UNDERSTANDING NORTH DAKOTA'S SOIL RESOURCE

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North Dakota soils are the result of the interaction of climate, native vegetation, geologic material, relief and time. The effects of these factors are expressed in varying degrees in all soils. Each soil has a unique set of morphological, physical and chemical properties which reflect its entire history. Soils are continually changing in response to their environment but changes in soil properties which occur naturally take place over a long period of time. About 250 different soils are currently recognized in North Dakota.

Soil use in North Dakota is dominated by field crop and native grass production. In addition, soils are used for waste disposal, construction material, building sites, recreational sites, wildlife habitat and reclamation of mined land. Because of its unique properties, a soil exhibits various levels of suitability for different uses. Many times, however, a particular soil is used for a purpose for which it is not well adapted. In these cases, measures that facilitate soil use while preventing soil degradation and subsequent failure can be employed.

To properly plan the use and management of a tract of land, the extent and distribution of the soils and the soil characteristics which govern the proposed land use must be known. At North Dakota State University, research in soil genesis, morphology and classification is directed toward the development of a statewide soil resource inventory, a soil characterization data base and an understanding of the processes responsible for soil development so that we may reliably predict soil suitability for agricultural and nonagricultural uses.

Statewide Soil Resource Inventory

Soil Survey

People often assume the soils on a particular farm or field are similar. They do not realize that great variation in soil properties can occur within short distances. Differences in slope, natural drainage, texture, seasonal wetness and salinity usually occur within the same field. Most of the soil differences that affect crop yields and govern land use are shown on detailed soil maps.

In preparing a detailed soil map, the soil scientist walks or drives over the landscape. At intervals the soil is examined and classified according to its observable properties — kinds, thickness and arrangement of soil horizons (layers) in the profile. The soil boundaries, natural drainageways and selected cultural features are recorded on an aerial photograph. The result is a soil map which shows the location and extent of areas of similar soil and slope (map units) for the tract of land. Some map units consist of mainly one kind of soil while others are complexes of two or more soils which cannot be separated at the selected scale of mapping. The soil maps, descriptions of map units, descriptions of the various soils and a series of interpretive tables, which show the suitability of the soils and map units for a variety of agricultural and nonagricultural uses, are compiled and published as a soil survey report for the county or area (4, 5, 24).

At present, detailed soil surveys are underway in about 10 counties in North Dakota. The major contributors to this effort are the Soil Conservation Service (SCS), the North Dakota Agricultural Experiment Station (NDAES) and the North Dakota State Soil Conservation Committee (NDSSCC). The SCS is responsible for the field mapping, quality control, and preparation and publication of the soil survey report. The NDSSCC contributes to field mapping and map compilation. The NDAES provides laboratory data to ensure proper classification of the soils, provides documentation for selected land use interpretations and assists with quality control in the survey area. Figure 1 shows the current status of the statewide soil resource inventory.

In addition to cooperating with the SCS and NDSSCC in the soil survey program, the NDAES conducts soil surveys of organized irrigation districts. Irrigation soil surveys are similar to conventional detailed surveys exept the soil is examined more frequently and to greater depths to detect textural barriers which can restrict water penetration and limit soil suitability for irrigation. Irrigation soil surveys were completed for the following irrigation districts:

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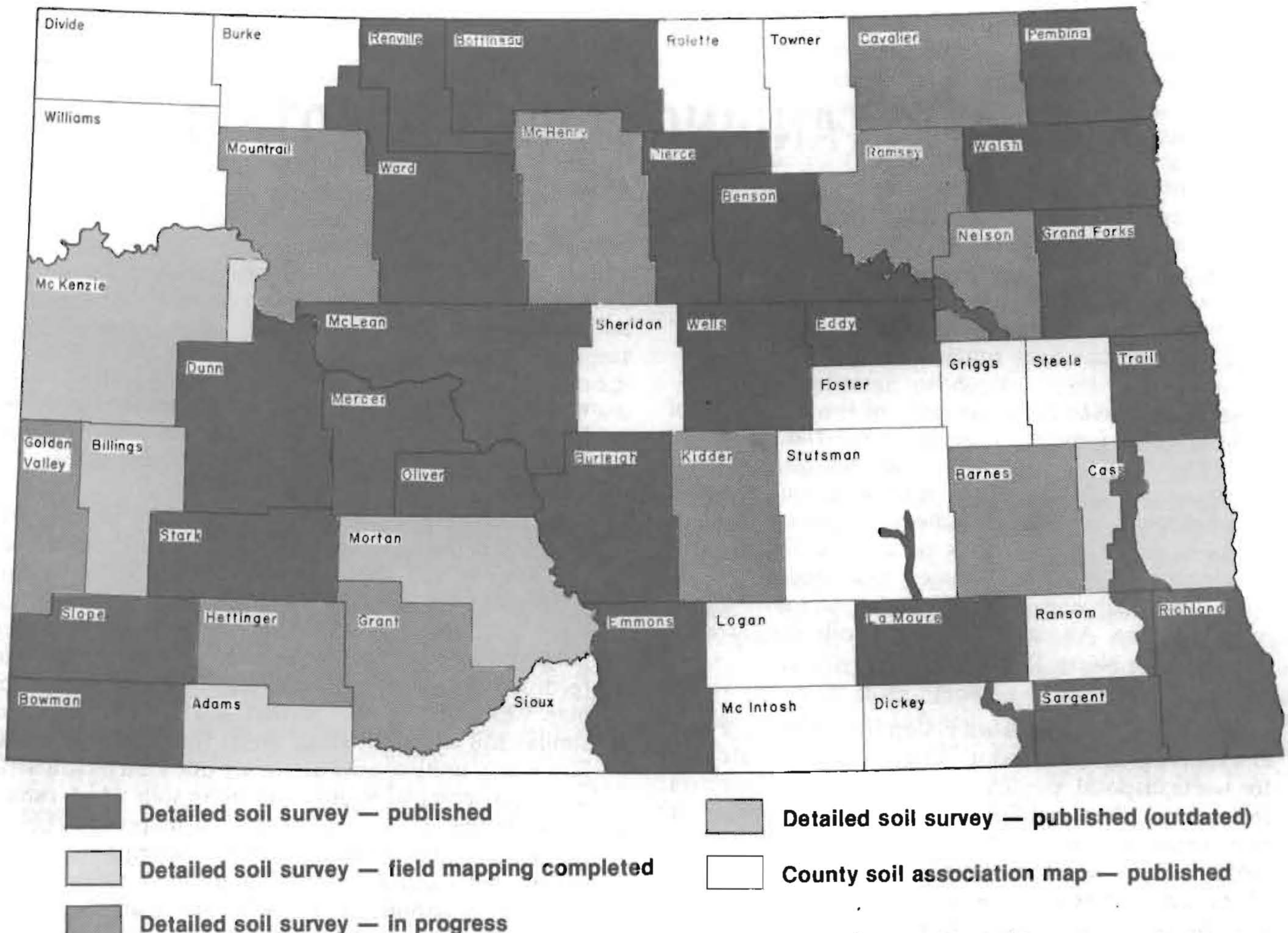

Source: Adapted from status of soil surveys in North Dakota — F.Y. 1983 (USDA-SCS)

Figure 1. Status of the soil inventory in North Dakota — July 1, 1983.

Tri-County area—parts of Cass, Richland and Ransom counties
West Oakes area—parts of Dickey County
James River area—parts of Dickey, LaMoure and Stutsman counties
Warwick-McVille area—parts of Eddy, Nelson and Benson counties
New Rockford area—parts of Eddy and Benson counties
Lincoln Valley area—parts of Sheridan County
Karlsruhe area—parts of McHenry County

In addition, NDAES soil scientists will complete a soil survey of parts of the Middle Souris and Mouse River irrigation districts in McHenry County in 1984. The results of the irrigation soil surveys were published separately or as parts of detailed county soil survey reports (10, 20).

A reconnaissance soil survey of North Dakota was authorized by the 1953 legislative assembly and completed in 1958. The results of this survey were published as county soil association maps with a scale of about 1:125,000 or 1 inch = 2 miles (13). County soil association maps provide a basis for comparing the soils among relatively large areas such as townships. Soil differences which are important in planning the soil use of an individual farm or field are not shown on these maps because of map scale. The county soil association maps are currently being revised to reflect our increased knowledge of soils and to conform to **Soil Taxonomy** (19). The maps have been used extensively by federal, state and local agencies and private industry for land use planning, routing of power and pipelines, evaluating soil productivity among townships and locating areas of potentially irrigable soils.

A general soil map of North Dakota with a scale of 1:1,000,000 or about 1/16 inch = 1 mile, based on the county soil association maps and available detailed soil surveys, was compiled and published (11). A revised version of this map with a scale of 1:750,000 or about

5/64 inch = 1 mile will be published within one year. A supplemental bulletin also is in preparation. General maps of this scale contribute to the understanding of soil-landscape relationships over large areas.

