Soil Taxonomy: An Overview

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Soil Taxonomy is a comprehensive soil classification developed from 1951 to 1974. In synthesizing the system, all soil properties were considered but selection of differentiating criteria was guided by modern theories of soil genesis. To the degree permitted by present knowledge, the class limits are defined in quantitative terms. The system was designed to be uniformly usable and applicable by competent soil scientists regardless of their area of training and experience. In this system, classification is objective in that it proceeds from properties of the soils themselves and not from the beliefs of the pedologist about soils in general. The system was intended to embrace all known kinds of soils including cultivated and eroded soils. Definitions for a few classes are incomplete because of lack of sufficient data. Soil Taxonomy is a six-category system that permits aggregation of soil data and interpretations at various levels of generalization, whether they are displayed as maps or statistics. It is the only soil classification with a consistent, systematic nomenclature that indicates location in the system and something about the properties of the soils in each class. Soil properties that are important for plant growth also affect the performance of soils for engineering and other nonfarm uses. Soil Taxonomy is a tool for communicating about soils and for extending modern technology into newly developing areas. Interpretations can be made for almost all farm and nonfarm uses.

Although soil is traditionally considered to be a medium for plant growth, the word soil has several meanings. In the development of Soil Taxonomy (1), the following definition is used: Soil

> is the collection of natural bodies on the earth's surface, in places modified or even made by man of earthy materials, containing living matter and supporting or capable of supporting plants out-of-doors. Its upper limit is air or shallow water. At its margins it grades to deep water or to barren areas of rock or ice. Its lower limit to the not-soil beneath is perhaps the most difficult to define. Soil includes the horizons near the surface that differ from the underlying rock material as a result of interactions, through time, of climate, living organisms, parent materials, and relief. In the few places where it contains thin cemented horizons that are impermeable to roots, soil is as deep as the deepest horizon. More commonly soil grades at its lower margin to hard rock or to earthy materials virtually devoid of roots, animals, or marks of other biologic activity. The lower limit of soil, therefore, is normally the lower limit of biologic activity, which generally coincides with the common rooting depth of native perennial plants. Yet in defining mapping units for detailed soil surveys, lower layers that influence the movement and content of water and air in the soil of the root zone must also be considered.

The American Geological Institute (2) defines soil for engineering and geological uses as "all unconsolidated earthy material over bedrock. It is approximately equal to regolith." Many older geological surveys do not discuss the unconsolidated surficial deposits. But in recent years both geologists and engineers have recognized that soils have distinctive properties both horizontally and vertically. According to Lambe and Whitman (3), "The determination of the soil profile is an essential step in almost all soil mechanics problems" and "The properties of the soils in a profile depend on (a) the nature of the components, (b) the method of profile formation, and (c) the alternation of the profile after formation." Thus, there is an increasing awareness that a knowledge of the soil profile and its properties is important in soil engineering. Soil scientists in cooperation with engineers can ensure that suitable interpretations of soil information are available for engineering uses. In the past, for example, there has been close cooperation between highway engineers and soil scientists.

CLASSIFICATION OF SOILS

Interest in soil classification probably developed after man first started to till the soil. Soils vary in some or nearly all their properties within variable distances and are seldom uniform over large areas. Although the best management practices for each soil could be discovered by trial and error, this was an expensive and time-consuming process. The discovery that soils with similar properties and in a similar environment respond similarly to the same management practices was a practical reason to develop a system of soil classification for the transfer of experience.

The soil survey program in the United States started late in the nineteenth century. Soil Taxonomy was initiated about 1951, at a time when there were about 5500 soil series recognized in the United States, each with a defined range in properties. These series were being classified according to the U.S. system of 1938 (4) in which classes were only loosely defined. As a result, there were differences of opinion about the classification of many soil series. Some did not seem to have a place in the classification system whereas others seemed to fit into more than one class in a category. Because many soil scientists of differing experience were classifying soils, consistency in soil correlation and soil interpretations was difficult to maintain. The number of defined soils continued to increase. It was recognized that more precise definitions of soil classes were needed as well as a more logical system of classification.

