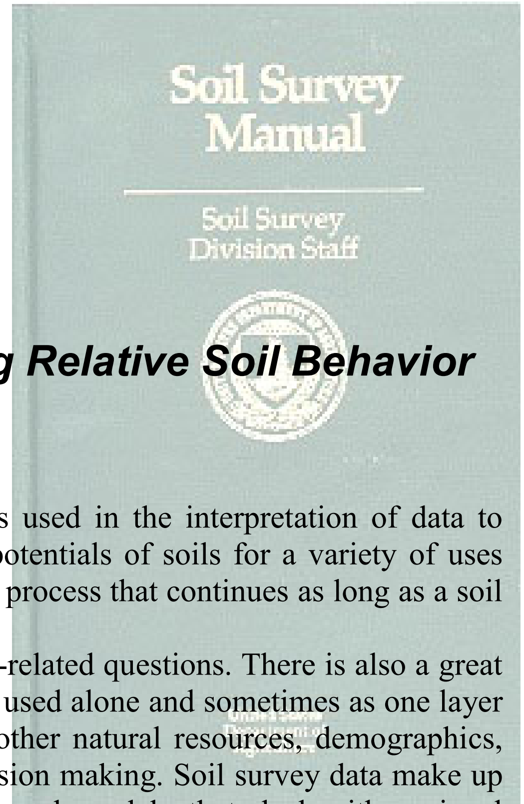
CHAPTER 6

Interpretations

Approaches to Generalizing Relative Soil Behavior



This chapter explains the concepts and principles used in the interpretation of data to evaluate or predict suitabilities, limitations, or potentials of soils for a variety of uses (see appendices for examples). Interpretation is a process that continues as long as a soil survey is in use.

Soil survey information answers a wide range of soil-related questions. There is also a great range in complexity as the soils information is sometimes used alone and sometimes as one layer of information in integrated systems that also consider other natural resources, demographics, climate, and ecological and environmental factors in decision making. Soil survey data make up a growing number of geographic information systems and models that deal with regional planning, erosion prediction, crop yields, and even modeling of global change.

Historically, soil survey interpretations have been concerned primarily with soil interpretative predictions for the public that are specific to a land use. This contrasts with genetic or taxonomic evaluation of soils by scientists. The level of data collection needed to execute the current interpretations program of the National Cooperative Soil Survey is in relevant parts of the *National Soils Handbook* (Soil Survey Staff).

Generally, preparation of interpretations involves the following steps: (1) assembling information about the soils and the landscapes in which they occur, (2) modeling other necessary soil characteristics from the soil data, (3) deriving inferences, rules, and guides for predicting soil behavior under specific land uses, and (4) integrating these predictions into generalizations for the map unit.

Soil interpretations provide numerical and descriptive information pertaining to a wide range of soil interpretative predictions. This information can be expressed in classes and units of measure of other disciplines. For example, presentation of particle size data includes both the soil separates of sand, silt, and clay, and the USDA Texture or UNIFIED classes. Generally, evaluations are made for specified uses. Soil properties that limit the land use or establish the severity of the limitation are usually indicated. Relative suitability of the soil and characteristics that determine the suitability may be given. In addition, soil interpretations may provide displays of soil interpretative evaluations for different uses on an areal basis at scales that pertain to a specific application.

Alternative management decisions can be derived from soil behavior information. For a particular land use, this requires information on soil response to management alternatives, identification of the kinds of management needed, and information about the benefit-to-cost relationship for the management selected.

A number of considerations should be kept in mind in the use of soil survey interpretations:

- An interpretation, such as suitability for septic tank filter fields, has a specific purpose and rarely is adaptable without modification to other purposes.
- Application of interpretations for a specific area of land has an inherent limitation related to the variability in the composition of delineations within a map unit. The limitation is related to how soil surveys are made and to the size of the area of interest relative to that of map unit delineations. These concerns are particularly significant for areas of land for which large capital expenditures are contemplated, as for example, house sites. These areas are usually small relative to the size of map unit delineations and may fall within a dissimilar inclusion of soils that have interpretations completely different from those of the major components of the unit. These concerns are increased for multitaxa units.
- The inherent variability of soils in nature defines the restraints in soil interpretations and the precision of soil behavior predictions for specific areas. Interpretations based on soil surveys are rarely suitable for such onsite evaluations as home sites without further evaluations at the specific site. Soil interpretations do provide information on the likelihood that an area is suitable for a particular land use; and, thereby, they are valuable for screening areas for a planned use. This likelihood may be expressed as a suitability or a limitation.
- Specific soil behavior predictions are commonly presented in terms of limitations imposed by one or a few soil properties. The limitations posed by a particular soil property must be considered along with those of other soil properties to determine the property that poses the most serious limitation. Shrink-swell, for example, may be the only limiting soil property for building houses with basements on some soils. Other soils, however, which have high shrink-swell, may also have bedrock at shallow depths. The shallow depth to bedrock may represent a greater limitation than does shrink-swell. Relatedly, some soils have low shrink-swell which is favorable to house sites, but they have limitations because of wetness, flooding, slope, or some other reason.
- Certain considerations that determine the economic value of land are not a part of soil interpretations but are an integral part of developing soil potentials for a given land use. For example, the location of an area of land in relation to roads, markets, and other services is considered by local groups when developing soil potential ratings based on costs to maintain the soil resource versus benefit derived.
- Some interpretations are more sensitive to changes in technology and land uses than others. Crop yields have generally increased over time and new practices may reduce limitations for nonagricultural uses. An example of the latter is the change to reinforced concrete slab-on-ground house construction, which has markedly reduced the limitation of shrink-swell for small building construction. Additionally, new uses of land will require new prediction models for soil interpretations.
- Finally, interpretations based on properties of the soil in place are only applicable if characteristics of the area of land are similar to what they were when the soil mapping was accomplished. Physical movement, compaction or bulking of soil material, or changes in the patterns of water states by irrigation, drainage, or alteration of runoff by construction may require that new interpretations be made.

Interpretative Systematics

Interpretations involve predictions about soil behavior or soil attributes. Interpretations are commonly made separately for all components in the map unit name. A summary rating for the whole unit may also be given.

The generalizations are based largely on a known or obtainable set of soil properties that are maintained or predicted for each kind of soil. These known or obtainable sets of properties or characteristics of soils are used to predict other attributes of soil, such as shrink-swell potential or potential for frost heave. In addition, documented experience with soils having certain sets of properties are used to generalize or predict. These generalizations are commonly formalized in interpretative criteria tables for computer-generated ratings.

The interpretative criteria may range from a narrow set of inferences for specific uses or applications (for example, limitation of the soil for trench-type sanitary landfill) to a highly integrative set of inferences about complex practices that are based on a large number of considerations, only some of which are interpretative soil properties (such as the Land Capability Classification System). The criteria may be based on knowledge of how soils perform under different uses or on research inferences.

Highly integrative generalizations are made for what are called management groups. Groupings of soils may be made for the purposes of various national inventories. These groupings may be highly integrative (as for example, prime farmland) or be based on a few, quite specific criteria (such as highly erodible lands). Because such interpretative groups as prime farmland, highly erodible land, and hydric soils are referenced in legislation, their care has become important in national environmental objectives.

The soil properties selected and the criteria employed for making the interpretative generalizations are applicable to a very wide range of soils on a national basis. The system is not sensitive to locally important differences among soils with the same interpretative placement. For local decisions, relative rankings within the same interpretative placement may be extremely important because frequently the question is how to make the best decision within a locale. Interpretative criteria may have to be adjusted to reflect regional or local peculiarities. Soil potentials attempt to rationalize between the constraints of a national interpretative system and the advantages of making decisions locally on a relative basis.

Management Groups

Management groups identify soils that require similar kinds of practices to achieve acceptable performance for a soil use. In practice, management groups are limited to uses that involve the growth of plants; in theory, management groups could pertain to nonagricultural uses. All of the soils in a management group are not expected to have identical management needs; although, the needs defined for each management group must apply to all of the included soils. The broader the groups, generally the less specific are the descriptions of the management needs. The number of classes for a management group depends on the range of soil properties, the intensity of use, the purpose of the grouping, the audience for which it is intended, and the amount of pertinent information available. The number of classes must balance between the need for homogeneity within a class and the complexity that results from increasing the number of classes. The advantages of management groups can be destroyed by making the classes either so broad that the soils within a group differ greatly or so narrow that the number of classes is large and the differences among classes too small.

The most generally applied soil management group is the land capability classification system for farming. Other management groups are the woodland suitability groups and range sites. Recently, management groups have been defined for purposes of a national soil inventory. Prime farmland, for example, is a kind of management group. More recent groups include the Fertility Classification System (Sanchez et al., 1982) and methods to group soils based on productivity indices and resilience of soils to certain uses.

