.3.2. Biological diversity and EPS

A similar high correlation links ethnopedological richness to biological diversity. Countries with extremely high and very high biological diversity (ICF, 1998) and having, at the same time, large numbers of EPS include Brazil, Indonesia, Mexico, Peru, Papua New Guinea, India and the Philippines (Fig. 8).

There is also a strong relationship between the original centers of plant domestication in the world (Vavilov, 1926) and the density of EPS (Fig. 9). Eleven of the fifteen countries with large numbers of EPS match 6 of the 12 early domestication centers. They include Mexico (South Mexico–Central America center), Peru and Bolivia (South America center), Brazil (Southern Brazil–Paraguay center), Nigeria (West Africa center), India and Nepal (India–Burma center), and Indonesia, Thailand, Papua New Guinea and the

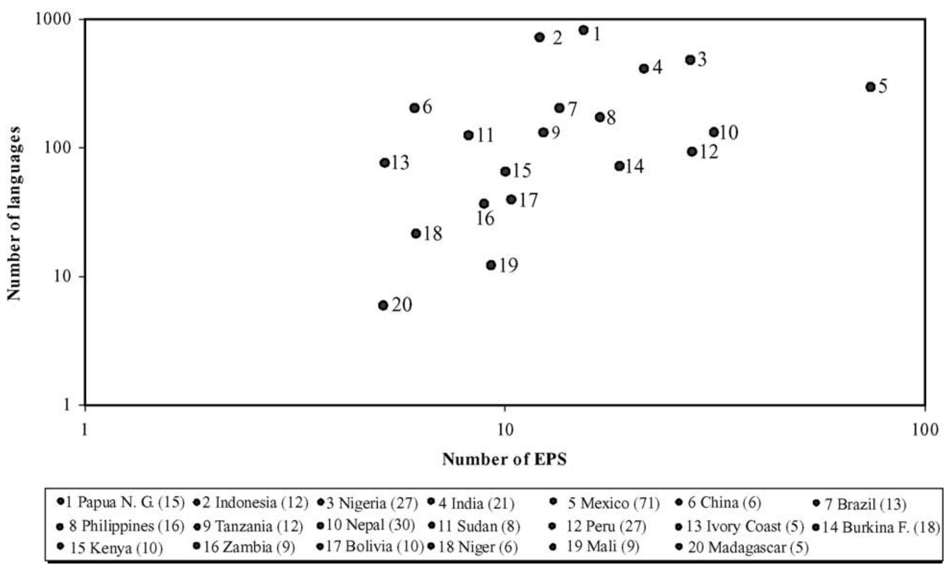

Fig. 7. Relationship between variety of local languages and abundance of ethnopedological studies (EPS), considering 20 countries with highest linguistic diversity and with five or more EPS (from 5 to 71 EPS).

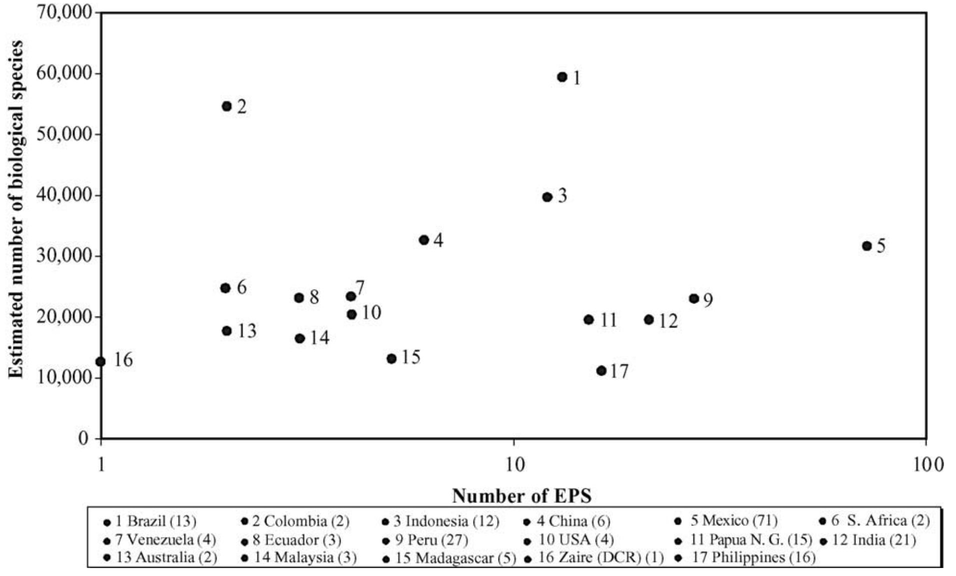

Fig. 8. Relationship between variety of biological species (mammals, birds, reptiles, batrachians, and vascular plants) and abundance of ethnopedological studies (EPS), considering 17 countries with the highest biodiversity and with ethnopedological information (from 1 to 71 EPS).

