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Soil Indices for Comparative Analysis of Agrarian Systems

JOHN J. NICHOLAIDES III AND EMILIO F. MORAN

One of the most fundamental processes in nature is the conversion of solar energy into plant biomass, or tissue. It is from this conversion that all biological processes are possible and that animals such as ourselves can exist. Plant growth and production are dependent on a number of factors, among them temperature, rainfall, soil nutrients, and soil texture. Human use of plants depends upon the plants' ability to produce a net yield that can be harvested. Because energy transfers are inherently inefficient, plants must absorb and convert far more energy than they can yield. A major portion of this energy goes into keeping the plant alive; the rest goes into energy to ensure its reproduction. This portion may be available to consumers. A great deal of attention has been spent in human history trying to understand how we came to domesticate plants and animals—and how in so doing we made many plants and animals dependent on our care for their very survival (Cohen 1977). Yet we depend to this day on a very small number of domesticated plants, leaving much of the biotic richness of the earth still unmanaged (National Academy of Science 1978).

The study of plants is intimately tied to the soils upon which they grow. Although temperature, rainfall, and other climatic factors are as important as soil, there is very little humans can do to manage or control these forces of nature (but see Wilken, Chapter 2, for the efforts to try to alter the odds; cf. Wilken 1987). By contrast, soils can be and often are managed by human groups. Most populations, particularly those dependent upon farming, possess ethnoecological expertise about soils and their characteristics. This is important information that may in many cases be superior in its richness of detail to that available from agricultural ministries and research stations (Conklin 1957; Carter 1969; Moran 1981, 1993; Posey and Balée, 1989).

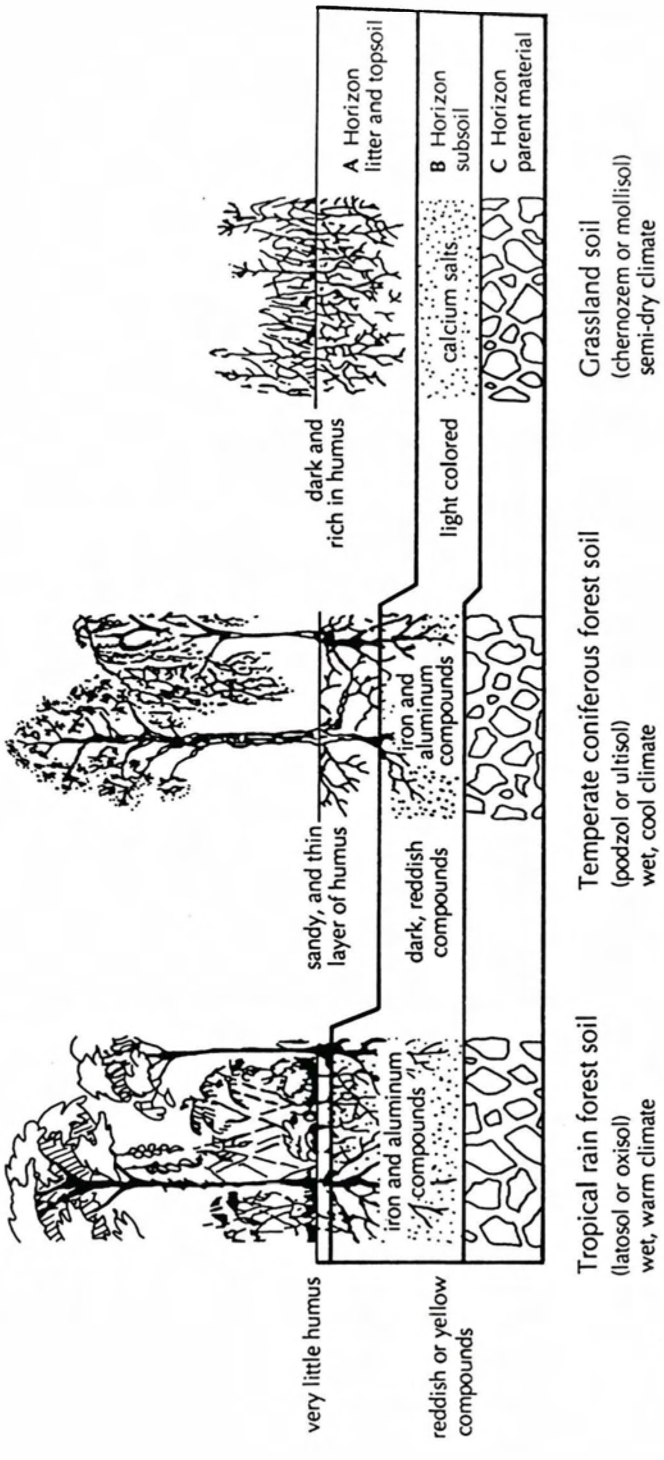
The soil is not an undifferentiated medium but is rather a dynamic one that is constantly in formation and undergoing transformation. Soils are distinguishable from bedrock and unconsolidated debris by their relatively high content of organic matter, an abundance of roots and soil organisms, and the presence of clearly distinguishable layers, or horizons (Brady 1984:9–10). Soils may vary even within short distances of each other. These differences may be the result of variations in surface, slope, weathering conditions, and plant activity. For example, soils originating from chemically basic (or alkaline) parent material (bedrock) will have a pH close to neutral (7.0), whereas those originating from acid rocks will tend to be acid (4.0–5.0). Soils on steep slopes will be shallower than those on gentler slopes if the steep slopes are not covered in vegetation capable of breaking the eroding impact of water and light.

