Outline THE SOIL SURVEY; PAST, PRESENT, AND FUTURE

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The Soil Survey: Past, Present, and Future

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Soil science has traditionally been an umbrella covering soil physics, soil chemistry, soil microbiology, soil fertility, soil morphology, genesis and classification, and soil technology. The area dealing with soils as entities in and of themselves has also been referred to as Pedology, and pedological activities in the United States have been prominent in the soil survey. Soil survey is the institutional construct that implements the concepts of the discipline of Pedology. As such it has grown and matured over the decades and now looks ahead. In the US the program has existed as a partnership of federal and state agencies and organizations collectively called the National Cooperative Soil Survey.

The mission of the soil survey has always been to help others understand soils. This suggests that first one must know something about soils - what they are, how to recognize them, where they are, how and when they formed, and how they function. We want to inform others about what we have discovered. An integral part of that learning has been an awareness of the fragility of soil ecosystems and how man's survival is influenced by the proper functioning of these ecosystems, therefore, we have also become advocates for the wise use of these resources.

The soil survey has evolved as a program which describes, identifies, classifies, characterizes, and maps soils, and interprets their behavior. The discipline of Pedology represents the philosophical core of soil science, the reason for a separate science.

Let us examine the tenets of Pedology. Tenets are those things which we believe and which guide our actions. By starting with the present we can describe the kinds of changes that have taken place in our history, and let it serve as a basis for looking ahead.

TENETS OF PEDOLOGY - WHAT WE BELIEVE

1. We believe that the current paradigm of pedology is based on connections between environmental factors (or conditions) and biogeochemical processes which result in an altered surficial mantle recognized as the pedosphere.

2. We believe that pedology, as a discipline of soil science, employs the scientific method in the study of the pedosphere.

3. We believe that functional relationships of spatial features of soils and landscapes are useful to develop models of soil patterns that guide the preparation of maps.

4. We believe that for ease in managing concepts and data, the pedosphere is conceptually divided into units with limited variability that can be described, defined, classified and used in naming delineated segments of the landscape.

5. We believe that other functional relationships are consistent enough to describe soil behavior and to predict responses to use and management.

6. We believe in continually improving the documentation of the space and time relationships between:
- soil forming factors and soil forming processes
- factors and landscape segments
-soil properties and soil behavior
- models and reality

7. We believe that sharing pedological knowledge with others is relevant to their making informed land use and environmental decisions. Our mission is to communicate effectively with our customers to help them better understand soils, their properties, functions and behavior.

8. We believe it is important to explain the reliability of our knowledge of the pedosphere, its formation, and its responses to changing environmental conditions.

9. We believe that decision making can be enhanced by :
- packaging information for each need
- explaining the rationale for decisions
- describing the impacts of decisions, and
- advocating stewardship of resources.

The Paradigm of Soils

When the soil survey began in the US in 1899 most of the people had backgrounds in the geological concepts of soils and were interested in applying their knowledge to agriculture. That is, soils were considered to be straight line weathering products of the parent rock (or its derived earthy products such as glacial till or saprolite). There was some animosity between Milton Whitney, the Director of the Bureau of Soils who emphasized the texture of soils as being the key to their productivity, and Eugene Hilgard, Professor in California who had emphasized the importance of climate and vegetation in the development of soil properties. This early period utilized an agrogeological approach to soils. When Curtis Marbut became the chief scientist he continued to use a similar approach until George Coffey in 1912 mentioned the Russian concepts types and their formation and finally published a translation in 1927. Marbut began to emphasize that soils were independent of geology and could be studied for themselves. Marbut used the concept of a “mature soil” as a meaningful reference. A mature soil was one whose properties expressed the impacts of climate and vegetation.

The first World Congress of Soil Science was held in Washington in 1927. As the lead speaker Marbut offered a definition of soil that he said had no element of theory in it and presupposed no process nor assumed any cause of the soil facts on which it was based. His definition was: ”The soil consists of the outer layer of the earth’s crust, usually unconsolidated, ranging in thickness from a mere film to a maximum of somewhat more than ten feet, which differs from the material beneath it, also usually unconsolidated, in color, structure, texture, physical constitution, chemical composition, biological characteristics, probably chemical processes, in reaction and in morphology”.

