SOIL ENGINEERS AND THE NEW PEDOLOGICAL TAXONOMY

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Soil engineers and pedologists can benefit by extending their training and sharing their knowledge of the soils of the world. Future cooperative endeavors can be made easier and more successful if engineers learn more about the new pedological system of classification and soil scientists learn more about the methodology and interpretations employed by soil engineers. Two features of the new soil taxonomy that facilitate a transfer of information are the quantification of major soil characteristics and the system of connotative nomenclature. These features are described, as are the structure and selected classes of the system. The concepts of soil series and mapping units are also discussed in the context of the Soil Taxonomy.

•ENGINEERS and soil scientists no longer deal with highways or farms as independent phases of development. The worldwide concern for an environment that permits mankind to survive and to achieve an overall improvement in the quality of life requires a new scientific conscience and a better integration of human and natural resources.

Soil scientists are pleased that engineers find pedological classification and soil survey of value in their work. That soil scientists have also learned from engineers is evidenced by the engineering interpretation sections of any recent soil survey report. These sections contain information that may assist in studies for developing industrial, business, residential, and recreational sites. In addition, they provide preliminary estimates of engineering properties of soils relevant to water management systems, location of construction materials, possible ground conditions affecting construction, and designate map units useful for correlation with performance of engineering structures. Soil surveys do not provide information about highway design or construction; such decisions require utmost attention to on-site conditions and involve the latest technology developed for such purposes. By soliciting a broader understanding of soil behavior, soil scientists have found that there is much information of mutual concern and benefit.

Traditionally, soil scientists have directed their studies of pedological units toward plant production, whereas engineers have amassed a wealth of engineering data based on the same pedological units—for the most part, at the soil series level of classification. As one's experience with soils expands—from one's own backyard to the next county, to another state, and, finally, to various parts of the world—so do the problems of keeping track of the many kinds of soils, their individual properties, and the correlations of known or expected behavior. Only a computer can recall data on the approximately 10,000 soil series recognized in the United States, and the need arises for a comprehensive, yet practical, soil classification system.

During a recent project in Venezuela, the author was overwhelmed by the numerous potential soil series. Although most did not have series names, it was possible to recall their major properties because they had been classified in the new Soil Taxonomy. When comparing the response of soils whose classifications were similar to soils of New York, the author found that the predicted and experienced behaviors were also similar. In many instances, the agronomic and engineering interpretations were so similar that it was like dealing with soils of New York.

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Such transfers of knowledge are possible with the new Soil Taxonomy because information on soil characteristics has been quantified; the transfer is facilitated by a systematic application of names that indicate major soil properties.

THE NEW CLASSIFICATION SYSTEM

Soil scientists and engineers have steadily improved their methodology for studying and classifying soils. When soil scientists first recognize soil engineering, they discover a new universe related to their sacred pedological units. The engineers' conceptual framework includes a different terminology, several classifications, and a seemingly endless desire to produce numbers. Soil engineers, on the other hand, are undoubtedly aware of the changes that have occurred in pedological soil classification during the past decade. At times, the only item that appears remotely familiar is the soil series. The long-standing engineering experience with soil series has been well chronicled in various publications; now, when soil scientists refer to "Typic Fragiochrepts," the "7th Approximation," and the "new Soil Taxonomy," any feeling of cooperative endeavor might seem lost.

In brief, the previous pedological classification system (1, 7, 10) was not precise enough in its definitions to make consistent generalizations about soil properties or taxa. About 1950, steps were taken to develop a system that would be more quantitative as well as more systematic. By 1960, the system had undergone seven approximations—the 7th Approximation (8)—involving hundreds of changes to accommodate known soils of the United States. Since the official adoption of the 7th Approximation by the National Cooperative Soil Survey in 1965, there have been additional modifications as more worldwide information was considered. The final version will soon be available as U.S.D.A. Handbook No. 436, Soil Taxonomy: A Basic System of Soil Classification for Making and Interpreting Soil Surveys. Its companion volume, which contains the list and classification of soil series in the United States, Puerto Rico, and the Virgin Islands, is now in print (9). Together, these documents will serve as the basic references for the new Soil Taxonomy.

OBJECTIVES AND APPROACH

Soil Taxonomy has two major objectives: (a) to organize available information and thereby assist the understanding of relations among similar as well as dissimilar soils and (b) to serve the needs of a soil survey program in which geographic areas of soils are identified, named, and correlated.

Two significant aspects of the new Soil Taxonomy are the classification of soils based on field investigations supplemented by laboratory investigations and the recall of important properties based on the name of a taxonomic unit.