Color is one of the most obvious things to notice about soils. It is an important indicator of various characteristics but not a foolproof determinant of soil type. When weathered, a red shale or sandstone may yield a red-colored soil, although the oxidation of iron is not the major process responsible for redness. In interpreting the nature of the soil, color must be used in conjunction with broader knowledge of the weathering factors in a given climatic zone. But color is always important data to report. In temperate regions dark-colored soils are usually high in organic matter. In the tropics, however, some dark clays may be poor in organic matter, whereas others may very well be rich organic soils. Bright red and yellow soils in the tropics may suggest high levels of iron oxides, but they also indicate good drainage and aeration (as compared with grayish mottling, which suggests poor drainage). This observation can be very important in evaluating plant performance and in planning management approaches to a given area. In poorly drained areas where oxygen is deficient, reduced iron yields bluish-gray soils, whereas sites of good drainage lead to oxidation of iron, producing red colors. Soil color data is commonly reported using the Munsell color charts.

Because chemical weathering, slope, and other influences vary at different depths, distinctive layers, or horizons, develop in most soils. These horizons, when taken as a group, form what is known as a soil profile, which expresses the types of processes experienced by the soil in the past and the factors important to the use of that soil in the future. Profiles are two-dimensional slices through a soil. Soils, in general, are said to have four major horizons: an organic horizon (O) and three mineral horizons (A, B, and C).

Of all the horizons, the organic layer is the most critical for plant growth (see Figure 3.1). This layer usually contains a disproportionately

Figure 3.1 Soil Profiles



Source: Moran 1979: 76-77.

