CHAPTER 1

Soil and Soil Survey

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This chapter describes the term “soil survey” within the context of the National Cooperative Soil Survey (NCSS) in the United States. It discusses the development of pedology and the important concept of soils as natural three-dimensional bodies that form as a result of the interaction of five soil-forming factors. The repeating patterns formed by these natural bodies of soil in the landscape allow soil scientists to develop predictive soil-landscape models, which serve as the scientific foundation for making soil surveys. Important milestones in the development of the Soil Survey in the United States are discussed at the end of this chapter.

Soil Survey—Definition and Description

A soil survey describes the characteristics of the soils in a given area, classifies the soils according to a standard system of taxonomy, plots the boundaries of the soils on a map, stores soil property information in an organized database, and makes predictions about the suitability and limitations of each soil for multiple uses as well as their likely response to management systems. The information collected in a soil survey helps in the development of land use plans and can be used to evaluate and predict the effects of land use on the environment.

A soil map consists of many individual delineations showing the location and extent of different soils. The collection of all delineations that have the same symbol on the map (e.g., 34B) are a “map unit.” Each map unit is named for one or more soils or nonsoil areas (e.g., Sharpsburg silt loam). Each kind of soil or nonsoil (e.g., Rock outcrop) making up the composition of a map unit is a map unit component. See chapter 4 for a full discussion of map units and their components.

The soils are natural three-dimensional bodies occupying a characteristic part of the landscape. Soil survey maps are therefore different from other maps that show just one or a few specific soil properties or other environmental information. The concept of soil survey as defined for the NCSS is related to, but does not include, maps showing the distribution of a single soil property (such as texture, slope, or depth) alone or in limited combinations; maps showing the distribution of soil qualities (such as productivity or erodibility); and maps of soil-forming factors (such as climate, topography, vegetation, or geologic material). A soil map from a soil survey, as defined here, delineates areas occupied by different kinds of soil, each of which has a unique set of interrelated properties characteristic of the material from which it formed, its environment, and its pedogenic history. The soils mapped by the NCSS are identified by names that serve as references to a national system of soil classification.

The geographic distribution of many individual soil properties or soil qualities can be extracted from soil maps and shown on separate maps for special purposes, such as showing predicted soil behavior for a particular use. Numerous interpretative maps can be derived from a soil map, and each of these maps would differ from the others according to its purpose. A map made for one specific interpretation rarely can serve a different purpose.

Maps that show one or more soil properties can be made directly from field observations without making a basic soil map. Such maps serve their specific purposes but have few other applications. Predictions of soil behavior can also be mapped directly; however, most of these interpretations will need to be changed with changes in land use and in the cultural and economic environment. For example, a map showing the productivity of crops on soils that are wet and undrained has little value after drainage systems have been installed. If the basic soil map is made accurately, and a wide array of soil property data is collected and stored in an organized database, interpretative maps can be revised as needed without additional fieldwork. In planning soil surveys, this point needs to be emphasized. In some cases, inventories are made for some narrow objective, perhaps at a cost lower than that of a soil survey. Generally, maps for these inventories quickly become obsolete. They cannot be revised without fieldwork because vital data are missing, facts are mixed with interpretations, or boundaries between significantly different soil units have been omitted.

The basic objective of soil surveys is the same for all kinds of land, but the number of map units, their composition, and the detail of mapping vary with the complexity of the soil patterns and the specific needs of the users. Thus, a soil survey is designed for the soils and the soil-related problems of the area. Soil surveys increase general knowledge about soils and serve practical purposes. They provide soil information about specific geographic areas needed for regional or local land use plans. These plans include resource conservation for farms and ranches, development of reclamation projects, forest management, engineering projects, as well as other purposes.

Early Concepts of Soil

One of the earliest scholars of soils in the United States was Edmund Ruffin of Virginia. He worked diligently to find the secret of liming and discovered what is now called exchangeable calcium. After writing a brief essay in the *American Farmer* in 1822, he published the first edition of *An Essay on Calcareous Manures* in 1832. Much of what Ruffin learned about soils had to be rediscovered because his writings were circulated only in the South.

E.W. Hilgard was one of the first modern pedologists in the United States. His early concepts of soil (Hilgard, 1860, 1884, 1906) were based on ideas developed by the German chemist Justus von Liebig and modified and refined by agricultural scientists who worked on soil samples in laboratories, in greenhouses, and on small field plots. Soils were rarely examined below the depth of normal tillage. The chemists had a "balance-sheet" theory of plant nutrition. Soil was considered a more or less static storage bin for plant nutrients—the soils could be used and replaced. This concept still has value when applied within the framework of modern soil science, although a useful understanding of soils goes beyond the removal of nutrients from soil by harvested crops and their return to soil through manure, lime, and fertilizer.