Soil Characterization

Laboratory determination of soil physical and chemical properties has been an essential part of most soil research for many years. Soil characterization is basic to research in soil morphology, genesis and classification. Many soil properties important in predicting soil suitability for various uses cannot be observed in the field. In moist soil, for instance, soluble salts remain in solution and are not visible. Plant available nutrients, pH and free iron are other soil properties that require laboratory determination. Certain soil properties, such as organic matter content and percent clay, can be estimated by field observation but require laboratory analysis for verification and quantification.

Soil characterization studies are effective only when used in conjunction with field studies of soil morphology. The laboratory can be used to detect properties that cannot be observed or measured in the field. Conversely, laboratory data cannot be properly interpreted without detailed descriptions of field morphology. Often joint field-laboratory studies are used to relate some observable soil characteristic to a related property that requires laboratory determination. Once the relationship between the two properties is established, prediction criteria are developed which facilitate soil classification, interpretation and field mapping.

In North Dakota, soil characterization is an integral part of the soil resource inventory. About 20 soil profiles are sampled and analyzed for various physical and chemical properties each year. In addition, numerous samples collected by SCS, NDSSCC and NDAES soil scientists are analyzed for selected properties. Several research projects currently in progress or recently completed have contributed information to the soil characterization data base. Each of these efforts helps us to better understand North Dakota soils and to predict soil behavior with greater precision.

A current priority in soil characterization is the development of a format and computer program for the input and retrieval of soil profile descriptions and data on soil physical and chemical properties collected during the last 25 years. The laboratory data and profile descriptions, along with a summary of laboratory procedures, will be published in a bulletin. Also, the data will become the basis for other publications which relate laboratory data to **Soil Taxonomy** (19) and soil properties to soil management. For example, herbicide application rates are affected by soil organic matter content, percent clay and, in some cases, soil pH. Data on various soil properties will be keyed to county and state soil association maps.

Soil Interpretation

Soil interpretation is the application of soil maps and soil information to the solution of soil and land use problems. Interpretations are predictions of the ways in which individual soils are expected to respond when used for various purposes. Soil interpretations indicate the use and management options available to land managers and anticipated results. They contribute to more intelligent land use decisions based on the physical and economic characteristics of land.

Soil interpretation facilitates the transfer of the results of research. Experimental results obtained on a site where the kind of soil is known can be duplicated, with minimal variation, on sites with similar soil characteristics. The need to repeat the experiment on all areas of the same soil is eliminated.

One basic system of classification (19) applies to all soils in the United States but many different kinds of interpretations are required. Some of the most widely used interpretations are highly dependent on changing economic conditions and must be updated frequently. Soil interpretations range from specific items such as the suitability of the soils on a residential lot for septic waste disposal to broadly defined qualities such as the overall suitability of a soil for crop production.

The information used in developing soil interpretations is obtained from soil characterization research, field experiments in soil management and the experience of those who use soils in various ways. Reliable interpretations result only from a data base which is adequate in both quality and quantity. As we learn more about our soils, we become better qualified to predict their response to various uses.

Most land managers who use soil maps in the decision-making process want specific rather than general interpretations. Relative suitability ratings which categorize soils as good, medium, fair or poor for the production of a particular crop do not fit the needs of most farm managers. For land valuation, indexes which reflect production costs often are preferred to those based on physical production estimates alone. Interpretations which employ economics require periodic revision to keep pace with current conditions. The demand for soil interpretations that require the input of interdisciplinary groups composed of soil scientists, range scientists, engineers and economists will increase.

At North Dakota State University, major emphasis has been placed on interpretations for agriculture. Crop yield and management data have been collected from experimental plots and farm fields for use in developing yield estimates for the most extensively grown crops. These data provide support for the crop yield estimates in the use and management sections of county soil survey reports. Productivity indexes based on crop yield estimates and soil maps of various scales have been used extensively by local governments and realtors for land valuation. A recent irrigation feasibility study was based partially on irrigated and dryland crop yield estimates (22).

Recent and Current Research

The research program in soil genesis, morphology and classification at North Dakota State University contributes substantially to the statewide soil resource inventory. The results of some of the more recent and current research activities are summarized in this section.