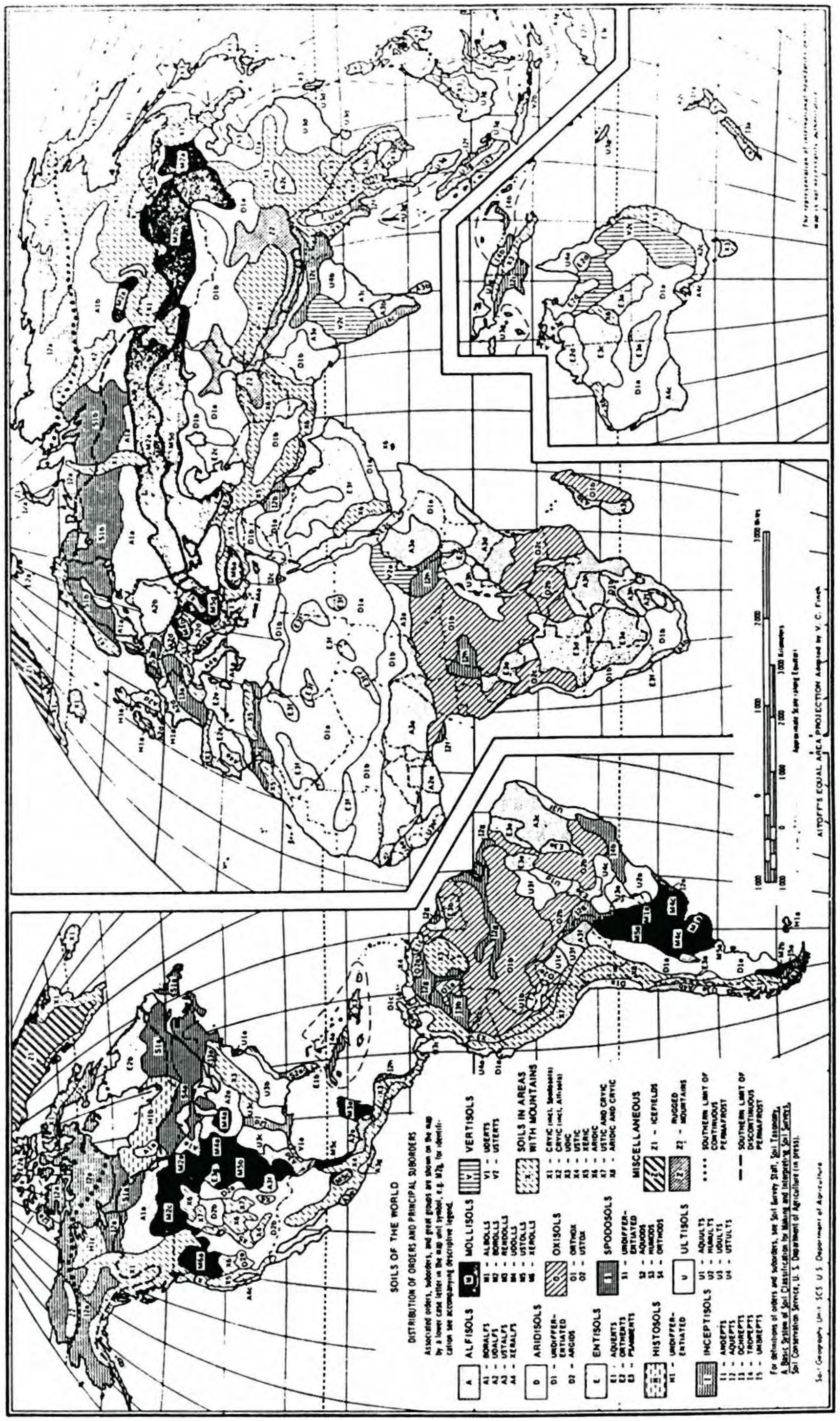
large portion of the total humus in a soil. Humus is important because it is capable of retaining water and nutrients and thus facilitates exchange of these elements (Brady 1984:266). Organic matter is also responsible for the loose, friable condition of productive soils. It is the source of phosphorus, sulfur, and nitrogen inputs, providing most of the sustenance for soil microorganisms. The majority of the domesticated plants utilized by the human population rely primarily on this humic layer for their nutrition (Brady 1984:14–16). That is why most soil sampling for estimating soil fertility and fertilizer needs takes place in the top few inches of soil ("the plow layer," or 0–20 cm). Sampling of the entire soil profile usually aims at soil classification rather than at practical assessments of fertility. Most ethnoecological systems give priority to the plow layer in making classificatory choices, although Western soil classification tends to give priority to subsoil characteristics. This difference reflects a greater interest in soil genesis in Western classifications than in the more pragmatic folk classifications, which correctly focus on the environment for the plants of local interest.

The mineral horizons are characterized by lesser concentrations of organic matter and varied particulate structure. The A-horizon is richer in organic matter than B or C and characterized by the presence of granular, platy, or crumb structures. The B-horizon is marked by alluvial concentrations of silicates, clay, iron, and aluminum and by the development of blocky, prismatic, or columnar structures. The C-horizon lies above the consolidated bedrock and has even larger particulate matter. It is the zone of transition between the B-horizon and the bedrock proper.

Knowledge of soil properties is useful when an investigation includes a focus on human management of land resources. Soil phenomena are of such complexity that a system of classification can be helpful in grouping soils that share natural properties. Native systems of classifying soils exist in most farming populations. Over four thousand years ago, the Chinese developed one based on color and structural characteristics (Steila 1976:64). The Hanunóo of the Philippines based theirs on vegetative cover (Conklin 1957:39), which is perhaps the most widely used criteria worldwide. The Kekchi of Guatemala used color, texture, drainage, root content, and vegetation cover (Carter 1969:21).