Early geologists generally accepted the balance-sheet theory of soil fertility and applied it within the framework of their own discipline. They described soil as disintegrated rock of various sorts—granite, sandstone, glacial till, etc. However, they also described how the weathering processes modified this material and how geologic processes shaped it into landforms (such as glacial moraines, alluvial plains, loess plains, and marine terraces). N.S. Shaler's monograph on the origin and nature of soils summarized the late 19th century geological concept of soils (Shaler, 1891). Other details were added by G.P. Merrill (1906).

Near the end of the 19th century, Professor Milton Whitney inaugurated the National Soil Survey Program (Jenny, 1961). In the newly organized soil research unit of the U.S. Department of Agriculture, Whitney and his coworkers discovered great variations among natural soils—persistent variations that were in no way related to the effects of agricultural use. They emphasized the importance of soil texture and the capacity of the soil to furnish plants with moisture as well as nutrients. About this time, Professor F.H. King of the University of Wisconsin also reported the importance of the physical properties of soils (King, 1910).

Early soil surveys were made to help farmers locate soils responsive to different management practices and to help them decide what crops and management practices were most suitable for the particular kinds of soil on their farms. Many who worked on these early surveys were geologists because only geologists were skilled in the field methods and scientific correlation needed for the study of soils. They thought of soils as mainly the weathering products of geologic formations, defined by landform and lithologic composition. Most of the soil surveys published before 1910 were strongly influenced by these concepts. Those published from 1910 to 1920 were further refined and recognized more soil features but retained fundamentally geological concepts.

Early field workers soon learned that many important soil properties were not necessarily related to either landform or kind of rock. They noted that soils with poor natural drainage had different properties than soils with good natural drainage and that many sloping soils were unlike level ones. Topography was clearly related to soil profile differences. Soil structure was described in soil survey as early as 1902, in the soil survey of the Dubuque Area, Iowa (Fippin, 1902). The 1904 soil survey of Tama County, Iowa (Ely et. al., 1904) reported that soils that had formed under forest contrasted markedly with other soils that had similar parent material but formed under grass.

Soils as Natural Bodies

The balance-sheet theory of plant nutrition dominated laboratory work, while the geological concept dominated fieldwork. Both approaches were taught in many classrooms until the late 1920s. Although broader and more generally useful concepts of soil were being developed by some soil scientists, especially Hilgard (1860) and Coffey (1912) in the U.S. and soil scientists in Russia, the necessary data for formulating these broader concepts came from the fieldwork of the Soil Survey during the first decade of its operations in the United States. The concept of the solum and the A-B-C horizon nomenclature were becoming central to pedology and soil survey (Tandarich et al., 2002). After the work of Hilgard, the most significant advance toward a more satisfactory concept of soil was made by G.N. Coffey. Coffey determined that the ideal classification of soil was a hierarchical system based on the unique characteristics of soil as “a natural body having a definite genesis and distinct nature of its own and occupying an independent position in the formations constituting the surface of the earth” (Cline, 1977).

Beginning in 1870, the Russian school of soil science under the leadership of V.V. Dokuchaev and N.M. Sibertsev was developing a new concept of soil. The Russian scientists conceived of soils as independent natural bodies, each with unique properties resulting from a unique combination of climate, living matter, parent material, relief, and time (Gedroiz, 1925). They hypothesized that properties of each soil reflected the combined effects of the particular set of genetic factors responsible for the soil’s formation, emphasizing the importance of the “zonal” concept (i.e., the bioclimatic zone in which the soil formed). Hans Jenny later emphasized the functional relationships between soil properties and soil formation. The results of this work became generally available to Americans through the publication in 1914 of K.D. Glinka’s textbook in German and especially through its translation into English by C.F. Marbut in 1927 (Glinka, 1927).

The Russian concepts were revolutionary. Soil properties were no longer based wholly on inferences from the nature of rocks or from climate or other environmental factors, considered singly or collectively. Instead, the integrated expression of all these factors could be seen in the morphology of the soils. This concept required that *all properties* of soils be considered collectively in terms of a completely integrated natural body. In short, it made possible a science of soil.

As a result of the early enthusiasm for the new concept and for the rising new discipline of soil science, some suggested that the study of soil could proceed without regard to the older concepts derived from geology and agricultural chemistry. Certainly, the reverse was true. Besides laying the foundation for a soil science with its own principles, the new concept made the other sciences even more useful. Soil morphology provides a firm basis on which to group the results of observation, experiments, and practical experience and to develop integrated principles that predict the behavior of soils.