DEVELOPMENT OF SOIL TAXONOMY

Soil Taxonomy was intended to accommodate all soils and as many of the existing classes as was reasonable. Large areas of the United States had soil surveys that were adequate for current needs. The mapping units were carefully defined and many of the classes were meaningful, particularly those in the intermediate category, the great soil groups, and the lower categories, series, and types. But many soils were classed in some of the great soil groups because the definitions for the next lower category, the family, had not been developed. This deficiency resulted in a wide range of properties in the soil series in different great soil groups. Some series were relatively narrowly defined and others were quite broadly defined.

After World War II there was considerable interest in the agricultural potential of the less developed nations. A better system of classifying soils and providing soil interpretations was needed so that knowledge about soils could be transferred between locations having similar soils and similar environments. The greatest stimulus to the development of an improved classification system resulted from a need to improve the organization of the increasing knowledge about soils and from the increased use of soil survey information. Although the agronomic applications of soil information have long been recognized, the use of soil as a construction material, as a base for low buildings and other structures, as a basis for tax assessment, and for planning purposes and other uses required that a comprehensive system of soil classification be developed to serve as many of these needs as was practical. To meet these needs more adequately, the range in soil properties of the more broadly defined soil series was appropriately reduced.

For most soil interpretations, the range in properties of a soil series is not small enough to provide the degree of refinement necessary for use and management decisions. Mapping units are designed that include only a portion of the range in characteristics of a soil series. These phases of soil series are the bases for soil interpretations. Soil slope characteristics, amount of soil removed by erosion, soil depth and texture, and content of coarse fragments are common phase criteria. The practical limit for restricting ranges in the properties of mapping units is the point beyond which errors of observation in making soil surveys become nearly as great as the range in characteristics of one or more properties.

Cline (5) applied Mill's logic of classification (6) to soil. Some important elements of that logic follow.

1. Classification is a creation of man for a specific purpose and should be designed to serve that purpose.
2. Classification consists of creating classes by grouping objects and ideas on the basis of their common properties.
3. Classification should deal with existing knowledge.
4. As knowledge grows, classification must change to make use of new knowledge.

Soil Taxonomy was designed to conform to these principles.

Soil Taxonomy was developed through many approximations. Seven approximations with extensive changes were tested in the field, as well as many less extensive modifications in the categories and classes. The sixth approximation was the first relatively complete classification that could be adequately tested in the field. It included family differentiae so that series could be classified into the five higher categories of the system. Testing consisted of classifying soil series in families of subgroups and examining the components of the families. For most uses the interpretations for the soil series in any one family should be more similar than for any other grouping. Many changes in definitions resulted from this testing. The 7th Approximation included these changes and, in turn, was tested and modified before its adoption for use in the United States in January 1965.

Certain characteristics of a soil classification system are needed specifically to serve the objectives of soil surveys. The classification must first consider all the soil properties that affect soil use. It must consider soil genesis because the pedologist uses a knowledge of the genetic factors to make maps and interpretations more accurate. Soil scientists of diverse education and experience, working independently, should be able to classify soils in the same classes. Such uniformity can be achieved only if the application is objective rather than subjective, that is, objective in the sense that classification proceeds from the properties of the soils themselves and not from the beliefs of the pedologist about soils in general.

To be useful the classification must embrace all known soils. In particular it must include cultivated soils and other disturbed soils as well as virgin ones.

The system should be multicategoric; there should be few taxa in the highest category and a large number in the lowest to permit the arrangement and comprehension of soil information by classes at different levels of generalization. A multicategoric system provides an orderly scheme for remembering what is known about soils and provides convenient bases for designing mapping units for soil surveys and soil maps of different scales and different degrees of detail.

SOIL TAXA, PEDONS, AND POLYPEDONS

Soil taxa are conceptual; they are not the real soils that are classified. The taxonomy should link the real soils being classified and the soil bodies delineated on maps to the conceptual taxa. The building blocks of soil taxonomic classes and soil mapping units are called pedons. Pedons are real, natural soil volumes just large enough to show all the soil layers present and their relationships (7). Soil individuals, called polypedons, are the real objects that are classified (8). They are collections of contiguous pedons, all of which have characteristics lying within the defined limits of a single soil series, and are comparable to individual pine trees, individual fish, and individual people.