The distribution of major soil orders affects what forms of agriculture are possible and what levels of productivity can be achieved. Because soils are the product of the weathering of rock materials, the prevalent climatic conditions play a crucial role in the formation of soils and help determine their characteristics. Thus, oxisols are dominant in wet, humid areas, whereas mollisols are characteristic of temperate grasslands.

Map 3.1 illustrates the distribution of soils on a worldwide scale. The association is not perfect, as pockets of unexpected soil types may be found



Map 3.1 Soils of the World

anywhere and can be very important in terms of local agrarian potential. Still, the association of soil orders with ecosystem types is remarkable. Tundra regions are dominated by inceptisols (young soils), deserts by aridisols (rocky, gravelly soils), temperate grasslands by mollisols, tropical savannas by ultisols, and tropical moist forests by oxisols. The areal significance of these major soil orders is variable. Aridisols, which present problems of high salt levels and high concentrations of other minerals, are the most extensive (19.2 percent of the total) and occur in regions with very low rainfall. The second most extensive soils (15.8 percent) are the inceptisols, which also can be problematic for farming because they are rocky or gravelly and still in the process of development. It is only with the third most extensive soil type, the alfisols (14.7 percent), that we get to a relatively fertile soil in regions with adequate rainfall and temperature for plant growth. Even these can present problems, as they do in West Africa. Thus, a crucial problem of farming populations is to locate areas of land with the best possible soils, given their scarcity. Location of such land requires knowledge of soil characteristics and their effective management.

The Minimum Data

Investigators should collect and report as minima the proportions of the major soil types and/or orders in the area of interest, their texture, color, pH, and the vegetation that grows on them. Crop productivity on the various soils can also be useful to colleagues in comparisons (see Hunt, Chapter 9). In most cases, these should be available from local agricultural research stations and will not require direct field collection.

Ten major soil orders are recognized at present: entisols (soils with little if any profile development); inceptisols (slightly more profile development than entisols, but less than other orders); mollisols (dark soils of temperate grasslands); alfisols (moist soils of medium to high fertility, often under forest); ultisols (moist soils found in the tropics, with percentage of clay increasing with depth); oxisols (most highly weathered soils, often found in the tropics); vertisols (dark swelling clays); aridisols (soils of dry areas); spodosols (soils with a subsurface horizon with organic matter accumulation, low in nutrients and often acid); and histosols (peat or bog soils, developing in water-saturated environments) (Brady 1984:436–453).

Texture is determined by the relative proportions of particles of various sizes in the soil. It is not subject to rapid change: A sandy soil tends to remain sandy, and a clayish soil remains dominated by the clay fraction. Soil analyses can include textural analysis, which provides the percentage of particle sizes for each category. Silt, clay, sand, and gravel (or coarse particles) are often used as categories in making textural discriminations (Brady 1984:36–37). The size of particles is important because it influences the adsorption of water, nutrients, and the tilth of a soil. Clay tends to hold water better than sand or silt. A textural class known as loam is hard to explain because it is a mixture of sand, silt, and clay particles "that exhibit light and heavy properties in about equal proportions" (Brady 1984:42).

Color is determined in the field with the use of the Munsell color charts. It is important to note if the soil is dry or wet. Color can be misleading in some cases, but it is relatively important in soil descriptions and thus facilitates comparison. The acidity or alkalinity of a soil is expressed by pH, which tends to fall on most mineral soils between 3 (acid) and 10 (alkaline). The range for productive cultivated soils is narrower, generally between 5 and 7 in humid regions and 7 and 9 in temperate regions. Soil nutrient availability tends to increase significantly if a soil's pH is raised from 5 to 6 or 7. At pHs below 5, aluminum, iron, and manganese are soluble enough to become toxic to many plants. At very high pH values, bicarbonates can have similar effects on plants. Some plants are more able to remain productive at the extremes of the pH gradient than others, and this knowledge constitutes an important component of how people manage soil-plant relationships (Jeffrey 1987).

In the process of conducting field study, effort should be spent on getting the local names for the soils and the population's assessment of each one, particularly as to what crops do better on which named soils and what specifically named soils present outstanding properties or are unacceptably infertile (Moran 1987; Behrens 1989; Johnson 1974; Conklin 1957). This effort can go hand in hand with the minima collected in connection with the ethnoecology of farming and the listing of locally cultivated crops (see Netting et al., Chapter 4).