Philippines (Indo-Malay center). These same countries also belong to the major food production areas of the world.

3.4. Abundance of EPS by agro-ecological zone

Agro-ecological zones, broadly defined from a loose combination of elevation, topography and climate, are appropriate environmental units to assess the abundance of EPS. This is the case since local peoples have developed, over time, the knowledge and abilities to efficiently exploit and manage the ecological heterogeneity of the landscape (Fig. 10). To a large extent, these peoples live in three of the most fragile ecological zones of the world: (1) warm and moist lowlands, (2) warm and dry lowlands, and (3) cold and dry highlands.

A remarkable feature is that dry (arid and semi-arid) areas have attracted more ethnopedological research than humid areas. About 66% of the EPS recorded in the database have been carried out in dry–cold highlands and dry–warm lowlands. Semi-arid areas alone account for 37% of the EPS. Out of a total of 232 studies that specifically provide agro-ecological information, 29% are located in dry areas. A few selected regions have received particular attention, including the Sahel and sub-Sahelian Africa, semi-arid India and northern Mexico. In these areas, local peoples have developed sophisticated land and water management practices to overcome water scarcity and unpredictable rainfall variability. These areas are also exposed to severe land degradation because of intensive land pressure following rapid population growth, resources depletion through uncontrolled overexploitation, and mismanagement of irrigation schemes. Furthermore, dry environ-

Fig. 9. Centers of plant domestication having ethnopedological studies.

