The Land Classification System of the San Nicolás Zoyatlán (S Mexico) Nahuatl Indigenous Community: A Basis for a Suitable Parametric Soil Use Proposal

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Abstract

The incorporation of ethnopedological knowledge in soil science and the inclusion of indigenous communities as beneficiaries of the agricultural technology are indispensable premises to make a better use of soil. However, to achieve this, it is necessary to have clearer communication and understanding between peasants and soil specialists. This paper contributes to the understanding of the way in which the ethnopedologic knowledge of the community of Zoyatlán (Mexico) has been used in making decisions on soil management and production. It also proposes a methodological alternative that will contribute to the communication among land users and soil specialists.

Our results show that Zoyatlán peasants identify seven soil types grouped into four classes according to their agricultural suitability. These classes are determined by distinctive land properties that enclose six agronomic characteristics of the topsoil and four specific characteristics of the work area. Based on this criteria, we designed a parametric method assuming that the agricultural suitability of the land is determined by several characteristics of the topsoil; among them topsoil thickness was outstanding. This characteristic was susceptible to being represented parametrically by numerical values (obtained from a mathematical model), which is a single numerical expression of topsoil thickness performance. The application of this methodology provided information that is useful and can easily be interpreted by both the peasants and the soil specialists. Furthermore, this information can be represented at different cartographic scales.

Keywords: *indigenous classification, geographical information systems, land use suitability, parametric method, topsoil*

Introduction

For over 4000 years, people have tilled, drained and irrigated soils for agricultural use. At the same time, they have classified them in accordance with their appearance, characteristics and productivity. The Chinese book titled Yugond (2,500 years B.P.) is probably the first text ever on soil classification, and in fact, most ancient civilizations produced effective interpretative classifications (Tabor and Krasilnikov 2002). The Nahuatl (Aztec) classification is an example of this, and currently such classification continues to be used by the indigenous communities of Mexico and the northern part of Central America (Williams and Ortiz-Solorio 1981).

On the other hand, in most developed countries, vernacular classifications have been replaced by scientific taxonomic and agrological systems, and have been theoretically designed to meet both basic and practical objectives; for example the selection of the best soil for a certain land use (Seymour-Fanning and Balluff-Fanning 1989). However, according to *The World Reference Base for Soil Resources* (WRB 1994), in developing countries, soil science lacks credibility and acceptance regarding the systems it has proposed for practical soil use. This situation probably has been caused by three major limiting factors.

The first one is related to the large soil diversity existing in different regions of the world. Due to their morphology and other characteristics, many of these soils are still unknown to soil scientists (Nachtergaele et al. 2000). A second important factor is the statistics used to define and establish soil quality parameters and soil limitations. Specialized personnel are required to generate this type of information as well as to develop an efficient logistic and technical infrastructure. All this requires extraordinary economic resources which are hardly available to developing countries (Tabor and Hutchinson 1994; Braimoh 2002). The third factor refers to the limited use that the peasants make of the documents and cartography available about soils. This happens mainly because of the purpose for which the published information is generated. For example, in many developing countries, Mexico included, the institutions in charge of elaborating soil maps make them with the purpose of having an inventory and a taxonomic classification of this resource. Maps thus produced are characterized by having a complex terminology which is unknown to non-specialist users (Ettema 1994; Tabor and Hutchinson 1994; Braimoh 2002; Krasilnikov and Tabor 2003). Another distinctive characteristic of these maps is the very general scale of cartographic representation (i.e. regional level 1:250,000). This condition technically prevents the peasants from using those maps with the level of detail that they need for improving use and management of their soils (Habarurema and Steiner 1997).

All these factors seem to show a lack of sensitivity from soil science towards the users' interests and needs. However, we contend that this may not be the case, since a large proportion of the limitations mentioned above happen because of the almost inexistent communication between the users of soil as a resource and the soil scientists. Other factors that make communication and exchange of experiences harder include the heterogeneity of local knowledge, the difficulty to correlate local and scientific knowledge, and the approach used to document ethnopedological knowledge (Niemeijer 1995).

The synergy of these factors has consolidated an unintentional, albeit negative effect of "technological discrimination," which globally affects the indigenous-peasant communities of developing countries. Yet, in the face of such an irregular situation, these communities have traditionally made use of their ethnopedological knowledge to classify and manage their soils. This fact points out the need to integrate local knowledge into soil sciences; however, to achieve this, it is first necessary to establish a dialogue that will allow for us to identify similarities and differences between both bodies of knowledge. Based on these considerations, our main goals for the research in the indigenous community of San Nicolás Zoyatlán were the following: (1) to gather information on the ethnopedological knowledge of this community, and to examine its relationship to socio-environmental conditions prevailing in the study area; (2) to analyze and synthesize the way in which knowledge and sets of conditions have been used in the current management of soils for subsistence productivity; and (3) to propose a methodological alternative feasible for Zoyatlán, contributing to the creation of a communication bridge between land users, extension workers and researchers.

To achieve these goals, we employed methodological tools from social and environmental sciences. The various approximations used are described in this article in four sections. In the first section we present the most relevant environmental and social characteristics of the research area. Then we explain in detail the methodological tools used to gather and synthesize the information. In the third section, the ethnopedological knowledge used by the peasants of Zoyatlán for classifying and managing their soils is described. We then discuss the differences and similarities between this local knowledge and scientific knowledge of soils. Some of the soils' properties that reflect the long process of antropization are highlighted. In the final section we present a methodological proposal that emphasizes various advantages that favor communication between peasants and soil specialists. The application of this methodology is exemplified and discussed for the soils of the research area.

Regional Setting

San Nicolás Zoyatlán (hereafter referred to simply as Zoyatlán) is located in the Southern Sierra Madre, in the eastern part of the state of Guerrero (Mexico), and it covers an area of 924 hectares (Figure 1). From the physiographic point of view, the area is a toposystem mainly characterized by slope eroding land forms, which show a morphometry of great contrasts. Elevation varies from 1300 to 1750 m, while slopes, generally complex and of great length, have gradients ranging from 0 to 100% (Cervantes and Hernández submitted). The topography of Zoyatlán causes a wide variety of climates. In general terms a tropical, semi-warm, sub-humid climate prevails, with an average annual temperature of 27.5˚C and a total average annual rainfall of 781 mm. From November to April, drought is severe (García 1988). Lithology is very complex but considered to be made up mainly of metamorphic rocks of the quartzite type, volcanic rocks, limestone outcrops, as well as alluvial and coluvial materials.

Zoyatlán has a long history of using its natural resources (Vega 1991; Dehouve 1995). It is estimated that at least since 1490 until a few years after the Spanish conquest, the land use of the community was mainly agriculture. However, around 1550, grazing was introduced (Cervantes and de Teresa 2004). In 1998 its population amounted to 681 inhabitants, most of them belonging to the Nahuatl ethnic group. Twenty four percent of the population speaks its mother tongue and the remaining 76% are Nahuatl and Spanish-speaking. The main activities are agriculture, cattle farming and collection of forest products. Agriculture is basically for subsistence and it takes place through five different production systems. The main difference among them lies in the availability of water for the culture and the frequency of the use of the soil (Cervantes and de Teresa 2004). According to the criteria established by some authors (Warman et al. 1982; Boserup 1984; Montañez and Warman 1985; Rojas 1985) most of these agricultural systems correspond to intensive and semi-intensive use. The main agricultural products cultivated in the region are corn, beans and pumpkins. In 1998 the production of maize fluctuated between 550 and 1500 kg/ha (Cervantes and de Teresa 2004).

According to Cervantes and de Teresa (2004), the ancient agricultural and grazing use and the land conflicts that the community suffered at the beginning of the 20th century have contributed to the fact that the natural vegetation of Zoyatlán is now reduced. In 1998, the distribution of soil use and plant cover was as follows: human settlements (3.2%), irrigation agriculture (2.3%), and rain-fed agriculture and free grazing stockbreeding (23.7%). According to Rzedowski's (1978) classification, the different vegetation types were distributed as follows: conifer (*Juniperus*) forest (2.4%), gallery forest (3.3%), primary tropical deciduous forest (0.9%) and secondary tropical deciduous forest (64.2%) (Cervantes and Hernández submitted).

