National Cooperative Soil Survey Centennial Highlights

Papers for the 1998 Annual Conference of the Soil and Water Conservation Society

Presented in July 1998 at San Diego, California

Foreword

The National Cooperative Soil Survey is celebrating its centennial in 1999. The annual conference of the Soil and Water Conservation Society in San Diego, California, July 5-8, 1998, included two special sessions on "National Cooperative Soil Survey Centennial Highlights." These two special sessions were planned to recognize this significant milestone, which marks a period of 100 years during which many private, local, state, and Federal groups have collectively worked together to produce quality soil survey maps, data, and soil interpretations for multiple resource assessments and other uses. The United States Department of Agriculture, in particular the Natural Resources Conservation Service, has had the Federal leadership for this work during the past 40 to 50 years.

This document includes the presentations made during the two special sessions. These presentations highlight some of the significant points in the development of the National Cooperative Soil Survey. These sessions were sponsored and coordinated by Jim Culver, Acting Director at the National Soil Survey Center, Lincoln, Nebraska.

The papers given at the first special session were written by Dr. Maurice J. Mausbach, Deputy Chief for Soil Survey and Resource Assessment, USDA, Natural Resources Conservation Service; David W. Smith, Soil Scientist, USDA, Natural Resources Conservation Service, West Regional Office, Sacramento, California; Horace Smith, Director, Soil Survey Division, USDA, Natural Resources Conservation Service, Washington, D.C.; and Dr. Randy B. Brown, Soil and Water Conservation Department, University of Florida, Gainesville, Florida. The papers given at the second special session were written by Maxine J. Levin, USDA, Natural Resources Conservation Service, East Regional Soil Scientist, Beltsville, Maryland; Kerry Arroues, Supervisory Soil Scientist, USDA, Natural Resources Conservation Service, Hanford, California; Dr. Ronald Amundson, Division of Ecosystem Sciences, University of California, Berkeley; and Sidney W. Davis, past President of the National Association of Consulting Soil Scientists, Georgetown, California.

A more formal recognition of the centennial of soil survey will occur at our national meeting next year in Biloxi, Mississippi.

James R. Culver
Acting Director, National Soil Survey Center
USDA, Natural Resources Conservation Service

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Papers for the 1998 Annual Conference of the Soil and Water Conservation Society

Assessment and Future Direction for a National Soil Survey Program

By Maurice J. Mausbach, Deputy Chief for Soil Survey and Resource Assessment, USDA, Natural Resources Conservation Service, Washington. D.C.

As Deputy Chief for Soil Survey and Resource Assessment and as a career soil scientist in the NRCS, I have given considerable thought to this topic, especially in the past 3 months. This presentation, therefore, will be from the perspective a soil scientist who is in a leadership position for soil survey and a person who is committed to the continued success of the program. In my presentation today, I would like to very briefly recap the 100 years of soil survey, look at where we are, and finish with future directions for a National Soil Survey program.

Before I begin, however, I want to stress that we in the Soil Survey and Resource Assessment area are committed to addressing the needs of the agency, especially the field staff, and our customers and partners. We are also dedicated to providing and utilizing the most current science and technology in soil survey, natural resource inventories, and resource assessments in our activities for all levels in the agency. To accomplish this goal, we plan to work with our NCSS research partners, research scientists in other agencies, and technical specialists in the institutes and state offices to adapt the technology for use by field staff. This technology will be transferred through innovative training materials to state technical staffs.

The First 100 Years

Most of the material for this section is from a paper by Roy W. Simonson entitled “Historical Aspects of Soil Survey and Soil Classification” (Simonson, 1987). The idea of a soil survey program for the nation is attributed to Milton Whitney, who was on the Maryland Agricultural Experiment Station staff. The first congressional authorization of soil surveys in 1899 was for mapping of tobacco lands and coincidentally Whitney loved cigars. The soil maps were at a scale of 1 inch per mile (1:63,360). The purpose of the first soil surveys was to show on maps the kinds of soils that differed in crop response, especially crop yields.

Can you imagine starting a soil survey from scratch without any of the documentation that we have today, such as *Soil Taxonomy*, the *Soil Survey Manual*, the National Soil Survey Handbook, and the Munsell color book? Throughout the first 100 years, all of these items have been developed and many have gone through numerous revisions. Marbut developed a rudimentary taxonomic system in the 1930’s. Guy Smith began development of the present system in the 1950’s, which culminated in 1975 with the publication of *Soil Taxonomy*. We have had three editions of the *Soil Survey Manual*, the first in 1937, the second in 1951, and the last in 1993. We have come from an age of horse-drawn carriages to hydraulic augers mounted on pickups; however, we still are artists with the spade and shovel. Some soil scientists believe that a person cannot fully describe the soil without first digging the pit by hand!

During the first 100 years, soil survey has endured the threat of competing programs between the Soil Conservation Service and the Division of Soil Survey, Bureau of Plant Industry, Soils, and Agricultural Engineering (BPISAE). These two programs merged as result of Memorandum number 1318 issued by the Secretary of Agriculture, Charles F. Brannan, in 1951. Charles Kellogg, W.H. Allaway, Roy W. Simonson, and Guy D. Smith from the Bureau, as well as Roy D. Hockensmith from SCS, were assigned leadership.

Soil survey has gone through a number of generations during the 100 years. The first era included the first 30 years or so, when mapping was completed on plane tables and without formal classification schemes. The next era was with the advent of aerial photography and the development of the first classification scheme in the 1930’s. The last era has been the so-called modern soil

survey, which dates to the development of *Soil Taxonomy* as well as advanced technical guidelines and aerial photography for the soil survey. As you can see, these eras have been connected to significant advances in technology and in the science of completing a soil survey. We have now entered the electronic era of soil survey as a result technological advances in the last decade with the availability of computers and the advances in storage of electronic data.

During the first part of this century, soil scientists formed the American Soil Survey Association, through which they exchanged scientific information. In the 1930's, this association was combined with the Soil Section of the American Society of Agronomy to form the Soil Science Society of America. This new organization was modeled on the International Society of Soil Science (ISSS). It is interesting to note that the ISSS has recently been accepted into the International Council of Scientific Unions. This acceptance is further recognition of soil science.

I would like to close this review by quoting from two pioneers in the development of soil survey. Charles Kellogg (1955) in an address to this convention 43 years ago in Green Lake, Wisconsin, said:

> Yet even now, people sometimes ask me, "When will the Soil Survey cease to change its methods and its nomenclature?" The obvious answer is: "When we shall have ceased to learn about soils." As more is learned, the new information must be incorporated into the soil classification and into its interpretation if our basic objective of assistance to farmers is to be reached as effectively as possible.

Maybe he was quoting R.S. Smith (Indorante et al., 1996), a pioneer of the soil survey in Illinois, who said:

> It is that the soil survey will never be completed because I cannot conceive of the time when knowledge of soils will be complete. Our expectation is that our successors will build on what has been done, as we are building on the work of our predecessors.

I believe more than ever now that soil survey will always be active because of the demands of the user of the information as well as the ever-developing science of soil survey.

Present State of Soil Survey

We have a world-renowned soil survey program that has no equal in any other country. *Soil Taxonomy* is internationally recognized as the standard for communicating soil information among countries. We have completely revised the 1975 publication and will print the new edition next year. As with other parts of soil survey, *Soil Taxonomy* will continue to be revised as we learn more about soils and how to best group soils into classes.

As I mentioned before, the ISSS has been accepted into

properties. Soil survey has been and continues to be a leader in maintaining the data base in a digital format. NASIS, the National Soil Information System, is the current system that we use to manage the data and to make the data available to customers.

The use of soil survey information is at an all-time high. The 1985 Food Security Act codified the use of soil surveys in the determination of wetlands (hydric soils) and in the identification of highly erodible lands. This one act has done more to institutionalize the use of soil survey information than any other in the first century of soil survey. In addition, soil surveys are used for tax assessment, urban planning and zoning, conservation and environmental planning, routing of roads and highways, engineering practices, precision agriculture, and many other purposes.

Future Directions for Soil Survey

Although it is always useful and interesting to look back at where we have been and come from, it is crucial that we have a vision and strategy for the future. I believe that we have a bright future for soil survey, but it will take diligent, hard work to maintain and enhance the program and science in a society of constant and rapid change. As I previously mentioned, we are now in the electronic age and must move the soil survey program and its products into this new age and fully utilize all of the technical tools available to us. Following is a brief discussion of some of the issues and opportunities for the next century and era for soil survey.

As Dr. Kellogg (1955) stressed, we need to maintain our high standards of scientific and ethical excellence in all that we do. We must continue to have a science-based product and base our interpretations on scientific models and accurate data. Soil scientists must continue to publish scholarly papers on each of the functional areas of the science, such as interpretations, classification, technical soil services, laboratory procedures, world soil resources, investigations, and operations.

Issues and opportunities:

1. Soil survey is entering an era in which field mapping, as we have known it, is nearing completion. In the new soil survey, we need to allow for the continuous updating of information on a physiographic basis. Thus, soil scientists must fully implement the MLRA concept for soil survey. The concept will need continuous adjustments to meet the changes in technology, science, and customer needs.

2. Because of electronic access to soil survey data and the increased needs of users of the information, we must develop statistical means of estimating the reliability of soil survey maps and associated attribute properties. Soil mapping activities have been based on a landscape model of the interrelationship of soils to landscape position. The composition of soils in map units has largely been determined through use of some form of transect. We need to continue to improve methods for collecting these data and move to a statistically based approach.

3. We must continue to maintain, enhance, and expand relationships with NCSS partners and customers, enhancing existing partnerships, expanding to new partners (being more inclusive), marketing our products and activities, and gathering input from internal as well as external customers as to needs. We need to continue to reach out to the private sector soil scientists and members of the National Society of Consulting Soil Scientists. We must involve them in the development of standards for soil survey and assure the availability of these standards for their work. It is absolutely crucial to our existence that we reach out to people in other disciplines within and outside soil science, such as soil biologists, soil chemists, soil physicists, ecological scientists, foresters, range conservationists, and agronomists, to address environmental issues.

4. We need to expand the scope and science of soil taxonomy. Up until now, we have concentrated on grouping soils for the use of soil scientists in mapping soils and to assist in the interpretation of the soil maps. The latter will be the focus in the future. In the United States we have more than 19,000 recognized soil series, and it becomes a difficult task to develop interpretative standards, such as soil health, for each of these soils for the many different land uses. The hydric class of soils is an example of a recent classification to aid in the identification of wetlands. We also need methods of grouping soils that perform similarly for use by modelers to predict outcomes on a regional or national basis. The modelers simply cannot deal with 19,000 individual sets of soil properties when running national analyses.

5. We are now able to address the dynamic properties of soils as they are impacted by human use and management. Throughout this century, soil survey has concentrated on mapping and characterizing the static properties of soils. In the next century we need to address the effects of human use and management on

soil properties and the health of the soils. Addressing these effects includes, but is not limited to, use of soil properties and knowledge of soil genesis in developing nutrient management strategies, developing nutrient loading capacities by kind of soil, monitoring contaminants, adapting soil surveys for site-specific management, and interpreting yield monitoring data. The following three quotations from a paper by Dr. Kellogg entitled "Soil Surveys in Modern Farming" (1955) are relevant to this issue:

> Thus the important knowledge we are now seeking about our soils is their response to management. Farmers produce their arable soils from natural soils through combinations of management practices. These may make small or great alterations in the natural soil.
>
> In the past we have had soil surveys that were not interpreted. They were not useful.
>
> Thus our soil survey to serve the farmers must be continually reinterpreted as conditions change.

Dr. Kellogg stated that a soil survey program without interpretations will not survive.

6. We need to continue our work on landscape and watershed interpretative models to address the needs of conservation planners and environmentalists. Soil surveys are landscape models; thus, it is natural for soil scientists to work with other disciplines in addressing environmental issues on the basis of a watershed or landscape unit.

7. We need to continue and enhance innovating efforts to make our products/information/data easier to use via Internet access, CD-ROM technology, training methods, or other methods. We need a seamless SSURGO product so that users will be able to join counties from different states and not be able to draw state lines based on inconsistencies in our product. In addition, we need to provide our clients all of the technical tools needed to fully analyze and use the information that meets their needs.

8. We need to continue to perfect geospatial techniques for analyzing and using soil survey information. I dream of a virtual geospatial system where, in real time, we model the movement of rainfall through a watershed by using digital soil surveys linked with soil property data and overlaid on digital elevation data. When developed, these models will be powerful tools for predicting the movement of chemicals in the watershed.

9. Soil survey is based on the study of how soils formed. We need to continue our studies of soil formation to address global change issues both nationally and globally. By studying the effects of past climate changes on soil properties, we can predict how soils change. Through these studies we can make predictions of the capacity of soils to sequester carbon based on land use and management practices.

10. We must fully institutionalize technical soil services. These services are tied directly to the mission statement "Helping People Understand Soils." They are especially critical in our effort to serve our Field Office Staff and provide them with the technical tools and training needed for them to perform their jobs. Technical soil services activities are an important part of an outreach, marketing, and educational program. Education and outreach are important as we promote the value of the soil resource to the general public. We need to concentrate on K-12 grade levels as well as the general public. As we help others use our product, we are also building a dedicated customer base.

In summary, as I said before, I believe the future is bright for soil survey and I am excited about being able to work with the soil science community and bring a viable soil survey into the 21st century. Thank you for your attention.

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Soil Survey During Its Infancy of the Late 1890's and Early 1900's

By David W. Smith, Soil Scientist, USDA, Natural Resources Conservation Service, West Regional Office, Sacramento, California.