Under the leadership of C.F. Marbut, the Russian concept was broadened and adapted to conditions in the United States (Marbut, 1921). As mentioned earlier, this concept emphasized individual soil profiles and subordinated external soil features and surface geology. By emphasizing soil profiles, however, soil scientists initially tended to overlook the natural variability of soils, which can be significant even within a small area. Overlooking the variability of soils seriously reduced the value of maps that showed the location of soils. This weakness soon became evident in the U.S., perhaps because of the emphasis on making detailed soil maps for their practical, predictive value. Progress in transforming the profile concept into a more reliable predictive tool was rapid because a large body of important field data had already been accumulated. By 1925, a large amount of morphological and chemical work was being done on soils throughout the country. The data collected by 1930 were summarized and interpreted in accordance with this concept, as viewed by Marbut in his work on the soils of the United States (Marbut, 1935).

Early emphasis on genetic soil profiles was so great as to suggest that material lacking a genetic profile, such as recent alluvium, was not soil. A sharp distinction was drawn between rock weathering and soil formation. Although a distinction between these sets of processes is useful for some purposes, rock and mineral weathering and soil formation commonly are indistinguishable.

The concept of soil was gradually broadened and extended during the years following 1930, essentially through consolidation and balance. The major emphasis had been on the soil profile. After 1930, morphological studies were extended from single pits to long trenches or a series of pits in an area of a soil. The morphology of a soil came to be described by ranges of properties deviating from a central concept instead of by a single "typical" profile. The development of techniques for mineralogical studies of clays also emphasized the need for laboratory studies.

The clarification and broadening of soil science also was due to the increasing emphasis on detailed soil mapping. Concepts changed with increased emphasis on predicting crop yields for each kind of soil shown on the maps. Many of the older descriptions of soils had not been quantitative enough and the units of classification had been too heterogeneous to use in making the yield and management predictions needed for planning the management of individual farms or fields.

During the 1930s, soil formation was explained in terms of loosely conceived processes, such as "podzolization," "laterization," and "calcification." These were presumed to be unique processes responsible for the observed common properties of the soils of a region (Jenny, 1946).

In 1941, Hans Jenny's *Factors of Soil Formation*: *A System of Quantitative Pedology* concisely summarized and illustrated many of the basic principles of modern soil science to that date (Jenny, 1941). Since 1940, time has assumed much greater significance among the factors of soil formation and geomorphological studies have become important in determining the time that soil material at any place has been subjected to soil-forming processes. Meanwhile, advances in soil chemistry, soil physics, soil mineralogy, and soil biology, as well as in the basic sciences that underlie them, have added new tools and new dimensions to the study of soil formation. As a consequence, the formation of soil has come to be treated as the aggregate of many interrelated physical, chemical, and biological processes. These processes are subject to quantitative study in soil physics, soil chemistry, soil mineralogy, and soil biology. The focus also has shifted from the study of gross attributes of the whole soil to the co-varying detail of individual parts, including grain-to-grain relationships.

Early Development of Soil Classification

C.F. Marbut strongly emphasized that the classification of soils should be based on morphology instead of on theories of soil genesis, because theories are both ephemeral and dynamic. He perhaps overemphasized this point because some scientists assumed that soils had certain characteristics without ever actually examining them. Marbut stressed that examination of the soils themselves was essential in developing a system of soil classification and in making usable soil maps. However, Marbut's work reveals his personal understanding of the contributions of geology to soil science. His soil classification of 1935 relied heavily on the concept of a "normal soil," the product of equilibrium on a landscape where downward erosion keeps pace with soil formation. Continued work in soil classification by the U.S. Department of Agriculture culminated in the release of a new system published in the 1938 Yearbook of Agriculture in the chapter "Soil Classification" (Baldwin et al., 1938).

In both the early classification developed by Marbut and the later 1938 classification developed by USDA, the classes were described mainly in qualitative terms. Because the central concept of each class was described but the limits between classes were not, some soils seemed to be members of more than one class. The classes were not defined in quantitative terms that would permit consistent application of the system by different scientists. Neither system definitely linked the classes of its higher categories, which were largely influenced by the genetic concepts initiated by the Russian soil scientists, to the soil series and their subdivisions that were used in soil mapping in the United States. Both systems reflected the concepts and theories of soil genesis of the time, which were themselves predominantly qualitative in character. Modification of the 1938 system in 1949 corrected some deficiencies but also illustrated the need for a reappraisal of concepts and principles. One continuing problem was that a scientist required knowledge about the genesis of the soil to classify it. This information was often lacking or was disagreed upon by soil surveyors. It was determined that a new classification system was required, one that could be applied consistently by an increasingly large and varied cadre of soil surveyors.

Modern Concept of Soil

Soil as defined in *Soil Taxonomy* (Soil Survey Staff, 1999) is "a natural body comprised of solids (minerals and organic matter), liquid, and gases that occurs on the land surface, occupies space, and is characterized by one or both of the following: horizons, or layers, that are distinguishable from the initial material as a result of additions, losses, transfers, and transformations of energy and matter or the ability to support rooted plants in a natural environment."