From an agronomic viewpoint, the most important soil units in this region are Regosols and Leptosols. These soils show different physical phases that in some cases make it difficult to work with, and always prevent the use of agricultural machinery.

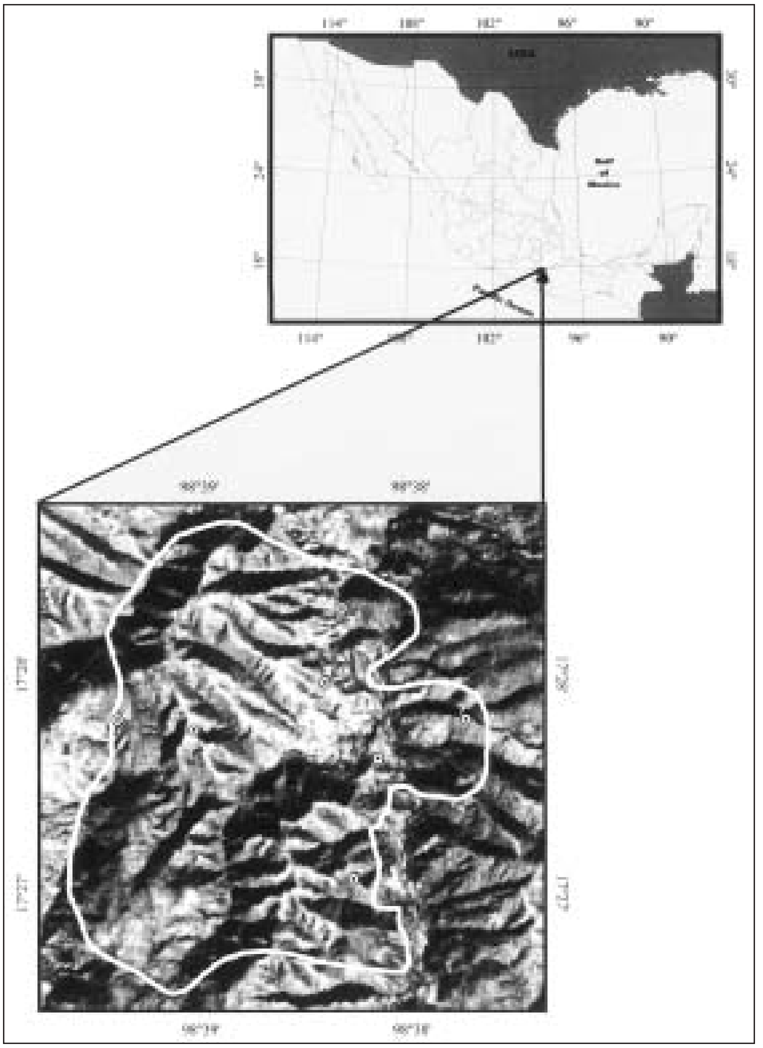

Figure 1. Geographic location of San Nicolás Zoyatlán, Guerrero state, Mexico. Numbered points depict the location of the representative profiles off the indigenous soils types. 1=Tlalcapochtic; 2=Tlaltezoquitl; 3=Texalli; 4=Tlalchichiltic; 5=Xalli; 6=Tlalnextli; 7=Tepetatl.

Methods

Peasants of Zoyatlán took part in this research, especially those considered in the community to be the most experienced ones regarding soil characteristics, properties and management. The study began in 1993 and ended in 1999. The methodological design consisted of three stages: (1) interviews and surveys; (2) soil field research and laboratory analyses of soil samples; and (3) soil mapping.

Interviews and Surveys

We undertook field prospecting and interviews with authorities and "principales" (old men council) of Zoyatlán. The interviews were focused on the following subjects: (a) community boundaries; (b) land ownership; (c) agricultural activities; (d) preferred areas for agriculture; (e) farming system variants; (f) preferred soils for agriculture and soils with the highest agricultural production. Afterwards, open interviews were structured in accordance with the Nahuatl classification of soils. At this stage, peasants ("principales" and the most experienced peasants) specified the different types of indigenous soils existing in Zoyatlán. During the field prospection, the morphologic, productive and management characteristics of soils were specified, especially those they consider to be the most representative. This allowed us to record and interpret the different concepts they use in their soil classification and the criteria used to identify the advantages and limitations of each soil type.

With the information obtained from the interviews, a survey with different topics was designed for 36 families. The most relevant topics for this study were the following: (a) cultivation systems and soil properties according to the indigenous classification and (b) use and management history of the plots pertaining to each family. In the first case, the survey was addressed to the heads of the families. In the second, the information came from both heads of family and their wives, as the ownership of plots frequently comes from a dowry or inheritance.

Soil Field Research and Laboratory Analyses

Cartographic information available for the research area was used to create the database. It included a topographic map at a 1:50,000 scale and an aerial panchromatic photo at a 1:80,000 scale (INEGI 1983). Both were initially used as the base map on which the environmental information obtained in the field was represented. The supplementary information required to carry out this study was gathered on site.

During the field study of soils, 73 soil profiles were described and sampled. The goals were the following: (a) to describe their morphology, properties and limitations; (b) to establish, as far as possible, the soil spatial distribution and variability within the landscape, as well as the originating factors; and (c) to select soil profiles that were representative of the community and then to analyze them. Soil profiles were described following the guidelines established by the SCS-USDA (1984). Later these soils were classified according to the criteria established by the WRB (1998). Laboratory techniques used for the analysis of the soil samples are summarized in the Appendix. In this paper, we selected seven representative Zoyatlán soil profiles for discussion (Figure 1).

Soil Mapping

Maps were created using an overlay approach (Borrough 1986). The thematic maps considered in the space model were altitude, exposure, slope, land form, and lithology.

Results and Discussion

An Overview about Zoyatlán's Indigenous Knowledge of Land and Soils

Field observations together with the interpretation of the information obtained from the interviews, allowed us to select some of the relevant principles upon which the ethnopedological knowledge of the producers of Zoyatlán is based. Peasants know intuitively that the formation and diversity of their lands and resources, including soils and their productivity characteristics, are conditioned by environmental factors; those standing out are relief and climate. Peasants realize that when these factors change (e.g. changes of elevation, land forms, slopes) the characteristics of lands and the resources related to them also change. Similarly, the peasant community of Zoyatlán possesses a detailed and accurate knowledge about the spatial distribution and extension of the land and soils in the landscape. This is of great ethnographic interest, as such knowledge was used by their pre-Columbian ancestors to produce different types of soil cartography (Ortiz-Solorio and Gutiérrez-Castorena 2001). This knowledge enables them to identify lands according to their spatial distribution and quality, which is basic for their classification into different soil types regarding quality, suitability and management.

As observed in Figure 2, local residents consider their habitat to be composed of different land systems ("Lands"). The term "Land" is locally used in an integrating sense to refer to a certain physical environment and its biophysical dynamics. In these dynamics, all human activities are included (present and past, as well as future) which are associated with the use of their natural resources. However, for practical purposes, local farmers subdivide land systems into different land facets ("Types of Lands"). Each land facet is a variable surface area which is defined by certain environmental factors and specific natural resources, as well as land quality properties and specific use limitations.