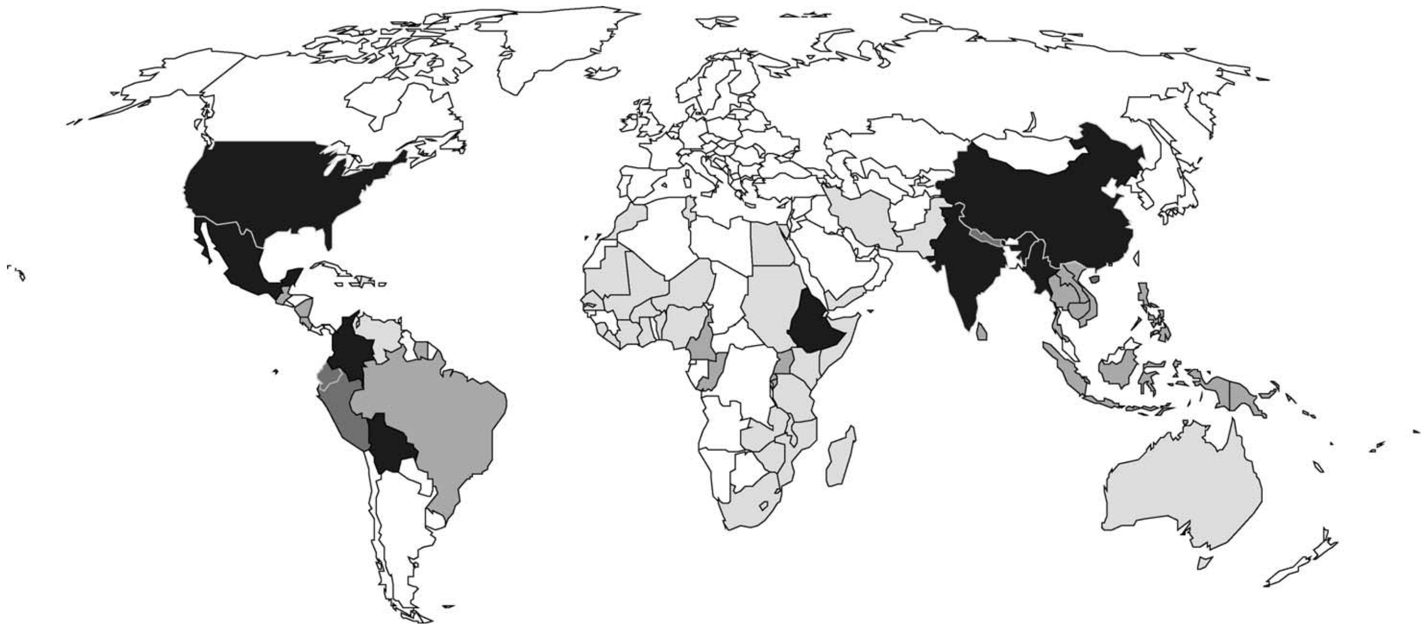

Fig. 10. Worldwide distribution of ethnopedological studies per main agro-ecological zones.

AGRO-ECOLOGICAL ZONES	AGRO-ECOLOGICAL MANAGEMENT
Warm and dry lowlands	**Main biophysical constraints:** scarcity and irregularity of rainfall. **Local measures:** mechanical, biological, and agronomic micro-local measures have been developed for water harvesting and soil moisture conservation to maintain land productivity, for soil fertility restoration and for salinization control. **Agro-ecological land management practices:** bunds, mounds, terraces, benches, fences; intercropping, mulching, alley cropping, fallowing, and run-off agriculture.
Warm and moist lowlands	**Main biophysical constraints:** soil nutrient depletion and high biological competition. **Local measures:** mechanical, biological, and agronomic micro-local measures have been developed to maintain or restore soil fertility and to prevent or diminish crop pests and diseases. **Agro-ecological land management practices:** water control agrosystems, multicropping, slash-and-burn agriculture, agro-sylvo-pastoral systems; mulching, fallowing, alley cropping, and crop rotation.
Cold and dry highlands	**Main biophysical constraints:** relief steepness, low rainfall, and environmental hazards such as frost, soil erosion, and landslides. **Local measures:** mechanical, biological, and agronomic micro-local measures have been developed to prevent, protect from and control erosion and to mitigate the effect of environmental hazards on soil fertility. **Agro-ecological land management practices:** terraces, benches, fences; intercropping, mulching, alley cropping, fallowing, run-off agriculture, agroforestry, agro-ecological zoning according to elevation.
Complex agro-ecological areas	Include two or more of the single agro-ecological zones, usually in complex patterns.

Fig. 10 (*continued*).

ments are particularly sensitive to global climate change and therefore strongly famine-prone.

Comparatively, the tropical warm and moist lowlands have received less attention, accounting for 34% of the EPS, with 21% in the humid tropics and 13% in the subhumid. Even less attractive so far have been the temperate environments, with only 13 EPS (mainly from Mexico), representing 5% of the studies recorded. Similarly, cold areas account for only 16% of the EPS, concentrated in the Himalayan and Andean highlands.

Altogether, the tropical zone has by far the highest number of EPS (186 studies, 72%). Within this general context, the most frequently studied areas include (1) the dry tropics in Africa, Asia and America, and (2) the moist tropical lowlands in Brazil, West Africa, Mexico and Southeast Asia. The 15 countries with the highest numbers of EPS cover the most fragile agro-ecological zones of the world and correspond to the countries with high indices of extreme poverty and severe land degradation.

3.5. Topical diversity of EPS

Peoples' cosmovision, including beliefs, symbols and rituals (the Kosmos sphere), has been considered in only 69 of the 432 EPS (16%). This reflects the relatively little interest for the subjective component of indigenous knowledge. Often, the researcher is unfamiliar with or does not fully understand the way the three domains of the K–C–P complex inextricably operate in the context of a given community and its territory (Toledo, 2000). The researcher's own cosmovision might lead him to separate nature and culture, and therefore disregard or underestimate the symbolic meanings, social rules and cultural ethics that control the local management of natural resources. Many case studies are basically concerned with analyzing the technical aspects of local soil knowledge (Corpus and Praxis), neglecting the relevance of beliefs and social institutions (Kosmos). The latter are, however, of fundamental importance when formulating development projects and planning rural land use. Neglecting the cultural context and rules has led to the failure of many development programmes in the Third World.

A large number of EPS (245 studies, 57%) addresses, among other topical fields, the analysis of the local cognitive systems, including knowledge and classification (the Corpus sphere). A significant research domain (158 EPS, 36%) covers ethnopedological taxonomies and the comparison of local and scientific soil and land classifications. A similar dominant trend exists in ethnobiological studies and other ethnosciences.