> *Much of the life of a soil surveyor (we say soil scientist now) may seem rather plain, troubled perhaps, sometimes dangerous, rarely glamorous. Yet, he is a very special kind of person, usually travelling, and accustomed to all kinds of places and people. No one can say precisely what he contributes to American Agriculture—not specifically in tons, bushels, pounds, or dollars. Certainly it has been a great deal. And in doing it he picks up, perhaps, a unique kind of humor and wisdom. Not that all soil surveyors are alike—indeed, far from it. Still, only a little experience is needed to spot one; and a group of them is always obvious (and nearly unintelligible to the outsider).* —Charles E. Kellogg, Foreword to *Crisscross Trails: Narrative of a Soil Surveyor* (Lapham, 1949)

Introduction

The soil survey of the United States formally began in 1899 with publication of the first report of field operations—USDA Report 64—of what was then the USDA Division of Soils (Lapham, 1949; McCracken and Helms, 1994; Simonson, 1952; Smith, 1982). This report included maps and texts for surveys of the Connecticut Valley, the Pecos Valley, and the Salt Lake Valley, where fieldwork had been conducted earlier during that same year.[1]

The advent of the centennial celebration of the soil survey serves as a good time for reflection. Why should we take the time to look back? One reason is because history provides perspective on the nature and complexity of past challenges and successes. That knowledge can help in carrying the work forward. As the old adage goes, "Knowing where you have been can help get you to where you want to go." Another reason is simply to enjoy our rich history. Numerous interesting and fun people, places, and events have been associated with soil survey. We should periodically take time to revel in that. The 100-year mark seems a good time to "take stock."

In this paper I will focus on the early period of soil survey, around the end of the nineteenth century and into the first two decades of the twentieth century. I will not go into great detail but will touch on what I view to be some of the significant pieces of the early story: a) the state of the science at the time, b) soil classification and mapping challenges, c) early field methods, and d) key people.

Through the Eyes of a Soil Surveyor

I will tell the story partly through the eyes of Macy H. Lapham, a soil surveyor who was there at the beginning, in 1899, and who spent the next 45 years making soil survey his life's work. He was there when the entire soil survey consisted of just 10 staff nationwide, before there was a soil classification system or written procedures on soil survey. He mapped soils in many of the Western States and then went on to serve as Inspector for the Western Division of the Bureau of Soils. He knew and worked alongside E.W. Hilgard, Milton Whitney, G.N. Coffey, Curtis Marbut, H.H. Bennett, Charles Kellogg, and others.

After Lapham retired in 1945, he wrote the book *Crisscross Trails: Narrative of a Soil Surveyor* (Lapham, 1949). In his words: "[I offer this book] as an unpretentious historical record of the organization and development of the soil survey in which the recital of associated personal observations and incidents has been included." I recommend the book to anyone who is interested in the story of the early soil survey and who can get hold of a copy (it is rare and out of print). I will use excerpts from the book in this paper because they are interesting and fun.

Charles Kellogg wrote the following about Macy Lapham in the Foreword of the book:

> Macy Lapham and the soil survey grew up together. He has seen changes in soil science, in the land, and in the people—has seen them all together. This is what he has written about. [He] writes simply about places and people. Yet, little by little he tells us a lot about soils and the plants that grow on them, about farms, and mountains, and deserts, and deep forests. Above all, he tells us good stories that involve hundreds of people. Yet, Macy obviously feels keenly of the seriousness of the work at hand. His contribution to it has been greatly enhanced by this telling of real life and study out of doors. Macy is a good representative of soil surveyors everywhere.

Excerpts from Macy Lapham's book will be used to help tell the story.

Whitney and the Start of the Soil Survey

In the late 1800's, the USDA became involved in the development and support of upcoming sciences in agriculture. The Division of Agricultural Soils was

[1] Fieldwork for a soil survey of Cecil County, Maryland, actually began earlier, in 1898, but the report was not formally published until later (McCracken and Helms, 1994).

established in February 1894 as part of the Weather Bureau. In July 1895, the Division of Agricultural Soils was recognized as an independent office within USDA. It became the Division of Soils in 1897. In 1901, its stature was raised by Congress to USDA Bureau of Soils (Lapham, 1949; McCracken and Helms, 1994).

Professor Milton Whitney served as the first Chief and is credited with starting the U.S. Soil Survey (Lapham, 1949; McCracken and Helms, 1994; Smith, 1982). His charge from Congress was to use the study of soils to promote agriculture. Prior to his appointment to USDA, he had conducted soil chemistry and soil fertility research at North Carolina State College and had also studied the physical properties of soils at the Maryland Agricultural Experiment Station.

Whitney was a visionary with regard to soil survey. It is said that in his capacity with USDA before the soil survey began, he saw and promoted the need for soil mapping and for providing immediate assistance to the farmer. Guy Smith (1982) credits Whitney with the statement "We need a soil survey in order to be able to transfer experience, from research to the use of soils, from the fields or areas where we have experience, to other soils where it is applicable."

Soil Science in the Late Nineteenth Century

Near the end of the nineteenth century, soil science was only just emerging as an independent discipline from the traditions of agricultural chemistry, geology, and geography. This "newness" would set the stage for certain challenges to be faced with respect to soil classification and mapping during the early years.

Publications by Simonson (1968) and Tandarich and Sprecher (1994) provide complete information on the history of the development of soil science and pedology. Those interested are encouraged to refer to those publications. Briefly, the chemical aspects of soils starting coming into focus during the 1700's and 1800's. This development led to an agricultural chemist academic tradition that lasted until the early 1900's. The science of geology was developing somewhat simultaneously and was really the first science to develop field methods that could be applied to soils. Around the mid-1800's, some geologists started studying the geography of soils and related agricultural conditions (however, they primarily viewed soils as a kind of weathered rock, not as an independent and organized body). This development led to an agricultural geologist academic tradition that lasted until the 1920's, when the name of the international organization representing that discipline was changed to the International Society of Soil Science.

Both the agricultural chemist and agricultural geologist schools of thinking about the concept of soil were present at the time the soil survey was beginning in this country. Disciplinary boundaries, however, were diffuse. It was relatively easy to work in several of today's narrowly defined specialties. The convergence of concepts by persons from both academic traditions provided the foundations of pedology. Vasili V. Dokuchaev, a Russian agricultural geologist, is largely credited with developing the factors of soil formation paradigm in the late 1800's. Eugene E. Hilgard, an American agricultural chemist, was working out pedological concepts simultaneously with Dokuchaev, but his work in that regard was not recognized in the U.S. or elsewhere until the 1920's and later.

Early Classification and Mapping Challenges and Controversy

Understanding of the factors of soil formation paradigm occurred more slowly in the U.S. than it did in Russia. Most American scientists (with the exception of Hilgard and, later, Coffey and Marbut) did not fully comprehend the "Dokuchaev school" of pedology until well into the 1910's. This fact had profound influence on early soil classification and mapping concepts and later led to controversy. I'll let Lapham tell the story:

> In the early work of the Soil Survey, classification and mapping were based mainly on differences in soil texture. Professor Whitney developed the [original] concept of the soil series [that] consisted of a group of closely related soils, similar in parent materials, and in most other respects, but differing essentially in physical texture. Under the classification at that time, [a series] might range [in texture] from sand to clay loam to clay. The usual units of mapping which make up the series are designated as soil types and are given a class name indicating the texture [of the whole soil]. For some years to come, the series that were recognized were not always well defined and were much too wide in concept. Some of these based mainly on similarities in texture and colors were carried boldly from one extremity of the country to parts having widely different conditions of climate and vegetation. Notwithstanding, the concept as developed by Prof. Whitney marked a definite step in soil classification in the U.S., although mapping under conditions then prevailing was admittedly incomplete, crude, and lacking in detail.

Whitney held the view that soil texture alone provided a direct index to moisture and temperature conditions important for plant growth. He concluded, on the basis of his observations of tobacco quality and yield on soils of

various textures in Eastern States, as well as his research on crop yields in part of Maryland, that all soils where high enough in nutrients for satisfactory plant growth. Whitney's views on the overriding importance of texture were built into the early soil mapping and classification methodology.

Whitney's view was strongly contested by at least two prominent scientists at universities in the U.S., Hilgard at UC Berkeley, who, as was already mentioned, had done pioneering pedological work, and Cyril G. Hopkins at the University of Illinois. Lapham wrote about what he called a "regrettable controversy" as follows:

> Controversy growing out of differences of opinion for a time endangered cooperative relations with some of the states and the usefulness of the soil survey. This resulted from the publication by Whitney and Cameron in 1903, in which the results of studies of water-soluble constituents of soils were interpreted as contradictory to the established principles of ag chemistry and the role of commercial fertilizers in crop production. The report at once aroused a storm of indignation and protest from the school of agricultural chemists, led by Dr. E.W. Hilgard of California and Dr. C.G. Hopkins of Illinois. The controversy was long and bitter, especially between Dr. Hopkins and the Bureau. It resulted in discontinuing of cooperative soil surveys begun in Illinois in 1902, and for many years prevented resumption of friendly relations with the State of Illinois, which instituted a State soil survey independent of the Bureau and based on a different system of classification and mapping. Not until years later was the breach in cooperative relations healed. Criticism by Dr. Hilgard was [also] outspoken, but less harmful [survey relations didn't break down in California].

Relations were apparently quite unfriendly between Whitney and Hilgard. Hans Jenny believed that Whitney actually withheld Hilgard's publications—including his soil profile concept published in 1906—from USDA soil survey field parties (Tandarich and Sprecher, 1994). It is reported that, as a result, Hilgard was largely unknown to the scientific community outside California until the 1920's.

Here is what Lapham had to say about Hilgard:

> I first met Dr. Hilgard in 1903 or 1904. I had visited a friend who was a journalist in the city of Oakland. He asked me to tell him something of the soil survey and what we were doing in California. From the brief information given, he contributed a rather lengthy and highly flattering article to one of the San Francisco newspapers. In the article, without my knowledge, and ignorant of the delicate situation between Dr. Hilgard and the Bureau, he said: "The Bureau of Soils is in very close affiliation with the Agricultural College of the University of California." A more provocative and touchy statement could hardly have been made. Immediately this was followed by an article given to the press by Dr. Hilgard in which he voiced his criticism of Bulletin 22, and cited the support given him by Dr. Hopkins. Dr. Hilgard also contributed further to the press implying that the article written by my friend had evidently been inspired by one of Whitney's subordinates. If guilty of having inspired the article in question, I certainly had not seen it previous to publication. I shortly afterward called upon Dr. Hilgard. Although firm in his opposition to the theories and pronouncements of Professor Whitney, I found him a sympathetic, courteous, and kindly gentleman. Dr. Hilgard was a broad-gauge product of the old school of agricultural chemists and was an accomplished linguist, botanist, and geologist as well as chemist. In after years I always took pleasure in seeing him when in Berkeley. I highly esteemed his friendship.

According to Cline (1979), Whitney's ideas carried through to the soil classification system published by Dr. Curtis Marbut and others in 1913. Marbut, who came to be a dominant figure in soil survey throughout the period from 1915 to 1935, had only recently joined the Bureau of Soils. He was apparently willing to accept Whitney's ideas at that time. Cline (1979), Simonson (1952, 1968), and others report, however, that the concepts of Dokuchaev and Hilgard were starting to be known by at least one experienced soil surveyor at the time, G.N. Coffey, who wrote about the broader perspective in 1912. It was Marbut, though, who ultimately led the next major advances in soil classification and mapping concepts. He widely introduced the soil-forming factors and soil profile concepts to American scientists when he translated the work of Glinka from Russian to English in 1917 and published it in 1927. With that came a new era in the development of soil classification and mapping in the United States.

Early Field Methods

Lapham's first season of fieldwork began in the spring of 1900, in the Sevier Valley of southern Utah. After a cross-country train ride to Richfield, Utah, he met up with Frank D. Gardner (who had mapped in the Utah Valley the

first season of 1899) and was "ushered into the technique of soil survey." About his first field day, he wrote:

> After a hearty breakfast, attired in old clothes, stout shoes, and canvas leggings, I was ready for the field. With two frisky western horses and a light ambulance-like canvas covered wagon, we stopped in a vividly green alfalfa field on a red alluvial soil. Here I was shown how to handle a six-foot auger and to note the character of the fine sandy loam soil, the boundaries of which were sketched on the pages of a notebook.

Lapham summarizes the field methods used in 1900 as follows:

> The usual western field equipment consisted mainly of a cumbersome electrolytic bridge and field kit for determining the character and amount of soluble salts, popularly but inaccurately known as "alkali." Included were a six-foot soil auger with extensions; a compass; protractor and scale; a shovel or spade; and a copy of the usually inadequate county or other available base map. Technique of determining and mapping soil boundaries was acquired by experience. At that time there were no soil surveyors with previous training and no place in this country or elsewhere at which training in soil classification and mapping might be learned. Soil boundaries, determined by noting differences in texture, color, structure, and in mineral character—by means of frequent borings—were, in the absence of a suitable base map, sketched into the pages of a blank township plat book ruled off into sections. These were also usually without provision for correcting errors in the original U.S. Land Office Surveys. Bearings were determined by compass, and courses were plotted by protractor and scale. Topographic quadrangles of the U.S. Geological Survey, where available, were made use of as base maps; but these were frequently on small scale or of earlier publication, and required a great deal of revision in bringing roads and other cultural features up to date.
>
> Transportation in the field was usually afforded by hired horse and buggy; at times this was supplemented by a saddle horse. Distances were measured by an odometer attached by a metal clip to the front axle of the buggy. This consisted of a dial traversed by yellow, red, and blue hands actuated by a spur or sprocket wheel turned by a metal pin driven into the wooden hub of the vehicle. This projecting pin engaged the spur wheel with each revolution of the buggy wheel. The dial was calibrated in units of number of revolutions of the wheel. With a standard-size wheel of 42 inches diameter, 100 revolutions were equivalent to a mile; the number of revolutions in multiples of 100 up to 40,000 were recorded. Careful determination of the wheel diameter was necessary. It was usually necessary to dismount from the vehicle and read the instrument from the ground for accuracy, though much of the time this could be checked from the seat for approximate distance traveled. A bell mounted on the back of the instrument was struck by a small hammer on completion of each 100 revolutions of the wheel. It often became necessary, even in those horse and buggy days to "get out and get under" (to fix the equipment). In extremity we could resort to the simple expedient of tying a bit of cloth to one of the buggy spokes and recording the revolutions with a tally register.
>
> Field parties were expected to obtain accommodations with farmers or in local towns and villages near enough the scene of operations to avoid undue expense and interruption in fieldwork necessitated by long drives. In the thickly settled Mormon communities of Utah this was usually not difficult; but the problem presented grave difficulties in other areas.