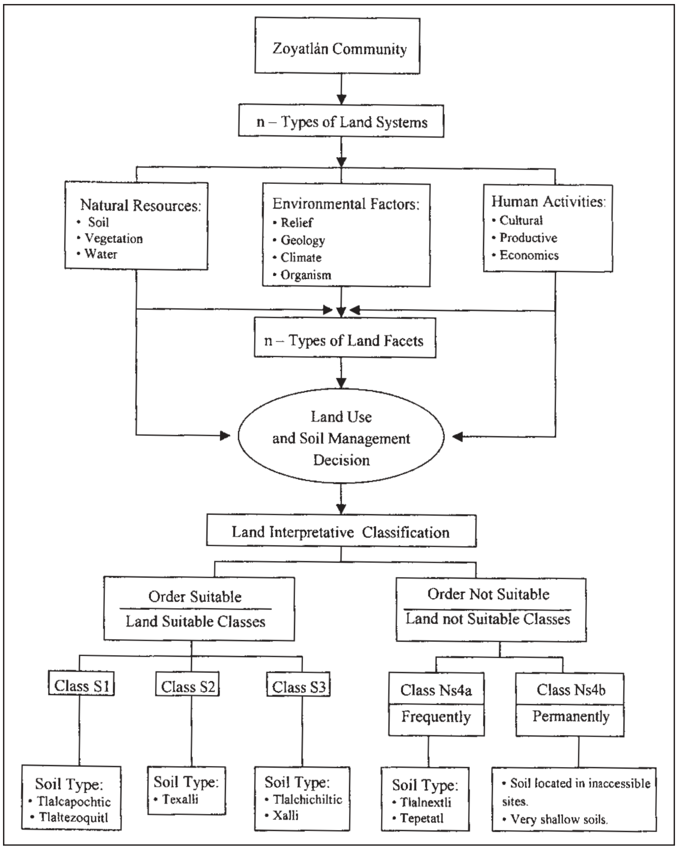

Figure 2. Synopsis of the principles and local factors upon which Zoyatlán Land Classification System is based.

Peasants view soil quality as an attribute of both land facet and topsoil for a specific type of use, either generated by humans or by the natural elements prevailing in a land facet. Empirically, this trait is measured mainly in terms of the following characteristics: (a) the natural availability of nutrients for crops (criterion: crop growth and yield); (b) water availability; (c) resistance to soil degradation; (d) spatial variability of soil characteristics; and (e) size, shape, and access to the land facet. The results of such evaluation influence peasants' decisions on the use and management of the soil type present in the land facet (Figure 2). They are also the basis for their establishment of the different levels used in their land classification system.

These findings closely match the information of several authors (Tabor 1993; Agrawal 1995; Ettema 1994; Habarurema and Steiner 1997; Talawar and Rhoades 1998; Winklerprins 1999), about local soil classifications being fundamentally contextual. Such classifications are a reflection of an integrated knowledge of the potentialities and limitations that the environment imposes on production. This knowledge, in turn, is expressed through the different forms of soil management. It is therefore possible to say that the principles and criteria used by the Zoyatlán peasants to evaluate their lands and associated resources, is similar in many aspects to the "Land Use Management System" concept defined by Rhoades (1994).

Zoyatlán Soil Types and Terminology

Our results show that the peasants of Zoyatlán recognize in their community seven different types of soils. These

Table 1. Ethnolinguistic terminology used in Zoyatlán for diagnostic soil features and designation of the distinct properties of topsoil. NS = not specified.

Soil Type	Soil Features			Topsoil Properties					
	Soil depth	Soil color	Stoniness	Fertility	Thickness and layers	Consistency	Texture	Water retention	Soil washing
Tlalcapochtic	Deep	Black	Moderate	High	≥ 30 cm, 1 layer	Loose "suelta"	Not clayey, not sandy "ni barrosa ni arenosa"	Cold soil "suelo frío"	Low
Tlaltezoquitl	Deep	Black, brown, red	High	High	≥ 30 cm, 1 layer	Very sticky "muy pegajoso"	Clayey "barrosa"	Very cold soil "suelo muy frío"	Very low
Texalli	Moderate to shallow	Brown, red	Moderate	Good	30 cm, 1 or 2 layers	Very loose "muy suelta"	Sandy "arenosa"	Hot soil "suelo caliente"	High
Tlalchichiltic	Moderate	Red	Low	Low	30 cm, 1 or more layers	Loose "suelta"	Not clayey, not sandy "ni barrosa ni arenosa"	Hot soil "suelo caliente"	High
Xalli	Moderate to shallow	Grey	Very high	Low	30 cm, 1 or more layers	Very loose "muy suelta"	Sandy "arenosa"	Cold soil "suelo frío"	Very low
Tlalnextli or Tlaliztac	Deep	White, ashy	Low	Very low	30 cm, 1 or more layers	Loose "suelta"	Sandy to loam "arenosa a suave"	Cold soil "suelo frío"	Moderate
Tepetatl	Very thin	Red, black	High	Very low	< 30 cm, 1 or more layers	Loose to firm "suelta a dura"	Sandy and clayey "arenosa y barrosa"	NS	Moderate to low

Table 2. Physical and chemical characteristics of representative soils at Zoyatlán. S = stoniness; R = rocks; BD = bulk density; PD = particle density; OM = organic matter; CEC = cation exchange capacity; BS = bases saturation; TN = total nitrogen; TP = total phosphorus. Number in parentheses next to thickness cultivation horizon indicates total depth of soil profile. 1a and 2a show the number of layers that constitute the cultivation horizon.

Characteristics	Class S1		Class S2	Class S3		Class Ns4a	
	Tlalcapochtic	Tlaltezoquitl	Texalli	Tlalchichiltic	Xalli	Tlalnextli	Tepetatl
Land Facet							
- Elevation (masl)	1490	1350	1470	1400	1326	1552	1480
- Slope gradient (%)	0 - 8	45	45	17.6	0	12	0 - 4
- Surface fragments (%)	S: 20 R: 0	S: 90 R: 10	S: 15 R: 0	S: 80 R: 0	S: 80 R: 20	S: 60 R: 10	S: 80 R: 10
Cultivation Horizon Properties							
Thickness (cm)	35 (75)	30 (130)	30 (54)	1a: 8 2a: 22 (60)	30 (30)	30 (90)	26 (26)
Color (moist)	Black (10YR2/1)	Black (10YR2/1)	Dark brown (7.5YR3/2)	1a: dark reddish brown (5YR3/4) 2a: dark red (2.5YR3/6)	Gray reddish (5YR5/2)	Gray reddish (5YR5/2)	Dark reddish brown (5YR3/4)
Texture (%)							
- Sand	66.0	52.6	65.0	1a: 56.6 2a: 43.4	90.0	36.8	61.4
- Silt	13.4	9.4	15.6	1a: 10.8 2a: 8.0	5.0	26.4	13.6
- Clay	20.6	39.0	19.4	1a: 32.6 2a: 48.6	5.0	36.8	25.0
BD	1.17	1.11	1.16	1a: 1.18 2a: 1.14	1.59	1.07	1.0
PD	2.49	2.41	2.61	1a: 2.64 2a: 2.60	2.56	2.50	2.43
Porosity (%)	53.01	53.94	55.6	1a: 55.30 2a: 56.15	37.86	57.31	58.85
Water retention (%)							
- 12 hrs	60.0	79.64	81.53	1a: 80.12 2a: 93.05	17.92	42.89	40.32
- 14 days		33.19	35.20	1a: 36.69 2a: 40.57			
PH							
- H_2O	8.2	8.2	8.4	1a: 6.1 2a: 5.9	8.1	7.5	8.0
- NaF	8.3	8.6	8.4	1a: 9.5 2a: 9.8	8.4	9.0	8.3
Erodability value	0.23	0.18	0.28	1a: 0.27 0.14	0.45	0.28	
OM (%)	3.45	2.93	3.62	1a: 2.76 2a: 0.86	0.67	2.05	2.79
CEC ($cmol^{(+)}Kg^{-1}$)	31.5	53.3	27.8	1a: 23.4 2a: 28.2	15.1	26.5	39.9
BS (%)	61.90	56.10	70.10	1a: 38.4 2a: 46.4	68.54	42.03	70.00
TN (%)	0.16	0.12	0.16	1a: 0.12 2a: 0.03	0.07	0.08	0.16
TP (ppm)	850	1156	1531	1a: 234.5 2a: 140.5	825.0	450.0	592.12

soils are locally named: (1) Tlalcapochtic ("capulín" [fruit of *Prunus capulli*] colored soil); (2) Tlaltezoquitl ("clayey" stony soil); (3) Texalli (sandy soil); (4) Tlalchichiltic (chilli-colored soil); (5) Xalli (sand originated by the action of water); (6) Tlalnextli (ash-colored or grey soil), also known as Tlaliztac (white soil); and (7) Tepetatl (mountain land, thin cover or thin mantle). As can be seen, the terminology used for these names incorporates some of the main morphogenetic characteristics of each soil type: color, texture, thickness, stoniness, spatial distribution and the process of soil formation. Moreover, these soil types differ in their degree of fertility (Table 1).