A third field of interest in EPS focuses on the inventory and analysis of local management practices (the Praxis sphere). This topic is not restricted to EPS and comes up frequently in studies of broad ethnopedological interest as well (in total, 532 out of the 895 recorded references). Of note in this context is the importance devoted to the indigenous soil and water conservation practices (ISWC) in 113 EPS, carried out mainly in arid and semi-arid areas, including the cold and dry highlands. These EPS focus on the inventory and implementation of local practices, mechanical as well as biological, but often neglect to scrutinize the cosmovision context that could explain why and when the practices are used.

A growing number of EPS deals with soil fertility management (72 EPS), soil conservation and erosion control (72 EPS), and soil management in general (92 EPS). This reflects an increasing concern for the land degradation issue and the importance of soil management at the field level. Also, more and more attention is being given to spatial soil variability as related to the genetic diversity of cultivars, the pattern of intensive polycultural land use, and the management of specific agro-ecological niches.

4. Conclusion

Peoples' knowledge about soils and their management constitutes a complex wisdom system, with some universal principles and categories similar or complementary to those used by modern soil science. Although an integrated ethnopedological approach still needs to be developed by combining the current trends, a promising bottom-up approach is gaining interest among scientists and farmers. Synergism could be strengthened by the implementation of GIS and KBS to integrate modern scientific and technical advances with historical wisdom and local needs.

At a worldwide scale, EPS are unevenly distributed. Some geographical entities, from continental to village level, have been privileged, others neglected. The frequency of studies decreases from Africa to America, Asia, the Pacific and Europe. Large differences in study density occur within subcontinents, countries and subdivisions of countries. Individual countries that have particularly attracted the interest of researchers and provided a substantial number of the references are Mexico, Nepal, Peru, Nigeria and India. Within countries, the village is the preferred study level, as the majority of EPS focus on the perception, knowledge and management of the soil resource at the local level. Since most EPS are concentrated in a few countries, the result is that some ethnic groups have received more attention than others.

Communities living in harsh environments, with limited resources, have developed complex land and water management systems to compensate for resource scarcity. Surviving indigenous communities are often restricted to marginal lands, while the better soils are devoted to large-scale, market-oriented, mechanized agriculture. Therefore, EPS are concentrated in a few broadly defined agro-ecological zones. The highest densities of EPS occur in dry lowlands and highlands, where the need to efficiently handle scarce natural resources has fostered an intimate co-evolution of eco- and socio-systems.

The present imbalance of topical research between the Kosmos, Corpus and Praxis spheres, respectively, suggests that more emphasis should be given to analyzing the role of beliefs, perceptions and rituals in decision-making by local peoples about land use and management. Shifting the research emphasis to Kosmos needs the support of and interaction with the local communities, especially those still able to maintain their K–C–P systems for preserving soil quality and agro- and biodiversity. Without the participation of local actors in the formulation and implementation of rural development programmes, the EPS will lose their practical relevance, as is often the case in conventional soil inventories.

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References

Abrol, I.P., 1990. Fertility management of Indian soils—a historical perspective. Proceedings of 14th International Congress of Soil Science, vol. V. Kyoto, Japan, pp. 203–207.

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, 257–272.

Appadurai, A., 1996. Modernity at large. Cultural Dimensions of Globalization. Public Worlds, vol. 1. University of Minnesota Press, USA.

Balachandran, C.S., 1995. LACONEX: a rule-based implementation to advise on plot-level land conservation in Vilathikulam, southeastern India. Land Degradation & Rehabilitation 6 (4), 265–283.

Barrera-Bassols, N., 1988. Etnoedafología Purhépecha. México Indígena VI (24), 47–52.

Barrera-Bassols, N., Zinck, J.A., 1998. The other pedology: empirical wisdom of local people. Proceedings of 16th World Congress of Soil Science. ISSS/AFES, Montpellier, France: CD-ROM.

Barrera-Bassols, N., Zinck, J.A., 2000. Ethnopedology in a worldwide perspective. An annotated bibliography. ITC Publication, vol. 77. Enschede, The Netherlands.

Berlin, B., 1992. Ethnobiological classification. Principles of Categorization of Plants and Animals in Traditional Societies. Princeton Univ. Press, NJ, USA.