Second-Level Intensity of Data Collection

Students of agrarian systems and ecology may very well want to go beyond the above minima, particularly by paying attention to soil sampling or making greater use of available local data. Soil sampling may take either of two forms, each of which reflects different research objectives. These forms are known as core sampling and profile sampling. In core (or surface) sampling, a soil sample is taken to a depth of between 10 and 20 centimeters (more commonly the latter). As this is the zone from which most domesticated plants obtain their nutrients, core sampling is the method commonly used to assess the soil nutrients available. The sample is taken with a core sampler. A single soil sample consists of fifteen to twenty "cores" collected in a random manner from a homogeneous soil surface area. A zigzag pattern is usually used. The cores that make up a single sample are deposited in a bag and thoroughly mixed before being sent to the laboratory for analysis. Each sample should be numbered and described in terms of where the sample was taken; what vegetation was in the area; what texture the soil had; what color it was (using standardized color charts, such as Munsell); and what the past use of the soil was (if known). Any other remarkable features (for example, drainage problems and slope) should also be noted.

Profile sampling goes to greater depth in the soil. A depth of 1 to 3 meters provides a fairly comprehensive cross-section of soil horizons applicable to the study of land uses such as tree farming or cultivation of special plants with deep tap roots. In profile sampling, a soil auger is used unless a pit is dug (which is far more time consuming). The aim of this type of sampling is to establish the various horizons and their characteristics. As the auger is turned, each layer is laid out on a sheet of plastic or other material in the order in which it was extracted. Each horizon is then described in terms of the same information noted in core sampling. Such descriptions help reveal the alternatives open to cultivators and can serve to test the accuracy of the population's ethnoecological knowledge. At this level it is desirable to construct more fully the local population's taxonomic knowledge of soils, noting which plants are indicative of which soils and the distinctive criteria for identifying them.

Third-Level Intensity of Data Collection

At this level, it becomes more appropriate to engage in assessment of soil fertility. It is important to note that soil fertility is a term with numerous connotations. A "fertile" soil may be one that needs no fertilizer additions, but the term is somewhat vague until some clear level of expected production is defined. Soil that has sufficient fertility to produce maize yields of 1 ton per hectare can be judged infertile when yields of 9 tons per hectare are anticipated. Infertility can also relate to soil water conditions, toxic salt concentration, a root-restricting hardpan, nematodes, or low soil temperatures.

Soil fertility, broadly conceived, connotes the ability of soil to grow plants. It does not connote, in itself, what is right or wrong with the many factors that influence plant growth. Crop yields are a function of at least four major factors—crop, soil, climate, management—and each one has various aspects that must be considered (Fitts 1959).

Evaluation of soil fertility should address not only what limits plant growth but also what steps may be taken to overcome those limitations, including a reassessment of what is planted on such soils. Soil fertility evaluation and extrapolation can be viewed as major tools in the comparative analysis of agrarian systems. Various groups make use of these tools, including researchers (both agronomic and anthropologic), extensionists, land-use policy planners, and farmers themselves. The primary constraint to soil fertility evaluation and extrapolation—and, as a consequence, to comparative analysis of agrarian systems—is the lack of a systematic technical grouping of surface soil properties by which research workers can define the limits of the uncontrolled variables within which field fertility research can be extrapolated (Buol and Nicholaides 1980). The alleviation of this constraint would be useful.

One of the most important things to note in this regard is that, for all practical purposes, soil classification and soil fertility management are usually at cross-purposes (Buol and Nicholaides 1980). Because the basic goal of soil classification is to record features that are at least quasi-permanent and not subject to management alteration, soil properties in the surface horizons are usually considered only at the lowest categories of most soil classification systems. Surface soil chemistry of the type directly related to fertilizer manipulation is usually not included in soil classification criteria to avoid the confusion that may result from the transient nature of the values encountered when soils are subjected to management. Thus, soil properties considered for taxonomic purposes (Dudal 1980) are not necessarily relevant for soil fertility management—nor should they necessarily be (Buol and Nicholaides 1980).

Conversely, soil fertility evaluation and improvement approaches (Cate and Nelson 1971; Waugh et al. 1975; Fitts 1974), though valuable, have not always related the numerous analytical data to kinds of soils via any classification system. Several such approaches have implied wide applicability over many soils, although the soil classification information usually is not given (Cate and Nelson 1971).