Lapham talks about using a plane table and alidade while mapping in the Salinas Valley during 1901:

> At the time of this early soil survey, some simple equipment had been acquired by the Bureau with which we undertook our first experience in plane-table surveying in the construction of a base map upon which soils were delineated. This consisted of a tripod upon which was mounted a detachable board, in one side of which was fixed a small brass box containing a compass needle. With a piece of heavy drawing paper attached to the board, and when set up in the field and oriented with the compass needle, sights were taken by means of a simple alidade; this permitted the sketching of roads . . . windmills, courses of streams, [etc.]. At the end of the day these were inked in, and soil types indicated by colored pencils. With latitude in recognition and mapping of soil types at the time, a half dozen colored pencils in the vest pocket might take the

> place of a hundred or more mapping units in the complicated soil map legend of today.
>
> These early plane-table surveys were crude; but with experience in technique, they have served well for many years, and are still serving a useful purpose in the absence of suitable topographic or aerial base maps.

Lapham also chronicles the first attempt to use an automobile in mapping:

> [Sacramento Valley, California, 1904] . . . the auto was making its bid as a practical means of transport. I foolishly became infected with ambition to substitute one for the old slow moving horse drawn vehicle [and] engaged in an abortive attempt to introduce auto to soil survey. . . . This consisted of a narrow-gauge vehicle powered by a single cylinder air-cooled motor mounted on rear. Chain and sprocket connected it to the rear axle. When started with crank . . . usually at expense of blisters, it made a terrible clatter, and would maintain speed of 15-20 mph on smooth oiled road [of which there were few]. It was without speedometer, but with ingenuity . . . I installed odometer . . . and finally succeeded in mapping a few miles of highway with its bordering soils. I believe this to be the first instance in which any form of auto transportation was used in the soil survey. Invention is, however, at times the mother of necessity and we soon returned to the slower and more dependable horse and buggy.

Lapham reports that in 1903 there were few college graduates with proper training in soil survey:

> [Agricultural college graduates had] only superficial training in soil science and none in soil classification and techniques in soil mapping. At no place in this country, or elsewhere, was this training being given. Those already in service [learned through on-the-job training]. Realizing the deficiencies in training and the importance of building well upon his skeleton personnel, Professor Whitney, in 1903, arranged with Cornell University for detailing Dr. Bonsteel [a member of the original mapping party from 1899] to that institution as Professor of Soil Investigations. He stayed for two years, and developed a course in soil science and soil surveying which was later amplified and carried-forth through the classrooms of C.F. Shaw and others who were students of Bonsteel at Cornell.

Selected Comments From Lapham About Key People

George Coffey:

> By the close of the year 1900, the Soil Survey personnel had been increased to ten, among who was George N. Coffey, now an attorney in Ohio. Coffey later participated in soil surveys in many states, and soon became active in development of the principles of soil classification as viewed at the time. He was responsible for much of the early correlation of soils mapped, and was for a time in charge of the Soil Survey. In other activities he helped organize the American Society of Agronomy and was its second president. George Washington University granted him a Ph.D. for original studies in soil classification, and his thesis was published later [in 1912] as Bureau of Soils Bulletin 85.

Curtis Marbut:

> The spring of 1910 is significant in the history of our organization: it was the year that Prof. C.F. Marbut was appointed as Scientist in the Soil Survey. He had for several years held the chair of Professor of Geology and Physiography at the University of Missouri. During the previous two years, through a cooperative agreement with Professor Whitney, he had made a reconnaissance survey of the Ozark Region in Arkansas and Missouri. He came to us as a geologist with an interest in soils, and was strongly interested in the close relationship between geology and soils. Having a strongly critical attitude of mind, he was outspoken in the criticism of some aspects of the work and met with some coolness on the part of the personnel. All who knew him later came to appreciate his honesty and sterling character and to value his criticism even though it hurt. As the years went by he became less of a geologist and more of a soil scientist. He proved himself to be a man who was not afraid to change his mind, even to acknowledging error if convinced he had been in the wrong. As he came under influence of the Russian school of soil science, in which climate and vegetation are stressed in soil development, he completely reversed his attitude as to the dominating influence of parent geologic materials on the character of soils. Shortly after he came into the bureau he remarked that inspectors were poorly qualified since they had little or no training in geology. I was somewhat

> nettled by this remark, and determined that, if necessary to hold my job, I would become a geologist. I purchased the three-volume edition of Chamberlain and Salisbury's Geology, which I assiduously studied. Before I had completed the task, he had so completely reversed his attitude toward the relationship of geology and soils that I never dared to tell him of my efforts to improve my qualifications for inspector by studying geology.

Hugh H. Bennett:

> As one of the early soil survey men, Hugh H. Bennett [Inspector, Southern Division, Bureau of Soils during the same time that Lapham served in that role for the Western Division] had become impressed with the seriousness of the erosion problems while on duty in the southern states. . . . He had made what is probably the first attempt to actually measure the loss of soil material by surface erosion in Louisa County, Virginia. With the extension of soil surveys the ravages of soil erosion became more apparent. While not the first to place results of extensive observations on paper, Bennett felt that it was time that something be done and he began to plan for some definite action in control of this widespread threat to the stability and permanence of agriculture. The earliest of his papers, insofar as records at hand reveal, began to appear in about 1926-27 as articles in Nature Magazine, American Forests and Forest Life, and the Dallas Weekly News. His first efforts to attract favorable attention of his associates and superiors were met with considerable reserve; but he finally won recognition with allotment of funds for establishment of a series of erosion experiment stations. It was from these erosion experiment stations . . . that the Soil Erosion Service and later the Soil Conservation Service . . . developed.

Conclusion

The history of soil survey during its infancy is truly rich, and as we approach the centennial celebration of soil survey, it is good to reflect. I hope that this abbreviated look back has captured your interest and has provided knowledge that can be used as we carry the work forward. Certainly, the excerpts from Macy Lapham's *Crisscross Trails: Narrative of a Soil Surveyor* have enhanced the storytelling. It is only fitting that I close this retrospective with this end quote from Macy's book:

> When the old horse and buggy stepped out of the picture and was replaced by the automobile, and when Dr. Marbut brought to us the principles of modern soil science, a new era was ushered into the Soil Survey. Modern field equipment and modern methods of observation and record have relegated the soil surveys of yesterday to a background of historical interest and of outmoded pedological and agricultural significance. Nevertheless, to one who has served through a pioneering period of slower tempo, recollection of the old horse and buggy jogging along a dusty country road with plane-table by side of the driver and a feed of oats and hay in the rear, brings nostalgic memories of many peaceful, pleasant country scenes.

Acknowledgment

I want to thank Leonard Wohletz, retired State Soil Scientist for California, who loaned me his copy of the book *Crisscross Trails: Narrative of a Soil Surveyor*. The book is out of print and hard to obtain. Leonard was a friend and colleague of Macy Lapham, the author. Macy signed Leonard's copy of the book with the inscription "To Leonard, companion of many little journeys of the trail."

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National Cooperative Soil Survey Accomplishments

By Horace Smith, Director, Soil Survey Division, USDA, Natural Resources Conservation Service, Washington, D.C.

Introduction

I welcome the opportunity to be here today. I consider it a privilege to talk to you about the National Cooperative Soil Survey (NCSS). This is an especially auspicious time for such a presentation. We soon will mark the 100th anniversary of organized soil survey activities in the United States. Today, I would like to talk with you about the proud history of the NCSS, highlighting our successes and the milestones that still await us.

History is very important. A sense of history provides unity of purpose and serves as a guide for future actions. However, I will not dwell long on past accomplishments. Looking back can provide great satisfaction, but, as the kids say, "The future is where it's at!" Therefore, I plan to spend a good part of my allotted time summarizing where I think the NCSS should go and what strategies we should employ to get there.

Our story starts about 100 years ago. Near the turn of the century, a report entitled *Field Operations of the Bureau of Soils* was issued by the USDA (Whitney, 1899). This report described early efforts to classify and map the soils in four widely separated areas of the United States. These original test projects are of great historic interest. They mark the beginning of a very ambitious effort: to classify and map the soils of an entire country. This was a first in the history of the world.

These four early surveys have led us down a long, rocky, yet fascinating road. The soil survey program in America expanded rapidly during its first few years. In fact, 720,000 acres was mapped the first year. By 1910, detailed soil surveys had been completed on nearly 137 million acres. Reconnaissance soil surveys had been completed on another 135 million acres (Whitney, 1910).

Soil survey work came to a virtual halt during World War I. After the war, work resumed, but at a much reduced level. Gradual expansion continued into the early 1930's. A USDA news release in 1932 stated that, during the preceding fiscal year, a total of 60 soil surveyors had been working in the U.S., Puerto Rico, and the Virgin Islands (Gardner, 1958).

Great changes took place in the 1930's. A new federal agency, the Soil Erosion Service, was set up in the Department of the Interior. This agency later was transferred to the USDA and renamed the Soil Conservation Service (SCS).

The SCS needed soil survey information to help private landowners plan and implement erosion-control measures. As a result, SCS, in cooperation with States and universities, soon had a rapidly expanding soil survey program.

In 1951, SCS was given overall responsibility for all soil survey activities in the USDA. The national soil survey program grew rapidly during the 1950's. By the early 1960's, more than 1,000 SCS employees were working on the national soil survey. This number eventually increased to approximately 1,500 (Simonson, 1989).

It is important to note that federal soil survey efforts have always been and still are highly leveraged. Numerous cooperators—including States, counties, and land grant universities—have contributed large amounts of both human and fiscal resources to the national soil survey effort.

Current Status

This brings us to the present day. It is important to stop and consider where our long-term, cooperative efforts have brought us. Where do we stand right now? We began our national soil survey program many years ago with some very ambitious goals. Let me summarize these goals as I see them:

1. Investigate the biological, physical, and chemical nature of America's soils.
2. Determine the potential uses and limitations of the nation's soils.
3. Classify the soils of America and prepare detailed soil maps for the entire country.
4. Make soil maps and information readily available to the American public in a form they can use effectively to make sound land use decisions.

Let's talk briefly about how much progress we have made in meeting each of these broad goals.

Goal number 1: Investigate the biological, physical, and chemical nature of America's soils.

An example best illustrates how far we have come in meeting this goal. At the National Soil Survey Laboratory in Lincoln, Nebraska, we now have analytical soil data for over 23,000 locations sampled nationwide. This information is augmented by the large amount of soil data that has been gathered and catalogued by cooperating state universities over a period of many years.

Numbers of analyzed samples do not equate directly to knowledge; however, they are a good indicator of the zeal with which we have tried to meet this goal. Another good indicator is the long list of excellent scientific papers in the field of applied soil science. Most of the classic papers were written by the early pioneers of soil survey and the NCSS during the first three-quarters of this century. I am

happy to say that our friends and colleagues at cooperating universities wrote a large number of these papers dealing with important soil survey issues.

Collectively, after many years of effort, we have learned a great deal about the chemical, biological, and physical properties of our soils. However, we—and by WE, I mean the soil science community as a whole—still have a long way to go. So much is yet to be learned. Therefore, research related to soil survey, or Soil Survey Investigations, is and will remain an important part of the soil survey program for the foreseeable future. It is fundamental and provides the foundation for everything we do in soil survey.

Goal number 2: Determine the potential uses and limitations of the nation's soils.

If we, as a nation, are going to manage our soils wisely, it is critical that we understand the uses to which they are best suited. There have been some exciting achievements in this area. For example, we have now developed computerized criteria capable of rating any soil in the country and providing information on its inherent potential as well as its limitations for a wide range of uses.

However, the general area of Soil Interpretation needs constant research and development, as well as constant testing of existing methods and concepts. Let me give you an example. Recently a number of soil scientists across the country have been trying to think about soil in a new way. They have been working to understand (and hopefully) to actually measure a very elusive entity—Soil Quality (Karlen et al., 1997).

Some of the best thinkers in our discipline are struggling with the best ways to both conceptualize Soil Quality and to quantitatively assess it. We think these efforts could be very important. Properly understood and well articulated, Soil Quality could be a key, unifying concept to help guide our activities for a long time to come.

Goal number 3: Classify the soils of America and prepare detailed maps for the entire country.

Years of soil survey and associated research have taught us much about the soils of this continent and of the world. We realized some years ago that, just as in most other natural sciences, we needed a classification system to help organize and transfer the large amount of knowledge we have accumulated.

Accordingly, we began work in the early 1950's on a quantitative system that could be used to classify not only all of soils in the U.S., but also all of the soils in the world. A large number of scientists from around the globe participated in this long-term cooperative project. These efforts culminated in the publication of *Soil Taxonomy* in 1975 (Soil Survey Staff, 1975). This system has been widely tested throughout the world, and numerous modifications have been proposed. Next year, 1999, we will publish a new edition of *Soil Taxonomy*, incorporating all of the technical changes that have been made since 1975.

Mapping progress.—Now I would like to give a progress report on our most important activity—which is soil mapping. The following table provides a summary of our progress in mapping the nation's soils:

National soil survey mapping status, October 1997[1]

Category	Total acres (millions)	Acres mapped (millions)	Percent completed
Private	1,521.6	1,385.0	91
Indian	99.2	46.6	47
All Federal	649.2	299.3	46
Total	2,270.0	1,730.9	76

[1] Water acreage is excluded.

As you can see, we have mapped more than 90 percent of the private land in the U.S. We now have detailed maps on a little less than 1.4 billion acres of private land.

The numbers are not so favorable for Federal and Indian lands. The soils have been mapped on a little less than one-half of all Indian and Federal lands.