Birmingham, D.M., 1996. Learning local knowledge of soils: improving linkages between land users and extension personnel. Journal of International Agricultural and Extension Education 3 (1), 43–51.

Bocco, G., 1991. Traditional knowledge for soil conservation in central Mexico. Journal of Soil and Water Conservation 46 (5), 346–348.

Boulaine, J., 1989. Histoire des Pédologues et de la Science des Sols. INRA, Paris, France.

Brodnig, G., Mayer-Schönberger, V., 2000. Bridging the gap: the role of spatial information technologies in the integration of traditional environmental knowledge and Western science. The Electronic Journal on Information Systems in Developing Countries 1, 1–15, www.

Buol, S.W., Hole, F.D., McCraken, R.J., Southard, R.J., 1997. Soil Genesis and Classification. Iowa State Univ. Press, Ames, IA, USA.

Chadefaud, C., 1998. Anthropisation et terre arable dans l'Egypte Ancienne: la "Kemet" (terre noire), techniques d'irrigation, pratiques culturales, macrorestes végétaux. Proceedings of 16th World Congress of Soil Science. ISSS/AFES, Montpellier, France. CD-ROM.

Chambers, R., 1997. Whose Reality Counts? Putting the First Last. Intermediate Technology Publications, London, UK.

Chase, R., 1995. GIS and long range economic planning for indigenous territories. Cultural Survival Quarterly 8 (4), 45–48.

Chingkwei, L., Shenggeng, C., 1990. History of soil science in China. Proceedings of 14th International Congress of Soil Science, vol. V. Kyoto, Japan, pp. 197–202.

Cleveland, D.A., 1998. Balancing on a planet: toward an agricultural anthropology for the twenty-first century. Human Ecology 26 (2), 323–340.

Conklin, H., 1957. Hanunoo agriculture. A Report on an Integrated System of Shifting Cultivation in the Philippines. FAO, Rome.

Critchley, W.R.S., Reij, C., Willcocks, T.J., 1994. Indigenous soil and water conservation: a review of the state of knowledge and prospects for building on traditions. Land Degradation & Rehabilitation 5, 293–314.

Ettema, Ch.H., 1994. Indigenous Soil Classifications. What are Their Structure and Function, and How Do They Compare with Scientific Soil Classifications? Institute of Ecology, University of Georgia, Athens, GA, USA. www.

FAO/UNESCO, 1988. Soil map of the world, revised legend. World Soil Resources Report, vol. 60. FAO, Rome, Italy.

Fujisaka, S., Hurtado, L., Uribe, R., 1996. A working classification of slash-and-burn agricultural systems. Agroforestry Systems 34 (2), 151–169.

Furbee, L., 1989. A folk expert system: soils classification in the Colca Valley, Peru. Anthropological Quarterly 62 (2), 83–102.

Gonzalez, R.M., 1994. GIS incorporating indigenous knowledge: the case of local soil classification and utilization in Costa Rica. MSc thesis. ITC, Enschede, The Netherlands.

Gonzalez, R.M., 1995. KBS, GIS and documenting indigenous knowledge. Indigenous Knowledge & Development Monitor 3 (1), 5–7.

Gonzalez, R.M., 2000. Platforms and terraces. Bridging participation and GIS in joint-learning for watershed management with the Ifugaos of the Philippines. PhD thesis. ITC Dissertation 72, Wageningen University/ITC, The Netherlands.

Grigg, D.B., 1974. The Agricultural System of the World: an Evolutionary Approach. Cambridge Univ. Press, Cambridge, UK.

Grimes, B.F., 1996. Ethnologue. Summer Institute of Linguistics, Dallas, TX, USA. www.

Guillet, D.W., 1989. A knowledge-based-systems model of native soil management. Anthropological Quarterly 62 (2), 59–68.

Guillet, D.W., 1992. Crop choice and soil management. In: Guillet, D.W. (Ed.), Covering Ground: Communal Water Management and the State in the Peruvian Highlands. University of Michigan Press, Ann Arbor, MI, USA, pp. 67–84.

Harmon, D., 1996. Losing species, losing languages: connections between biological and linguistic diversity. Southwest Journal of Linguistics 15, 89–108.

Harmsworth, G., 1998. Indigenous values and GIS: a method and a framework. Indigenous Knowledge & Development Monitor 6 (3), 3–7.