Most management practices for cultivated crops occur in the upper 20 centimeters of soil, and the effects of these management practices are reflected in this layer. Thus, soil taxonomic systems often do not use surface soil criteria. Likewise, soil fertility evaluations do not utilize the classification systems because the latter do not reflect soil management practices. Neither group, therefore, provides a strong basis for consequent extrapolation of soil fertility evaluation and improvement (Buol and Nicholaides 1980) or for comparative analysis of agrarian systems.

It should be reemphasized that subsoil properties do not have as great an effect on crop yields as do surface properties. For example, a survey of 441 field trials in North Carolina found that properties of topsoils, individually and collectively, better explained crop yield variability than did the corresponding subsoil properties (Sopher and McCracken 1973).

Nearly forty years ago, it was written that some problems related to soil fertility evaluation and extrapolation could be overcome by technical classifications for specific, applied, practical purposes (Cline 1949). One such technical classification is the Fertility Capability Classification system, or FCC (Buol et al. 1975). Technical classification systems do not replace soil taxonomic information and soil surveys but rather build on them to become useful in practical agricultural development initiatives (Johnson 1980).

The FCC was developed (Buol et al. 1975) to group soils with similar limitations of fertility management (Buol 1972) and thereby provide a guide for extrapolating fertilizer response experiences (Buol and Couto 1981). It centers on surface soil properties most directly related to field crop management, and it can be related to a more inclusive natural soil classification system (Buol and Nicholaides 1980).

The proposed system consists of the following three labels:

1. Soil type—texture of surface soil (0–20 centimeters).
2. Substrata type—texture of subsoil if within 50 centimeters of surface.
3. Condition modifiers—specific properties noted if a specific range of conditions is encountered.

Thus every soil is named at the highest category by the surface texture present, and further properties are noted as needed in a systematic fashion. The description of type, subtype, and condition modifiers (Buol et al. 1975) follows:

Soil Type. Definition: Texture of plow layer or surface 10 centimeters, whichever is shallower.

1. S = sandy topsoils: loamy sands and sands. High rate of infiltration, low water-holding capacity.
2. L = loamy topsoils: <35 percent clay but not loamy sand or sand. Good water-holding capacity, medium infiltration capacity.
3. C = clayey topsoils: >35 percent clay. Low infiltration rates, potential high runoff if sloping, difficult to till except when *i* modifier is present (see below).
4. O = organic soils: >30 percent O.M. to a depth ≥50 cm or more. Artificial drainage is needed, and subsidence will take place. Possible micronutrient deficiency, high herbicide rates usually required.

Texture of subsoil. Used only if there is textural change from the surface or if a hard root restricting layer is encountered within 50 centimeters.

S = sandy subsoil
L = loamy subsoil
C = clayey subsoil
R = rock or other hard restricting layer.

Condition modifiers. Where more than one criterion is listed for each modifier, only one needs to be met. The criterion given is preferred, but additional criteria are selected to facilitate semiquantitative use in the absence of desired data.

1. g = (gley): Soil or mottles ≤2 chroma within 60 centimeters of surface and below all A horizons or saturated with water for >60 days in most years. Limitations: Denitrification frequently occurs in anaerobic subsoil and tillage operations, and certain crops may be adversely affected by excess rain unless drainage is improved by tiles or other drainage procedures.
2. d = (dry): Ustic, aridic, or xeric soil moisture regimes (subsoil dry >90 cumulative days per year within 20–60 centimeter depth). Limitations: Soil moisture is limited during the growing season unless irrigated. Planting date should take into account the flush of N at onset of rain.
3. e = (low cation exchange capacity or CEC): <4 meq/100 g soil by bases + KCl extractable Al, or >7 meq/100 g soil by cations at pH 7, or <10 meq/100 g soil by cations + Al + H at pH 8.2. (Applies only to plow layer or surface 20 centimeters, whichever is shallower.) Limitations: Low ability to retain nutrients, mainly Ca, K, Mg, for plants. Heavy applications of these nutrients should be split. Potential danger of overliming.
4. a = (aluminum toxic): >60 percent Al saturation of CEC by bases +KCl extractable Al within 50 centimeters, or >67 percent exchangeable acidity (EA) saturation of CEC by cations at pH 7 within 50 centimeters, or >86 percent EA saturation of CEC by cations at pH 8.2 within 50 centimeters, or pH <5.0 in 1:1 H_2O except in organic soils. Limitations: Plants sensitive to aluminum toxicity will be affected unless the lime is deeply incorporated. Extract of soil water below depth of lime incorporation will be restricted. Lime requirements are high unless an e modifier is also indicated. Aluminum tolerant varieties should be considered in these soils.
5. h = (acid): 10–60 percent Al saturation of CEC by bases + KCl extractable Al within 50 centimeters, or pH in 1:1 water between 5.0 and 6.0. Limitations: Strong to medium soil acidity. Requires liming for most crops. Aluminum-tolerant varieties should be considered in these soils.
6. i = (high phosphorus fixation by iron): percent free Fe_2O_3 divided by percent clay >0.15 and >35 percent clay, or hues of 7.5 YR or redder and granular structure. Limitations: High P fixation capacity. Requires high levels of P fertilizer. Sources and method of P fertilizer application should be considered carefully. (Used only in clay (C) types.)