The taxonomy is a comprehensive system for classifying soils based on properties that have been quantitatively defined in terms of conventional field and laboratory measurements (8, 9). Cation exchange capacity, for example, is commonly the sum of cations extractable with ammonium acetate at pH 7. The degree to which a soil profile is saturated with basic cations (base saturation) is used as a criterion for classification. The quantitatively defined soil features that are diagnostic in the system are then supplied names or name elements, most of which are derived from Latin or Greek and are, therefore, somewhat familiar. "Eutro," for example, is the name element used to indicate a high base saturation soil, while "dystro" denotes a soil of low base saturation.

Overall, the new Soil Taxonomy is designed to facilitate communication and understanding. The systematic naming of quantitatively defined properties provides a means with which to generalize major features of soils in a region, thereby making it easier to share knowledge and experience with other regions.

CATEGORIES OF THE TAXONOMY

Orders

Soil Taxonomy contains six categories: order, suborder, great group, subgroup, family, and series. The highest category has 10 classes, or orders, whose properties are thought to reflect the dominant kinds and strengths of soil-forming processes. To illustrate, recent alluvium, sand dunes, and tidal marshes rarely have evidence of significant alteration of the soil materials. The soils may be so recent that processes have not had time to develop recognizable horizons, or the materials may be so resistant that internal changes are relatively small. These soils are classed together as the order Entisols; the element "ent" connotes recent, and the ending "sols" means soils. At the other extreme are soils whose properties indicate the most advanced state of weathering. These soils have residuals of resistant minerals, crystalline clays of very low activity, and an "oxic" horizon that is dominated by iron and aluminum oxides and is diagnostic for the order Oxisols.

Some soil orders have sets of properties that are thought to be a consequence of specific conditions affecting horizon development. Soils in arid zones (Aridisols) have little water to promote weathering or move components, clayey soils that churn and invert themselves (Vertisols) have little opportunity to develop definite horizons, and organic materials composed of decaying plant tissues (Histosols) do not develop the same kinds of horizons as do mineral soils. Other orders have horizons of clay accumulation (argillic horizons) as a primary diagnostic feature. Those with a high base reserve, like Pedalfers of the old system, are called Alfisols; those with a low base reserve, indicative of an ultimate stage of base removal, are referred to as Ultisols.

Suborders

At the suborder level, properties were selected to indicate the existing stage of horizon development or to indicate conditions affecting future horizon development. For example, all orders except Aridisols, Histosols, and Vertisols have suborders of wet soils, such as Aquents of Entisols and Aquox of Oxisols. Additional suborders are based on soil climate. Alfisols occur from the Arctic to the tropics; but at the suborder level, Boralfs are restricted to cold boreal regions, Udalfs to cool humid regions, Ustalfs to areas that have hot dry summer periods, and Xeralfs to areas of winter rainfall and summer drought, where xerophytic vegetation is common. All wet Alfisols are subclassed as Aqualfs, regardless of their environment, because the internal moisture regime is thought to be more significant than differences of soil water temperature.

Entisols have little horizon development, and their suborders are designed to indicate the main conditions for this lack. Wet Entisols are Aquents, those that are very sandy and either resist change or are young are Psamments, recent fluvial sediments are Fluvents, and most of the remaining kinds of Entisols are Orthents. For the Entisols, soil climate is indicated in the next lower category.

Great Groups

Most classes at the great group level (the third category) are designed to indicate the degree of development of the particular horizons considered to be diagnostic for their order and suborder. In some cases, great groups indicate the presence of additional horizons, bedrock at shallow depth, or soil climate. In the humid temperate, glaciated regions, for example, many well-drained soils with textural B-horizons are classed as Hapludalfs at the great group level. They are Alfisols because of their argillic horizon and high base reserve, they are Udalfs because the profile is usually moist, and they are Hapludalfs because their horizon sequence is relatively simple. Within the same area, however, there are related soils that have a fragipan below the textural B-horizon. These soils are called Fragiudalfs to indicate the presence of both a fragipan and the diagnostic argillic horizon.

Subgroups

At the subgroup level it is possible to indicate features that grade to properties that are diagnostic for other kinds of soils, or features that are extra and not diagnostic for other kinds of soils. Associated with the well-drained Hapludalfs previously noted are Hapludalfs exhibiting some gray mottles, indicative of wetter conditions for some periods of the year. The well-drained Hapludalf would be classed in the Typic subgroup, and the Hapludalf intergrading to a wet soil would be classed in the Aquic subgroup. If bedrock occurred at shallow depth (an extragrade feature), the subgroup would be Lithic.