Reclamation of Mined Land

The quality of the materials available for top dressing reshaped mined land is governed by the characteristics of the soils in the permit area prior to mining. Unavoidable changes in some soil properties occur in the process of stripping, stockpiling and spreading suitable plant growth material. Other properties do not change appreciably unless suitable plant growth material is contaminated. Omodt et al. (12) identified and discussed the major soil and landscape characteristics known to affect plant growth and soil erodibility. Those properties not subject to great change in the mining process which have considerable effect on plant growth and erodibility are organic matter content, electrical conductivity, exchangeable sodium percentage and percent carbonate in the surface layer. Soil characterization data were used to establish critical limits for these properties. The criteria were incorporated into the North Dakota mining law in 1975.

Patterson and Schroer (14) discussed the soil properties over which man has some control in surface mining and reclamation. They used soil characterization data to predict the impact of surface mining on the soil resources and land use of an area in western North Dakota. Schroer (18) demonstrated the value and limitations of detailed soil inventories and soil characterization data in predicting the properties of underlying geologic materials. Richardson and Wollenhaupt (16) observed that lignite, in certain stages of degradation, creates water repellency and should not be placed near the soil surface in mined land reclamation.

Wollenhaupt and Richardson (23) noted the relationship between microrelief and plant growth on plots on reclaimed soils at the Falkirk Mine near Underwood, N.D. Microrelief accounted for more variation in crop yield than soil thickness. The plots with concave surfaces tended to have higher yields than convex plots because of moisture accumulation. In the same study Wollenhaupt and Richardson noted that relief and surface shape controlled the natural revegetation of orphan mine spoils. The convergent landscape positions where runoff water accumulates were consistently vegetated with a good cover. Convex runoff slopes usually were bare in the spoil areas studied. Landscape shape was more important than slope gradient, and very steep slopes, if convergent, had a relatively dense cover of vegetation. Shape of slope is a critical factor in restoring the productivity of mined land and in interpreting natural landscapes.

Soil-Landscape Relationships and Soil Development

Bauer et al. (1) studied the effects of available nitrogen and water regime on wheat yield on a toposequence of till soils in the Drift Prairie of eastern North Dakota. Differences in water supply among soils caused by surface runoff from one soil to another contributed to yield differences. A change in yield potential can occur before or during the growing season because additional water can affect the timing and/or intensity of water deficit. Anticipated yield differences occurred among unfertilized soils. The elimination of nutrient deficiencies among soils resulted in yield variation that was attributed to water supply.

Malo et al. (8) studied a closed drainage basin in similar terrain. The textural properties of the soils were attributed to erosional-depositional processes. The upper convex slopes were subject to erosion and tended to be drier. Soils with thickened A horizons and slightly finer textures occurred on the midslopes. The poorly drained soils in the basin center were fine-textured and had thick A horizons.

Rosek and Richardson (17), in a preliminary study, analyzed the Davis Creek drainage basin in the Little Missouri Badlands. Four major landform groups were delineated in order of importance: 1) the steep, erosional hillslopes (backslopes); 2) gently sloping, erosional footslopes (pediments); 3) alluvial floodplains and terraces; and 4) dissected high terraces and pediments which are now summits above younger backslopes. Soil age and thickness can be estimated from these landforms. The summits are the oldest and have more strongly developed soils. The other sites are young with shallow-to-bedrock soils on the backslope, stratified alluvial soils on the floodplain and relatively thin alluvium over bedrock on the pediment.

These studies provide a clearer understanding of agricultural production in terms of soil-landscape relationships, and allow the creation of landscape models and the prediction of potential erosional sites.

Wetlands and Wetland Soils

Bigler and Richardson (2) studied wetland soils in relation to vegetation types. The soils were stratified Entisols (young soils) with abundant organic matter. Soil textures were coarser on the wetland edge and in the surface layer compared to fluvial (stream deposited) landscapes which tend to be finer on the edge of the area and in the upper parts of the soil profile. These soils should be distinguished from more strongly developed soils on wetlands, which are often dry for part of the growing season, and from fluvial soils. Using factorial analysis, the three factors which best characterized wetland soils were 1) salinity factor (measured by electrical conductivity and soluble sodium), 2) organic factor (organic matter and calcium carbonate), and 3) sedimentation factor (clay content and calcium carbonate) (15). These properties correlated well with vegetation types and zones in wetlands (6). The results of this work are used in wetland soil classification.