Translation and interpretation of this terminology allowed us to infer that the terms used by the peasants make it possible to semi-quantitatively designate several differentiating properties of soils that are useful for their agronomic classification. For example, the peasants deem a soil to be "deep" (e.g. Tlalcapochtic, Tlatezoquitl and Tlalnextli soils; Table 1) when there is not a rock or a hard and continuous layer within the first 60 cm from the surface (Table 2). In contrast, a soil is "very thin" when its total depth is less than 30 cm (e.g. Tepetalt soil; Tables 1 and 2). They use the term "stony soil" to indicate the presence of stones, gravel or pebbles on or in the soil (e.g. Tlatezoquitl and Xalli soils; Tables 1 and 2). Regarding fertility, they contend that soils showing horizons and/or superficial dark layers (topsoil) are generally the best for agricultural use (e.g. Tlalcapochtic and Tlatezoquitl soils; Tables 1 and 2).

With respect to the topsoil, there is also a precise terminology to designate its differentiating characteristics (Table 1). However, the ethnolinguistic terms employed in its characterization, differ substantially from those used in the scientific classification of soils. A good example of the latter is the expression "loose consistency" (e.g. Tlalcapochtic, Tlalchichiltic and Tlalnextli soils; Table 1). According to USDA-SSDS (1992), the term "loose consistency," in a general sense, refers to a soil material which is neither coherent nor adhesive. In contrast, from a micromorphological analysis performed on a Tlalcapochtic topsoil sample, we found that such a term indicates the presence of individual grains (primary minerals) and very stable organic-mineral aggregates, of fine (< 1.0 mm) and very fine (< 0.25 mm) size. These aggregates are soft in dryness and moderately friable in moisture (Figure 3). The term "very loose" consistency (e.g. Texalli and Xalli soils; Table 1) indicates the presence of fine and very fine soil aggregates, mixed with non-structural units (mineral grains) which are not cohesive and show an erodability ranging from light to moderate. The terms "very sticky" (e.g Tlatezoquitl soil; Table 1) and "loose to firm" (e.g. Tepetatl soil; Table 1) indicate, respectively: (a) the presence of a topsoil of an adhesive consistency in moisture, and (b) that the topsoil is made up primarily of sand and very fine pebbles (> 2 mm, but < 4 mm).

Other examples of a similar nature are the following. The term "sandy texture" (e.g. Texalli and Xalli soil; Tables 1 and 2) only indicates a low clay content in the topsoil. When the clay content increases lightly, the texture of the topsoil is often called "sandy to loam" (e.g. Tlalnextli soil; Tables 1 and 2). "Non clayey, non sandy" is a local term used to refer to a topsoil with a sandy loam (e.g. Tlalcapochtic soil; Tables 1 and 2) to loamy texture (e.g. Tlalchichiltic soil; Tables 1 and 2). "Clayey" is only applied to those topsoils that because of their content and type of clays, it is difficult to work with them (e.g. Tlatezoquitl soil; Tables 1 and 2).

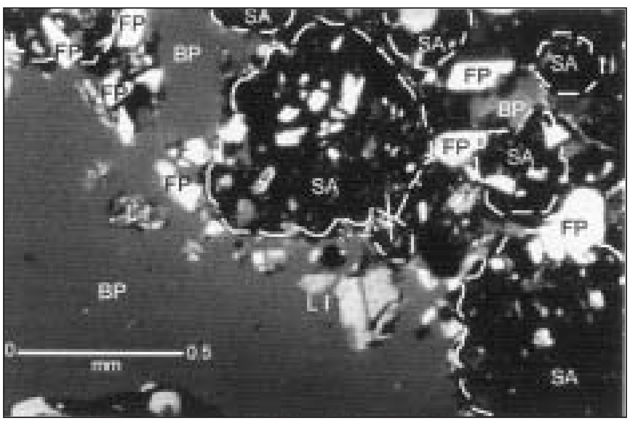

Figure 3. Microstructure of the topsoil of a Tlalcapochtic soil, showing the distribution of spaces and solids in the soil matrix. Note the presence of biopores (BP), sand-size grains, both lithic (LI) and those composed of feldespars (FP), as well as structural aggregates (SA). These aggregates are characterized by their very fine to fine size, a spherical shape, and a very high stability to dispersion in water.

The expressions "cold soil" and "hot soil" are local agroclimatic terms which point to the capacity for water retention of the topsoil. A "cold soil" (e.g. Tlalcapochtic, Xalli and Tlalnextli soils; Tables 1 and 2) preserves humidity temporarily for agriculture, whereas a "hot soil" loses it rapidly (e.g. Texalli and Tlalchichiltic soils; Tables 1 and 2). When such soils accumulate a significant amount of humidity, it is called "very cold soil" (e.g. Tlatezoquitl soil; Tables 1 and 2). The term "soil washing" refers to the loss of the topsoil caused by water erosion (Tables 1 and 2).

The analysis of the terminology presented above, as well as the understanding about their context shows that the local knowledge is based on principles similar to those used worldwide in other indigenous classifications (Dialla 1993; Etemma 1994; Habarurema and Steiner 1997; Braimoh 2002; Ericksen and Ardón 2003; Birmingham 2003). In all these classifications, the perception about the agronomic quality of the characteristics that differentiate the soil is summarized in conspicuous criteria. Their ponderation varies according to most limiting factors (such as salinity) or of greater interest to users (such as productivity). Furthermore, these criteria are always directed at characterizing the topsoil even when the depth of the soil might be a well-identified variable, as is the case of the peasants of Zoyatlán.

In agreement with many authors (Etemma 1994; Habarurema and Steiner 1997; Talawar and Rhoades 1998; Braimoh 2002; Ericksen and Ardón 2003; Birmingham 2003), we argue that the characterization of the topsoil is a constant principle in most indigenous classifications; representing also, one of the core differences between local and scientific classifications. The former describes and evaluates only the topsoil whereas the latter are based on the pedogenetic study of the soil, that is, the development and evolution of the different horizons of the soil (topsoil and subsoil). This fundamental difference is based in the fact that local producers and scientists pursue different goals and therefore apply different principles. Peasants try to define and assess the natural suitability of the land for the production systems that are viable in the soils of the region and allow them to meet their basic needs. In turn, scientists attempt to characterize soils in accordance with universal patterns (Tabor 1993; Ettema 1994; Habarurema and Steiner 1997; Talawar and Rhoades 1998).

Nevertheless, we argue that the various criteria empirically used by peasants to characterize soils must be taken into account in the agronomic studies to be able to make a diagnosis of the productive potential of the soil. In addition, some of the research that has compared the physical and chemical characteristics of the soils obtained through laboratory analysis, with the criteria used by local classifications, point out a great similarity between both sources (Williams and Ortiz-Solorio, 1981; Bellon 1990; Habarurema and Steiner 1997). The same was obtained for the soils of Zoyatlán, where the differences in properties identified by the peasants for the seven types of soil (i.e. fertility level, "soil washing," "cold soil," color, texture, etc.; Table 1), were often consistent with the characterization obtained from the laboratory analysis (Table 2). Because of those similarities, researchers such as Barrera-Bassols and Zinck (2000, 2003) and Krasilnokov and Tabor (2003), among others, have suggested that the principles upon which ethnopedological knowledge is based are similar or supplementary to those used by the modern soil science.