Including all land categories (private, Federal, and Indian), detailed soil maps have been completed for approximately 76 percent of America's land base. The map entitled "Status of Soil Surveys," which is on page 14, shows where the unmapped land remains—mostly in the western part of the United States. We are formulating plans to complete mapping of the remaining unmapped lands—both private and public—during the first few years of the next century.

Goal number 4: Make soil maps and information readily available to the American public in a form they can use effectively to make sound land use decisions.

Many people in my generation are amazed at how quickly computers have impacted everything we do—banking, communications, education, and, yes, even soil survey. Some years ago we concluded that we had to move as rapidly as possible to start producing soil surveys in a digital format. We formulated a long-term goal of making soil maps and interpretive information for the whole country available directly on computers. I would say we are making slow but steady progress.

Here are some of the things we are doing. We have instituted a program to acquire digital orthophotography for every soil survey area in the country. The map entitled "Digital Orthophoto Quadrangles," which is on page 15, summarizes the status of our program for acquiring national coverage of digital orthophotography. Our current plans are to have complete orthophotography on all private lands by the year 2000 and on all public lands by 2002.

Digital orthophotography is used to accurately compile soil maps on a rectified, stable base as a first step in digitizing them.

Our ultimate goal is to digitize the soil maps for every survey area in the country. The map entitled "Status of Soil Survey Digitizing (SSURGO)," on page 16, shows that we still have a long way to go in our national digitizing program. As of June 1, 1998, we have 223 surveys digitized and certified to Soil Survey Geographic Data (SSURGO) Standards. We are extremely pleased with our achievements in this area during the past year. If the current digitizing pace continues, we project that we will have more than 350 surveys SSURGO certified by the end of the year. Our plans are to continue accelerating digitizing with special funding. Complete digitizing of every survey area in the country will culminate with the completion of mapping.

This effort at nationwide digitizing of soils is both ambitious and exciting. Our ability to analyze resource data, conduct environmental assessments, and evaluate the performance of environmental programs will be enhanced by the availability of digital soils data. Even the wisest among us do not understand the full implications of this technology; however, the effects are going to be positive and far-reaching.

Conclusion

My objective today was to present a generalized status report on the National Cooperative Soil Survey. I hoped to give you some insight into our past, tell you a little about our present activities, and then describe what I think our future will be.

I am very fortunate to work in the NCSS at this point in its evolution. We are, I believe, in an enviable position. We have a rich history. Many well-met challenges and a record of real accomplishments are behind us.

As for now—we have a very busy, stimulating, and productive present. The demands for our services and products keep increasing. Our nation is becoming increasingly aware of the need for wise resource management and sound environmental stewardship. Such a nation needs and demands more and more detailed soils information. We in the NCSS, along with our partners and cooperators, are positioning ourselves to meet these needs for many years to come.

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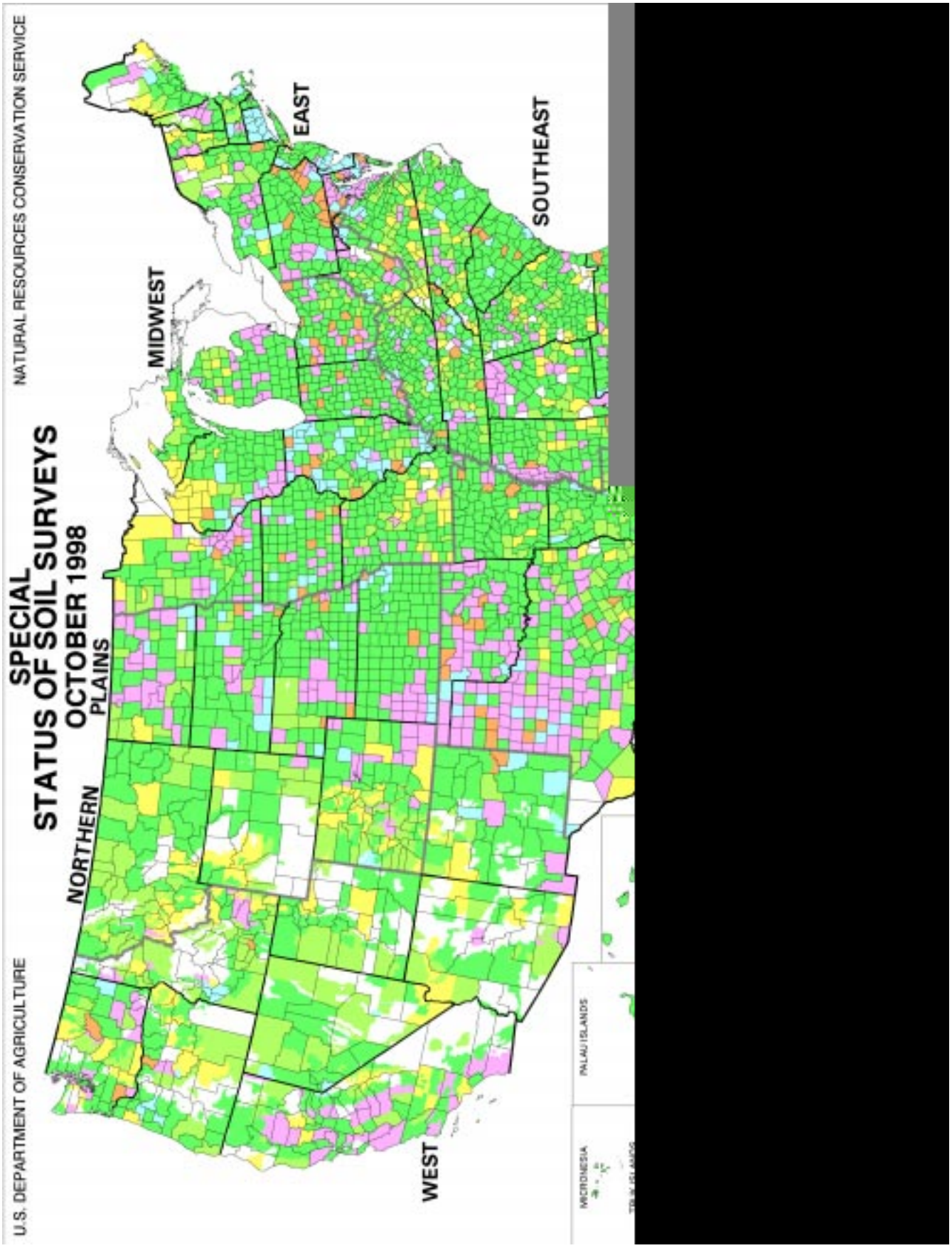
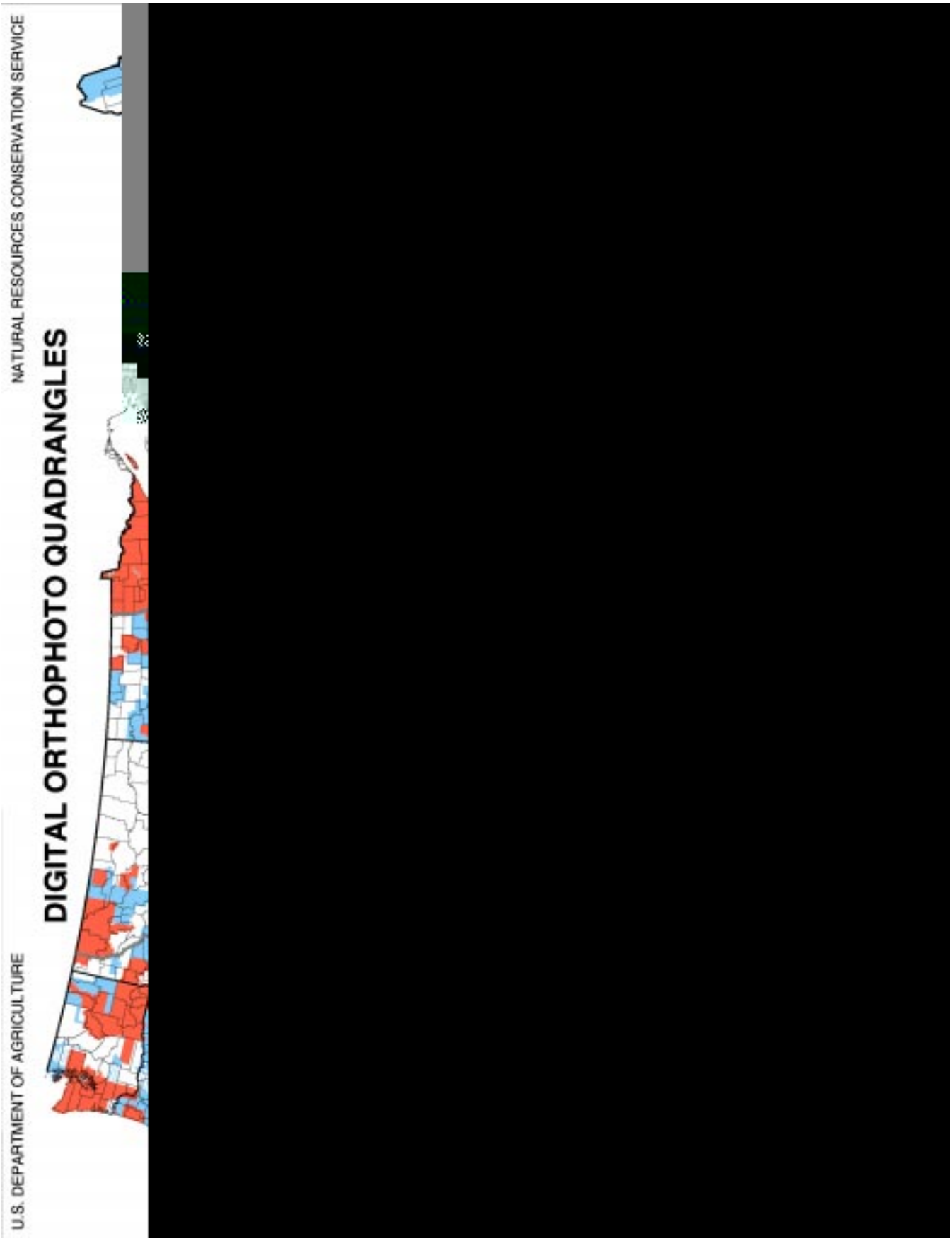

U.S. DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE
SPECIAL
STATUS OF SOIL SURVEYS
OCTOBER 1998
NORTHERN PLAINS
MIDWEST
EAST
SOUTHEAST
WEST
PALAU ISLANDS
MICRONESIA


U.S. DEPARTMENT OF AGRICULTURE
DIGITAL ORTHOPHOTO QUADRANGLES
NATURAL RESOURCES CONSERVATION SERVICE

Educating the Users and General Public on Application of Soil Survey Information

By R.B. Brown, Soil and Water Science Department, University of Florida.

Use of Soil Survey

Soil survey, with its roots in both the geologic and horticultural sciences, continues to give us a highly useful inventory of soil and land resources. Our older soil surveys constitute an invaluable historical record not only of soil survey as an organization and an endeavor, but also of changes in land and land use over the last century. Indeed, when dealing with soil survey users and the general public, one can and should make extensive use of whatever historical soil survey information/documentation and other information/imagery (e.g., air photos) are available. Users can be pulled into the subject with amazing ease by bringing to their attention the changes in land use over the years and the existence of soil survey and soil science in general as long-standing, established scientific disciplines with relevance to today's land users.

Modern soil surveys provide useful inventories of soil resources and, if presented with enthusiasm and imagination, provide the user with three-dimensional mental images of the near-surface environment, with attendant useful information on soil interpretations, ecosystems, and underlying geology. Moreover, the standardized format employed in most soil survey reports in the U.S. allows the informed user to move easily among different soil survey documents and find similarly presented information.

When we work with users, it is important that we impress upon them the fact that the landscape is a three-dimensional entity that, in spite of its enormous complexity, contains systematic, predictable changes in soils across the landscape. Three-dimensional block diagrams depict generalized soil patterns and associations quite well, as can quickly prepared, ad hoc, two-dimensional, vertical cross sections of particular landscapes that may be under discussion at any given time.

Accuracy and Precision in Soil Survey

It also is important for the user to understand the implications of map scale and the fact that soil surveys generally do not capture and display every intricacy of the landscape (Brown et al., 1990). For many uses and for many audiences, a scale of 1:24,000 to 12,000 (which constitutes the range of typical map scales in modern published reports and in digitized soil maps in the U.S.) is sufficient (Hudson, 1990; Hudson and Culver, 1994). There are growing numbers of instances, however, where these scales are insufficient for highly sophisticated analysis of the soil-landscape (Bouma, 1986; Foussereau et al., 1993; Finke et al., 1996; McSweeney and Norman, 1996; Brown, 1996; Sadler et al., 1998; Wagenet, 1996). The message that needs to be conveyed to users is that soil surveys in general are accurate but imprecise, both as to their cartography and as to the interpretations and statements that are made about soil map units (Brown, 1985, 1988a, 1988b; Brown and Huddleston, 1991; Byrd and Kleiss, 1998). This message, if conveyed properly, should not constitute a barrier to the users' understanding of the soil survey or to their appreciation of its value. Any map has elements of imprecision, and any map may be inadequate for some uses because of this imprecision. The challenge for soil scientists is to continue to work with users who need greater precision and to deliver that precision to the extent possible through site-specific mapping and other highly detailed investigations (e.g., Society of Soil Scientists of Northern New England, 1997).

Variability is not the only limitation of soil surveys. The effects of human activities, including tillage, organic matter depletion (or, conversely, addition of high tonnages of organic materials to the soil), contamination, and radical cutting and filling, can be subtle or extreme. Major contamination and physical alterations can lead to wholesale changes in the soil profile that we classify, map, and interpret (Bryant et al., 1997; Evans et al., 1999; Fanning and Fanning, 1989; Goddard et al., 1997; Hernandez and Galbraith, undated). Even seemingly minor human impacts, such as those caused by tillage and land-leveling, can change the soil from its original morphology and behavior and alter our ability to understand natural soil processes (Amundson, 1998).

