Soil Survey: Different Types and Categories[1]

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Soil is a natural object, and as such, it is an indispensable object of study, both as an entity itself and to understand the action of its formative factors in order to determine its genesis and evolution, its place in a natural and rational classification, and its global distribution.

Since soil is one of the fundamental components of terrestrial ecosystems, we must therefore attempt to ascertain how soil interacts with them. These ecosystems are often transformed directly or indirectly by man into agro-ecosystems which furnish food, fiber, and other products such as textiles, wood, oil, etc. The study of soil types must therefore be performed with the goal of determining their possible adaptation to these utilizations.

Soil survey, the field and subsequent laboratory study of soils, is based on grouping individual soils into units defined by their characteristics, properties, and evolution, elements which permit the expression of their specificity, the role they play in ecosystems, and their possibilities for utilization. Mapping is performed to show the spatial distribution of these defined units.

OBJECTIVES AND TYPES OF SOIL CLASSIFICATION FOR USE IN SOIL SURVEY AND MAPPING

As mentioned above, the fundamental objective of soil survey is to define map units by classifying grouped elements that are a function of soil characteristics, their relationship with the environment and their evolution. These map units may be ultimately expressed as a distribution on a rational map.

Soil surveying and mapping on a pedological level

Classification. The various categories of soils do not always correspond to natural classification units, which for practicality must not be extremely complex; consequently, they do not always represent the range of natural variability. Frequently a classification system is the basis of a soil legend: this legend can include *intergrades* or *taxadjuncts*, units related genetically to the pure units which form the real framework of the survey site.

The representation of complexes on soil maps is a difficult problem to resolve. Whatever may be the legend and scale of the soil map, there are varying numbers of

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areas containing such numerous and intricate soil units that it is impossible to accurately represent the exact position or area of each of the units, regardless of whether the survey was sufficiently detailed to locate them with precision.

Several solutions to this problem are possible, and their applicability depends on the scale of the map and its objective. In the case of interpretive pedological maps with scale ranges of 1:500,000 to 1:5,000,000, one could try to represent the most characteristic soils, even at the risk of exaggerating certain points and not representing others. For medium scale maps, (1:50,000 to 1:200,000, and occasionally 1:500,000), which are suitable as a regional planning base, the method utilized is entirely different. Here, cartographic units correspond to soil associations. Sometimes it is possible to replace these simple, most utilized soil complexes with toposequences, or successions of toposequences, or even catenas of soils. This last method is the most satisfactory, especially for determining more explicit applications for regional planning. First, it is necessary to show the existence and extent of these catenas. Already the utilization of toposequences in areas where they are developed greatly improves the cartographic representation of the soil survey results, and allows the faster production of more informative maps. In large scale maps, the same complex units are employed, but their proportion with respect to "pure" units is normally more limited, if the survey was sufficiently precise and detailed.

Factors of formation. In surveying, the relationships between the kinds of soil and their various factors of formation and evolution assume great importance. Often it is essential to make these characteristics a component of the system, especially for intermediate map scales. In the French classification system the characteristics of parent material are included at the family level. Vegetation and geomorphology parameters are not incorporated in the definition of soil, except for their occasional use at the series level (where judgments based on the criteria of soil depth are more effective). However, the cartographic regrouping of soil units can be accomplished based on the consideration of these two factors, which are themselves consequences of soil genesis. As did Tricart (1974), Kilian (1974) defines cartographic units on the basis of geomorphology. Under this premise, it seems preferable to regroup soils into landscapes in which their distribution and relationships are more precisely shown in detailed maps (Eschenbrenner and Badarello, 1975).

Pouget (1977) has integrated the study and representation of vegetative groupings and soils, in surveying soils of the steppe areas of Algeria; this permits him to create for a medium scale of 1:100,000 a more complete map illustrating the potential uses of landscapes.

Another procedure is to include on each page of the map itself, small scale schematic diagrams showing the general distribution of the genetic factors: geomorphology, vegetation, climate, etc. This has been done with the French soil maps at the 1:100,000 scale and the New Hebrides soil maps.