The Russians presented 13 booklets about Russian Pedological Investigations (1927) at the Congress. They are good summaries of the ideas of Dokuchaev, Sibirtsev and others. The papers are important because they enabled many scientists to become aware of progress in Pedology. The papers were:

1. Dokuchaev’s ideas in the development of pedology and cognate sciences. K.D. Glinka.
2. Achievements of Russian science in morphology of soils. S. A Zakharov.
3. Genesis of soils. S. S. Nesustruev.
4. Achievements of Russian science in the province of chemistry of soils. I. V. Tiurin.
5. The classification problem in Russian soil science. J. N. Afanasiev.
6. Cartography of soils. L. I. Prasolov
7. Russian investigations concerning the dynamics of natural soils. V.V. Hemmerling
8. Contributions of Russian scientists to paleopedology. B. B. Polynov
9. Achievements of Russian science in the field of agricultural Pedology. S.P. Kravkov
10. Russian Pedology in agricultural experimental work. N.M. Tulaikov
11. Brief review of the progress of applied soil science in USSR. A.A. Yarilov
12. Soil science in the construction of highways in USSR. N. I. Prokhorov
13. Russian progress in geobotany as based upon the study of soils. B.A. Keller

Charles Kellogg was appointed as chief scientist in charge of the soil survey in 1934. In 1936 and 1937 he wrote about the “normal soil” and functionally related it to soil forming factors. He further stated that the principles of geography associated with the modern concept of the soil as a dynamic natural body in equilibrium with its environment, leads us to consider both the destructional results of weathering, and the constructional forces of biology. He stated that the whole process of soil genesis is one of evolution together with the development of the entire landscape, of which it is a part, and that age, in a relative sense, is important.

Textbooks were beginning to reflect these ideas but it was not until after World War II that Prof. Hans Jenny’s 1941 book on the formation of soils made a huge impact on American soil science. Jenny presented the functional relationships as S= f(cl, o, r, p, t). Soil was considered to be a function of the interactions of climate, organisms, relief, parent material and time. Even today this is the fundamental basis for talking about soils.

The concepts of Dokuchaev as espoused by many throughout the world gave rise to soil science as a new and separate science based on the independence of soils as natural entities. The science of soils as developed in the US has had a strong association with agriculture and the production of plants of interest to society. For some this is agropedology; soil for the sake of agriculture, rather than pedology which deals with soil for the sake of soil.

In a broader context, the pedosphere is the interface of the lithosphere, the biosphere, and the atmosphere. Occasionally the interface is also with the hydrosphere per se. The surficial materials altered by the processes of pedogenesis give rise to the pedosphere as distinct from the more comprehensive geoderma which is the geologic cover of the earth's terrestrial portion.

Scientific Methodology

Research consists of those activities that involve the use and application of the scientific method to search for solutions to problems of scientific merit. Basic research is commonly thought of as investigations to determine fundamental properties of our universe, and applied research more often deals with the integration and use of existing information in solving pragmatic problems. In a physical sense, most activities of general interest to society do not attempt to find basic laws and theorems.

Research has several steps or stages as the scientific method is being used. The stages include: collecting information or data; classifying and organizing the information; developing ideas (hypotheses) about relationships among the data; making predictions based on the hypotheses; and evaluating the results relative to the proposed predictions. Based on these results, the original hypotheses often are modified and adjusted to provide more precise or accurate predictions for further testing and use.

A major distinction in developing and testing hypotheses occurs when controlled versus uncontrolled experiments are involved. A controlled experiment consists of systematic variations of treatments applied to a relatively homogeneous population. The object is to evaluate results for differences that can be attributed to the differences in the treatments. An uncontrolled experiment is one in which the experimenter has little or no control over the treatments and only limited control (or knowledge) of the population.

It is rather well known that if a landscape is adequately sampled, the results are differences that can be interpreted as differences of the intensity and the interactions of the climate-vegetation treatment with the landscape. We recognize these differences as soils and as more observations are made, distinct trends and patterns within the uncontrolled experiments of nature are detected.

Most laboratory characterizations of soil samples follow agreed on procedures of analysis, however new methods are developed to refine and extend the results. The principles of physics, chemistry, mineralogy and biology are applied in the examination and evaluation of soil samples.

The information from uncontrolled geomorphic and pedologic experiments is organized into meaningful associations which then become working hypotheses about soil formation and soil distribution. For some scientists the trends and patterns which seem to be universals are thought to be "laws of pedology".

The scales of observations, the tools for examining soils, and the concepts of soils and their functional relationships have been modified over and over again throughout the years of the soil survey. Intensity of land use such as grazing and cropping, or irrigated and non-irrigated, have influenced the degree of exploration, and consequently the kind and detail of soil data so obtained.

Functional Landscape Relationships

Unraveling the results of uncontrolled experiments is the process in soil survey known as "legend building". The relationships are working models that are hypotheses to be tested and refined. Soil survey is a dramatic example of applied research based on uncontrolled experiments whose results are the recognition and distribution of the variability of soils.

Classically the soil forming factors are climate, biota (vegetation mainly), parent material, topography, and time. The influence of climate and biota as modified by the topography acting on the parent material produces soil horizons that differentiate the parent material into recognizable morphologic and chemical-physical entities that are called soils. The basic underlying premise is that soils in the natural environment are the result of the interactions of soil forming factors that influence processes and that the interactions of those processes gives rise to the formation and distribution of soils on the earth's surface.