Bouma (1986) pointed out that the level of sophistication of our analysis and understanding of soils in the landscape tends to vary inversely with the areal applicability of our findings and understanding. For example, the farmer or county agent has experiences that allow accurate generalizations about the soil-landscape that are applicable over wide areas. The simulation modeler, at the other extreme, is apt to have a very detailed and elaborate understanding of soil processes; lack of sufficiently detailed data about the soil over a wide area, however, makes these findings and understanding limited in their areal applicability to the (usually very) small study site where the requisite, detailed data were gathered.

The Soil-Landscape: What Do We Know?

Hillel (1990) provided a light but elegant treatment of the tortuous path we follow in building scientific understanding. We start out with a supposition that leads us to deduce something about the object of our interest. Only by going to that object (in the case of soil survey, the object is the soil itself, *in the landscape*) and gathering empirical information through direct observation of that object can we verify the supposition or discard it for a better one based on our observations. Having made observations at a point or points in the landscape, we then employ inductive reasoning to create a hypothesis about the larger population or universe of soils across the landscape. We then return to the landscape to make measurements and verify or reject our hypothesis. With this new and improved understanding, we again use inductive reasoning to make generalizations about the larger landscape based on the observations, measurements, and experiments we have done at points in that landscape. This process may lead to simulation models that truly represent the nature and behavior of the soils in the landscape, but this outcome can happen only if we continually take our models back to the soil-landscape for verification.

The process of alternating deduction/induction and ultimate verification leads to advancement of knowledge and of science. There is so much to know about the landscape in so many different contexts, however, that we can never know everything about the soil. Meanwhile, there is a high risk that some significant part of the science that we do will find itself getting farther and farther away from the original object of our interest. Models may end up being tested against data sets gathered for some other purpose or tested against progressively smaller elements of the landscape (thus reducing their areal applicability). Perhaps most worrisome, the modeling may become an end in itself, missing that vital ingredient, information gathered first-hand in the real world (Lovelock, 1987, pp. 136-138).

Hoosbeek and Bryant (1992) created a useful three-dimensional graphic that captures some of the disparities among different kinds of data gathered at different scales and with different degrees of complexity and quantitativeness. At any given scale (ranging from molecular to worldwide), data may be purely empirical and functional (least complex) or they may be mechanistic (most complex) or anything in between. Data also range from purely qualitative to highly quantitative. Any scientist would strive to gather and use data at the highest degree of complexity and in the most quantitative manner possible at the scale under consideration and with the tools available. Soil survey tends to be qualitative and can range widely from functional to deterministic, depending on the sophistication and excellence of mapping/interpretations. Molecular-level studies of soil processes, on the other hand, tend at their best to be highly mechanistic and quantitative.

Bouma (1997) took the array of scales of Hoosbeek and Bryant (1992) and showed how information gathered at different scales and with different degrees of sophistication can be put together by means of research chains, moving progressively from one scale to another and from one level of complexity/quantitativeness to another, leading toward an understanding that would have been unattainable if the information gathered at different scales had simply been force-fitted into a simulation model or paradigm.

We must not forget that most if not all science—and certainly all of soil science—is in the end empirical, inasmuch as every supposition, hypothesis, and simulation must be tested against the behavior of real soils in real landscapes in order to have any validity at all. Neither must we forget that soil processes vary widely not only in space but also in time—from microseconds to millennia. Again, we are a long way from knowing everything there is to know about the soil-landscape.

All of this imprecision in our understanding leads to uncertainty in the predictions we make about soil behavior, about the behavior of potential contaminants in the soil/geologic continuum, and about the vulnerability of soils, water bodies, and aquifers to contamination (National Research Council, 1993; Yates and Jury, 1995). It usually happens that sophisticated attempts to determine vulnerability to contamination fail to do the job. If stakeholders are appropriately involved, however, a beneficial result obtains all the same: Citizens become better informed about the science of their environment and its vulnerability and about the limitations of science in finding answers to urgent questions (National Research Council, 1993).

In the end, a relatively unsophisticated technique for dealing with contamination and potential contamination may very well be the only feasible approach. For example, in the San Joaquin Valley, when a pesticide or its degradation products are detected in a well water sample and the pesticide is judged to have contaminated the water source as a result of a *legal* agricultural use, the section of land in which the well is located is declared a Pesticide Management Zone (National Research Council, 1993). The eastern part of the San Joaquin Valley has more than 50 percent of the PMZ's in California. Coarse-textured soils with a low carbon content are ubiquitous in this area and are represented in more than 3,000 sections (National Research Council, 1993). Note that this technique for identifying vulnerable areas is relatively unsophisticated, nonquantitative, and highly empirical, with little if any use of modeling in the identification of vulnerable zones. Nevertheless, citizens can learn, albeit in a rough way,

where the most vulnerable areas are and can act accordingly.

Need for Collaboration with Other Disciplines

Soil science and geology tend to operate independently of each other. In many if not all efforts to understand the landscape, both are important and need to be integrated (National Research Council, 1993; Brown, 1996; Caudill, 1996; Miller, 1996). All the barriers that separate soil science from geology and from other relevant disciplines, such as geotechnical engineering and ecology—be they intellectual, institutional, or legal—are artificial and have nothing to do with science. It is long past time for the many disciplines striving to understand the landscape to engage not in competition, not in distrust, not in disdain or ignorance of one another's work, but rather in *collaboration*. We ought to be pooling our intellectual and financial resources to learn what we must about landscape resources.

Unfortunately, while fruitful collaborations have occurred and continue to occur here and there and while acknowledgments/affirmations of soil science by geologists do happen (Lindholm, 1994; Caudill, 1996), soil science is too often perceived as an agricultural enterprise and not as an earth science. Note the minimal mention—or lack of any mention at all—of soil survey, of the National Cooperative Soil Survey, or of soil science in articles and opinion pieces in the geologic literature having to do with national mapping efforts, funding for the geosciences, and related subjects (e.g., Applegate, 1997; Bohlen, 1998; May, 1998). We have much work to do in building our identity and in gaining the respect of our colleagues in the earth sciences.

One step we are taking is to rid ourselves of the idea that there is a lower boundary of the soil. There is a continuum from the domain of soil scientists into the realm of the geologists; our different experiences, skills, and views can and should come together to synergistic and positive effect as we strive to understand the surface/near-surface/subsurface environment as well as the ecosystems that are associated with that environment (Cremeens et al., 1994). One area of particular mutual interest and potential is in the continued development of noninvasive geophysical methods for exploration of the soil-geologic continuum (e.g., Doolittle and Collins, 1998; Doolittle et al., 1998).

The Scope of Soil Survey

Soil survey is steadily expanding its scope. Private firms are more and more visible in soil mapping and soil interpretations and site evaluations (Byrd and Kleiss, 1998). Land use agencies are calling for consistency and reliability in soils reports, and certifying bodies are slowly, haltingly recognizing soil scientists as professionals with unique training and skills (e.g., Society of Soil Scientists of Northern New England, 1997). Both public agencies and private firms are moving into new and more sophisticated interpretations of soils for a wide variety of uses not contemplated when soil survey began 100 years ago. Soil quality is being defined, and new methodologies are being developed for its assessment, with due attention to scale (Karlen et al., 1997). The reliability of soil survey and other data for modeling and risk assessment continues to be examined (Nettleton et al., 1996). Interpretations for soil gases and soil water quality are being called for (Evans et al., 1999). Nutrient retention capacities of soils and whether or not these capacities are captured taxonomically and cartographically in soil surveys are being explored (e.g., Harris et al., 1996).

As soil survey expands its boundaries, the responsibility of the soil scientist is expanding commensurately. Publicly and privately employed soil scientists have found that it is not enough any more simply to do science, learn the facts, and publish results in the scientific literature for other scientists. Similarly, it is no longer enough for the soil surveyor to do the mapping and publish the survey and move on. A second and equally important responsibility for the soil scientist is to impart facts and knowledge to the land user, so that land use decisions—small and large—will be made in an *informed environment* (Brown and Miller, 1989).

Field soil scientists operate in an exceedingly difficult environment, not only in the soil-landscape (which in many instances is highly complex and imponderable enough), but also in the societal/cultural/legal/political/ethical environment where soil survey information is used. Field soil scientists deal with private citizens, planners, attorneys, regulators, statisticians, modelers, engineers, and other scientists on complex issues. It is important for us to understand the decision-making process completely but at the same time to remain objective and not to let emotions overtake us. Soil survey has highest value when and where it constitutes a visible and objective body of knowledge relevant to the needs of land users (Brown and Miller, 1989).

What Soil Survey Must Be in Its Second Century

Wysocki (1998) has pointed out that soil and water conservationists must show leadership at all levels when decisions on resource management are made and must carefully think through decisions to balance the needs of people, land, water, and other resources. The same is true for soil scientists, including soil surveyors. Indeed, soil survey must be something far larger than a published

document, a layer in a geographic information system, or a data base of soil properties and interpretations. Soil survey must be *all* of the following (Brown, 1988a):

- Maps, legends, and interpretations;
- Experiences/insights of *mappers*;
- Experiences/insights of *users* (an invaluable source of information about the landscape and of feedback regarding the utility of soil survey information in understanding that landscape);
- Skills in the science and the craft of mapping and interpreting soils; *and*
- **A dynamic, expanding body of knowledge** concerning the occurrence and behavior of soils in the landscape.

The measure of quality in soil survey is the degree to which the client—i.e., the decision-maker) comes to understand the soil-landscape, with all its complexity and wonder. To expand upon Brown (1988a), we soil scientists will have an impact where we take the time and trouble to understand the questions being asked, where we convey knowledge clearly, where we are flexible, where we eagerly engage in interdisciplinary communication/collaboration, and where we put heavy emphasis on fostering the quality of our *science*—and the quality of our *scientists*—in both the public and private sectors.

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Women in Soil Science

By Maxine J. Levin, USDA, Natural Resources Conservation Service, East Region, Beltsville, Maryland.

The following presentation is a brief overview of the history of women's contributions to the field of soil science. Since almost nothing has been written on the topic, my comments are based on oral histories that were done in last few months and some preliminary research at the National Archives and National Agricultural Library in Washington, D.C. Most of the information is anecdotal and from the interviewee's own experiences. With a little historical framework, I have tried to tie some of this information together. I have not included the Russians in this study, though their contributions are extensive and significant to the general study of soil science. I want to thank John Tandarich (historian for the Soil Science Society of America [SSSA]), Douglas Helms (historian for the Natural Resources Conservation Service [NRCS]), Gordon Huntington (UC Davis), and Gary Sposito (UC Berkeley) for their assistance. They have been investigating the history of soil science for several years and provided me with very helpful comments. I also want to thank the 20 or so other men and women whom I interviewed informally over the phone for their thoughts and experiences.

The Pioneers (1895-1965)

For the most part, early soil survey activity by women in the United States was limited to clerical work, copy editing of manuscripts, and cartographic drafting of maps. Women were allowed to do lab work if they had a chemistry background (*4, 19*). The first reference to women in soil survey was "the honorable mention" of Miss Janette Steuart and Miss Sorena Haygood, who maintained laboratory and field records in Washington, D.C., for the Soils Division of USDA. According to Macy H. Lapham's account, Miss Steuart was hired on January 4, 1895, and was the first appointee to the Soils Division of what was then the U.S. Weather Bureau of USDA. Miss Steuart retired in 1923, and Miss Haywood retired sometime later (*1*).

In Macy H. Lapham's book *Crisscross Trails*, he briefly mentions the next female pioneer in soil survey, a Miss Julia R. Pearce. Mr. Lapham's all male field party in Hanford, CA (sometime between 1900 and 1906) received a notice from Washington that Miss Pearce had been appointed to their crew as an assistant in the soil survey. It seems that Secretary of Agriculture Wilson (President McKinley's Cabinet) had attended the annual commencement program at the University of California at Berkeley. During the Secretary's address he commented that, with only two students graduating in agriculture, it was a distressing situation for the country. He emphasized in his speech that the Department of Agriculture needed men and women trained for technical positions. After the speech, Miss Pearce (one of the two graduates) said that "she was ready and willing to come to the relief of the Department" and accept an appointment. So the Secretary sent her to the field party at Hanford, CA, which was the closest departmental office at hand. In Macy Lapham's book, it is not clear whether he actually sent the telegram but the "joke" in Washington, D.C., was that the day she arrived, Lapham sent a telegram that said, "Miss Pearce is here, what in hell shall I do with her?" He did put her to work copying maps. A short time later she was transferred to Washington to work in the physical laboratory (*2*). The 1929 and 1952 records of the USDA Bureau of Soils do not list her name as a past employee.

As is obvious by this account in Lapham's memoirs, fieldwork was out of the question for women before the 1940's. It was not true, however, that women were not in the field, just not officially. In a 1992 taped interview with Mary Baldwin, the wife of Mark Baldwin (a soil inspector for soil survey from 1912 to 1944), Mary described mapping with her husband in the Boundary Waters of Minnesota in the early 1920's. She and her husband mapped for the summer months, camping and using a small boat to go from island to island. Mary would drop her soil surveyor husband off on one side of the island. He would map on foot, and she would pick him up with the boat on the other side. While she waited for him, she might search for survey markers or make observations of the general area on her own. At one point during the interview, she said that, of course, she couldn't map because she did not have the background. There were times, however, when she wished that she could have tried mapping on her own. As it was, she accompanied her husband everywhere during his remote mapping experiences, transcribing or taking field notes for him and assisting with the sampling (*3*).