7. x = (X-ray amorphous): pH >10 in 1N NaF, or positive to field NaF test, or other indirect evidence of allophane dominance in clay fraction. Limitations: High P fixation capacity. Amount and most convenient source of P to be determined. (Applies only to plow layer or surface 10 centimeters, whichever is shallower.)
8. v = (Vertisols, very sticky plastic clay): >35 percent clay and >50 percent of 2:1 expanding clays; COLE >0.09. Severe topsoil shrinking and swelling. Limitations: Clayey textured topsoil. Tillage is difficult when too dry or too moist, but soils can be highly productive.
9. k = (potassium deficient): <10 percent weatherable minerals in silt and sand fraction within 10 centimeters of soil surface, or exchangeable K <0.20 meg/100g, or K <2 percent of bases, if bases <10 meg/100 g. Limitations: Low ability to supply K. Availability of K should be monitored and K fertilizers may be required frequently for plants requiring high levels of K.
10. b = (basic reaction): Free $CaCO_3$ within 10 centimeters of soil surface (effervescence with HCl), or pH >7.3. Limitations: Basic reaction. Rock phosphate and other water insoluble phosphates should be avoided. Potential deficiency of certain micronutrients, principally iron and zinc.
11. s = (salinity): >4 mmho/centimeters of saturated extract at 25 C within 1 meter depth. Limitations: Presence of soluble salts. Requires special soil management practices for alkaline soils.
12. n = (natric): >15% Na saturation of CEC within 50 centimeters of soil surface.
13. c = (cat clay): pH in 1:1 H_2O is <3.5 after drying and jarosite mottles, with hues of 2.5 Y or yellower and chromas 6 or more are present within 60 centimeters. Limitations: Potential acid sulfate soil. Drainage is not recommended without special practices. Should be managed with plants tolerant of flood and high water table levels.

Interpretation of FCC condition modifiers. When only one condition modifier is included in the FCC class nomenclature, the above limitations or management requirements apply to the soil. Interpretations may be slightly modified when two or more modifiers are present simultaneously or when textural classes are different.

A worldwide survey of published descriptions and analytical data of 244 soil profiles representing a broad geographical and morphological range grouped the soils into 117 fertility capability classes (Buol et al. 1975). Types L, C, LC, and S represented 92 percent of the total, and 10 condition modifiers accounted for 515 of the population. Five modifiers (v, n, s, x, i) never occurred alone, reflecting the fact that several fertility-related parameters occur together in many soils. Soil profiles of 678 Brazilian soils were grouped into 84 fertility capability classes (Buol et al. 1975).

Soils from 73 potato fertilization trials (McCollum and Valverde 1968) in Peru were grouped into five classes by FCC (Buol et al. 1975). Gross returns to fertilizer applications were higher when recommendations were based on a combination of the FCC and surface soil test results. This strongly emphasizes that there is no substitute for on-site reporting of the soil properties, including both soil characteristics and soil test determinations, to arrive at the most accurate recommendations.

A strong push for more complete soil characterization at experimental sites and more careful on-site soil evaluation in extrapolation work was made in a solid discourse on fertility management interpretations and soil surveys of the tropics (Buol and Couto 1978). Such a combination of the FCC, using data from soil survey reports and standard soil test results following on-site sampling, allowed extrapolation of proper fertilization practices for peanuts and soybeans from a Haplustox with a clayey textured surface soil in Brazil and a Paleudult with a loamy surface soil in Peru to a Paleustult with a loamy textured surface soil in Bolivia (Nicholaides et al. 1978). A slight modification (Pope and Buol 1976) of the FCC was used when the FAO/UNESCO soil map of South America was converted to FCC units (Sanchez et al. 1982).