Hecht, S.B., 1990. Indigenous soil management in the Latin American tropics: neglected knowledge of native peoples. In: Altieri, M., Hecht, S. (Eds.), Agroecology and Small Farm Development. CRC Press, Boca Raton, FL, USA, pp. 151–158.

ICF, 1998. Megadiversity Country Data Tables. International Conservation Foundation, Washington DC, USA. www.

Jarvis, K.A., MacLean, A., 1995. Geomatics and political empowerment: the Yuquí. Cultural Survival Quarterly 8 (4), 58–61.

Kloppenburg Jr., J., 1991. Social theory and the de/reconstruction of agricultural science: local knowledge for an alternative agriculture. Rural Sociology 56 (4), 519–548.

Krauss, M., 1992. The world's languages in crisis. Language 68 (1), 4–10.

Krupenikov, I.A., 1993. History of soil science. From its inception to the present. Russian Translator Series, vol. 98. Balkema, Rotterdam, The Netherlands.

Lawas, M.C., Luning, H.A., 1996. Farmers' knowledge and GIS. Indigenous Knowledge & Development Monitor 4 (1), 8–11.

Lawas, M.C., Luning, H.A., 1997. Capturing resource user's knowledge in a geographic information system for land resource management. Geographical Studies of Development and Resource Use 2, 27.

Licona, A.L., Ortíz-Solorio, C.A., Pájaro, D., Ortega, R., 1992. Metodología para el levantamiento de tierras campesinas a nivel regional en ejidos del centro de Veracruz, México. Agrociencia. Serie Suelo, Agua y Clima 3 (4), 91–105.

Mafalacusser, J.M., 1995. The use of indigenous knowledge for land use planning in part of Xai-Xai district, Gaza Province, Mozambique. MSc thesis. ITC, Enschede, The Netherlands.

Maffi, L., 1998. Language: a resource for nature. Nature and Resources: The UNESCO Journal on the Environment and Natural Resources Research 34 (4), 12–21.

Maffi, L., 1999. The "business" of language endangerment: saving languages or helping people keep them alive? Manuscript. Northwestern University/Terralingua, USA. May.

Malinowski, B., 1935. Coral gardens and their magic. A Study of the Methods of Tilling the Soil and of Agricultural Rites in the Trobriand Islands, New Guinea, vol. 1. George Allen Publisher, London.

Needham, J., Gwein-Djen, L., 1981. Chinese geo-botany in *status nascendi*. Journal d'Agriculture Traditionnelle et de Botanique Appliquée XXVIII (3–4), 199–230.

Niemeijer, D., 1995. Indigenous soil classifications: complications and considerations. Indigenous Knowledge & Development Monitor 3 (1, April), 20–21.

Niles, R.K., 1999. Indigenous Knowledge for the Classification, Management and Conservation of Soil. Bibliography and Selected Abstracts. Natural Resource Ecology Laboratory, Colorado State University, Fort Collins, CO, USA. www.

Ortíz-Solorio, C.A., Pájaro, D., Ordaz, V., 1989. Manual para la cartografía de clases de tierras campesinas. Cuadernos de Edafología 15 (62 pp.).

Östberg, W., Reij, C., 1998. Culture and local knowledge: their roles in soil and water conservation. In: Blume, H.P., Eger, H., Fleischhauer, E., Hebel, A., Reij, C., Steiner, K.G. (Eds.), Towards Sustainable Land Use: Furthering Cooperation Between People and Institutions. Advances in Geoecology 31, vol. 1. Catena-Verlag/ISSS, Reiskirchen, Germany, pp. 1349–1358. 2 vols.

Osunade, M.A.A., 1992. Land resource appraisal by small farmers in Swaziland. UNISWA Research Journal 6, 93–104.

Pawluk, R.R., Sandor, J.A., Tabor, J.A., 1992. The role of indigenous soil knowledge in agricultural development. Journal of Soil and Water Conservation 47 (2), 298–302.

PRATEC, 1996. Crianza del Suelo en Los Andes. PRATEC, Lima, Perú.

Pretty, J.N., 1995. Regenerating Agriculture: Policies and Practice for Sustainability and Self-reliance. Earthscan, London, UK.

Queiroz Neto, J.P., 1998. Soil science—its nature and the challenges it must face. Proceedings 16th World Congress of Soil Science. ISSS/AFES, Montpellier, France. CD-ROM.