Officially, the first woman soil scientist in the field for the Soil Conservation Service (SCS) was Mary C. Baltz (Tyler). Mary graduated from Cornell University and joined the soil survey as a "junior soil surveyor" in 1946. World War II labor shortages provided an opening for her to work in a job that, up to that time, seemingly was reserved for men (*4*). Erwin Rice , a retired soil scientist in New York, started mapping under Mary Baltz's direction in 1951 in Madison and Oneida Counties, NY (*5*). He remembered Mary as a confident, petite woman who enjoyed mapping in the field. He called her a "splitter," a soil scientist who tends to separate out concepts for new soils as opposed to lumping them together under general categories of old soil names. She had a good sense of humor and felt comfortable with the all-male crews. At that time, Mary Baltz was responsible for all soil survey

activities in Madison and Oneida Counties. Later, she was assigned the task of doing map measurement for the whole State of New York. The work was done by cutting out the delineations on copies of the field sheets. All the areas with the same label were piled together and weighed. A factor converted the weight to acres. She hired a team of women to do the job in the winter months (*6*). Mary Baltz worked for SCS until about 1965. She married Duane Tyler (an employee from the Army Corps of Engineers) and quit SCS when Duane was transferred to Whitney Point, NY (*5*).

Women's contributions to soil survey in the 1930's, 1940's, and 1950's mainly involved editing, writing erosion history, and lab work. In 1937, for example, Miss Lois Olson and Dr. Arthur Hall spoke on studies in erosion history as part of a series of research seminars for the Soil Conservation Service. Some of the thoughts on interpretations of the soil survey and field practices to control erosion could be attributed to this series of lectures between 1936 and 1937. Miss Olson, a geographer by training, was the head of the Erosion History section of the Soil Conservation Service (*7*). Lillian H. Weiland (the first female employee of the Soil Erosion Service, 1933) was a secretary for Hugh Hammond Bennett (*4*) but also put together a bibliography on soil conservation complied in the office of the Chief of SCS (1935, revised by June Henderson in 1936), which consolidated ideas on erosion-control technology for the new agency (*8*). Charlotte Whitford (Coulton) graduated with an M.S. in botany from Ohio State University before taking a job as a secretary with the SCS field soils staff in Zanesville, OH, in the mid-1930's. She was recruited by an old classmate, J. Gordon Steele, to work as an assistant soil technologist in Washington, D.C., on a series of reports on soil erosion. She later worked as an editor on soil surveys and eventually became head of the publications staff of the SCS. She retired in the 1980's (*4*).

On the academic side, Ester Parsons Perry was the first woman to receive a Ph.D. in soil science in the United States. She received her Ph.D. from the University of California, Berkeley, in 1939. Her thesis was entitled "Profile studies of the more extensive primary soils derived from granitic rocks in California" (*9*). After reading her thesis, Gary Sposito, professor at the University of California, Berkeley, said that she was one of the first students to use x-ray defraction to look at the clay mineralogy structure in soils. Charles Shaw was her major professor. Kelly, Doer, and Brown were mentors and co-workers with her in Riverside, CA, where she worked at the Subtropical Horticulture Research Center. During her graduate studies, she worked in Riverside as well as Berkeley (*12*). According to *American Men of Science* (1944), she worked as a tree surgeon in Riverside and then from 1928 to 1939 as an associate soil technologist for the California Agricultural Experiment Station (*9, 10*). From 1939 to when she retired, she worked in and essentially ran

Forsyth, and Elizabeth Klepper. There may be more names. Unfortunately for my search, scientific research usually lists scientists' names by their first initial and there are no computer sorts by gender. These are the names that I found by word-of-mouth from their students and colleagues. For those who are not familiar with these women and their specialties, I have written a short synopsis below.

Dr. Jane L. Forsyth is a professor of Geology at Bowling Green State University in Ohio. She earned a Ph.D. from Ohio State University in 1956. She has taught at the University of Cincinnati, Miami University, the University of California at Berkeley, and Ohio State University and has been a professor at Bowling Green since 1965 (*13, 15, 16*). Her research has centered on the age relationship of soils and till to northern Ohio glacial geology. She has also done ecological studies relating plant distribution to geological substrates. One of her colleagues, Pete Birkland, University of Colorado, Boulder, says that her peers have affectionately dubbed her "Queen of the Pleistocene" (*13*).

Dr. Jaya Iyer is a professor in soil science at the University of Wisconsin, Madison. She originally came to the United States with a Ph.D. in botany from the University of Bombay in India. She had an external referee for her Ph.D., Dr. Segvis Wild, a soil scientist at the University of Wisconsin (Wisconsin Forestry Hall of Fame) who encouraged her to study soils. She eventually also got a Ph.D. in Soils, University of Wisconsin, Madison, in 1969 and began an extremely successful career as the national expert in soils for tree nurseries (urban, Christmas tree, and forestry production) (*17*).

Nellie Stark earned a Ph.D. in botany (ecology) from Duke University in 1962, with a minor in Soils from credits she collected at Oregon State University in 1961. For several years she did ecological research with the Desert Research Institute, looking at soils and nutrient cycling of litter in the tropical ecosystems of Brazil and Peru. She formulated a theory called the "biological life of a soil," which described how soils and plants interact during both developmental and decline phases of soil development. Indirect nutrient cycling which involves uptake of ions from the soil predominates when a soil is young, while direct cycling (litter to roots, bypassing the soil) occurs as the soil becomes older and depleted by weathering. From 1970 to 1992, she was a tenured professor as a Forest Soil Ecologist at University of Montana at Missoula. She sponsored a soil chemistry lab for forestry, which received and processed samples from all over the world (*18*).

Elizabeth L. Klepper is a recipient of the prestigious Fellow awards from all three agronomic research societies: ASA, CSA, and SSSA. In 1985, she became the first woman ever to receive that honor from SSSA. She is a research leader and plant physiologist at the Columbia Plateau Conservation Research Center, Pendleton, OR. Dr. Klepper hold degrees from Vanderbilt University and Duke University. Her research has concentrated on root growth and functioning under field conditions and plant and soil water relations (*19*).

I have very little information on Cornelia Cameron. She was a geologist for USGS in Reston, VA. Her specialty was peat soils. She is somewhere in her eighties now. According to Jennifer Harden, USGS, Menlo Park, CA, Cornelia Cameron was a prolific publisher and quite a character in the field (*22*).

In the case of each of these women, their specialty was not originally soils. Intellectual curiosity combined with their original interests, however, led them in that direction. As scientists and teachers, they have spent a good deal of their careers mentoring others (both men and women) and value that aspect of their careers greatly.

My own education in soil science began in 1970. These women were peers to my professors in college. In my own experience I heard stories about Ester Perry at Berkeley which encouraged me on some level to continue my studies despite setbacks. It was sort of "mentoring by mythology." The Soils 105 field trip that UC Berkeley and Davis puts on each summer was the single event in my college career that convinced me that soil survey could be a lifelong interest and career path. The course has been going on since the 1930's, but no women attended the field course until 1955. In that a year, an Israeli woman named Eva Esterman demanded that she be allowed to take the course. The university arranged for her to take a parallel class by herself with a separate schedule and arrangements for sleeping and comfort stops. Dr. Frank Haridine, the dean at the time, considered the experiment a complete disaster and swore publicly that no women would ever again go on the field trip. This statement triggered Ester Perry to step in and offer a Soils 105F (for female), which she planned and taught for 3 years (1956-59). The trip was soil survey oriented but with a different approach than the regular trip because Ester had different contacts than those of the regular professors. Three women attended in 1959. One of the women, Janet Heater of San Francisco, CA, was from the basement soils lab in Hilgard. There were no women who wanted to take the course from 1960 to 1964. In 1965, the Soils 105 course officially became co-ed and Ester accompanied the two women attendees one more time as a chaperone with a larger group (*14*). By the time I took the course in 1972, the class was 50 percent women and no doubt the young men and professors needed more protection than we did.

In the Classroom, in the Field, and in the Lab (1970-1990's)

In 1962, Charles Kellogg, Assistant Administrator for Soil Survey, United States Department of Agriculture, Washington, D.C., gave a talk before the Agronomic Education Division, American Society of Agronomy, Ithaca, NY. Over 30 times the male gender was referred to directly as part of this recruitment paper. Examples of the language used are as follows:

> The Soil Conservation Service annually recruits a considerable number of men who have completed the work for a BS degree in soil science or in agronomy.
>
> Our service offers a scientific career with opportunities for research to men in the field of soil science.
>
> Our staff includes some of the outstanding men in the field of soil science.
>
> We are becoming increasingly concerned about recruitment, especially of well-trained, broadly educated young men who can develop rapidly (*21*).

Reading that recruitment paper convinced me that attitudes have changed as we move into the 21st century. By 1975, when I and many other young women were attempting to start careers in nontraditional fields, attitudes had changed some but not completely. While the 1960's career counseling documents focused on helping girls plan for work and marriage, the documents in the 1970's began to discuss ways to channel girls into nontraditional careers. Encouraging young women to enter nontraditional occupations carried through as a theme into the 1980's (*24*).

In spite of some encouragement, I do still remember specifically in my soil science classes a pervasive male orientation to the instruction, particularly in the form of humor. Chris Evans, presently Soils professor at the University of New Hampshire, reminded me of a film called "Movement of Soil Water," produced by Washington State University in the 1950's but used up to the 1980's in university soil science classes. It used a cutout of a woman in a bathing suit to depict movement of water in a soil system. I also remember the classroom example of a soil profile, "Polly-Pedon," which was a picture outline of a woman with a "Barbie Doll" figure used to depict the clay bulge development one sees in lower soil horizons (*25*). The image so impressed me that in the 1980's in the field, some friends and I thought up a possible T-shirt for women soil scientists that said, "What a B2t!" (The B2t is the old field designation in soil survey for an increase in clay and soil development below the surface layer of a soil profile.) The difference in humor was that "B2t" sounds a lot like the word "beauty," so I would like to think that the humor was more empathetic to women. My personal opinion from observation is that overall changes in attitudes have slowly changed what is appropriate material for a classroom presentation. What was okay in 1970 would never fly now. The atmosphere in the classroom hopefully is more conducive to women in general in the earth sciences.

In federal employment, legal changes slowly opened doors for more career opportunities for women (if only a crack to get a toe in for the persistent). Title VII of the Civil Rights Act of 1964 prohibited sex discrimination in federal employment. The Civil Service Reform Act of 1978 required that the federal work force reflect the nation's diversity (*4*). There was also a Women in Science and Technology Equal Opportunity Act in 1980 that I thought opened up more opportunities for women to receive support in the university setting.

According to SCS records in the 1970's (*23*), there were fewer than 15 women hired at any one time nationally in the Soil Scientist 470 series despite an acceleration in soil survey mapping and a general increase in field crews. Most of the women I talked to who started at that time thought that they were the only women in the agency who were soil scientists. Those of us in the field were not allowed to talk with employees outside our geographic area (county based in SCS, USDA). There were no professional organizations for field soil scientists outside some informal state organizations. The Association of Women Soil Scientists (AWSS) was not started until the early 1980's, by a group of women soil scientists in the U.S. Forest Service (Barbara Lueulling, USFS, MN, president) (*23*).

In the 1970's and in the early 1980's, SCS, USDA, California, had five women field soil scientists: Arlene Tugel, Nancy Severy, Chris Bartlett, Lisa Holkolt, and myself. We were a crowd compared to other states. Carole Jett was the only woman soil scientist in SCS in Nevada, and Carol Wettstein was the only one in Florida. Margie Faber and Marilyn Stephenson were in New York. Gay Lynn Kinter worked in Michigan as a state employee. Margaret Rice was in Mississippi. Sue Southard was in Utah (another temporary state employee). Mary Collins was in Iowa before she went on to graduate school. Janet Cormier and Sandra Nelson were in Maine. Debby Brasfield was in Tennessee. Other field soil scientists were Gretta Boley (New Mexico), Barb Cencich (Colorado), Diane Hoppe (Virginia), Deborah Prevost (Arizona), and Kathy Newkirk (Virginia) (*23*). There may have been more women, but records of employees at that time are spotty and appear to have not been saved comprehensively in SCS-USDA archives.

Not all these women worked continuously throughout

their careers as field soil scientists, nor did they work in the same years. Some converted to soil conservationists so as not to move. Some changed careers to follow their families. Some went into private consulting or other agencies. Some went back to school for higher degrees. In all, their contribution to soil survey was sizable with millions of acres mapped and plenty of blood, dust, sweat, and private tears. We all worked alone with no field partners. Carol Wettstein remembers the snakes and alligators in the Florida swamps. I imagine Janet Cormier experienced black flies for the 8 years she spent in the Great North Woods of Maine. For myself, hostile landowners and runaway logging trucks in northern California were my biggest fear. None of us had radios for safety in isolated areas until the late 1980's. At the same time, despite rough conditions, we took the science seriously. Soil science is first and foremost a field-based science, and mapping took us to where the base knowledge was collected. That base knowledge of observation was what later validated and complemented the lab soil scientist's work.

As a tribute to her hard work, Carol Wettstein was the first woman state soil scientist (SCS Maryland 1988-89) and later was state soil scientist in Colorado (1990-95). Carole Jett was state soil scientist in California in 1991, and Carol Franks was a state soil scientist in Arizona in 1994. Of published soil surveys where women were the party leaders (or the principal field investigators), I am only sure of three: Sacramento, CA (Arlene Tugel); Baltimore City, MD (Maxine Levin); and Indian River County, FL (Carol Wettstein). All three surveys were completed in the 1980's. Because there were significantly more women who were made project leaders of soil surveys in the late 1980's and 1990's, several more soil surveys with women as lead scientists should published in the next few years. Constrictions with time-in-grade factors and mobility issues limited the number of women in SCS-USDA who received credit for their service through published soil surveys.