This basic premise appears simple and it is, as are most fundamental philosophical bases of scientific disciplines. The ramifications are astonishing. Each soil-forming factor has a geographic or spatial distribution that permits hypotheses to be developed and tested for the accuracy of the predictions. There are many, many working models used in Pedology; some are very good and others are in the initial stages of development.

Any association of sets of soil properties and specific landscape positions is, in fact, a hypothesis. The details of the relationship observed in one location are thought to be representative of other areas and thus the working hypothesis is used as a predictor of soil patterns at other sites. Legends for mapping the landscape segments are built in this manner and tested by the mapping of similar landscapes. Observations are repeated again and again for each working hypothesis; they may be randomized or systematic as means to validate interpretations of some of nature's uncontrolled experiments. This testing of working hypotheses occurs with every observation of soils in the field.

If the experimental results do not refute the original proposal then the model is judged to be satisfactory for further use and testing. If the observations at a new site differ significantly from the original prediction, then a search is undertaken to explain the features observed, and a revised or new hypothesis is developed.

When a sufficient number of working models of a general area are developed and tested, the rapid assessment of an area can begin. Field mapping is the application or implementation of the working models. The number of models necessary to conduct field research depends on the objectives of the survey and the requirements for soil information in that survey area.

As technology introduced new techniques and procedures of measurement there have been important changes in how soil properties were described and interpreted. For example, x-ray analysis enabled clay minerals to be studied in more detail, micro-morphology examined the spatial relationships of small places, C14 refined dating of events and features in soils, and satellite data and imagery provided new opportunities of pattern recognition.

Soils as Individuals

Sets of facts are commonly used to characterize objects of interest. Relationships among the measured facts provide a basis for classification. The ideas or concepts that permit the human mind to perceive order and causal relations are, therefore, the basis for arbitrarily defining and naming parts of the real world and for developing classifications that assist in consolidating such information into abstract models of the complex world about us.

Marbut pointed out that the work of creating the ultimate soil unit, as it existed in 1921, was done by the Americans. The soil man, in his opinion, had to determine what features of soil have been acquired during their development as soils after the soil material was accumulated by geological processes, and what features had been inherited from the geological formations which furnished the soil material. The soil man had to define the soil unit in terms of soil characteristics; that is, he had to create the soil unit. Marbut outlined ten features of the soil profile that permit the designation and recognition of soil series and their types. He concluded that the recognition of soil horizons and the description and identification of soils on the basis of the number, character, arrangement and composition of horizons constituted probably the most significant contribution to soil science that had been made by soil survey.

Guidance to field parties was issued in the beginning of the survey as part of the annual report on the activities of the soil survey. These served as the standards for conducting the surveys. C. E. Kellogg prepared a Soil Survey Manual in 1937 detailing the procedures and rationale for the description, mapping, and interpretations of soils. The utilitarian land surveys of the Soil Conservation Service also had a Field Manual prepared by E. A Norton in 1936. When the two surveys were combined in 1951 a new revised Soil Survey Manual was published. This provided the world with a complete description of how surveys were being conducted in the US and provided leadership for survey organizations around the world.

There is an apparent dichotomy of thought when considering soil geography. On one hand, soil is thought of as a continuum of surficial material that meets the definition of soil and as such, the landscape is segmented into different kinds of soil. As with any method of segmenting a continuum, attention is focused on the limiting profiles or boundaries produced by applying class limits to the continuum. On the other hand, soil is thought of as a collection of natural bodies which focuses attention on central or typifying concepts of the natural bodies. In this perspective, soils are described by a range of properties deviating from a central concept and, as such, are natural bodies not only as profiles but as landscapes occupying space.

Each factor of soil formation has a geographic distribution on the earth's surface and the patterns resulting from their overlapping give rise to those unique combinations which are recognized as different soils. This overlapping of geography implies that not only are soils areally distributed but that they also form a continuum of functional relationships in landscapes. Within this continuum no two spots have exactly the same combination of interactions of factors and processes, thus geographic variability is inherent in this model of soil.

It has been suggested that an ideal basic unit for classification should be an object which is observable and measurable in three dimensions and includes the whole vertical thickness of the soil, be independent of all taxonomic systems, have clear boundaries even though arbitrarily fixed, and be of a size convenient for study, measurement and sampling. Most soil surveys are made with a particular taxonomy in mind that guides the naming of delineated areas and in some instances also guides the location of boundaries that are not readily visible by external features.

A taxonomic soil class is a defined segment within a multidimensional array of sets of soil properties that are known from studying pedons or other sampling units of landscapes. As such, a taxonomic class is not conceived as a group of bodies of soil, but as a segment of a continuum of related soil properties with focus on the defined limits that bound the segment.