The "natural bodies" of this definition include all genetically related parts of the soil. A given part, such as a cemented layer, may not be capable of supporting plants. However, it is still a part of the soil if it is genetically related to the other parts and if the body as a unit is either capable of supporting plants or has horizons or layers that are the result of the pedogenic processes, i.e., additions, losses, transfers, and transformations (Simonson, 1959). Nearly all natural bodies recognized as "soil" are capable of supporting plants. Some that cannot support higher plants are still recognized as soil because they are affected by pedogenic development. Soils in very harsh environments, such as Antarctica, are an example. The definition of soil also includes natural bodies that are capable of supporting plants even though they do not have genetically differentiated parts. For example, a fresh deposit of alluvium or earthy constructed fill is soil if it can support plants.

Bodies of water that support floating plants, such as algae, are not considered soil because these plants are not rooted. However, the sediment below shallow water is soil if it can support bottom-rooting plants (such as cattails, reeds, and seaweed) or if the sediment exhibits changes due to pedogenic processes. These soils are commonly referred to as "subaqueous soils" (see chapter 10). The above-ground parts of plants are also not soil, although they may support parasitic plants. Also excluded is rock that mainly supports lichens on the surface or plants only in widely spaced cracks.

The transition from nonsoil to soil can be illustrated by recent lava flows in warm regions under heavy and very frequent rainfall. In those climates, plants become established very quickly on the basaltic lava, even though there is very little earthy material. They are supported by the porous rock filled with water containing plant nutrients. The dominantly porous, broken lava in which plant roots grow is soil.

Marbut's definition of soil as "the outer layer" of the Earth's crust implied a concept of soil as a continuum (Marbut, 1935). The current definition refers to soil as a collection of natural bodies on the surface of the Earth. It divides Marbut's continuum into discrete, defined parts that can be treated as members of a population. The perspective of soil has changed from one in which the whole was emphasized and its parts were loosely defined to one in which the parts are sharply defined and the whole is an organized collection of these parts.

Development of Soil Taxonomy

More than 15 years of work under the leadership of Dr. Guy Smith culminated in a new soil classification system. Categories and classes of the new taxonomy were direct consequences of new and revised concepts and theories. This system became the official classification system of the U.S. National Cooperative Soil Survey in 1965 and was published in 1975 as *Soil Taxonomy: A Basic System of Soil Classification for Making and Interpreting Soil Surveys* (Soil Survey Staff, 1975). The system's most significant contribution was the establishment of taxonomic class limits and their quantitative definitions, whereby an individual soil could belong to only one class. Soil genesis was no longer used directly in determining the correct classification. Instead, diagnostic horizons and features that are the morphological expression of major known genetic processes were defined and used. In this way the current understanding of soil genesis, while indirectly incorporated in the taxonomy, is one step removed from the process of classifying a soil (Smith, 1963). The application of quantitative diagnostic horizons and features as criteria to be used in soil classification has been widely adopted in other soil classification systems around the world, perhaps most notably by the World Reference Base (IUSS Working Group WRB, 2014), sponsored by the Food and Agriculture Organization of the United Nations.

The system of soil classification discussed in *Soil Taxonomy* is dynamic and can change as new knowledge is obtained. The theories on which the system is based are tested every time the taxonomy is applied. During the 1980s and 1990s, nine international committees contributed to major revisions of the taxonomy. This work culminated in the printing of the second edition of *Soil Taxonomy* (Soil Survey Staff, 1999). In addition, many individual proposals for change have been incorporated in editions of the *Keys to Soil Taxonomy,* which have been published periodically since the first edition of *Soil Taxonomy* was published in 1975. The work of a 10th international committee, which addressed the impact of human influences on soils, resulted in important changes. These changes are reflected in the 12th edition of the *Keys to Soil Taxonomy* (Soil Survey Staff, 2014).

Scientific Foundation of Soil Survey

Soil survey is grounded in scientific principles that can be described by the factors of soil formation and by the relationships between landscapes, landforms, and soils. The soil-forming factors are responsible for the genetic development of soil profiles. The relationships between landscapes, landforms, and soils are used to understand the predicable patterns of natural soil bodies in the landscape.

Factors that Control the Distribution of Soils

The properties of soil vary from place to place, but this variation is not random. Natural soil bodies are the result of climate and living organisms acting on parent material, with topography or local relief exerting a modifying influence and with enough time for soil-forming processes to act. For the most part, soils are the same wherever all elements of the five factors are the same. Under similar environments in different places, soils are similar. This regularity permits prediction of the location of many different kinds of soil. This fundamental principle makes soil survey practical (Hudson, 1992).