Modifiers at the subgroup level are applied as separate words, and each ends in "ic." This allows quick recognition of both the categorical level and the kinds of intergrade or extragrade features, distinguishing one soil from another. The previous examples may be summarized as follows:

1. Alfisols—a soil order (sols) with a diagnostic argillic horizon and a high reserve of bases (alf);
2. Udalfs—a soil suborder (two syllables) indicating Alfisols having a humid temperature soil climate;
3. Hapludalfs—a soil great group (three or four syllables) indicating Alfisols in a humid temperate zone, which have a simple sequence of diagnostic horizons;
4. Fragiudalfs—a similar soil great group except that the soils also contain a fragipan;
5. Typic Hapludalfs—a soil subgroup (great group word modified by one or more "-ic" words) indicating that these are the typical well-drained Hapludalfs;
6. Aquic Hapludalfs—a subgroup of Hapludalfs that have evidence of periodic wetness (a property diagnostic of Aqualfs);
7. Lithic Hapludalfs—a subgroup of Hapludalfs that have bedrock at shallow depths (less than 50 cm); and
8. Aquic Lithic Hapludalfs—a subgroup of Hapludalfs that have evidence of periodic wetness (a feature intergrading toward Aqualfs) and are shallow to bedrock (an extragrade feature).

Families

In addition to orders, suborders, great groups, and subgroups, soils in the taxonomy are further subdivided into a fifth category, the soil family. Properties selected at the family level are those believed to have further significance to plant production, namely, the supply of air, water, and nutrients. For most soils, the family includes specific information about the internal soil temperature, the texture in a defined control section of the soil profile, and the mineralogy of clays in fine-textured soils or the mineralogy of silts and sands in medium- and coarse-textured soils. In other soils, reaction and calcareousness, depth, slope, consistence, and permanence of cracks have been used to increase the precision of definitions and separation of soils.

By the time all criteria from an order to a family are accumulated, there are many statements and interpretations that can be made. Particle size classes at the family level have been particularly useful for grouping soils of similar parent materials, thereby producing units of greater familiarity to engineers and pedologists alike (3). It is also possible to examine relations among soils of similar textures even though they may have different kinds of diagnostic horizons; for one interpretation, the soils may be grouped together, yet for another their expected behavior may suggest they be kept separate.

Series and Mapping Units

Refinements of the limits of properties accumulated at the family level, or additional properties of local importance, are used to provide the present concepts and descriptions of soil series. Since 1965, the National Cooperative Soil Survey has been redefining the soil series of the United States to conform with the new Soil Taxonomy. In most instances, there has been little change, but in some areas there has been a drastic overhaul of the pedological units (9). This is not a subterfuge to undermine the long-time confidence in soil survey and pedological classification; it is an attempt to improve accuracy and precision as more information becomes available.

Soil surveys have always had to resolve the variations observed in the field with the scales at which delineations are made and units named. Soil borings and pits are conceded to be samples of some larger body of interest. The sample volumes are now referred to as pedons, the smallest sampling unit that exhibits genetic relations among the horizons. By arbitrary agreement, the surficial area of a roughly circular pedon ranges from about 1 to 12 sq m, depending on the amount of horizon variability. The geographically associated collection of pedons having properties within a specified range is referred to as a polypedon. The limits of polypedons are fixed first by the criteria accumulated in the highest five categories of the taxonomy and are further restricted by the criteria used to define soil series. The sum of characteristics used to define soil series fixes the allowable range for polypedons observed in the field.

In the standard detailed soil surveys of the National Cooperative Soil Survey, delineations are named for the dominant series that occurs in the mapped area. Inclusions in a mapping unit refer to pedons or polypedons of different series or phases that cannot be separated at the mapping scale of about 1:20,000. Soil types are no longer considered as a category in the classification; rather, they are treated as surface-texture phases of their respective series and continue to be a significant part of the designated map units. It is important to realize that, although the characteristics of pedons at geographic points are the basis for classifying and delineating polypedons, when reference is made to soils delineated on a map, the statements relate only to geographic areas (4). On-site investigations are required before accurate statements can be made about geographic points—whether for fertilizer recommendation or for highway route location.

CONCLUSIONS

In 1950, Olmstead (2) indicated the need to place greater emphasis on engineering correlations, and one measure of the value of any soil map is the number and precision of interpretations that can be made about each mapping unit (5). Because the definitions of soil classes at all levels of the new Soil Taxonomy are substantially more specific than in the previous system, there is potential to increase the value of soil maps with a greater number of engineering correlations. In addition, the systematic nomenclature of the taxonomy provides an excellent aid for information transfer. Given quantitatively defined soil properties and a systematic nomenclature, engineers can easily derive information from regions mapped and classified according to the system (6). It is hoped, however, that present and future engineers will supply information to the system and work with soil scientists toward a better understanding and use of the soil resources of the world.

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