CLASSES

There are six categoric levels in Soil Taxonomy: orders, suborders, great groups, subgroups, families, and series. The highest category, the order, has 10 classes, the suborder category has 47 classes, and each succeeding category has an increasing number of classes. In the United States, 10 orders, 44 suborders, 185 great groups, and about 1000 subgroups, 5000 families, and nearly 11 000 series are known. The system is capable of expanding to include any soils that may be observed. As knowledge and experience with soils in the United States and other parts of the world increase, some classes will have to be redefined, some definitions elaborated, and some new classes established.

NOMENCLATURE

Early in the development of Soil Taxonomy, the need for an entirely new nomenclature for soil classes was recognized. Most classes in the 1938 classification were loosely defined and inconsistently used, and many names had become meaningless. Accordingly, names were improvised from appropriate Greek and Latin roots in order to make the class names as connotative as possible. The new nomenclature was also designed so that class names were indicative of the category in the system. In many languages, the new terminology requires little translation.

Categories

The names of the classes in each category are distinctive. All order names have "sol" for a final syllable, from the Latin solum. The suborder names consist of two syllables, the first identifying a common characteristic of the suborder and the second distinguishing the order. Great group names are formed by prefixing another formative element to the suborder name. Subgroup names are formed from great group names with one or more modifiers that indicate properties intergrading to some other class or to some aberrant soil property. The fifth category, the family, has a polynomial name based on criteria used to differentiate families. The sixth category, the soil series, is usually named after a community or geographic feature located close to the place where the soils were originally defined.

The following table gives the categories and the classification in Soil Taxonomy for two different soil series. Note that all Alfisols and Mollisols between the order and series categories have a suffix—"alf" or "ol"—derived from the order name.

Category	Classification
Order	Alfisol
	Mollisol
Suborder	Udalf
	Ustoll
Great Group	Hapludalf
	Argiustoll
Subgroup	Typic Hapludalf
	Aridic Argiustoll
Family	Fine-loamy, mixed, mesic Typic Hapludalf
	Fine, montmorillonitic, mesic Aridic Argiustoll
Series	Miami
	Richfield

Names in other orders are similarly derived.

Intergrades

Subgroups with properties that intergrade to other classes are named according to the basis of the intergrade. For example, Richfield soils are drier than members of the subgroup Typic Argiustoll. Thus, these soils intergrade to Aridisols, dryness being a property of that order. But if Richfield soils also crack widely on drying and have some vertisolic properties, a torrertic subgroup name would be appropriate because the Torrerts are Vertisols that occur in arid climates. If a soil is similar to a Typic Hapludalf but has more wetness characteristics than is permitted in the typic subgroup, the soils would intergrade to the Aqualfs. The name, however, is contracted to Aquic (rather than Aqualfic) Hapludalf. The names of intergrades to another order are never contracted because the basis of the intergrade is changed. For example, a soil too wet and with too dark a surface horizon for a Typic Hapludalf is classified as an Aquollic Hapludalf because the Aquolls have dark surface horizons and wetness characteristics. The rule is that adjective modifiers are as short as possible to indicate the basis of the intergrade.

Extragrades

Soils of some great groups have the properties of the typic or another subgroup except for one property. If this property is not that of a known kind of soil in a class of a great group or higher category, an extragrade is provided. For example, no classes in Soil Taxonomy are differentiated solely on the basis of shallowness, for uneven distribution of organic matter with depth, or for an overthickened surface horizon. If a typic subgroup definition excludes soils as shallow as 50 cm (19.5 in), soils with irregular distribution of organic matter with depth, or soils with a surface horizon thicker than 50 cm, lithic, cumulic, or pachic subgroups respectively are appropriate. Twenty-two kinds of extragrades are defined.

Soil Moisture Regimes

Five principal moisture regimes are defined in Soil Taxonomy. They are used to differentiate all four higher categories and, to some extent, the lowest category. This is to be expected because of the close relationship between moisture and vegetation and many soil properties. Buol's paper in this Record discusses the moisture regimes in some detail.