When soils are studied in small areas, the effects of topography (or local relief), parent material, and time on soil become apparent. In humid regions, for example, wet soils and the properties associated with wetness are common in low-lying places while better drained soils are common in higher lying areas. The correct conclusion to draw from these relationships is that *topography* or *relief* is important. In arid regions, the differences associated with relief may be manifested in variations in salinity or sodicity, but the conclusion is the same. In a local environment, different soils are associated with contrasting parent materials, such as residuum from shale and residuum from sandstone. The correct conclusion to draw from this relationship is that *parent material* is important. Soils on a flood plain differ from soils on higher and older terraces where there is no longer deposition of parent material on the surface. The correct conclusion to draw from this relationship is that *time* is important. The influence of topography, parent material, and time on the formation of soil is observed repeatedly while studying the soils of an area.

With the notable exception of the contrasting patterns of vegetation in transition zones, local differences in vegetation are closely associated with differences in relief, parent material, or time. The effects of microclimate on vegetation may be reflected in the soil, but such effects are likely associated with differences in local relief.

Regional climate and vegetation influence the soil as well as topography/relief, parent material, and time. In spite of local differences, most of the soils in an area typically have some properties in common, which reflect the soil-forming factors influencing the soils regionally. The low-base status of many soils in humid regions or regions with naturally acid rock or sediment stands in marked contrast to the typical high-base status in arid regions or regions with calcareous sandstone or limestone. In old landscapes of humid regions, however, low-base status is so commonplace that little significance is attached to it when considered only from the narrow perspective of old landscapes in a humid region alone.

Regional patterns of climate, vegetation, and parent material can be used to predict the kinds of soil in large areas. The local patterns of topography/relief, parent material, and time, and their relationships to vegetation and microclimate, can be used to predict the kinds of soil in small areas. Soil surveyors learn to use local features, especially topography and associated vegetation, as indicators of unique combinations of all five soil-forming factors. These features are used to predict boundaries of different kinds of soil and to predict some of the properties of the soil within those boundaries.

Soil-Landscape Relationships

Geographic order suggests natural relationships. For example, weathering and erosion of bedrock by running water commonly sculpt landforms within a landscape. Over the ages, earthy material has been removed from some landforms and deposited on others. Landforms are interrelated. An entire area has unity through the interrelationships of its landforms.

Each distinguishable landform may have one kind of soil or several. Climate, including its change over time, commonly will have been about the same throughout the extent of a minor landform. In addition, the kinds of vegetation associated with climate will likely have been fairly uniform. Relief varies within some limits that are characteristic of the landform. The time that the material has been subjected to soil formation will probably have been about the same throughout the landform. The surface of the landform may extend through one kind of parent material and into another. Of course, position on the landform may have influenced soil-water relationships, microclimate, and vegetation.

Just as different kinds of soil are commonly associated in a landscape, several landscapes are commonly associated in still larger areas. These areas cover thousands or tens of thousands of square kilometers. Many can be identified on photographs taken from satellites. From this vantage point, broad physiographic regions are apparent. Examples in the U.S. are the East Gulf Coastal Plain, the Appalachian Plateau, the Wyoming Basin, and the Great Plains. These broad units typically have some unity of landscape, as indicated by such terms as "plain," "plateau," and "mountain." These physiographic units are composed of many kinds of soil.

The main relief features of a physiographic unit are commonly the joint products of deep-seated geologic forces and a complex set of surface processes that have acted over long spans of time. Within a physiographic unit, groups of minor landforms are shaped principally by climate-controlled processes. The climate and biological factors, however, vary much less within a geomorphic unit than across a continent.

Still broader than the geomorphic units are great morphogenetic regions that have distinctive climates. For example, one classification recognizes glacial, periglacial, arid, semiarid-subhumid, humid-temperate, and humid-tropical climatic regions associated with distinctive sets of geomorphic processes. Other major regions are characterized by seasonal climatic variation. These geomorphic-climatic regions are related to soil moisture and soil temperature regimes. Thus, the great climatic regions are divided into major physiographic units. Landscapes and associated landforms are small parts of these units and are commonly of relatively recent origin.

The landforms important in soil mapping may include constructional units, such as glacial moraines and stream terraces, and elements of local sequences of graded erosional and constructional land surfaces. These bear the imprint of local, base-level controls under climate-induced processes. Most surfaces that have formed within the last 10,000 years have been subject to climatic and base-level controls similar to those of the present. Older surfaces may retain the imprint of climatic conditions and related vegetation of the distant past. Most present-day landforms started to form during the Quaternary period; some started in the late Tertiary period. In many places, conditions of the past differed significantly from those of the present. Understanding climatic changes, both locally and worldwide, into the far past contributes to understanding the attributes of present-day landforms.