The FCC, or some modification thereof, can serve as the basis on which to group soils for specific soil management evaluations and land-use planning. An example is CIAT's computerized tropical America land-resource study, which also uses climatic data and satellite and side-looking radar imagery (Cochrane et al. 1979). Recent work (Sanchez and Benites 1987) has shown that the FCC could be useful in identifying soil constraints that could affect low-input cropping systems' performance in other soils.

However, as one views the possibilities with FCC, it is important to note that one can transfer the results of research and experience on named kinds of soil between countries and continents in order to estimate potential for use. But farming systems are developed and used by people, and what they can and should do also depends on their social habits and goals (Kellogg, personal communication 1975).

Only one example (Moran 1987) was found in the anthropological literature where the FCC was used in an attempt to explain why some immigrants in colonization schemes have succeeded while others have not. In that study, just as important as (and perhaps more important than) the soil fertility levels of the various farmers was their farm management experience. Those with more farming and management experience did better than those with less.

Conclusions

The need to regard soils as a fundamental element to be assessed in the study of agrarian systems can hardly be doubted. No less important is to understand how people modify the soil environment within which plants grow in order to achieve their goals. Thus, reports should begin by indicating people's understanding of their soils (their ethnopedology, if you will). This can be supplemented with basic information such as color, texture, pH, and vegetation associated with particular soils. Major soil constraints can be reported, although it can be just as useful to note what soils are good for what crops according to the local classification. Additional data based upon core sampling and soil profile samples can also be given should greater detail be appropriate. The need for a quantitative grouping of surface-soil properties that define the boundary conditions of the uncontrolled variables within which field research is conducted is the most critical constraint to soil fertility evaluation and extrapolation of research results—and, as a consequence, a constraint to comparative analysis of agrarian systems. All user groups of soil fertility evaluation, anthropologists, land-use planners, extension workers, and both small and large farmers rely on information developed first by soil researchers. Soil researchers should, in turn, rely more on available anthropological data to ascertain the applicability of their extrapolations in diverse sociological settings.

A technical classification system such as the FCC, built upon quantitative natural soil classification systems, is suggested as the most immediate, obtainable tool in the extrapolation of soil-related research results. Each technical classification system has to be organized using quantitative criteria of practical significance to the applied technology. However, no single technical classification will equally serve all purposes.

When properly used (by building on soil taxonomic information) and combined with soil testing, the FCC could enable soil researchers to help farmers—no matter how small or remotely located—reduce risks and increase their chances of producing economical crop yields. The FCC can provide an initial basis for comparing agrarian systems' soil capabilities.

However, systems of interpretation must provide flexibility to adapt to local conditions and to specific uses and users of the land. In judging the reliability of the FCC, we must consider the fact that agricultural productivity of agrarian systems depends as much on the differing social habits and goals of people as it does on any soil index. This fact should not deter one from trying to characterize this important information on the physical conditions for plant growth. In so doing anthropologists, geographers, and agronomists have much to learn from each other.

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4

The Social Organization of Agrarian Labor

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> It must . . . be stressed that it is the social organization of labor, and not the tools and resources themselves, that are the proper subjects of our study [of cultural ecology], for it is only through the process of labor that nature and technique play their parts in molding society (Murphy 1970:157).

It is curious to observe that fieldwork for cultural anthropologists, even fo those who study farmers, has seldom dwelt on their subjects' work in th fields. As a well-known Africanist observed to me once, "You can't ver well follow people around with a stopwatch, now, can you?" Agraria labor is so omnipresent, so diverse, and so mundane as to be uninteresting and when it does become complex, hierarchical, and industrial, then th time/motion people from sociology and business management can tak over with their vaguely threatening flow charts and tables of time allocation. But if Murphy was right and the empirical, quantitative and qualitative, *scientific* study of labor is both necessary and possible, we mus devise the methods to collect standardized minimum data sets that permi comparisons of agricultural task performance, both within societies ove time and cross-culturally (Epstein 1979).

Though the structure and function of human groups has always bee a prime object of anthropological study, and although the social relations o production are basic for many more than merely Marxists, adequate studie of nonmechanized agriculture are usually seen as requiring too much tim

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