Soil surveying and map-making for utilization

The knowledge of soils and their properties, process of formation, and distribution is generally required only for formulating plans for soil utilization. Usually this utilization is agricultural development, although at times it is for public works or urbanization (including recreational areas), for the preservation of the ecosystem and its integral complexity, or for environmental goals (to create reserves, national parks, etc.). It is very certain that if the evaluation of suitabilities or limitations of a soil with respect to a

certain type of use depends initially on the soil itself, its characteristics and properties, and often its process of formation and evolution, this evaluation must also place particular importance on diverse factors (geomorphological and topographic conditions, vegetation, etc.) and consider certain of its environmental elements, and even general or local conditions that are exterior to the soil itself (for example, technical or socio-economic conditions) (Brinkman and Smyth, 1973). These last factors have great temporal variability and consequently the possibilities of integrating them into maps are limited because with the time and cost considerations involved, the results should be representative for as long as possible.

Diverse methods have been proposed to accomplish the transition from surveying to graphic representation of the soils' possible use.

1. Synthesized. The interpretation of the accumulated knowledge of soils and their environments, in the context of the latest agronomic techniques and local ecological conditions, can be expressed in a synthesized manner. In certain cases this can be represented as explanatory paragraphs on the fertility and utilization of each soil unit, or as a summarizing chapter in the text of the soil survey report. This has been frequently effected during the O.R.S.T.O.M. studies in tropical Africa and in Maghreb (Maignien, 1969 and Segalen, 1970).

Usually however, it seems most effective to report the results obtained on a map called optimum utilization (a term previously used by Aubert and Fournier, 1954; Riquier, 1954; etc.) or cultivation potential of the land. These are qualitative agronomic terms that express the data of a pedological map either generally or as a function of local soil-based recommendations for crop groupings or land use types. In effect, the level of fertility of a parcel may be very different, as may be its cultivation or use potential, depending on its assignment to annual crops, tree crops, pasture, or forest. Besides the agricultural categories, recommendations could be made for the assignment of a certain field to recreational or industrial installation areas.

In arid regions, the development should be considered with and without the presence of irrigation. Aside from the soil map or cultivation potential map, a map of potential productivity indicating cropping possibilities following improvements such as drainage, removal of calcareous crust or other activities could be compiled (Vieillefon, 1967; Riquier, Bramao, and Cornet, 1970). This kind of interpretation must consider not only soil characteristics, but also environmental ones: slope, degree, danger of erosion, and even vegetative cover. Maps which depict these factors must be based on studies made with a very large scale, or marginally with a medium scale.

2. Analytical. The interpretation of soil maps for agronomic planning or for more general area land use planning must be analytical. The method may be parametric, given the utilization of complex indices with weighted parameters based on ecological zones, principal crops, and envisaged uses (Riquier, 1974).

More commonly, the method is simply analytical, or essentially based on values obtained for relevant soil characteristics (such as depth, texture, pH, etc.), environmental characteristics (for example slope), or for a combination of characteristics (perhaps erodibility), which are judged to have primordial importance for agricultural development or generalized land uses. These characteristics and especially the limiting values, or thresholds, vary as a function of local climatic conditions.

Such factors can be depicted in the format of analytical maps (of texture, hydrodynamic properties, permeability, etc.) (Lévêque, 1975), cultural constraint maps or as soil resource maps (Boulet, 1976 and Fauck, 1977).

3. Interpretative. Interpretation, irrespective of whether it is interpretative or analytic, may also be thematic or designed for a particular type of use, especially cultivation. This form of interpretation is often of transitory value due to the tremendous control external factors such as economics, problems of location, etc. have on the possible use of the land. For example, the suitability of land for banana production typically depends on the proximity of a shipping port or marketplace. With the inherent risks involved in this type of land evaluation, the technique is becoming progressively less utilized, despite persistent demands for it by economists. Rather this strategy has been replaced by the intermediate interpretative type of approach, either thematic or analytical (Boyer, 1974).