SOIL ORDERS, SUBORDERS, AND GREAT GROUPS

A brief review of the major properties of the classes in the three higher categories of Soil Taxonomy follows. In general the soils are discussed in order of increasing degree of weathering.

1. Histosols are soils derived mainly from organic soil materials. Except for the Folists, the soils in all suborders were developed when some or all of the soils were saturated with water. The Folists have less than 1 m (3.3 ft) of organic material overlying bedrock and are rarely saturated with water. The Fibrists, Hemists, and Saprists are distinguished on the basis of the decomposition of the surface organic layers. Great groups are separated on the basis of soil temperature or kind of organic materials.
2. Entisols are recently deposited or recently exposed soils that have not been in place or exposed to weathering long enough for much to happen to them. These soils occur in all climatic regions. Suborders are established because of wetness, disturbance by man, sand content, stratification, and moisture regime.
3. Vertisols are clayey soils that occur in environments where the soils develop deep, wide cracks during periods of dryness. Because soil falls down the cracks and the soils tend to remoisten from the base of the cracks up, some churning of these soils results. This mixing of the soil is sufficient to prevent any appreciable horizon differentiation. Suborders are based on moisture regimes and great groups on the chroma of the upper 30 cm (12 in). The higher chroma Vertisols are better aerated than those having lower chroma.
4. Inceptisols are characterized for the most part by indistinct horizons. Most are believed to be young soils, but some that are composed of very stable minerals may be very old. They are found in most environments except those that are very dry. Vegetation is extremely variable between classes. Suborders are distinguished by wetness, presence of amorphous and vitreous material, manmade layers, high temperatures, light colors, high organic matter content, and low pH. Great groups are distinguished by their moisture and temperature regimes, presence or absence of distinctive horizons, and composition.
5. Aridisols are distinguished mainly by being usually dry or at least physiologically dry because of high salt content. Suborders are distinguished on the basis of the presence or absence of a horizon of clay accumulation. Great groups have different kinds of horizons, such as duripan (silica-cemented), petrocalcic (carbonate-cemented), and salic and gypsic horizons.
6. Mollisols have dark-colored surface horizons that are rich in bases. Most of them developed under grass, which returns a copious supply of plant residues to the upper soil. The soils are naturally fertile but, under continuous cultivation, respond well to suitable fertilizers. They occur most commonly in subhumid to semiarid areas of the midlatitudes of all continents. Of the seven suborders, four are separated on the basis of their moisture regimes, one because it is cold, one because of high $CaCO_3$ content, and one because of profile characteristics. Great group separations are based on the presence or absence of distinctive horizons.
7. Spodosols have either a horizon in which amorphous mixtures of organic matter and aluminum have accumulated or, less commonly, a thin, black or dark reddish pan cemented by iron or iron-manganese, or an iron-organic matter complex is present. At undisturbed sites, the upper mineral layer is usually gray or light gray. The soils occur in cool to hot, humid climates. Four suborders are recognized on the basis of wetness and the ratio of free iron to carbon. Great groups are separated on the basis of cold temperatures, the minimal difference between mean summer and winter temperatures, and cemented or compact pans.

8. Alfisols are intermediate in many properties between Mollisols and Ultisols. All Alfisols have a zone of clay accumulation and do not have the dark surface horizon that characterizes the Mollisols. Alfisols contain fewer bases than Mollisols but more than Ultisols. In general, they are more erodible than Mollisols when cultivated, have a higher fertilizer requirement, and are not in an environment favorable to the accumulation of organic matter. Some Alfisols have silica-cemented layers (duripans) and dense layers (fragipans), both of which are absent in Mollisols. Four suborders of Alfisols are distinguished on the basis of moisture regime and one on the basis of low temperature. Great groups are distinguished by the presence or absence of distinctive horizons. Alfisols are found in most environments except those that are usually dry.

9. Ultisols contain translocated clay but are relatively low in bases. Thus, the soils respond well to suitable applications of fertilizers. Ultisols are extensive in warm, humid climates. One suborder is distinguished on the basis of the organic matter content of the upper portion, but the other suborders are distinguished by moisture regime. Great groups are distinguished by the kind and distinctness of horizons.