Geomorphic processes are important in mapping soils. Soil scientists need a working knowledge of local geomorphic relationships in areas where they map. They should also understand the interpretations of landforms and land surfaces made by geomorphologists. The intricate interrelationships of soil and landscape are best studied by collaboration between soil scientists and geomorphologists. Standards and protocols for describing landscapes and geomorphology are discussed in chapter 2.

Development of the Soil Survey in the U.S.

Soil surveys were authorized in the United States by the U.S. Department of Agriculture Appropriations Act for fiscal year 1896, which provided funds for an investigation "of the relation of soils to climate and organic life" and "of the texture and composition of soils in field and laboratory." In 1966, Congress expanded the scope of the Soil Survey Program and further clarified its intent in Public Law 89-560, the Soil Survey for Resource Planning and Development Act. This legislation recognized that soil surveys are needed by States and other public agencies to support community planning and resource development in order to protect and improve the quality of the environment, meet recreational needs, conserve land and water resources, and control and reduce pollution from sediment and other pollutants in areas of rapidly changing uses.

Many soil surveys have been initiated, completed, and published cooperatively by the U.S. Department of Agriculture, State agencies, and other Federal agencies. The total effort is the National Cooperative Soil Survey (NCSS). The NCSS is a nationwide partnership of Federal, regional, State, and local agencies and private entities and institutions. This partnership works to cooperatively investigate, inventory, document, classify, interpret, disseminate, and publish information about soils of the United States and its trust territories and commonwealths.

The following discussion highlights some of the important developments that helped shape the U.S. soil survey over its more than 100-year history.

1896 to 1920

In 1899, the U.S. Department of Agriculture completed field investigations and soil mapping of portions of Utah, Colorado, New Mexico, and Connecticut. Reports of these soil surveys and similar works were published by legislative directive. At the same time, the State of Maryland, using similar procedures and State funds, completed a soil survey of Cecil County.

The early soil surveys investigated the use of soils for farming, ranching, and forestry. Eventually, soil survey data began to be applied to other uses, such as highways, airfields, and residential and industrial developments. As more surveys were made and their use expanded, the knowledge about soils—their nature, occurrence, and behavior for defined uses and management—also increased. The Highway Department of Michigan was applying soil survey data and methods in planning highway construction in the late 1920s. At about the same time, soil surveys in North Dakota were being used in tax assessment.

1920 to 1950

Soil surveys published between 1920 and 1930 reveal a marked transition from earlier concepts that emphasized soil profiles and soils as independent bodies. The maps retained significant geologic boundaries as soil maps do today. Many of the surveys of that period provide excellent general maps for evaluating engineering properties of geologic material. In addition, maps and texts of the period show more recognition of other soil properties significant to farming and forestry than do earlier surveys and have value for broad generalizations about farming practices in large areas. To meet the needs of planning the management of individual fields and farms, greater precision of interpretation was required. The changing objectives of soil surveys initiated changes in methods and techniques that would make surveys more useful and forced scientists to reconsider the concept of soil itself.

Beginning in the 1930s, the Soil Conservation Service (SCS) emphasized the control of soil erosion as it used soil surveys for the resource conservation planning of farms and ranches. In the 1950s, soil survey information was used extensively in urban land development in Fairfax County, Virginia, and in the subdivision design of suburban areas of Chicago, Illinois. Soil surveys were an important base for resource information in regional land use planning in southeastern Wisconsin. Rural land zoning also relied on soil surveys.

Several other advancements contributed to the expansion and increased precision of soil survey. An early change was the use of aerial photographs as base maps in detailed soil mapping during the late 1930s and early 1940s. Aerial photos served not only as base maps that improved the surveyor's ability to locate their positions in the field but also were used in stereo pairs to view the landscape in three dimensions.

The use of stereo pairs greatly enhanced the surveyor's ability to place soil boundaries correctly in relation to position on the landform.

Before 1950, the primary applications of soil surveys were farming, ranching, and forestry. Applications for highway planning were recognized in some States as early as the late 1920s, and soil interpretations were placed in field manuals for highway engineers of some States during the 1930s and 1940s. However, the changes in soil surveys during this period were mainly responses to the needs of farmers, ranchers, and forest managers.

1950 to 1970

During the 1950s and 1960s, nonfarm uses of the soil increased rapidly. This created a great need for information about the effects of soils on these nonfarm uses. Beginning around 1950, cooperative research with the Bureau of Public Roads and with State highway departments established a firm basis for applying soil surveys to road construction. The laboratories of many State highway departments assisted soil survey operations by characterizing soils for properties such as particle-size distribution, plasticity index, and liquid limit in order to determine their proper placement in engineering classification systems. Soil scientists, engineers, and others worked together to develop interpretations of soils for roads and other nonfarm uses. These interpretations, which have become standard parts of published soil surveys, require different information about soils. Some soil properties that are not important for plant growth are very important for building sites, sewage disposal systems, highways, pipelines, and recreational development. Because many of these uses of soil require very large capital investments per unit area, errors can be extremely costly. Consequently, the location of soil boundaries, the identification of the delineated areas, and the quantitative definition of map units have assumed great importance.