There are other aspects of the National Cooperative Soil Survey which do not leave a paper trail of published soil survey citations or publications. Soil correlators and data management specialists in the NRCS state offices, such as Sue Southard (CA), Renee Gross (NE), Carmen Santiago (PR), Panola Rivers (PA), Kathy Swain (NH), and Deborah Anderson (NC), make significant contributions to soil survey data and manuscripts but are never cited in the soil survey itself. Also, in last few years there are women soil scientists who have led the effort to digitize soils information but are not cited in the published material—Vivian Owen (TX), Jennifer Brookover (TX), Darlene Monds (MA), Caroline Alves (VT), Lindsay Hodges (ME), Caryl Radatz (MD), and Jackie Pashnik (RI). In the National Cooperative Soil Survey, there are also field soil scientists who work mostly with soil survey interpretations and education. Like agricultural extension specialists, these soil scientists act as a bridge between university research, soil survey mapping, and the public, interpreting soil surveys for practical use by agencies and individuals. Onsite field investigations are also involved. Examples of women soil scientists who specialized in interpretations, as well as soil survey mapping, are Sue Southard (CA), volcanic soils and Vertisols; Lenore M. Vasilas (MD), hydric soils; Jeannine Freyman (VA); and Deborah Prevost (NM).

Women in the SCS-USDA, now the Natural Resources Conservation Service (NRCS), have perhaps made more traceable and visible contributions to soil science in the National Soil Survey Laboratory (NSSL) and the National Soil Survey Center (NSSC) or as researchers in the Soil Quality and Watershed Sciences Institutes. Carolyn G. Olson, as a research scientist at the National Soil Survey Center, Lincoln, NE, received honors as a 1996 Fellow with SSSA (*19*). She graduated with a Ph.D. from Indiana University in geology under Robert Ruhe. After a 10-year stint with USGS in Menlo Park, CA, and Reston, VA, she transferred to the SCS-USDA, National Soil Survey Center, and has worked in Lincoln since 1989 (*27*). Her research focuses on soil-geomorphology, Quaternary geology, and clay mineralogy (*19*). Other female soil scientists at the NSSL or NSSC are Rebecca Burt (working with physical soil properties), Joyce Scheyer (urban soil properties), Susan Samson-Liebig (soil chemistry), Lea Ann Pytlik (technical soil services, retired 1998), Sharon Waltman (national soil survey data bases and GIS interpretations), and Carol Franks (soil biology). In the institutes, Arlene Tugel (NM), Betty McQuaid (NC), and Cathy Seybold (OR) have been working with soil quality and watershed health indicators (*26*).

Other federal agencies, such as the United States Geological Survey (USGS), have also provided avenues for women in soil science research. Jennifer W. Harden, USGS, Menlo Park, CA, received her Ph.D. in Soils at the University of California, Berkeley, in 1982. She was the last Ph.D. graduate student to work directly under Hans Jenny and Rodney Arkley. Her thesis work used a soil chronosequence in the Central Valley of California as a hazard assessment to date geologic faulting. She developed the Harden Index from that data, which used soil horizons and carbon dating to measure time in the alluvium sequencing. Since then, she has also worked on the effect of climate on soil, particularly as it relates to ground-water recharge and wetland assessment. Since the mid-1980's, she has been a frontrunner in research on global change issues of soil carbon, CO_2 emissions, and soil carbon sequestration (*22*). Marith Reheis, USGS, Denver, CO, has done significant research using soil properties as a paleoclimatic record for chronosequence mapping in Rocky Mountain glacial outwash. Originally a geologist by

training, she received her Ph.D. in soil science under Pete Birkland, University of Colorado, Boulder, in 1984 (*29*). At NASA's Goddard Space Flight Center, Elissa Levine has been working with soils in forested ecosystems since 1987. She has been modeling soil physics and soil chemistry to access watershed leaching, soil carbon ecosystem effects, and the effects of acid precipitation on soils and ground water. She was recently appointed Lead Scientist for the NASA Global Change Master Directory and was selected as a Fellow of the Brandwein Institute for Science Education (*31*).

Since the 1970's, the U.S. Forest Service (USFS) has had scattered women around the country involved in National Cooperative Soil Survey ecological unit inventories as well as technical soil interpretations in the specialties of forest soil productivity, soil erodibility, fire ecology, and forest ecosystem health. Since each national forest has its own infrastructure of field staff, it is harder to summarize the contribution of USFS women to soil science through my personal contacts. USFS women with longtime activity in soil science that I am aware of are Gretta Boley (Washington, D.C.), Clare Johnson (Six Rivers NF, CA), Carol Smith (SCS-USDA and Tahoe NF, CA), Barbara Leuelling (Superior NF, MN), Connie Carpenter (White Mtn. NF), and Mary Beth Adams (NE Forest Experiment Station, WV) (*23*).

In U.S. universities, there are at this time three female pedology (soil genesis) professors: Janice L. Boettinger, Utah State University, Logan, UT; Mary Collins, University of Florida, Gainesville, FL; and Chris Evans, University of New Hampshire, Durham, NH. Both Janice Boettinger and Chris Evans are associate professors in their respective departments. Chris Evans is focusing her research in the field of describing anthropogenic (human-influenced) soils and developing terminology to describe soil properties derived from human activity (*25*). Janice Boettinger has been working on an extensive review of worldwide zeolite mineral occurrences in soils and the use of zeolite and clinoptilolite for waste-disposal systems of animal production operations. She is also characterizing selected soil resources of Utah in studies that include research on saline, wet soils and irrigation-induced hydric soil characteristics (*30*). Mary Collins was made a Fellow of ASA in 1996 and a Fellow of SSSA in 1997. Her research at the University of Florida focuses on the genesis, morphology, and classification of soils; identifying and delineating hydric soils; using ground-penetrating radar to study subsurface properties; and pedoarcheology (*19*). She is best known for her dedication to the field and for reaching out to other countries to spread soils technology. As part of the People to People Program, she first opened the door to doing ground-penetrating radar soil investigations in China and Portugal (*27*).

Other female SSSA Fellows who have provided outstanding contributions to soil science are Mary Beth Kirkham (1987), Mary K. Firestone (1995), and Jean L. Steiner (1996). Mary Beth Kirkham is a professor at Kansas State University, Evapotranspiration Lab, and has worked on heavy metal uptake by plants and soil-plant-water relations for over 20 years. Mary K. Firestone is a professor of soil microbiology at the University of California at Berkeley. Besides being a SSSA Fellow, she also has received the Emil Truog Soil Science Award. Her research focuses on the microbial population basis of carbon and nitrogen processing in ecosystems. Jean L. Steiner is Director of the USDA-ARS Southern Piedmont Conservation Research Laboratory in Watkinsville, GA. Her research is in humid region water balance studies in complex topographies. Diane E. Stott, a 1997 ASA Fellow, is a soil microbiologist with the USDA-ARS in West Lafayette, IN. She has researched the effects of organic-matter dynamics on soil structure and erodibility and has worked on modeling the effects of plant residue decay on erodibility (*19*).

The women described above are only a sampling of the women who contributed research, mapping, applications, and education to the field of soil science in the last 25 years. Examples of other contributing scientists (to name a few) are Nancy Cavallaro, University of Puerto Rico (soil chemistry and tropical soil fertility); Laurie Drinkwater, Rodale Institute, PA (sustainable agriculture); Kate Skow, University of California, Davis (soil microbiology); Jerry Berc, NRCS-USDA (soil conservation); and Katherine Newkirk, Woodshole Marine Biological Lab (global warming). Soil scientists in the private consulting sector have also contributed to the knowledge base, though their work has not been published often because of restrictions of privacy for clients. Examples of excellent consulting soil scientists I have known are Laura Kuh (Redding, CA), Marie E. Davis (Georgetown, CA), and Janet Cormier (ME). Janet Cormier started a private consulting firm specializing in pedoarcheology after she left SCS-USDA in 1988. She was honored (posthumously) in 1997 by the State of Maine with the dedication of an archeological Indian site in southern Maine in her name (*32*).

The "Yes" Generation (1990 and on)

As the number of women has increased in the classroom, lab, and field, I have seen changes in attitude within the discipline of soil science. With these changes, the women who are graduating in soil science in the 1990's appear to me to be more confident, more intellectually engaged, and less defensive than I was in the 1970's. I asked my co-worker, Lenore M. Vasilas, NRCS/ACOE, Baltimore, MD (who finished her M.S. in Soils in 1997) what she thought. She responded, "Oh we don't think about

it. . . . We just go ahead and do it!" I thought, "That says it all right there" (*33*). *Newsweek* described the new work force of the 1990's as the "Yes Generation," and I like the title.

According to the Fall 1996 Enrollment for Agriculture, Renewable Natural Resources and Forestry Report by FAEIS, between 1987 and 1996 soil science, education, communication, and social science experienced the largest growth in percent female participation. The field of soil science was 16.2 percent female in 1987 and 32 percent female in 1996. General enrollment of students (for B.S., M.S., and Ph.D. degrees) in soil science has held relatively steady between 1987 and 1996, fluctuating between 1,200 and 1,500 students. In 1996, there were 228 female B.S. graduates in soil science, almost double from 10 years before. Doctoral and masters candidates in the soil sciences in 1996 are also about one-third female, once again double from 10 years before (*34*).

What does this mean in terms of diversity in the workplace? I suspect it means we will eventually see more women working in the field in soil survey and private consulting firms and as teachers and researchers in university and laboratory settings. In 1985, there were 85 women soil scientists employed by SCS-USDA. In May 1998, there were 94 women soil scientists in various positions. This was not a large increase. The overall population of soil scientists in the agency decreased with downsizing, so actually the percentage of females increased significantly (*35*).

There is a world of difference between Miss Julia Pearce's experience in the early 1900's and Ms. Vasilas's reality in 1998. "What in hell shall I do with her?" has changed to a common professional assumption that the employee knows what to do and will do quite well if she's given the chance. Personally, I am confident about the future of soil science and the women in it, and I look forward to the next 100 years of investigation and discovery.

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Students and Education Commitment in Making the San Joaquin Soil "The Official State Soil of California"

By Kerry Arroues, Supervisory Soil Scientist, USDA, Natural Resources Conservation Service, Hanford, California.[1]

Connection With Other States

I received a thank-you letter a couple of weeks ago from an NRCS office in the Midwest. The letter explained that people in their state had tried to pass a state soil bill in the past, but were unsuccessful. The person who wrote the letter went on to say that California's approach

students' prized, school-project bill to name an official state soil. 'I think the Senate ought to be embarrassed today; I am personally,' declared Senate President Pro Tem Bill Lockyer after the day's senatorial mud wrestling drew to a close."

An article in the Madera Tribune dated April 10, 1997, and titled "Soil-Stained Dreams Will Carry on Despite Temporary Senate Defeat" quoted Genesis 3:19: "In the sweat of your face you shall eat bread till you return to the ground, for out of it you were taken. For you are dust, and to dust you shall return."

The state soil bill was reconsidered and passed on to the State Assembly on April 17th. A delegation of 14 students who had prepared presentations were told that they would not be allowed to speak to the Assembly Governmental Organization committee because of a full calendar of scheduled bills. Mr. Lehman told the students that the outlook for their presentations was bleak but that he would continue to lobby for some time for their presentations. Perseverance was rewarded when the students were given sufficient time to give their presentations and have a significant impact on influential California Assembly members. Valerie Brown, the Chair of the Assembly Governmental Organization Committee, said: "I'm going to tell you that never in the history of my time here in the legislature, which has been five years, have you ever held members to such attention, and it will truly go down in history as one of the finer moments for this legislature. We actually learned something." Again, the important point is the process, which stressed students working toward a common goal. The 14 students and their families, teachers, and supporters traveled to Sacramento. All who were involved, including school students and teachers and soil scientists who acted as advisors, felt a sense of accomplishment.

Publicity and Education

There were a number of ups and downs in the legislative process as this bill progressed. I have mentioned a couple of roadblocks that surfaced, and there were others. The important point to remember through this entire process was the goal of education and soil awareness. Each "problem" increased media coverage and contributed to the goal. Even the use of the word "dirt" rather than "soil" was valuable. I would estimate that at least 25 percent of the publicity involved the "state dirt" theme. Of course, being a soil scientist who respects soil, I wouldn't normally refer to soil as dirt. We began to look at headlines about "state dirt," dirty bills," and setbacks in the legislative process pragmatically. All publicity was considered good publicity. Even such headlines as "New laws more than a pile of Valley dirt" or "Here's the latest dirt" should be considered valuable because they contribute to an awareness of soil. Of course, the best headline was the one announcing that the San Joaquin series is the official state soil of California.

Accomplishments

The passage of SB 389, which established the San Joaquin series as the official state soil of California, did not end the journey. We hope it is just beginning.

The NRCS and the Professional Soil Scientists Association of California supported a video titled "The California State Soil Story," and PBS California Heartland series did a program on the California state soil. A brochure describing the San Joaquin series and associated information is now available. There is a State Soil web site link to the California NRCS Home Page. Many San Joaquin soil monoliths are being worked on under the direction of Kim Chang from the Fresno NRCS office. These monoliths are being distributed to a variety of institutions and individuals who have significant contact with large numbers of people.

What Do We Do Now?

Commitment was required from a large cross section of individuals to get to this point. But where are we? We had an impact and are having an impact utilizing the San Joaquin soil as a teaching tool. Does the public really make the connection between soil, agriculture, and the food on their table? The answer is probably "No." If we agree that the public is not adequately educated about environmental matters, such as soil, then we have a responsibility to educate and do something to increase awareness of these matters. It is also logical that we concentrate on areas that will have the greatest impact on the largest numbers of people. The California state soil project was just such an attempt. We need to be ready to recognize opportunities for education that will make a difference. Education of large numbers of students via the computer is one significant opportunity that is being pursued at this time.

Recognition of Our Opportunities for Education

Opportunity does not always wait for us to respond. If we recognize the opportunity and react, we can have a significant impact. For example, 9 days ago I toured the Forestiere Underground Gardens in Fresno. These underground gardens were the life's work of Baldasare Forestiere, an Italian immigrant who spent over 40 years of his life sculpting an underground complex of 100 rooms, gardens, arches, a chapel, and fish ponds from the San Joaquin soil in the early part of this century.