10. Oxisols are old soils that have low cation exchange capacity of the fine-earth fraction, low cation retention, and no more than traces of primary aluminosilicates at depths above 2 m (6.5 ft), or they have an iron-rich mixture of clay, quartz, and other diluents with a mottled appearance (plinthite) that forms a continuous phase within 30 cm (12 in) of the soil surface. Plinthite changes irreversibly to an ironstone hardpan or to irregular aggregates on exposure to repeated wetting and drying. Without amendments the soils are unproductive. Most Oxisols are in tropical and subtropical, moist environments. Suborders are separated on the basis of kind of moisture regime and organic matter content of the upper part of the soil. The bases for separating great groups are surface and subsurface accumulation of humus, very low cation retention, presence of plinthite or gibbsite, and cation exchange capacity.

SUBGROUPS, FAMILIES, AND SERIES

The great groups of all orders are subdivided into subgroups on the basis of intergrades to other classes and extragrades, as previously described. The central concept of the great group defines the type subgroup and is divided by restricting the limits of the great group definition, just as great groups are defined by segmenting the suborder definition and suborders are segments of orders. For example, the Hapludalfs are those Udalfs that have no more than 15 percent tongues of albic material (uncoated mineral grains) in the argillic horizon; have 5°C (41°F) or more difference between mean summer and mean winter temperatures; lack a fragipan, a natric horizon, or an agric horizon; and have a specified kind of argillic horizon. With respect to tonguing, the Typic Hapludalfs are defined as having almost none. Those with as much as 15 percent tonguing are classified as Glossic Hapludalfs, whereas those with 15 percent or more would be classified in a subgroup of Glossudalfs, assuming that all other properties are the same. Differences between mean summer and mean winter temperatures separate the Tropudalfs and Hapludalfs. By placing additional restrictions on properties of the typic subgroup—for example, depth or base saturation—provision can be made for lithic or ultic subgroups. Whereas a great many subgroups are possible in each great group, differences must be great enough that the soils can be separated in the field and that differences in use and management are significant at the subgroup categoric level.

Differentiae for families are based on classes of particle size, mineralogy, calcareousness and reaction, temperature, depth, slope, consistency, coatings of silt and clay, and cracks. Two to four differentiae are commonly used to describe a family, but the number and differentiae used vary between classes. Control sections to which differentiae for the classes apply are defined. Series differentiae include all differentiae that apply to the classes in higher categories that are appropriate for the series as well as some pertinent subdivision(s) of any of these differentiae. More than 60 percent of the families are represented by 1 series, 10 percent by 5 or more series, and about 2 percent by 10 or more series. However, the range of characteristics of a single series in a family covers only part of the range that is possible for the whole family.

MAPPING UNITS AND CATEGORIC LEVEL

Each category in Soil Taxonomy is intended to include all existing soils. The soils in classes at each categoric level are more uniform in their properties than they are between that level and other classes. Thus, map units can be designed as phases of any categoric level suitable to meet the needs of the soil survey. Where detailed planning information about contrasting soils is needed for areas as small as 1 hm^2 (2.5 acres), a map scale of about 1:20 000 is necessary. Most map units are phases of soil series. For planning larger areas such as counties, states, or regions, broader soil relationships are more important. For county planning, a map scale of 1:100 000 is common. Associations of phases of soil series are the commonest map units at this scale. For national planning, a map scale of 1:7 500 000 may be desirable with map units that are phases or associations of phases of great groups. The scale of the base map for soil surveys and the kinds of mapping units used are designed to fit the objectives of the soil survey. In general, the smallest scale map that can show the smallest delineations necessary to meet the objectives of the soil survey is selected because of ease of preparation and cost.

When soil maps of any scale are used, limitations in map preparation must be recognized. For example, the most detailed published soil surveys usually have a map scale of 1:15 840 or smaller. The minimum size delineation is usually about 0.5 by 0.5 cm (0.19 by 0.19 in) on the map, which represents about 1 hm^2 (2.5 acres) on the ground. Thus, on-site investigations are always needed before any construction is undertaken or small areas are planned for intensive use.