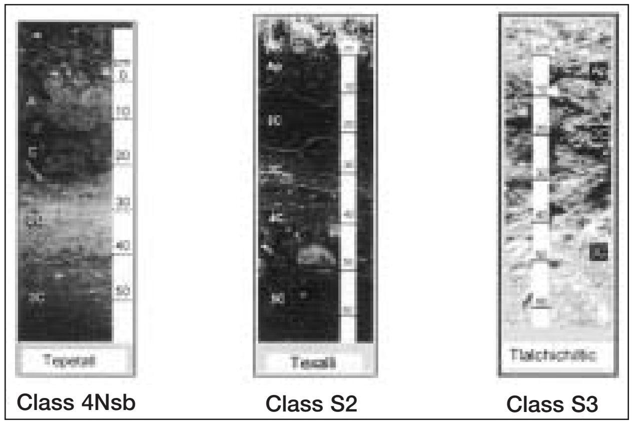

Figure 4. Macromorphologic features diagnostic of the profiles of some representative soils at Zoyatlán. Soil typogenesis is characterized by a small effective soil depth due to the presence of gravel, pebbles, stones, or hardened layers, in addition to the presence of textural and lithologic discontinuities (indicated by numerical prefixes), which cause very sharp limits between profiles layers.

Formalization of the Zoyatlán Land Classification System and Hierarchical Characterization

From the information described in the two previous sections, we were able to realize that the Zoyatlán land classification system (ZLCS) fulfills many of the taxonomic requirements of a formal interpretative classification (Figure 2). This means that the knowledge of the indigenous community about their lands and soils is used and agreed upon by the indigenous group, and can be organized at different hierarchical levels (Tabor 1990; Ettema 1994; Krasilnikov 2002). This information allowed us to understand that the ZLCS is founded on the natural suitability of the land for a certain use, and from its design it is possible to identify the limitations and risks intrinsic to the system (mountainous relief, poorly developed soils, and the climatic seasonality characterizing the dry tropics). It is worth mentioning that the concept of suitability in this paper was built on the basis of the technology and consumables criteria that are specifically and traditionally used by local peasants. This assessment included a basic inventory of the land resources, the understanding of the requirements of each land facet and associated soils for their use, a database of the socioeconomic characteristics of peasants, in addition to learning about their goals. Based on this, we contend that the Zoyatlán land classification system can be structured on three main classification levels: (1) Order, (2) Class, and (3) Soil Type (Figure 2).

The order distinguishes the suitability (S) or non-suitability (Ns) for a specific land use type (Figure 2). Due to the small cultivation land surface in the study area, most of the soils used in the land facets are considered suitable for agricultural use in the different classes. Only those soils located on extremely steep slopes or those occurring in rock areas with outcrops and very thin soils were excluded by the peasants as suitable (Figure 4). These areas preserve tropical deciduous forest vegetation and are included in class Ns4b (Figure 2).

The classes reflect the gradation of land suitability, not just suitable versus not suitable (Figure 2). This is determined by four characteristics related to the land facet (Table 3) and six differentiating properties, inherent to the topsoil of each soil type (Table 1). The characteristics belonging to the work area (land facet) are: (a) access to the site; (b) limitations to work in it; (c) type of viable crops; and (d) consumables required to obtain agricultural products. Accessibility is related both to physical effort necessary to reach the working area (e.g. surface morphometry) and to distance from settlements. Workability is related to weed density, physical obstacles and the use of the tools needed by peasants for sowing and cropping. Regarding cultivation type, peasants differentiate those seeds providing the best yields in relation to soil fertility and its propensity to pests. These two criteria determine the use of consumables, such as fertilizers and insecticides, to favor crop growth (Table 3). Regarding the six differentiating characteristics of the cultivation horizon, peasants underline thickness and the number of layers present in the cultivation horizon, and its fertility.

Peasants conceive fertility of the topsoil as a feature providing nutrients to crops. Empirically, they recognize the existence of two types of fertility, which are measured in terms of the production of their basic crops (corn, beans and pumpkins). The first type of fertility is associated with the nutrients budget contained naturally in the soil, and to its physical con-

Table 3. Characteristics of land facet for soil use, according to Zoyatlán's land classification system. Hybrid seed = improved varieties (corn and beans) introduced by governmental programs; "criolla" seed = several varieties (corn, beans and pumpkin) native to the area.

Land facet properties	Tlalcapochtic	Tlaltezoquitl	Texalli	Tlalchichiltic	Xalli	Tlalnextli	Tepetatl
Accessibility	Variable	Variable	Variable	Variable	Easy	Difficult	Difficult
Workability	Moderate	Difficult	Easy	Easy	Easy	Easy	Difficult
(a) Weedy	High	Very high	Low	Low	Very low	Very low	Low
(b) Stoniness	Moderate	High	Moderate	Low	Very high	Low	High
(c) Tools employed	Plough (animal traction). The soil "is light."	Plough (animal traction). The soil "is heavy."	Plough (animal traction). The soil "is light."	Plough (animal traction). The soil "is light."	Plough (animal traction). The soil "is very light."	Plough (animal traction). The soil "is very light."	Zero tillage, sowing is performed with a stick ("coa").
Viable crops	Very good yield of corn, bean and pumpkin (hybrid and "criolla" varieties).	Very good yield of corn, bean and pumpkin (hybrid and "criolla" varieties).	Good yield of corn, bean and pumpkin (hybrid and "criolla" varieties).	The yield is improvable with hybrid seed use.	The yield is improvable with hybrid seed use.	The yield is improvable with "criolla" seed use. The pumpkin is not successful.	Always make use of maize, bean, and pumpkin "criolla" seed.
Plague incidence	Low	Moderate	Very low	Low	High	Very low	Very low
Input							
(a) Fertilizer	None	None	Nitrogenated fertilizer	Nitrogenated and phosphorated fertilizer	Nitrogenated and phosphorated fertilizer	Nitrogenated and phosphorated fertilizer	Nitroenated fertilizer
(b) Pesticide	None	None	None	Some times is used	Always is used	None	None

dition (Table 1); in turn, the second type of fertility is considered to be a dynamic soil characteristic, which can be manipulated and enriched. This is achieved by using different techniques, such as the use of organic and chemical fertilizers (Table 3).

Thickness and number of layers of the topsoil represent an important basis upon which the Zoyatlán land classification system is structured. The optimum is a cultivation horizon with a thickness of 30 cm or more and comprising a single layer, as was the case of Tlalcapochtic and Tlaltezoquitl soil (Tables 1 and 2). This criterion is probably based on the fact that often the physical, chemical and mineralogical nature of the layers making up the cultivation horizon are very heterogeneous (e.g. abrupt changes in permeability and moisture retention, as well as in texture, bulk density, erodability, percentage of organic matter, exchangeable bases, phosphorus retention capacity, etc.). Peasants know that in tilling the land these layers get mixed, which could negatively affect both the capability of operating in such horizons (Williams and Ortiz-Solorio 1981; Johnson 1983; Bellon 1990), as well as the agricultural production. As observed in Table 1, Xalli soil is represented by a topsoil of 30 cm minimum thickness, which may have one or two layers (Figure 4). Tlalchiciltic, Xalli and Tlalnextli soils refer to the presence of a topsoil made up of one or several layers; the latter being the most common case (Figure 4).