To a soil mapper, a taxonomic class is generally viewed as a group of physical entities and even though the idea of the group is a concept or a model, the constituent bodies of soil are real things. The natural bodies of soil are being studied to determine acceptable relationships on which to predict their distribution and then the areas are classified and named with taxa that have predetermined limits. The art and scale used in map making and the recognition of intermingled soil bodies having contrasting qualities preclude delineating areas containing the same limits of variability as taxonomic classes.

At our current stage of comprehension it is very difficult to aggregate the knowledge about soils and their landscapes obtained in large-scale mapping into a hierarchical system of classification of soils as geographic entities. The ambiguity of "orders" of soils surveys in the US illustrates the problem.

The exact combination of physiochemical and biological reactions that have actually transformed materials over time into soil horizons of a specific soil can never be known with certainty. Many useful generalizations have, nevertheless, guided the attempts to organize the available knowledge about soils. In an attempt to emphasize the combinational aspects of processes Roy Simonson discussed the general concepts of gains, losses, translocations and transformations. Thus by inferring the initial state of materials accumulated in a profile and observing the present state of a soil, the overall net changes of soil development and combinations and rates of processes could be estimated.

The concepts of soil development are entrenched in pedologic thought and have influenced most soil classification systems. Sandstone soils, granite soils, and glacial soils provided specific provinces for the soil series in the early years of the soil survey. The shift to soil as independent natural bodies saw the change to climate and vegetation groupings of the soil series and over time the Great Soil Groups such as Gray Brown Podzolic, Brunizem, and Reddish Chestnut were recognized as having features thought to result from particular pathways of development. The soil series and soil types were very much the property of the field mappers, whereas the higher category groupings were the speculative domain of others. Advances in classification concepts and their use are recorded in systems published since 1909. The 1938 Yearbook of Agriculture was devoted entirely to the soils of the United States. In 1950 the soil survey staff began to design a new comprehensive system of classification, Soil Taxonomy, was first published in 1975, updated periodically with keys, and in 1999 was published as a new volume.

Behavioral Functions of Soils

Humankind's connection and concern with soils has usually been with the productivity that is associated with the growth and harvest of plants of interest. Good wheat soils, or rice soils, were recognized and used to advantage. Quality has generally been appreciated as an attribute ascribed by some people. It is a judgement about the degree of usefulness or satisfaction of some situation or service, consequently society behaves as a customer of the goods and services provided by soil resources.

Because time is crucial to feelings about quality, it is recognized that some soil properties have existed a long time or have taken a long time to develop and are thought of as "inherent" or inherited properties. Changes of these properties are imperceptible on the scales of time we are familiar with. Some soil properties change much more rapidly, for example, moisture in soils. It changes daily and seasonally and such changes are thought of as dynamic.

Soil quality relates to the functioning of soils, how well they perform a function, and what we expect them to do. It may be good, or bad, or somewhere in between. Functions of soils can be grouped into the following for convenience of discussion: biomass transformations (productivity), water partitioning and reservoirs, geomembrane filters and buffers, biological habitats, direct uses, and cultural support.

Productivity is the most common function associated with soils. Agriculture and grazing and forestry are dependent on the establishment, growth and maturity of plants for the benefit of society. Kellogg eloquently and simply described the "ideal arable soil" as one in which the needs of plants for physical support, nutrients, air and water were appropriately balanced and maintained; also as one that was resilient against degradational forces and was economically viable.

Because soils mantle most of the earth they are the interface of precipitation with the lithosphere and as such they partition water from higher areas to lower areas, from impermeable to permeable areas, and retain moisture according to their physical and chemical compositions. The mediation of moisture through and by soils has been of major interest to society throughout the centuries. Draining wetlands, irrigating deserts, and diking and bunding other lands are examples of how man has modified this natural function of soils.

The pedosphere serves as a sensitive geomembrane at the earth's surface which mediates the transfer of air, water and energy into and out of its thin cover. Solar energy would possibly scald plant roots and microorganisms if it were not for the moderating effects of soils. The mean residence time of pesticides, herbicides and other contaminants in soils enable more effective remediation measures to be devised and implemented. Soils are also recognized for their potential to affect the flux of greenhouse gases, both positively and negatively. The formation of an Environmental Protection Agency attests to the importance that our society has placed on soils as the protective geomembrane of the earth.

Soils are the homes for many macro- and micro-organisms. Complete life cycles take place with the soil - at varying time and space scales. Soil fertility revolves around healthy, thriving communities of micro-organisms. Adaptation to harsh and inhospitable environments are so common that soil, by definition, must contain, or be capable to support, biological activity.

Throughout the world's history soil has been an important construction material used to build houses, roads, fortresses, dams, and support the infrastructure of civilization after civilization. It is so commonplace that often soil is overlooked as vital for these functions. Soils also serve as the waste disposal receptacles for the refuse of evolving societies.