CONCLUSIONS

Soil Taxonomy makes it possible to classify all soils. Its structure serves equally well for organizing existing knowledge about soils for project planning and for relating test results and research to specific soil properties. Knowledge about soils can thus be increased in a structured manner that permits application of new knowledge in planning future projects. This has not been possible with previous systems of soil classification. Now ways must be found to use this capability to the fullest extent so that all disciplines can make maximum use of soil information.

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Diagnostic Soil Horizons in Soil Taxonomy

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This paper discusses the major kinds of soil horizons, their use in Soil Taxonomy, and their significance in engineering soil behavior. The characteristics of the soil in any place are a result of the combined influence of climate and living organisms on a specific kind of parent soil material, conditioned by relief, over a period of time. The combined effect of these factors is reflected in most soils as soil horizons of unique kinds. The presence or absence of kinds of soil horizons is an important criterion in the definition of classes in Soil Taxonomy. Each key soil horizon has a unique morphology that reflects its genesis and composition and a unique behavior due to its properties. Some soil horizons have accumulated clays, organic matter, or iron and other minerals. Other soil horizons have lost such materials. In the classification and mapping of soils, the pedologist studies the properties of each soil horizon in situ and, on the basis of this study, selects sites for obtaining samples of soils for characterization in the laboratory.

The diagnostic soil horizons more commonly referred to as the A, B, or C horizons are used as the building blocks of the soil classification system. They reflect soil weathering processes and are the result of the combined influence of climate and animal and plant organisms on a specific kind of soil parent material. Soil Taxonomy includes those inherent soil characteristics that affect plant root-soil relations and soil-engineering relations. J. S. Mill (1) wrote that the useful classification is one that uses the properties of constituent objects chosen to identify groups that are causes of, or at least sure marks of, many other properties. Soil horizons are the marks of many other properties. They are the link between Soil Taxonomy and soil genesis.

A soil horizon is defined as a layer that is approximately parallel to the soil surface. It has some sets of properties that have been produced by soil-forming processes, and it has some properties that are not like those of the layer just above or beneath it (2). Soil horizons are the marks that now exist in the soil that indicate the genesis of the natural soil. For example, a soil with an argillic horizon indicates a soil formed under a climate that enhanced rock weathering, leaching of the base, and a downward movement of clays.

The objective of this paper is to define some of the key soil horizons, explain their role in Soil Taxonomy, and relate their significance to engineering soil behavior.

INTERPRETATIONS USING SOIL TAXONOMY

Soil Taxonomy has enhanced soil-use interpretations because of the many soil-engineering and soil-plant relations interwoven throughout the system. The diagnostic horizon encompasses both the effect of soil genesis and, indirectly, the impact on soil behavior. The most precise predictions are made at the phase level of the soil series. These units are more precise because they are based on additional criteria such as slope, surface texture, and soil temperature. The diagnostic horizons are used in the higher categories to define broad soil groups. The more exact quantitative definitions introduce a higher degree of standardization in the A, B, C horizon concept than that found in former systems. This avoids subjectivity in definition and allows for greater consistency and for easier comparison between soils of different areas. The system is also better equipped to facilitate the transfer of research information from one area to another. All of this leads to increased effectiveness in using soil surveys for planning and building better road systems and other engineering works.

SELECTION OF CRITERIA

Diagnostic horizons are used as criteria in Soil Taxonomy because they are the result of the soil weathering process. Soil weathering encompasses those processes that produce the natural soil in situ. The natural soil is born as soon as earthy material is exposed to the soil-forming elements. The effects vary. Water moving freely through calcareous soil material begins to move soluble calcium carbonates out of the soil system. Figure 1 shows how pH or soil acidity changes with depth in three soils in Tensas Parish, Louisiana (3). The oldest soil, Dundee silt loam, is estimated to be 3000 years old and has the lowest pH. It has a B horizon that meets the requirements of an argillic horizon. The fresh alluvial deposits have no reduction, and the Commerce silt loam is in between in age and has experienced some leaching. The B horizon in the Commerce soil classifies as a cambic horizon. No clay