Table 2 shows the main physical and chemical characteristics of these soils. According to peasants, Tlalcapochtic, Tlaltezoquitl, Texalli and Xalli are the most valued soils from the agricultural perspective. Due to their quality (thickness, fertility and accessibility), we included the first two in Class S1 (has no significant limitations for its agricultural sustained use), and the third one in Class S2 (has some limitations for its agricultural sustained use, which can reduce productivity to an acceptable level). Class S3 (has substantial limitations in its natural fertility for agricultural sustained use; Tables 1 and 2) is represented by Tlalchichiltic and Xalli. However, Xalli, because of its spatial distribution in the land facet (restricted to alluvial terraces) shows favorable conditions for irrigation, which increases its productivity and thus, changes its aptitude class, although this always mean the use of external inputs (Table 3). Class Ns4a (generally not suitable in its present condition, either because of its low natural fertility and difficulties of access, or due to the topsoil thickness) includes the Tlalnextli and Tepetatl soils (Tables 2 and 3). Peasants consider the latter soil to have the lowest value for agriculture due to greater difficulties in its management.

Soil Management Generalities

Notwithstanding that between users, consumable use and soil management are variable and complex, we were able to recognize that the most relevant aspect of soil management is the frequency of agricultural use for a certain soil. This is not only conditioned by the soil class, but also by socioeconomic factors such as the cultivable surface available for the peasants and the size and demographic structure of their families.

Examples of the interactions between these factors are those extreme cases occurring when the farmer's family is small (families newly formed, made up by old people, or having migrant members). When a family of this type owns a small cultivation surface area, they are forced to use Class Ns4a soils more frequently, e.g. some Tepetatl. In this case, an agricultural cycle is implemented and then lands are left in fallow for a four-year period. In contrast, there are families owning a sufficient number of plots of different qualities but without enough workforces for agricultural activities. Therefore, the use of Tepetatl soils is substantially less frequent, and the fallow period can be up to eight years. There is also another group of peasants who, in addition to owning sufficient plots, have soils in their plots that are generally of good quality. In this case, plots in use are only those capable of meeting their family's consumption needs (Cervantes and de Teresa 2004).

However, under ideal conditions peasants cultivate the Tlalcapochtic and Tlaltezoquitl soils (Class S1) every year (a system locally known as "anual de secano"). The Texalli soils (Class S2) are cultivated every other year with alternation of one year fallow periods (a system locally known as "año y vez"). In the case of Tlalchichiltic (Class S3) and Tlalnextli soils (Class Ns4a), fallow periods are longer. In the former type the most common system is one year of cultivation followed by two of fallow; in the latter, fallow periods vary between three and four years.

There is an exception regarding this traditional management of the use-fallow cycle of Zoyatlán soils. This exception is the presence of some low fertility soils under rain-fed agriculture conditions, but they are easy to work with and are located close to population settlements and water reservoirs (Tables 2 and 3). The most common example is the intensive use of Xalli soils (Class S3). These soils have been subject to irrigation as well as fertilizers and pesticides, which make it possible to have two annual harvests with a practically inexistent fallow period. However, even in these irrigated areas the socioeconomic factors prevail in plot management. Families with few members of productive age or a small number of plots, always cultivate the basic local products during the two cycles. If the family has several working age members and a sufficient number of plots, they use Xalli soils during the first cycle for sowing corn and beans. In the second cycle, they grow chilies, onions, tomatoes, peanuts, squash or "jícama," an edible tuber. In this case, the destiny of production is determined by both the market and family consumption.

In addition to the variants of use-fallow practices in the different soil classes, the Zoyatlán peasants also carry out activities aimed at the conservation of soil productivity. For example, in the case of Tepetatl soil, peasants are aware of the fact that the layer for cultivation they can use is very thin. Therefore, they try to preserve that thickness by avoiding cultivating in slopes steeper than 20%. Also, soil removal is minimal as sowing is done manually with a "coa" (sowing stick or cane). In addition, they always establish large cover crops such as the corn-bean-pumpkin combination (Table 3). Together all these strategies help to reduce erosion risks and preserve soil fertility. In the best class soils, when the area available for cultivation shows variable slope steepness, peasants combine different sowing systems. These include, depending on the slope, the use of the "coa" or the animal traction plow. Despite the differences among the sowing systems, fallow periods traditionally assigned to each soil type are maintained constant.

A further example related to plot productivity conservation is the rotation of crops in space and time. With the exception of the Tepetatl and Tlalnextli soils, in the remaining plots it is possible to observe rotation between the combined crop (corn-bean-pumpkin) and the corn monoculture or "mata" beans, a sturdier variety, or monoculture and/or peanuts. This rotation can be made within the sowing cycle (spatial rotation) or in consecutive cycles, i.e. between years.

Physical and Chemical Characteristics of the Agricultural Soils at Zoyatlán

Conceptually, the Zoyatlán soils represent the initial stages of soil evolution, in which few or no clearly expressed soil characteristics have developed (Table 2). According to these characteristics, they meet the requirements to be classified as Anthropic Regosols (they always show evidence of profound modification by human activity) and Mollic Leptosols (WRB 1998).

From a morphological point of view, some of these soils, like Tlalcapochtic, Tlaltezoquitl, and Tlalnextli, commonly reach a considerable soil depth (Table 2). However, in all these soils the thickness of the topsoil frequently oscillates between thin (< 26 cm) to moderate (35 cm), due to the presence of different physical and chemical barriers (soil limitants). For example, the gravelly and stony layers that may underlie the first layer of the topsoil in the Tlalchichiltic soil (Figure 4) are poor or very poor in organic matter and total nitrogen. Furthermore, in these layers the percentage base saturation is less than 50%. A similar situation is observed for the Tlanextli soil, although the topsoil thickness in this soil comprises a single homogeneous layer (Table 2). According to FAO-UNESCO (1994), such percentages generate a low fertility level which may be ameliorated by using a high dosage of fertilizers. Moreover, as suggested by particle density values (Table 2), primary minerals in these soils are mostly poor in ferromagnesians and alkaline-earth bases (Ca^{++} and Mg^{++}), necessary elements for the development of crops.

With the exception of Tlaltezoquitl, Tlalchichiltic and Tlalnextli, the texture of the other soils is apparently mostly coarse (Table 2), although in some cases this may be somewhat different. For example, petrographic microscopy observations of the textural element content in the Tlalcapochtic soil matrix show that its textural elements do not only comprise simple loose mineral grains. In this soil, there are also stable structural sand-size aggregates (0.25-2 mm). Such aggregates show a complex organic-mineral composition that confers to soil a great erosion resistance and do not favor its biological and physical degradation (FAO-PNUMA 1980; Figure 3). In addition, the presence of stable aggregates in the topsoil indicates appropriate soil management.

Table 2 shows that bulk density values tended in general to be low, probably because of the presence of numerous spaces between those particles in forming the soil matrix (Figure 3). Therefore, soil porosity is high, mainly in the topsoil, which allows a good aeration and water flow, thus facilitating root growth. Only in soils such as Xalli, and sometimes Tepetatl, do those porous spaces tend to consolidate and become compact when the soil loses humidity.

Laboratory analyses show that with the exception of the Xalli soil type, the other soils show some physical and chemical characteristics which are unique. Such characteristics have a direct and positive influence on soil fertility. Among them, the most outstanding are: (1) a very high water retention capacity; (2) high values of cation exchange capacity (CEC), (3) high organic matter contents in the topsoil; and (4) low erodability (Table 2).

The large soil water retention capacity (Figure 5), high CEC, and low erodability values (Table 2) are mainly due to the large specific surface characterizing the mineralized organic matter (Maeda et al. 1978). These soil properties also suggest the presence of non crystalline products (Jongmans et al. 1994) resulting from the weathering of the volcanic materials present in the soil (ashes, pumice, volcanic glass). So far, the performed analyses (not reported in this article) indicate the presence of amorphous minerals of proto-alophane type, as well as ferrihydrite. Only in the case of Tlalchichiltic soils, the pH-NaF value showed that alophane is present in well-characterized mineralogical terms (Table 2). All these amorphous minerals, have a large specific surface and a great absorption capacity (Gama-Castro et al. 2000). When combined, all these characteristics also contribute considerably to the natural fertility that characterizes many of the soils at Zoyatlán.