Indigenous peoples maintain sanctity of the earth in their daily lives as they interface with, and are part of, nature. Urbanized peoples have all too often lost touch with their cultural roots in the soil, and only occasionally when used as a cemetery, or as part of a recreational wilderness are the threads recognized. For most people soil is also dirt that is a nuisance needing to be washed out and removed. Out of the mystery of sanitation has come the source of marvel drugs and medicines helping us realize the role that soils play in the larger scheme of things. Culturally soil is revered as the final resting place for earthly bodies and archeological investigations reveal the evolution of humankind's struggles to live in harmony with the environment.

Modern society is becoming aware that soil quality is the capacity of a specific soil to function for a specific use and that there is both an inherent capacity based on the innate or inherited properties of soils, and a dynamic capacity based on the changing conditions influenced by use and management. The intricacies of natural interactions and the modifications brought about by humans often present disharmony and conflict in the functioning of soil resources.

The slowly evolving attitude of America about its soil resources is recorded in the soil survey series that have been published since 1900. These documents follow the changes of models of soils, and of the importance of functions of soils, especially that of biomass transformations. In 1966 when Congress approved the "town and country" aspects of soil survey, a new era of assisting urban citizens began. No longer was the soil survey only for the benefit of agricultural pursuits.

Observing kinds of soils and their patterns of behavior when used or treated in specific ways has been an ongoing process during the course of the survey. As correlations were established in one area for certain soils, they could be tested in other similar areas for consistency and accuracy. New machinery and techniques of managing land, new crop varieties, improved fertilizers, herbicides and pesticides, and heightened awareness of the ravages of degradation all have been important influences on the soil behavior relationships.

Soil truly is a limited resource. Globally there is a desire and an awareness that this resource should be carefully conserved and used in ways that are sustainably productive, environmentally safe, economically viable, socially acceptable and technologically feasible.

Improving Documentation

The National Cooperative Soil Survey holds regional meetings every two years alternating with a national conference. The topics for discussion are assigned by a steering committee of each conference and the participants contribute through written and oral correspondence with other members of their technical committee. The results of these deliberations are published internally for use by members and friends of the survey. There have been many different technical committees over the years that have discussed soil properties such as color, texture, structure, and numerous morphological features like clay cutans, roots, and pores. Other committees have discussed measures of reliability, procedures for updating surveys, marketing and research strategies, and items of a similar nature.

The results of these conferences are also reported to members of the Cooperative Soil Survey at annual state level meetings of the cooperators. In this way dialog and feedback are maintained so that new issues can be brought to the attention of other scientists and pedologists. The development of NASIS, the national soil information system maintained by NRCS, in the 1990's benefited greatly from the input and testing by many cooperators.

Research is the foundation of a successful and viable soil survey program. In the US, graduate students mainly at the Land Grant Universities working with their major professors have examined soils, their landscapes and processes, and provided this information to the various activities associated with the survey.

In addition the soil survey program of USDA has initiated and sponsored numerous research projects including the major studies of soil and geomorphology in four representative areas during the 1950's, 60's and 70's. They included: coastal plain sediments in North Carolina, loess mantled glacial tills in Iowa, desert pediments in New Mexico, and various materials of the Willamette Valley in Oregon. Other studies were conducted in Puerto Rico and Hawaii. Concepts and approaches to field research have been continued by both the researchers of the soil survey staff and by many students and professors throughout the country.

After the advent of Soil Taxonomy the continuing search for improvement of the classification system and the scientific relationships that support it were bolstered by USAID when they provided financial assistance for the Soil Survey Management Support program. Workshops, training sessions, correlation trips and other conferences enabled soil scientists from around the world to share and learn from each other. Important additions and modifications were proposed and accepted as Soil Taxonomy and its supporting laboratory data were enhanced during the 1980's and 1990's.

During the economic boom of the 1980's agricultural production in the US was enormous and at the same time there was increasing concern with environmental conditions, both at home and abroad. Farm programs included new ways to reduce overproduction, namely through conservation reserves of land and protection of wetlands. Soil surveys were important in assessing the levels of anticipated production. As a result of the national and global interests in the environment, soil quality began to take its place with water and air quality. The NRCS established a number of centers and institutes to work on some aspects of these issues. One of them was the Soil Quality Institute which undertook collaborative research to provide for better description, definition and monitoring of soil quality conditions throughout the country.

Advances in technology have been beneficial to the soil survey program. Ground penetrating radar and an electromagnetic bar let scientists look beneath the surface and estimate unseen properties more correctly. Data loggers facilitate transferring field descriptions to computer files, and data tablets let surveyors in the field directly enter lines on base maps. New laboratory equipment has made it possible to go from manual aspects to machine-facilitated automatic procedures, in addition to measuring more things more quickly. As computer software rapidly advanced it became possible to join, digitize, and package soil maps on CD-ROMs for users.