In 1966, the Soil Survey for Resource Planning and Development Act recognized the expanding role of soil survey in supporting efforts to protect and improve the environment. It led to increased efforts to provide technical assistance in the use of soil survey information for land use planning, conservation, and development activities.

1970 to 2000

The use of aerial photography in soil survey was further enhanced by the introduction of orthophotography for the base map in publications. Aerial photographs contain inherent cartographic distortion and are therefore not true to scale across all parts of the image. Orthophotographs are digitally rectified to correct the spatial relationship of locations on the photo. Therefore, they provide a cartographically accurate base map to which field-drawn boundaries can be transferred. This advancement, coupled with advances in computer technology, soon led to the proliferation of digitized soil surveys throughout the 1990s and early 2000s. These surveys became widely available for use in geographic information systems (GIS) and over the Internet. Combining soil survey data with other resource and cultural data layers in a GIS greatly enhanced the ways in which soil survey information could be used.

The adoption of Soil Taxonomy in 1975 as the official system for classifying soils in the U.S. (discussed above) had several important effects on soil survey. Through the use of quantitative class limits and diagnostic horizon definitions, all soil scientists, regardless of experience, were now able to classify soils correctly and consistently. Because of the need for data to properly classify the soil, the quality of field morphological descriptions was enhanced and efforts to obtain data measured in the laboratory increased. The use of Soil Taxonomy also improved the process of correlating soils from one soil survey project to another.

From the 1970s onward, much emphasis was devoted to the development of automated systems to store observations and manage data and interpretations, culminating in the National Soil Information System (NASIS). In addition, many soil surveys were digitized and made available electronically for use in geographic information systems. The development of digital soil information is discussed in greater detail in chapter 7.

In the mid-1970s, a new and important interest in soil survey emerged. The U.S Fish and Wildlife Service was charged with developing a wetland inventory of the United States. It partnered with the Soil Survey Division of the Soil Conservation Service to develop the concept and definition of “hydric soils” in support of the broader definition used to identify wetland areas for the inventory. Many established soil series were identified as likely to meet the definition of a hydric soil. The areas shown on soil survey maps that are composed of these soils were considered likely wetland areas for inclusion in the National Wetland Inventory. The soil survey became an important tool, along with other sources of hydrologic and vegetative information, for identifying wetlands for the inventory. A decade later, as a result of the Farm Bill passed by Congress in 1985, the demand for soil survey information increased further with the need to support the environmentally important “Swamp Buster” and “Sod Buster” provisions of the legislation. The soil survey maps and information were crucial for identifying hydric soil areas as well as areas considered to be “highly erodible.” As a result, soil survey has been a major supporter of national efforts to protect and enhance the Nation’s resources.

2000 and Onward

More recent efforts (since about 2000) to digitize all soil surveys and make them widely available through Internet access via the Web Soil Survey (Soil Survey Staff, 2016) have led to yet greater use of and demand for soil survey information for an ever wider group of users (see appendices). Now that users have electronic access to soil survey maps and information, the demand for hard-copy soil survey reports has decreased (see chapter 7 for a fuller discussion).

In addition to aerial photography, a wealth of multi-spectral data sources from airborne platforms and satellites have provided a wide range of remotely sensed information that can be used to infer the kinds and influence of soil-forming factors in digital soil mapping efforts (discussed in chapter 5). Noninvasive field tools, such as ground-penetrating radar, electromagnetic induction, portable X-ray fluorescence, and other proximal sensing technologies, also are being used to rapidly assess soil properties. These tools are discussed in greater detail in chapter 6.

A series of specialized interpretations have been developed for use by emergency response agencies. Soil information can be useful in providing rapid response to natural disasters and other civil emergencies. For example, it can be used to address oil spills or mass animal mortality in the agricultural sector (such as by avian flu) and the need to dispose of carcasses safely.

In the United States, after more than 100 years of soil survey work, nearly all of the Nation’s lands have been surveyed. The emphasis is no longer on making soil surveys where none existed but on maintaining and modernizing existing soil surveys. Technology and standards have evolved, and the kinds of information needed have changed. In addition, there remains an ongoing effort to better coordinate and join the individual soil surveys over large areas. The NCSS program is focused upon completing soil surveys for the few remaining unmapped areas and coordinating and updating existing soil surveys through correlation activities and data collection. It provides a cadre of trained soil scientists to assist soil survey users with the application of soil survey information for land resource management. The four fundamental goals guiding the NCSS program are: (1) completing the inventory of soils in the United States, (2) keeping the inventory current, (3) providing interpretive information about the soils, and (4) providing access to and promoting use of soil information. The NCSS motto is "Helping people understand soils."