Reij, C., Scoones, I., Toulmin, C. (Eds.), 1996. Sustaining the Soil. Indigenous Soil and Water Conservation in Africa. Earthscan, London, UK.

Sandor, J.A., Eash, N.S., 1995. Ancient agricultural soils in the Andes of southern Peru. Soil Science Society of America Journal 59 (1), 170–179.

Scott, C.A., Walter, M.F., 1993. Local knowledge and conventional soil science approaches to erosional processes in the Shivalik Himalaya. Mountain Research and Development 13 (1), 61–72.

Shah, P.B., 1995. Indigenous agricultural land and soil classifications. In: Schreier, H., Shah, P.B., Brown, S. (Eds.), Challenges in Mountain Resource Management in Nepal. Processes, Trends, and Dynamics in Middle Mountain Watershed. IDRC/ICIMOD, Kathmandu, Nepal.

Sillitoe, P., 1998. Knowing the land: soil and land resource evaluation and indigenous knowledge. Soil Use and Management 14 (4), 188–193.

Soil Survey Staff, 1998. Keys to Soil Taxonomy. USDA, Natural Resources Conservation Service, Washington DC, USA.

Stacishin de Queiroz, J., Norton, B.E., 1992. An assessment of an indigenous soil classification used in the Caatinga region of Ceará State, Northeast Brazil. Agricultural Systems 39, 289–305.

Tabor, J., 1990. Ethnopedology: using indigenous knowledge to classify soils. Arid Lands Newsletter 30, 19–28.

Talawar, S., Rhoades, R.E., 1998. Scientific and local classification and management of soils. Agriculture and Human Values 15, 3–14.

Tamang, D., 1993. Living in a fragile ecosystem: indigenous soil management in the hills of Nepal. International Institute for Environment and Development. Gatekeeper Series 41 (23 pp.).

Toledo, V.M., 1992. What is ethnoecology? Origins, scope and implications of a rising discipline. Etnoecológica I (1), 5–21.

Toledo, V.M., 2000. Indigenous knowledge on soils: an ethnoecological conceptualization. In: Barrera-Bassols, N., Zinck, J.A. (Eds.), Ethnopedology in a Worldwide Perspective. An annotated Bibliography. ITC Publication, vol. 77. ITC, Enschede, The Netherlands, pp. 1–9.

Thrupp, L.A., 1989. Legitimatizing local knowledge: from displacement to empowerment for Third World people. Agriculture and Human Values VI (3), 13–24.

UNESCO, 1997. Nuestra diversidad creativa. Informe de la Comisión Mundial de Cultura y Desarrollo. Correo de la UNESCO, México.

Vavilov, N.I., 1926. Studies on the origin of cultivated plants. Institute of Applied Botany and Plant Breeding. State Press, Leningrad, USSR.

Vavilov, N.I., 1949–1950. The origin, variation, immunity and breeding of cultivated plants. Chronica Botanica 13, 1–336.

Wallerstein, I. (Coord.), 1996. Abrir las ciencias sociales. Informe de la Comisión Gulbenkian para la reestructuración de las ciencias sociales. Serie El Mundo del Siglo XXI. Siglo XXI Editores/CIIH-UNAM, México.

Weiner, D., Harris, T., Levin, R., Warner, T., 1995. GIS approaches to the political ecology of rural land reform in

Kiepersol, South Africa. Proceedings of the International Congress on Agrarian Questions. Agricultural Univ. of Wageningen, The Netherlands.

Weinstock, D., 1984. Getting the right feel for soil: traditional methods of crop management. Ecologist 14 (4), 146–149.

Wilcox, B.A., Duin, K.N., 1995. Indigenous cultural and biological diversity: overlapping values of Latin American ecoregions. Cultural Survival Quarterly 8 (4), 49–53.

West, R., 1947. The cultural geography of the Tarascan area. Institute of Social Anthropology, vol. 7. Smithsonian Institution, WA, USA.

Williams, B., 1975. Aztec soil science. Boletín del Instituto de Geografía, UNAM 7, 115–120.

WinklerPrins, A.M.G.A., 1999. Local soil knowledge: a tool for sustainable land management. Society & Natural Resources 11 (7), 151–166.

Yaalon, D.H., Berkowicz, S. (Eds.), 1997. History of soil science: international perspective. Advances in Geoecology, vol. 29. Catena-Verlag/ISSS, Reiskirchen, Germany.