The accuracy and precision of soil survey work are dependent on the relationships that are discovered and reported. There are many different kinds of associations and some are very important to the survey. There are those concerned with soil genesis; relationships between factors and processes and their interactions throughout time; and those that are geographical whereby factors and landscape segments are correlated thereby improving soil mapping. When properties of soils and landscapes are linked to points and areas of landscapes there are new possibilities through GIS and other thought processes, like neural networks, to extrapolate and interpolate points to points, and points to areas. The application of fuzzy sets and fuzzy logic to soil geography verifies some relationships and improves others. Interpretations of soils have traditionally been for crop production and simple soil engineering practices. Experiments by researchers and practical experiences of many others offer new and exciting avenues for extending and sharpening the insights about soil behavior and responses to management. The possibilities of checking and evaluating models with the realities of nature are always exciting. Such opportunities are to be welcomed as they open the door for innovative and creative efforts to learn more about the pedosphere and its role in global ecosystems.

The challenge for a soil survey program is finding an appropriate balance of the essential research with the conduct of the operational aspects. Being aware of the different areas of relationships that backstop a viable soil survey program is an important component of any strategic plan.

Sharing Pedological Knowledge

Pedologists want to tell others what they have discovered about soils and the relationships of soils to the environment. There are many ways to communicate with each other – orally, with written words, with pictures, and by doing. It has been the philosophy of Pedology in the US since its inception to provide information related to the growing of specific crops and which soils are better suited for certain crops. From the early reports on tobacco and grapes to the mixed farming, grazing, and specialty crops of today there have been many kinds of interpretations prepared and presented to the agricultural community. It is believed that people will make better and wiser decisions about land use if they have available the best soil information that can be provided at the time.

Soil survey reports have traditionally included general information about the properties and attributes of soils that favor cropping and conservation of the soil and water resources. Detailed scientific information about specific soil features, how soils form, and how they are distributed in landscapes are reported in the scientific literature, both here and abroad.

Because the soil survey program relies on standards to describe, identify, classify and map soils, the preparation and availability of those standards have been common. The Soil Survey Manual has provided the definitions and procedures used in carrying out the soil survey program. Operational details that are known to be successful are described in the Soil Survey Handbook, and the details of classifying soils have been provided in Soil Taxonomy and in the Keys to Soil Taxonomy. The soil survey staff of NRCS (formerly the Soil Conservation Service) has been charged with the Federal leadership of the soil survey program for USDA and it maintains the records of the standards agreed upon by the members of the National Cooperative Soil Survey.

A valuable component of the soil survey program is the outreach and extension to scientists in other countries. The US has been fortunate to have had one of the largest, most successful programs in the world and it has continually offered its counsel and shared its standards with others around the world. The program in China was enriched by the work of Dr. James Thorp during the 1930’s and a viable exchange of ideas and scientists has occurred ever since. Working through the International Society of Soil Science many US pedologists have contributed to the expansion and dissemination of soil information. The new classification system was introduced as the Seventh Approximation at the World Congress of Soil Science in 1960 held in Madison, Wisconsin. Interactions with Iron Curtain scientists began in 1980 as work started on a world correlation scheme that eventually was introduced at the 1998 World Congress in Montpelier, France as the World Reference Base for Classification.

Under the auspices of the US Agency for International Development, USAID, numerous conferences and field correlation meetings were organized by the Soil Management Support System, a program administered by the Soil Survey Division of SCS/NRCS. Contacts were established throughout both the developing and developed world enabling an open exchange of knowledge about soils in many parts of the world. Over the years the input and counsel from foreign soil scientists have been valuable contributions in the testing and modification of Soil Taxonomy. Many US soil scientists have had opportunities to visit other countries, examine and sample soils, and offer training in various aspects of the American soil survey. Such activities are consistent with the mission of helping others understand soils and are important in the global strategy of the soil survey program.

Reliability of Information

The description of soils, their occurrence, and interpretations about their behavior have been cornerstones of the soil survey program. It was assumed and presumed that this information was the best available and that it could be used with confidence. Standards and accepted procedures were used in the conduct of the field and laboratory work of the National Cooperative Soil Survey, and as these were published or readily available it was assumed that users were aware or the limitations of such information.

As statistics developed and matured in the agricultural sciences, some concepts were applied to soil survey products. Laboratory data was quantified and thus easy to manipulate and analyze for statistical parameters such as means, standard deviations, and coefficients of variation. The precision of analytical data was used to evaluate new methods and equipment. Field observations such as thickness of surface horizons or depth to some underlying layer often had more variability than laboratory measurements; however they could also be expressed in statistical terms if desired.

As a soil series was described and re-described, emphasis was given to a modal concept and the range of characteristics which were thought to exist. Data from pedons were evaluated and the results commonly used in a descriptive paragraph that provided a central concept for a particular soil series. This information was used extensively in the correlation process with eventual modifications to bring the properties in line with those permitted in Soil Taxonomy. This meant that the use of taxadjuncts became important components of soil map units. Taxadjuncts are very similar in the range of properties of a specific series but which differ slightly (outside of the range) such that they strictly are a different series but which are included because of their similarity in use, management, and location in the landscape.