TYPES OF MAPS AND LEGENDS

As indicated in the preceding discussion, in most cases the results of both soil surveys and studies derived from them are expressed in the form of maps indicating the distribution of different recognized units and their relationships. Pedological and non-pedological soil maps include a vast variety of forms, but these can be distinguished by the density and precision of their detail, their scale, and their legend (Aubert and Tavernier, 1972).

Different kinds of maps as a function of the density and precision of detail contained in their information

In those regions, now globally rare, where essentially no valuable surveys of terrestrial resources exist, maps of the "probable" distribution of principal soil types expected as a function of existing information on soil formative factors (geologic deposits, climate, topography, and even vegetation), can be compiled. These maps do not have definite significance except at the scale of synthesis (1:1,000,000 to 1:5,000,000), or at medium scales (1:200,000 to 1:500,000).

Habitually, three levels of cartography are distinguished on the basis of precision, as the above-mentioned type of map is rarely encountered:

1. Reconnaissance maps. These are based on observations and results obtained from traverses conducted throughout the study region and on known elements of factors of formation, as well as relationships which have been established during the course of the investigation between the observed soils and those diverse factors . . . in particular, at the end of the study of the toposequences formed over the principal parent rocks of the area. The soil map of France at the scale of 1:1,000,000 conforms to this definition, at least for the majority of the country.

2. Semi-detailed maps. Such surveys are carried out using traditional procedures, but the precision of observation, at least theoretically, corresponds to one observation per cm^2 of the map.

3. Detailed maps. These maps are the result of very precise, detailed studies. The level of precision necessary for this category is minimally four observations for each cm^2 of the map.

Such limits of precision are very theoretical, and are hard to apply to practical situations since calculations of the gain in precision are difficult (the coefficient by which it would be necessary to divide the preceding recommendations or multiply the envisaged surfaces for a known point) due to the use of aerial photography and additional satellite imagery.

Although the use of these modern techniques permits greater rapidity and more detail in establishing the limits between the map units, it certainly needs to be supported by numerous traverses and observations of the soils.

Different kinds of maps as a function of scale

Another common habit is the classification of soil maps as a function of their field scale. However, it should be remembered that field work is often undertaken at a scale that is at least double, and preferably quadruple to, that at which the map is published. (For example, in France the field scale is 1:25,000 for a 1:100,000 published map). Classification on this basis has different potential possibilities and significance for the use of these documents.

1. Small scale maps. Maps at the scale of 1:1,000,000 or smaller permit general interpretations. As such they are of great didactic value since they permit the performance of interesting geographical studies of soils in either diverse regions or on several continents, and allow useful extrapolations about the consequences of land use, in particular agronomic use. According to our conception with respect to the French classification system, the legends of such maps can include classification levels as low as subgroups with their associated phases, and can even distinguish those families which have particular importance.

2. Medium scale maps. Scales of 1:50,000 or 1:100,000 are correlated with maps designed for regional planning. These in effect serve as a base for prospective work. In France, those at 1:100,000 have been retained simply because of the time and effort invested; those at 1:50,000 are more interesting in terms of their applications. In tropical countries a scale of 1:200,000 as in the soil map of Bossangoa (Boulvert, 1974) or 1:500,000 in the map of Upper Volta (Fauck, 1977), is more commonly utilized. Of course with the last scale, the document clearly represents an intermediate stage with respect to the preceding case.

In the legend of these maps the soil families as distinguished by the lithographic nature of the parent material can be indicated, even as can be soil series that generally correspond to significant gradations of soil depth for the land use, especially if it is principally agricultural.

3. Large scale maps. At scales larger than 1:50,000, the soil map permits practical applications for local development planning and area development. Soil series, and even phases of those characterized by different erosion intensities or internal drainage conditions, are distinguished on the legends of these maps.