There are obvious opportunities here for education of the public about soil. Among these opportunities are the following:

1. A unique use of the San Joaquin official state soil.
2. A closeup and personal view of soil profiles deep underground.
3. Unique varieties of trees, such as strawberry, carob, numerous citrus species, pomegranate, and avocado, grown above and below the ground in areas of the San Joaquin soil.
4. A struggle for the preservation of a unique and historic resource.
5. A man's life work in soil that took tens of thousands of years to form.
6. An opportunity to reach people from all over the world as they tour this man's legacy.

This is just one example of an opportunity to make a difference by educating the public about our soil. The state soil project was just such an opportunity a year and a half ago. With the perseverance and hard work of students and teachers, soil scientists, state universities, legislators, and many others, the San Joaquin official state soil project was instrumental in making a difference in the education of the public.

Are Soils Endangered? The Vanishing Soils of the West

By Ronald Amundson, Division of Ecosystem Sciences, University of California, Berkeley.

Soil care is integral to the existence of the soil sciences. Over the past century, most of the emphasis on soil care has been on the wise use and maintenance of soils for agriculture and pastoralism, activities that can broadly be categorized as soil conservation. Yet, another role of the soil sciences is to derive an understanding of natural soil processes in nonagricultural landscapes. These two activities are, in my estimation, coming into conflict as agricultural and urban expansion (partially fueled by improved science and technology) are rapidly diminishing many undisturbed soils around the world. I suggest that there is a critical need for the soil sciences to adopt soil preservation—preservation of soilscapes (both undisturbed and agricultural)—as a new, and intensive, soil care effort—an effort critical to the future our science. In this paper, I present a scientific rationale for soil preservation, review current literature related to rates of soil loss, and discuss issues pertinent to soil preservation.

Nature of Pedology

Pedology, in the American usage of the word, can be viewed as the study of soil properties and processes *in situ* on the landscape. It is but one of the several recognized branches of the soil sciences (e.g., soil chemistry and soil physics), but it is arguably the only one whose very existence depends on the availability of undisturbed soils for study. Stated differently, pedology is largely an historical, and observational, science. While there are certainly great experimental research opportunities in pedology, and also many pressing opportunities for research in disturbed landscapes, it is the "natural" soils (i.e., the landscapes not disturbed by human activities) that provide the theoretical framework on which the science exists.

Soils, the objects of study in pedology, are historical objects, representing the end result of natural experiments that have been ongoing for thousands to millions of years. The age and events—i.e., the historical contingencies (Phillips, 1998)—that shape this mantle vary greatly from place to place, producing an almost infinite array of soils. It is possible that the factors that form any soil are unique and singular, and that exact examples of any modern soil have not occurred in the past and cannot be repeated in the future. While soils are defined in numerous ways in our textbooks, their historical nature continues to be poorly emphasized. The recognition of these qualities is critical in efforts to develop conservation and preservation strategies.

The paradigm of pedology (e.g., Jenny, 1941) indicates that any change in one of the factors of soil formation inevitably leads to a new, or at least different, soil. The scientific literature is filled with case studies of changes in soil properties (organic matter, structure, hydraulic properties, etc.) brought about by cultivation, pastoralism, industry, and urbanization. The changes brought by these activities greatly change the ability of the soil to be used for an understanding of any number of natural processes or the relationship of the soil with its natural environment. Jenny (1984) referred to agricultural soils as "domesticated soils," a term that allows us to split soils into two great classes (domesticated and undomesticated) and to view soils as analogous to living organisms.

The issue critical to the future of pedology is the diversity, and areal extents, of the Earth's soils in both domesticated and undomesticated states. Today, a primary factor determining the extent and future of domesticated soils is global urbanization. For undomesticated soils, urbanization and continued agricultural expansion are major processes which control the quantity of remaining undisturbed soils. Only partial quantitative information on the rates of loss of each of these soil types is available. The greatest amount of the available information is on urbanization of agricultural soils. The issue of loss of remaining undisturbed soils is only beginning to receive attention, and I will address this issue with a few qualitative examples. Before we proceed into these issues, however, the concept of soil diversity and the means by which it is quantified in various regions must be addressed.

Soil Diversity

Conceptually, it is well accepted that soil forms a continuum at the Earth's surface. Although soils vary greatly from one location to another, spatial changes may occur either abruptly or nearly imperceptibly along these gradients. Soil surveyors worldwide have used various soil classification schemes in attempts to break this continuum of soils into defined classes based on soil profile characteristics. As a result, the concept of what constitutes an individual soil type varies somewhat from one country or agency to another and from one soil map scale to another.

Despite sometimes significant differences between approaches, there is an international commonality of views as to what constitutes significant differences between soil types. This shared vision provides a basis for quantifying both the total areal extents of various soil types worldwide and the percentages of each soil type in natural states and in cultivated, urban, and other land uses.

The difficulty in using existing data of global land use to estimate decline in natural soil diversity is that, as I will discuss below, land use change is quantified by biotic type (i.e., vegetation). While it should be possible to merge soil and these biotic-based data bases, this work (to my knowledge) remains to be undertaken. Next, for the purposes of illustrating the importance of the loss of soil diversity, I review several recent compilations of the percentages of the Earth now in agricultural uses and in urban uses.

Losses of Undisturbed Soils

As was mentioned earlier, compilations of natural soil loss have not been made, but ecosystem-based analyses have been undertaken as various maps and remotely sensed data are digitized and analyzed. A widely quoted (Williams, 1994; Graetz, 1994) compilation of prehuman and present-day ecosystems is that of Matthews (1983), who compiled a global land use data base using approximately 100 published sources complemented by satellite imagery (table 1).

Table 1.—Estimated changes in areas of the major land-cover types from preagricultural times to the present (x 106 km^2)[1]

Land-cover type	Preagricultural area	Present area	Percent change
Total forest	46.8	39.3	-16.0
Woodland	9.7	7.9	-18.6
Shrubland	16.2	14.8	-8.6
Grassland	34.0	27.4	-19.4
Tundra	.4	7.4	0
Desert	15.9	15.6	-1.9
Cultivation	0	17.6	+1,760.0

[1] Table 2 from Graetz (1994) derived from data from Matthews (1983).

As the data illustrate, certain biomes have been more preferentially utilized for cultivation than others. In particular, the grasslands have been more heavily impacted, in terms of both total area and percentage of the total.

What remains is for these data bases to be overlain on world soil maps in order to develop a sense of the loss of specific soil classes to agriculture. Qualitatively, we know that certain biomes and soil types are likely to be severely impacted. As an example, the former tall grass prairie of the Great Plains of North America has almost been completely converted to crop production, and locating undisturbed soils for scientific study is difficult in this area. In some portions of this area, we have found that cemeteries contain the last remaining undisturbed landscape segments (Kelly et al., 1991).

Urbanization of Agricultural Soils

Concern over the loss of agricultural soils to urbanization is a long-standing issue. As Imhoff et al. (1997) note, however, obtaining accurate estimates of the amount of land devoted to urban use and the rate of urban land growth has proven to be difficult.

In the United States, the Natural Resources Conservation Service has initiated a long-term monitoring program to estimate land use changes. This data base has been used in recent compilations to emphasize the role of urbanization in the reduction of high-quality farmland in the United States (Sorenson et al., 1997). Estimates of urban land as it occurs globally appear varied (Douglas, 1994) because of differences in the definition of urban land and in the various data bases used for comparison. Douglas (1994) estimates that 247 x 106 ha of the world is now in urban areas.

Imhoff et al. (1997) have developed a unique means of compiling urban land areas based on nighttime city light footprints obtained from satellite imagery. Using this data base, these authors showed that about 2.7 % of the USA is urbanized (agreeing well with independent estimates). By overlaying the city lights data on the FAO soil map of the USA, they also showed that urbanization is preferentially concentrated on certain soil types (up to 50 to 70 % of some FAO soil types are now in urban use). This innovative GIS-based approach using satellite data and soil inventory data reveals the important concept that human alteration of the landscape is not evenly dispersed and that many soil types are far more susceptible to change than others. The expansion of this approach to the entire globe is critical in an assessment of the effects of both urbanization and cultivation on soil types.

Arguments for Preservation of Soil Diversity

Many of the issues relevant to soil diversity are shared by those concerned with biodiversity. Ehrlich and Wilson (1991) argue that the preservation of biodiversity is important for four reasons: ethical, aesthetic, and economic considerations and the sustainability of the Earth. To these four reasons, all relevant to soil diversity, I will add a fifth: scientific. The following brief discussion of these reasons for soil preservation is a means of establishing a dialogue as to why we should consider this issue important in the soil sciences.

Ethical reasons for preservation: Homo sapiens is but one of up to 30 million animal species on Earth, but today

it essentially has altered or nearly controls many of the planet's biogeochemical cycles (Vitousek et al., 1986). Ehrlich and Wilson (1991) argue that we have a moral responsibility to protect the other inhabitants of the planet and, by extension, their environments (including soils).

Aesthetic reasons for preservation: Aesthetic arguments for preservation would seem to ring true primarily for plants and animals, those components within our field of vision and comparable in size to human beings. However, solid scholarly arguments have been advanced for the aesthetic value of soils (Jenny, 1968; Jenny and Stuart, 1984). With respect to soil aesthetics, Jenny (Jenny and Stuart, 1984) said:

> Well, soil appeals to my senses. . . . As yet, neither touch nor smell sensations have been accorded aesthetic recognition, but colors delight painters, photographers, and writers. . . . Warm brownish colors characterize fields and roofs in Cezanne's landscape paintings of southern France, and radiant red soils of the tropics dominate the canvases of Gauguin and Portinari. . . . I have seen so many delicate shapes, forms, and colors in soil profiles that, to me, soils are beautiful. Whenever I offer this reaction to an audience, I notice smiles and curiosity, but when I follow up with slides that depict the ebony black Mollisols of Canada, titian-red Oxisols of Hawaii, and gorgeous soil profile paintings by such famous artists as Grant Wood of Iowa, Dubuffet of France, and Schmidt-Rotluff of Germany, the hesitancy turns into applause.

Economic reasons for preservation: There can be no argument that the preservation of our presently cultivated (domesticated) soils is of utmost importance to the preservation of our species. We are an increasingly urban species which relies on the growing and uninterrupted flow of food from agriculture. The economic-based arguments for natural soil preservation have not received as much thought or analysis. Several economic arguments can be advanced here. First, there is a growing recognition that new generations of medicines and chemicals may be derived from plant species. Large expanses of natural landscapes are needed to preserve the biodiversity required to sustain a stock for these products, and these landscapes by default also include the soils. One might even extend this argument to the soil itself. We know almost nothing about the geographical distribution of soil micro-organisms and their metabolic abilities. Yet it is from the soil that some of our greatest antibiotic success stories—streptomycin, for example—have come (Logan, 1995). Other useful products derived from the soil microflora and fauna may hold enormous potential in future medical and agricultural research.

Earth sustainability reasons for preservation: Complete undisturbed ecosystems (soils, plants, animals) are part of the great biogeochemical fluxes that have made, and continue to make, the Earth habitable for humans. The general importance of soils in these cycles is well recognized, but the quantitative role is at best poorly known as soil science research slowly shifts from agricultural applications to global geochemistry. Through soils pass many of the trace gases of our atmosphere—particularly CO_2 (Amundson et al., 1997), and changes in the proportion of undisturbed soils have had, and continue to have, a profound effect on the CO_2 concentrations of the atmosphere (Sundquist, 1993). Weathering processes and exchange reactions in soils likely have the major control on the chemical composition of the streams and rivers of the world, ultimately affecting the chemistry of the ocean. While numerous case studies from today's scientific literature will support the view that soils are major components in global water chemistry, the importance of this function may have been best summarized by da Vinci nearly 500 years ago (Richter, 1970): "It has been said that the saltiness of the sea is the sweat of the Earth."

Scientific reasons for preservation: From a purely self-serving perspective as a scientist, I argue that study of undisturbed soils and soil processes constitutes the "raison d'être" of pedology. Undisturbed soils are needed for pedology to function as a science that helps us (1) to understand the type and rate of natural soil-forming processes and (2) to provide a benchmark for human alteration of the environment. As we continue to reduce the extent of many of the soil types of the world, or eliminate them completely, we leave a diminished set of natural experiments for ourselves and our scientific progeny. We have much, or nearly everything, to learn about soil processes and properties and how they control the world we live in and how they can tell us about our past and help us evaluate our future.

Conclusions

In this paper, I have advanced the argument that as pedologists we live in perilous times. We can rightly make the claim, now that we are beginning our second century, that we are a *bona fide* branch of the natural sciences with a certain degree of maturity. Yet, despite our growing legitimacy as a science, the very objects of our study (soils) are disappearing at an alarming rate. Stemming the rate of this loss will result only from support initiated by the scientific community, support that will require both education and political action.

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Role of the Private Consulting Soil Scientist

By Sidney W. Davis, DAVIS2 Consulting Earth Scientists, P.O. Box 734, Georgetown, California 95634.

The role of the private consulting soil scientist is first and foremost one of service to his or her client. This service involves advancing the best information available over a wide variety of soil motifs, at a competitive price, and in a timely fashion. There are few “one trick ponies” in the private soil consulting business. Versatility on the part of the practitioner is a must. Oftentimes this requires inventing or researching areas that are outside the traditional role of a soil scientist, but nonetheless within the realm of our education and expertise. Soil permeates our biome and the need for soils information, often overlooked by allied professions, is a necessary component of a project, and if omitted, usually causes unnecessary financial hardship.

One can achieve versatility in the job market by staying true to the basics, collecting data in a thorough and methodical way, and applying standard interpretations to fit the subject or problem at hand. Regardless of what type of project is being pursued, there are generally five main ingredients: 1) site survey or mapping, 2) sampling, 3) testing, 4) interpretation, and 5) conclusion or recommendation. Simple but elegant solutions and speed of delivery produce a steady clientele, referrals, and satisfied customers. A consulting business will thrive if the practitioner pays close attention to the basics, job by job.

Being a client advocate is essential in private consulting,