Genesis of Soil Structure

Gunnerson (7) used wet aggregate stability methods to study the kinds of synthetic organic molecules most likely to stabilize soil structure. Long chain, straight or unbranched, organic molecules with amine, ether, ethyl or similar organic groups were found to be most effective. Soils with relatively stable structure in the A horizon tend to resist erosion. Moen (9) developed three methods for increasing knowledge of soil aggregates: 1) ultrasonic vibration measures bonding strength; 2) heat of wetting measures the surface activities of organic matter, inorganic soil particles and water; 3) hygroscopic water at various tensions measures the relationship between water and particle surfaces or ions on or near the surface. Using these methods bonding strength and the influence of a bonding material on a particle surface can be observed.

Soil Permeability

In a preliminary study, Conta and Richardson (3) noted that percolation tests were inadequate for estimating the permeability of soils with greater than 35 percent clay because of large fractures caused by drying. Percolation tests, however, work well on soils with less than 35 percent clay. Conta and Richardson observed that clay percentage provides enough information for permeability prediction on clayey soils. Particle size analysis has replaced the percolation test as a basis for granting septic absorption field permits in Cass County, N.D.

Crop Yield Modeling

Ulmer and Patterson (21) studied the effects of soil, climatic and management variables on yields of hard red spring wheat and sunflower. Preliminary results indicate that soil water at seeding, degrees greater than 90°F (seeding to harvest), precipitation (seeding to harvest), total nitrogen (soil N plus fertililzer N), organic carbon and plant available water capacity were the most useful of the variables tested in explaining wheat yield variation. Soil water at seeding, precipitation (seeding through the first 10 weeks of the growing season), total nitrogen, degrees greater than 90°F (seeding to harvest), combined thickness of A and B horizons and organic carbon explained more yield variation in sunflower than did combinations of a similar number of other variables. The models will be useful in predicting the effects of various factors on the yield of spring wheat and sunflower. Information of this kind is essential to the development of reliable crop yield estimates needed for planning the use and management of North Dakota's soil resource.

Future Program Direction

Historically the soil resource inventory program in North Dakota, and in the nation, was oriented toward soil mapping. Little emphasis was placed on soil characterization, interpretation and other research required for documentation. A successful program, however, requires sound research effort in soil genesis, morphology and classification.

Over the past 30 years, the research effort in North Dakota has received increasing consideration. When the irrigation district survey work in McHenry County is completed, field mapping by NDAES soil scientists will be limited to projects related to research. NDAES personnel will concentrate on projects designed to increase our knowledge of North Dakota soils and landscapes. Some of the projects will provide documentation for soil classificaiton and interpretation. In addition, NDAES soil scientists will continue to cooperate with personnel of other federal and state agencies and private industry in various aspects of the soil resource inventory program.

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although difficult to quantify, is perhaps unsurpassed in all the state-supported programs.

The various subdivisions for research activities in soil science include the following: soil chemistry/plant nutrition; climatology/soil microclimate; soil and water conservation; soil classification, survey, and genesis; soil fertility; soil management; soil physics; and soil testing. In this issue of North Dakota Farm Research, a summary of past and present research programs in these areas will be reported. Although a great deal of research has been accomplished over the past few decades, many challenges remain as cropping systems change, economics become more important, and as emphasis changes from maximum production to maintaining and improving the quality of the soil resource. Two important research areas in maintaining our soil resource in a productive state are soil erosion by wind and water and soil salinization. Both these problems will receive high priority in our future research efforts.

Research activities in the Department include laboratory, greenhouse, and field experiments. Other departments including Agronomy, Botany, Geology, Animal Science, Agricultural Engineering, Agricultural Economics, Bacteriology, Horticulture, Plant Pathology, Biochemistry, and the Land Reclamation Research Center at Mandan contribute substantially to the research program in soil science. The complicated and involved aspects of most research problems dealing with the soil resource necessitates a team approach. Field research at the branch experiment stations is an integral part of the overall effort in soil science research. Various state and federal agencies, industry, and other individuals cooperate and support the research in soil science.

The service portion of the work in soil science at North Dakota State University is accomplished mainly by personnel of the Extension Service. Those in the soil science area are Dr. Carl Fanning, Dr. Ed Vasey, and Dr. Allan Cattanach. Mr. Frank Sobolik, stationed at Williston, has a split appointment with the Extension Service and the Department of Soil Science. In addition to activities of the Extension personnel, most of the research-teaching staff participate in field days and answer numerous requests for informatoin on subjects such as soil testing, soil fertility and management systems, climatic data, irrigation, soil survey interpretations, and soil and water conservation.

The teaching, research, and service activities dealing with the land resource are vital for a growing and prosperous agriculture in North Dakota. Hopefully, the efforts put forth by the Department of Soil Science and its numerous cooperators will result in the wise use and preservation of that precious "skin of the earth."