Even if these two general methods of soil map classification are clearly different, their results nevertheless partially overlap. For example, maps at a scale of 1:1,000,000 or at smaller scale are in general types of reconnaissance maps if they are not really derived from a synthesis of more detailed maps, such as those at the 1:200,000 or 1:100,000 scales. Similarly, maps at larger scales are not always reconnaissance maps; rather they are more often detailed maps.

Different kinds of maps as a function of their objectives

This subject has been briefly considered in the first part of the report and specific recommendations have been given in the preceding paragraphs of the second part.

1. Pedological maps. Theoretically, for pedological maps, the kinds of maps and legends follow the rules of the precision and level of information, as a function of their scale as given in the beginning of the second part of this paper. The legend is linked as narrowly as possible to a soil classification system, as for example, the morphogenetic (soils map of France) or morphological (soil map of the U. S.) classification systems.

2. *Regional planning maps.* In the last several years, it has become increasingly more apparent that representation of the milieu at a medium scale (1:100,000 or 1:200,000) is insufficient as a basis for regional planning. The global characterization of the evolution of diverse soil types, their distribution, and even their relationships with various factors will not suffice for a general description of the milieu for expressing the general possibility of its use. Thus various authors have attempted to accomplish the objective at this level by presenting maps that are both pedological and morphogenetic.

Without remaining at the initial stage of French soil maps where geomorphological descriptions do not appear except in the form of accessory maps at a smaller scale, nor proceeding to the morphogenetic maps (such as those prepared by Tricart and Kilian) in which soil characteristics appear only in a secondary form, the methodology of Beaudou and Chatelin (1976) can be followed: A description of the pedological regions, followed by pedological soil landscapes, and finally functional segments or elements of toposequences and catenas of soils. Eschenbrenner and Badarello (1975) used schematic drawings to describe and explain morphogenetic landscapes of the northern Ivory Coast (Odienne region).

In this method, the landscapes are defined by the presence of characteristic morphological elements: inselbergs, residual relief, buttes (which are generally cupped with ironstone), the remains of plateaus, derived forms more or less flattened or convex with an appearance of the slopes of lower bottoms, and nick-point values. Landscapes are also defined by the relative importance of soils at the level of the subgroup and their associated phases, and even of the families.

Maps of grouped morphopedological landscapes have been constructed at the scale of 1:200,000; but each of them is supplemented by a pedological detailed map, at the scale of 1:50,000, which is representative of a typical landscape, and by corresponding airphotos.

3. *Maps of agronomic application.* As has been previously stated, maps of agronomic applications can be very different, both in their detail and scale, but they must be based on a soils map established on an identical or larger scale.

a. Maps of soil resources are established at smaller scales (such as the 1:500,000 map of Upper Volta), and they are analytical in nature. They include delineation of agro-climatic zones and emphasize texture, primarily that of the surface horizon, but also that of the lower horizon to the extent that it affects plant performance. Taxonomic units are indicated with respect to the principal kinds of improvements proposed for various characteristic features: drainage conditions, actual water consumption, organic matter content, exchangeable bases, physical properties (particularly unfavorable ones), and the presence of toxic elements.

Some subunits are defined by the association of different component units in a zone or "spot" of the soils map, as this had been indicated in the units of the pedological map.

In northern climatic zones, cultivatable lands have been separated into areas suitable for dryland and irrigated agriculture and rangelands. On the map itself, a table was compiled that indicated the order of the units and subunits as assembled on the pedological map, and these units were given values characteristic of the various land uses for each of the retained fertility factors.

b. At medium and detailed scales (1:100,000) or larger, synthesized maps of optimum agricultural utilization or suitability for cultivation are assembled. The legend includes units of "universal agricultural value" and the principal possible uses as a function of the soil characteristics themselves (their type of evolution, parent material, depth, etc.) and also as a function of their environment, slope, degree of erosion, etc.

The most interesting system (such as the one utilized by Roederer in Tunisia), as previously mentioned, indicates for each unit of land the relative fertility for each of the principal kinds of use or possible cultivation groupings, and the principal forseen improvements. It is of course indispensable that these documents be prepared with collaboration of an agronomist.