Further advantages of organic matter content in the study soils are related to the availability of phosphorus and the regulation of pH. In most soils of Zoyatlán, total phosphorus (TP) shows considerable accumulation in the topsoil (Table 2). However, due to the fact that alkaline pH (pH-H_2O) prevails in such horizons, it is reasonable to conclude, in accordance with Lindsay and Moreno (1960), that this element is generally accumulated in forms which are not available for crops (e.g. hydroxiapatite, fluorapatite). Moreover, there seems to be a direct relationship between TP retention and the alkaline condition level of the cultivation horizon. In contrast, in the case of Tlalchichiltic, where pH is acidic, TP contents are considerably lower. This is probably due to the lixiviation of this element, as a result of its pH value (Table 2). These results suggest that there are potential deficiencies of assimilable phosphorus in the topsoil (retention – lixiviation), but these deficiencies may also be attenuated by the organic matter content of such horizons. Thus, besides a tendency to regulate pH, organic matter is the main source of phosphorus immediately available to crops. This is likely the explanation as to why the peasants of Zoyatlán use phosphatized fertilizer to till the Xalli, Tlalchichiltic and Tlalnextli soils (Table 3). In these soils, organic matter contents were lower (Table 2).

Finally, we assert that some of the data in Table 2 are "atypical" for non-cultivated Regosols (i.e. characteristics of topsoil, high water retention, presence of alophane). However, it is possible that they are fully

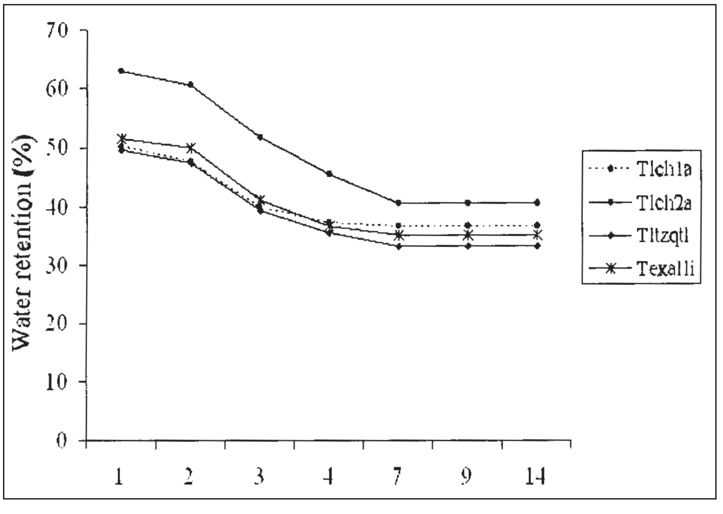

Figure 5. Percent water retention of the topsoil of some soils at Zoyatlán. Representative profiles with percent retention values above 60% after 12 h of draining are depicted. Tlch1a and Tlch2a = first and second layer of the topsoil of a Tlalchichiltic soil, respectively; Tlzqtl = Tlaltezoquitl soil.

acceptable for soils deeply transformed by the intensive and prolonged anthropedogenic processes, as is the case in Zoyatlán. Anthropic Regosols are the most important soils in the community, and they have been used for agricultural production since ancient times (Dehouve 1995; Cervantes and de Teresa 2004). The large varieties of characteristics that these soils possess render them complex for their detailed study and definition. Similarly, they pose a great challenge in terms of future technical recommendations of soil science regarding their use and conservation.

An Alternative Methodological Approach

A Multifactor or Parametric Proposal

Based on our results, we believe that the integration of ethnopedological knowledge with soil science requires the use of different methodological tools. At first, these should be aimed at retrieving and understanding local ethnopedological knowledge. However, the systematization of such information must necessarily establish a link between environmental and socioeconomic factors used by peasants in their soil classification. Therefore, we argue that to integrate the variety of criteria used by the peasants of Zoyatlán in their interpretative classification of their soils as well as to facilitate the construction of a common language among the users and the soil specialists, it is necessary to use a parametric method for establishing land use agricultural suitability.

Parametric methods allow for the integration of different kinds of information; they are easy to apply and to interpret by soil specialists and non-specialists; and they give one single number for taxation in order to rate land from “good” to “bad.” These methods consist of single numeric factors, usually values of land and soil characteristics, which are combined to reach a final single numeric rating. Thus, all land is rated from excellent (100) to useless (0), and this is assumed to be a ratio scale. For example, land rated 80 is “twice as good as” land rated 40. Thus, it would be a fair basis for taxation. Factors can be combined by adding or multiplying, and normalizing may be possible, depending on the system (Rossiter 1994).

In the case of Zoyatlán, as in many other indigenous communities, the use of parametric methods allows the peasants to trustfully define the criteria for selection of key land and soil properties. From there, these properties can be easily correlated with production by agronomic experts. It is important to restate that the peasants are the ones who must select the land and soil properties to be used in the creation of this system, otherwise, the results obtained would be subjective and not reliable for technical decision making.

Other advantages that parametric methods offer are the following. In general, they require data and information that are inexpensive for most countries to generate. Also, according to the characteristic of the data used, it is possible to generate cartographic information at various scales. Also, the use of parametric methods is familiar to most of the technicians and agronomy students from developing countries. An example of this is the parametric methodology proposed by FAO-PNUMA (1980) to estimate soil degradation. Furthermore, methods of this nature are currently being used to generate indices and indicators of land and soil quality as well as environmental sustainability (INEGI-SEMARNAP 1999; Segnestman et al. 2000; SEMARNAP 2000). In what follows, an example for designing and implementing a parametric index for the soils at Zoyatlán is provided.

Example of a Single Land Characteristic

As pointed out before, peasants of this locality stress the importance of the topsoil, considering it to be one of the essential agricultural factors. According to their classification, we know that the best agricultural soils have a topsoil thickness ≥ 30 cm, and that such thickness is optimal when it is homogeneous (i.e. comprising one single layer). These two criteria may be integrated in a representative (parametric) value of the existing variants of the topsoil of these soils. Such integration is demonstrated in Table 4, where how these criteria were weighted proportionally is also shown. On this basis, the index combines parametrically both the existing variants for this land characteristic and its relationship with the ideal thickness of the topsoil. The parametric index for the topsoil thickness (TsT) is expressed as follows:

$$TsT = (TXPvTs) / 30 \text{ cm}$$

where T = thickness (cm) of topsoil; PvTs = parametric value according to number of layers present in the topsoil; 30 cm = ideal standard thickness for the topsoil. When the thickness of the first layer in the topsoil does not meet the ideal standard, underlying layers of the subsoil are added until the ideal 30-cm standard is approximately reached. The addition of values resulting from applying the formula to each layer corresponds to the TsT final value. In Table 4b a numerical example is provided.

The results obtained with this index have the advantage of summarizing the topsoil characteristics regarding the ideal expected condition in a single value. In turn, they also represent the suitability hierarchies or categories for this land characteristic: TsT = 1, Ideal Condition; TsT = 0.66, Acceptable Condition; TsT ≤ 0.33, Deficient Condition (without including its variants; Table 4). The values of this index are consistent with the valuation of the same factor in the Zoyatlán land classification system. In the case of Tlalcapochtic soil, its category for TsT = 1 was optimal; in contrast, in Tepetatl soil, the value for this category was the lowest, TsT = 0.286 (Tables 1, 2 and 4).