Soil surveyors are familiar with the ambiguity between a taxonomic unit and a map unit. The former is a member of a class in a category of a hierarchical classification and often refers to a soil series. A map unit is a geographic entity that has been named for the dominant soil component but which includes small areas of other soils that cannot readily be delineated at the common scale of mapping. Most map units are multi-component areas and this variability is explained again and again in discussions about the soil survey.

Map unit delineations on maps vary in size and shape and there are no agreed-upon standards for their description or classification. Some interpretations of soil resources are improved as the individual components of map units are recognized, described, and interpreted. This has been recognized in precision farming and site specific management practices. Quantitative measures of map unit variability are not very familiar to most users although probabilities of accuracy have been estimated and reported in some soil survey reports. Fractal dimension values have not been demonstrated to be easily interpreted for collections of map units. The use of fuzzy sets and fuzzy logic allow one to examine possible membership of a data set into different classes and have been applied in developing some interpretations.

It is unclear at this time what customers and users of soil information want or are willing to use in their decision making. It has been suggested that the lower limit of probability confidence of a data set is a customer threshold and that the upper limit of probability confidence is a provider threshold. Soil scientists would like to minimize the risk to consumers, at least the risk associated with the consistency of the scientific data and information provided. Economics commonly plays an important part, often overriding the scientific information, in decisions about the use and management of soil resources.

Enhancing Decision Making

The utility of a soil survey program is determined by the users of the information. Customers wanting to know which soils are suited for their purposes whether it is to grow plants or to hold up buildings expect reliable information on which to base their decisions. Government programs designed to assist farmers and ranchers rely on data and their evaluation. Thus customers and stakeholders are critical to the success of any soil survey. Over the years flexibility in providing for the needs of society has been a hallmark of the American soil survey. When people were uncertain of the products or the types of information needed, the scientists in the soil survey provided their findings in published soil reports for survey areas, usually counties. In arid regions, data were interpreted for grazing and irrigated and non-irrigated farming. In humid regions, data was interpreted for enhanced nutrient and water management to conserve the soil resources.

Specialty crops require specialized information and where possible that has been provided in reports, fact sheets, and by word of mouth. Improved conservation practices rely on information about the properties of soils that influence the installation and use of those practices. Determining which lands to retire from crop production is easier when soil productivity and resilience information is available. The identification and delineation of hydric soils is essential in determining which lands are wetlands. Rural and urban planning are facilitated with digital maps of soils and other land resources. It has been the policy of the soil survey program to be aware of the needs and desires of society and to provide the best information that is available or can be obtained in a reasonable manner.

The standards for making and interpreting soil surveys have always been published and made available to the members of the National Cooperative Soil Survey and now they are becoming available to the public via the Internet. Thus the Soil Survey Manual, the Soil Survey Handbook, Soil Taxonomy, and data and methods of their interpretation are packaged for much broader use than formerly.

The experiences with the development and use of a soil classification system have demonstrated that people who are told the reasons or explanations for the selection and use of criteria are more comfortable. They can follow the line of reasoning and arrive at the same conclusions with the same information. Much of the rationale for parts of Soil Taxonomy was provided some years after the book was distributed. There had been confusion and disagreement about how and when to use certain soil properties which were partially cleared up when the rationale was provided. The National Soil Survey Handbook explains many of the methods and techniques and procedures followed in the soil survey enabling others to more fully understand the process and operation of the program.

Letting people make their own interpretations of soils requires a systematic organization and treatment of the data used by soil scientists. NASIS, the national soil information system, was designed to let many people use the soil information and to provide their own criteria for evaluating to data and judging its appropriateness for their purposes. This approach is now being used in many other parts of the world, although there is not yet a global system for managing such data.

Decision makers have a need to understand what the impacts of their decisions may be. This is also true of those who want to use soil information. Earlier interpretations were often presented as three classes; the red, yellow, and green similar to traffic lights. They would suggest that it was possible to go, or to be cautious or to stop (don't do it), however there was very limited information about the impacts of these alternatives. There have been important changes in the way soil information can, and is, presented. Soil quality and the multiple functions of soils are relevant in community, watershed, and state planning perspectives. Information about expected outcomes from alternative uses and management practices, from single fields to groups of farms, are often as important as are the impacts of a single use at a single site. There likely will be many modifications and new approaches in presenting interpretations as soils and environments are understood in more comprehensive ways.