An example is given by the management maps compiled for the high-plateau steppes of Algeria which were prepared by Pouget (1977) in collaboration with geomorphologists, botanists, and agronomists. The maps include recommendations and forseen management and the potential yield of forages.

c. Maps of cultivation constraints have been rarely established by French pedologists, as many of the previous map types include in their taxonomic descriptions constraints such as "utilizable depth" or various other unfavorable physical properties.

However, maps have been made for the northern Cameroons by P. Brabant that analyze depth, texture, profile differentiation, insufficiency or excess of available water, and degree and danger of erosion. They have also been made in France by the "Organization for the Management of the Hills of Gascogne." The limiting factors are primarily the slope and the depth of usable land, and extreme textures, the excess of calcareous materials and any fertility or chemical insufficiencies.

d. In France, purely thematic maps are also established at very detailed scales with regard to drainage operations (various working groups of INRA), or for particular irrigated cultivations (Organization for the Management of Lower-Rhône Languedoc). The maps compiled at very small scales (1:1,000,000 or 1:5,000,000) concerning the dangers of desert formation and the degradation of soils [R. Pontanier (1976) in Tunisia] and the salinity of soils [Aubert (1977) for Africa] can also be included.

CONCLUSION

I would like to point out some of the main fundamental problems that keep soil survey from better achieving its objectives.

1. We need an improved soil classification as a basis for the map legends, especially for the small scale general soil maps.
2. For medium scale soil maps we have to work on a better use of the geomorphological soil characteristics of the landscapes for the definition of the soil complex units.
3. For detailed soil maps at the large scale level we have to give more regular definition of the soil series and their phases, to get an easier interpretation for land utilization.
4. For agricultural use interpretation we need a more precise study of the relations between soil properties—mostly physical properties and the yields of main crops of various ecological zones.
5. For general land use, we need to work on the most important soil conditions for every type of non-agricultural use.

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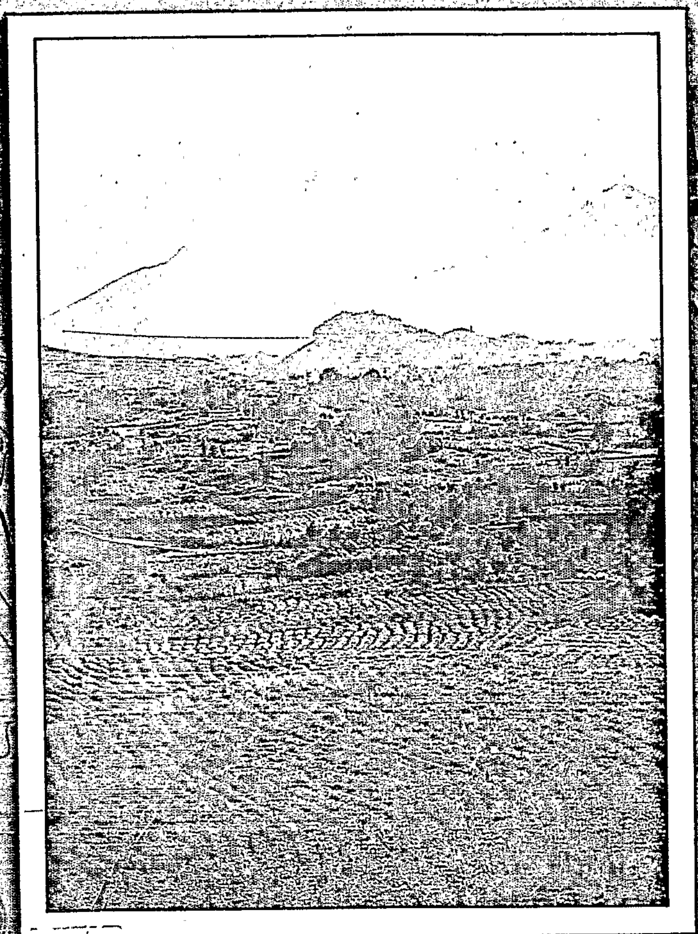

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