Table 4. a) Parametric values established in order to relate number of soil layers and thickness (T) of the topsoil (Ts); b) example showing the calculation of the parametric index for three soil types at Zoyatlán.

a)

Soil Factor	Thickness (T)	Parametric Value (PvTs)
Topsoil Thickness	T: ≥ 30 cm, 1 homogenous layer	1.00
	T: ≥ 30 cm, 2 or more layers	0.66
	T: ≥ 24 < 30 cm, 1 layer	0.33
	T: ≤ 24 cm, 2 or more layers	0.165

b)

Topsoil thickness parametric index
TsT = (T X PvTs) / 30 cm

Soil type	Topsoil thickness	Parametric index
Tlaltezoquitl	30 cm - one homogenous layer	TsT = (30 X 1)/30 = 1.0
Tlalchichiltic	30 cm - two layers: 1a layer - 8 cm; 2a layer - 22 cm	TsT = (8 X 0.66) + (22 X 0.66)/30 = 0.66
Tepetatl	26 cm - one homogenous layer	TsT = (26 X 0.33)/30 = 0.286

Representation of Parametric Information

As mentioned above, the parametric method provides a set of values that can be represented in cartographic terms. This may be achieved if the categories (values) obtained through the TsT index are expressed in terms of thematic maps: altitude, exposure, slope, landform, and lithology (Figure 6). This process may be easily performed with geographical information systems, and consists of the reclassification of the thematic maps, in terms of the environmental factors defining the categories of the parametric index; this process results in the creation of Boolean maps. The interception of Boolean maps allows us to know the spatial distribution of each category (category-1, category-2, category-3). As to a second interception, the combination of three categories is obtained. The resulting map of this process allows us to describe the spatial interaction of the various TsT categories (Figure 6).

Following similar reasoning, it is possible to build parametric indices by incorporating the complexity of the peasants' ethnopedologic criteria used in land management. The advantage lies in the fact that the selected criteria may be adequately synthesized, provided the relationship between each of them is known and the hierarchies established by the users are respected. For example, for the soil fertility factor, the parametric index would have to relate both the differences identified by peasants regarding natural and potential soil fertility, as well as topsoil thickness. An additional advantage is that cartographic representation of the indices proposed can be made independently (as illustrated in the previous example for the topsoil thickness index), or can be the result of combining different indices of interest.

With the use of a parametric method of soil use aptitude, it is possible to describe and incorporate, with great accuracy, the complexity of Zoyatlán peasants' ethnopedologic knowledge. Through their use, it has even been possible to gain peasants' trust since they can easily interpret the cartographic information offered and they are able to focus on the factors that interest them. Due to its content and interpretation, the cartography produced can be accessible not only to peasants but also to extension workers and researchers. This situation may contribute to filling in the existing gaps regarding concepts, language and communication that currently prevail among land users and soil specialists.

Conclusions

The combination of methodological tools used by social and environmental sciences allowed us to know and interpret the ethnopedological knowledge of the indigenous community of Zoyatlán, as well as to relate the environmental, social and cultural factors upon which such knowledge is based.

Ethnopedologic knowledge is synthesized in a classification system based on the aptitude of the natural land use. This classification is expressed at different hierarchical levels, which are assigned to specific land uses in terms of the most important limitations for the production of basic crops. This management reflects the natural limitations of community's soils and also highlights those factors which are particularly interesting for local residents.

Although the socioeconomic factors usually affect the management traditionally assigned to each soil type, it is worth mentioning that in several cases the topsoil showed a set of pedological physical and chemical properties indicative of adequate soil management. This is likely to be a result of the knowledge and rational use of the soil, which, as much as possible, recognizes its suitability and natural limitations.

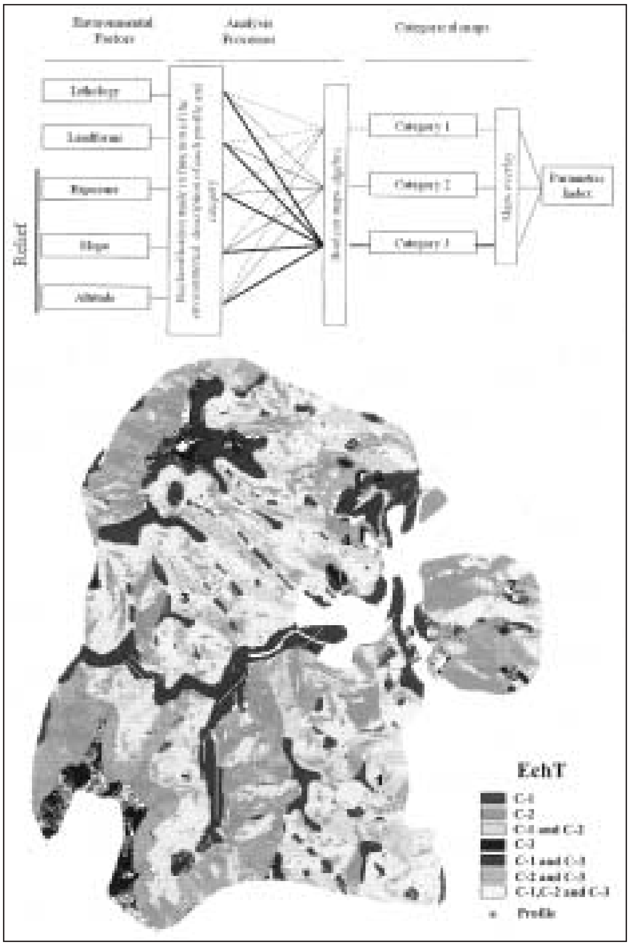

Figure 6. Diagram illustrating the elaboration process of the cartography that shows the spatial distribution of the parametric index for topsoil thickness (TsT). The map illustrates the spatial distribution of representative soil profiles at Zoyatlán (1=Tlalcapochtic; 2=Tlaltezoquitl; 3=Texalli; 4=Tlalchichiltic; 5=Xalli; 6=Tlalnextli; 7=Tepetatl). Their correspondence to those categories that summarize the topsoil thickness characteristics of each soil type are also shown.

Local soils are characterized by some unique properties that are little known to soil science classifications. All these properties are related to topsoil fertility, and they are likely to be the result of a positive anthropization process that has taken place for centuries in the community lands.

The parametric tools allow for the integration of the various criteria involved in the indigenous classifications. Their acceptance and implementation is feasible because they have emerged from an environmental and sociocultural reality. The multifactorial basis of these methods is a condition that allows for the inclusion and combination of variables measured on different scales (e.g. social, economic, and environmental). Moreover, its results can be represented in different ways (diagrams, tables, maps), which help simplify its interpretation by different users. The use of parametric methods is a valuable avenue to pursue dialogue between peasants and soil science specialists, leading to the construction of a common language between primary resource users, extension workers and soil scientists. Such conditions will allow us to establish conceptual and methodological tools that can facilitate the integration of local and scientific knowledge of soils.

Endnote

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Appendix

Soil Analyses

All the physical and chemical analyses were performed on air-dried samples, sieved through a 2 mm mesh.

Soil Analyses	Method
Physical	
Soil colour (moist and dry)	Determined by comparation to Soil Color Charts (Munsell 1992).
1. Soil texture 2. Soil particle density (PD) 3. Soil bulk density (BD)	Determined by the USDA-SSS method (1994).
Soil porosity	Based on the BD an PD values (%Porosity = 1-BD/PD(100).
Soil erodability	Assessed in accordance with Wischmeier's nomogram (Wischmeier and Smith 1978).
Soil water retention	Determined through a semi-quantitative method, through the loss of weight of the soil sample, initially saturated and then air-dried (SCS-USDA 1984).
Chemical	
Soil pH (H_2O 1:1; KCl 1:1; NaF 1:50)	Determined by the SCS-USDA method (1984).
Soil total organic matter	Determined with the procedure described by Blakemore et al. (1981).
Soil total nitrogen	Determined with the procedure described by Blakemore et al. (1981).
1. Cation exchange capacity 2. Extractable Ca^{2+}, Mg^{2+}, Na^{2+} and K^{1+}	Both determined by the SCS-USDA method (1984), extracted with 1M NH4OAc to pH 7.
Soil total phosphorus	Determined with the procedure described by Blakemore et al. (1981).
Micromorphological	
Soil micromorphology	Thin sections were prepared with the soil samples impregnated with the Crystal MC-40 resin, and later examined under the petrographic microscope (Bullock et al. 1985).