The soil survey has learned some valuable lessons about the soil resources that they describe and map and classify. There are fewer really good soils than previously imagined. The soil resources of the United States are phenomenal; however, they are not unlimited. And globally there is a scarcity of high quality environments where the food products can provide for an expanding world population. There are soils whose productivity can be improved and maintained, while there are others whose productivity is a fragile and delicate characteristic and so easily degraded. Soil abuse has shown how some soils no longer benefit humankind and how costly it is to try to reclaim lands that have been misused, whether by accident or by design. We understand more about the potentialities of soils than ever before and this has caused us to become staunch advocates for the stewardship of those soil resources. We do not own the soil resources, nor are we the keepers of them, however, our knowledge indicates that a sustainable future will not be a reality unless global inhabitants know, understand, and care about the precious pedosphere on which they depend.

THE FUTURE

A look at the science of pedology reveals that it is mostly qualitative; consequently it is sure that many parts will be examined and that many more aspects will be quantified. These efforts will be incorporated into new working models of how soils form and how they behave. Thus the science itself will continue to grow and develop as new minds have fresh looks at this novel discipline and its philosophy.

Will there be changes in the tenets in the future? It is possible, of course, but maybe we have ones that have weathered well and may exist for many years. Will there likely be new tenets added? If, so, hopefully they will relate to broader global concerns about quality environments on the planet and the role that soil scientists and soil information can play to assist society achieve a sustainable future with a quality existence for all.

Various aspects of soil survey and soil science may be dissected, examined, evaluated, and synthesized into a comprehensive whole with improved understanding of the interactions and functions that operate in the pedosphere. The philosophical concepts underlying pedology such as basic units for classification and for soil geography will be examined. Alternative schemes of classifying objects will provide options and flexibility to ongoing research and operational components of a soil survey program. It is not likely that a world-wide, coordinated endeavor like the Genome project to map all genes of the human body will occur but an analogous situation may give rise to widespread collection and sharing of soil data and their interpretations. The processes that have occurred and that are occurring in soil landscapes will be combined through interdisciplinary activities into realistic working models that undergird the interfaces among the spheres in the earth system.

Fundamentals and principles can be stated and restated to obtain consistency with advances in knowledge. The language of soils may stabilize and facilitate communication between and among groups of individuals. Efficient and effective organizations may arise to assist in developing data sets consistent enough to meet many of society's rapidly expanding desires and needs for environmental behavior information. The fragmented efforts of the 20th century may amalgamate with the result of a new entity better than its parts and negate isolationism as well as any potential downside of globalization.

New techniques enabling more approaches to pattern recognition will likely promote clearer recognition of functionalities and details of integration and interaction not previously detected. The strides in mathematical modeling sharpen the need for precise measurements and improve our understanding of uncertainties. Opportunities and abilities to express, store and transmit knowledge about soils will not be limited by information technology, rather the capability to convert and update and maintain future systems may be a larger limitation.

The Tenets of Pedology in Review

1. The functional relationship paradigm of soils can be improved by refining the conditions and details of each factor and how it interacts in providing the biogeochemical processes that result in the features we know as soils. Parent material and its properties inherited in soils is not as well documented as it might be and as such it seems to be limiting in our models in Pedology. It is not clear that a new paradigm is needed yet, although there will be many attempts to convince us otherwise.

2. Employing the scientific method in pedology has been beneficial and there is little reason to expect that to diminish. The creation of alternatives and multiple hypotheses enables us to remain open to new possibilities and to examine the uncertainties that exist as we search for new patterns and novel explanations.

3. Functional relationships are devises to show how we think things fit together and in which ways they operate. They are always with uncertainty and therefore there will always be serendipity in discovering things we did not know before. If this is lost then so will the program that we knew as the soil survey.

4. A pedosphere of segments has proven to be useful in understanding similarities and differences among and between soils. Learning how to deal with continua instead of discrete units is still a challenge but appears to be closer to a meaningful solution as a way to comprehend the pedosphere.

5. Interpretations are based on research, on observations, and on experience and that likely will be common in the years ahead. Improvements will always be possible as measurements are made with new technologies that let us see smaller, more quickly, and from farther away. The challenge is mental, not technological.

6. Documenting space and time relationships has been the backbone of the soil survey and has grown with the science and art of the program. There are so many areas where new things will be observed, measured, and interpreted that this generality should hold for a long time.

7. It is very difficult to imagine that soil survey is not done to help people understand soils. The users of soil information, whether casually and for curiosity, or seriously and for decision making, are the rationale for a soil survey program that is government sponsored and supported.

8. As responsible scientists and technicians the members of the soil survey have a responsibility to explain their information, how it was obtained, what it seems to mean, and how good or how uncertain the information may be. Without such a responsibility to the customers, the public, and to science there would not be the keen sense of pride and accomplishment of being professionals.

9. Decision making on many levels, for many reasons, for many soils, for many purposes, and by many people is a major focus of a soil survey program. The information obtained and the knowledge gained are valuable assets and their use for the improvement of the environment

and the quality existence of humankind and Nature is good common sense. Stewardship is a powerful message about the social acceptance of sustainability.