References

Baldwin, M., C.E. Kellogg, and J. Thorpe. 1938. Soil classification. *In* Soils and men, 1938 Yearbook of Agriculture, USDA, Washington, DC, pp. 979-1001. Available at http://naldc.nal.usda.gov/download/IND43893640/PDF. [Accessed 26 August 2016]

Cline, M.G. 1977. Historical highlights in soil genesis, morphology and classification. Soil Science Society of America Journal 41:250-254.

Coffey, G.N. 1912. A study of the soils of the United States. USDA Bureau of Soils Bulletin 85.

Ely, C.W., G.N. Coffey, and A.M. Griffin. 1904. Soil survey of Tama County, Iowa. Available at http://www.nrcs.usda.gov/Internet/FSE_MANUSCRIPTS/iowa/tamaIA1904/tamaIA1904.pdf. [Accessed 26 August 2016]

Fippin, E.O. 1902. Soil survey of the Dubuque Area, Iowa. Available at http://www.nrcs.usda.gov/Internet/FSE_MANUSCRIPTS/iowa/dubuqueIA1902/dubuqueIA1902.pdf. [Accessed 26 August 2016]

Gedroiz, K.K. 1925. Soil-absorbing complex and the absorbed soil cations as a basis of genetic soil classification. Nossov Agriculture Experiment Station Paper 38:1-29, Leningrad. (Translated by S.A. Waksman in 1927)

Glinka, K.D. 1927. The great soil groups of the world and their development. Edward Bros., Ann Arbor, MI. (Translated by C.F. Marbut)

Hilgard, E.W. 1860. Geology and agriculture of the State of Mississippi.

Hilgard, E.W. 1884. A report on cotton production in the United States; also embracing agricultural and physiogeographical descriptions of the several cotton States and California in volumes 5 and 6 of the 10th Census of the United States.

Hilgard, E.W. 1906. Soils: Their formation, properties, composition, and relations to climate and plant growth in the humid and arid regions.

Hudson, B.D. 1992. The soil survey as a paradigm-based science. Soil Science Society of America Journal 56:836-841.

International Union of Soil Sciences (IUSS) World Reference Base for Soil Resources (WRB) Working Group. 2014. World reference base for soil resources 2014. World Soil Resources Report No. 103. FAO, Rome.

Jenny, Hans. 1941. Factors of soil formation: A system of quantitative pedology. McGraw Hill Book Company, New York, NY.

Jenny, Hans. 1946. Arrangements of soil series and types according to functions of soil forming factors. Soil Science 61:375-391.

Jenny, Hans. 1961. E.W. Hilgard and the birth of modern soil science. Pisa, Italy.

King, F.H. 1910. A textbook of the physics of agriculture, 3rd edition.

Marbut, C.F. 1921. The contribution of soil surveys to soil science. Society for the Promotion of Agricultural Science Proceedings 41:116-142.

Marbut, C.F. 1935. Soils of the United States. *In* U.S. Department of Agriculture atlas of American agriculture, part III, Advance Sheets, No. 8.

Merrill, G.P. 1906. A treatise of rocks, rock-weathering and soils.

Shaler, N.S. 1891. The origin and nature of soils. U.S. Geological Survey Annual Report 12, pp. 213-345.

Simonson, R.W. 1959. Outline of a generalized theory of soil genesis. Soil Science Society of America Procedures 23:152-156.

Smith, G.D. 1963. Objectives and basic assumptions of the new soil classification system. Soil Science 96:6-16.

Soil Survey Staff. 1975. Soil taxonomy: A basic system of soil classification for making and interpreting soil surveys. Soil Conservation Service. U.S. Department of Agriculture Handbook 436.

Soil Survey Staff. 1999. Soil taxonomy: A basic system of soil classification for making and interpreting soil surveys, 2nd edition. Natural Resources Conservation Service. U.S. Department of Agriculture Handbook 436.

Soil Survey Staff. 2014. Keys to soil taxonomy, 12th edition. USDA Natural Resources Conservation Service.

Soil Survey Staff. 2016. Web Soil Survey. USDA Natural Resources Conservation Service. http://websoilsurvey.nrcs.usda.gov/ [Accessed 26 August 2016]

Tandarich, J.P., R.G. Darmody, L.R. Follmer, and D.L. Johnson. 2002. Historical development of soil and weathering profile concepts from Europe to the United States of America. Soil Science Society of America 66:335-346.