National Specific-Use Placements

This section considers nationally developed evaluations for closely defined soil uses. Most of the interpretations for narrowly defined objectives can be stated as either limitations or suitabilities. Some users may prefer an expression that employs both approaches, such as stating the suitability and also listing the limiting properties according to severity or difficulty to overcome.

Historically, limitations have been the favored form for prediction about the interpretations of a soil for a particular use. Actually, the expression of interpretations may take any form that suits the needs of the user. Some users prefer a positive statement with a listing of limiting properties. The septic tank absorption system suitability rating is an example of a prediction based on limitations.

Interpretations that involve the soil as a source of something or as a material (for example, top soil) have been framed in terms of relative suitabilities rather than limitations. In addition to limitations and suitabilities, interpretative generalizations employ the probability of occurrence (such as source of sand and gravel) and a listing of the restrictive interpretative soil properties without a class placement (such as aspects of water management).

Limitation ratings.—Soils may be rated according to limitations for soil uses. Limitation ratings are usually based on hazards, risks, or obstructions presented by properties or characteristics of undisturbed soil. Limitation ratings use terms of severity such as slight, moderate, or severe.

Slight. Presents, at most, minor problems for the specified use. The soil gives satisfactory performance with little or no modification. Modifications or operations dictated by the use are simple and relatively inexpensive. With normal maintenance, performance should be satisfactory for a period of time generally considered acceptable for the use.

Moderate. Does not require exceptional risk or cost for the specified use, but the soil does have certain undesirable properties or features. Some modification of the soil itself, special designs, or maintenance are required for satisfactory performance over an acceptable period of time. The needed measures usually increase the cost of establishing or maintaining the use, but the added cost is generally not prohibitive.

Severe. Requires unacceptable risk to use the soil if not appreciably modified. Special design, a significant increase in construction cost, or an appreciably higher maintenance cost is required for satisfactory performance over an acceptable period of time. A limitation that requires removal and replacement of the soil would be rated severe. The rating does not imply that the soil cannot be adapted to a particular use, but rather that the cost of overcoming the limitation would be high.

Some soils have such extreme limitations that they should be avoided for certain uses unless no reasonable alternatives are available. Such soils have one or more features that are so unfavorable for the use that the limitation is extremely difficult and expensive to overcome. For example, shallow bedrock or inundation for a long duration are extreme limitations for onsite sewage disposal and for underground utilities. The rating of very severe is sometimes used for such extreme cases.

Suitability ratings.—Soils may be rated according to the degree of suitability for specific uses. Suitability ratings are based on the characteristics of the soils that influence the ease of using or adapting a soil for a specific use. A three class suitability system is commonly used.

Good. Includes soils that have properties favorable for the specified use. Satisfactory performance and low maintenance cost can be expected.

Fair. Includes soils that have one or more properties that make the soil less suitable than those rated good.

Poor. Includes soils that have one or more properties that are unfavorable for the specified use. Overcoming the unfavorable properties requires special design, extra maintenance or cost, or field alteration.

A fourth class, *unsuited*, is sometimes used for soil or soil material that is unacceptable for the specific use unless extreme measures are employed to alter the undesirable characteristics.

Suitability ratings may also be supplemented with the restrictive features that affect the performance of a soil for a specific use. These restrictive features may be a list of soil properties that are important for a specific use and may be listed with each class for which they apply. An example is, *fair*—watertable at depths of 25 to 50 cm, *poor*—bedrock at depths of less than 50 cm. Listing suitabilities with restrictive features in this manner gives the user more complete information by identifying other properties or features that may need treatment for the given use.

Other generalizations.—Evaluation of limitation or suitability is not feasible for some uses. For sand and gravel as construction material, a kind of soil may be rated only to show the probability of finding the material in suitable quantity. For some uses, the restrictive features may be given without a rating; for example, the features affecting use of the soil for irrigation or drainage of cropland. Commonly, the location is fixed for such soil uses and alternative sites are less of a consideration. The question then becomes what are the problems rather than whether to use the soil for the desired purpose. Merely noting features can be helpful to users, especially if important interactions are recorded.

Local Relative Placements

If interpretations are locally made, it becomes feasible to rank soils on a strictly relative basis and to introduce local knowledge about soil behavior that may have been excluded from more general national ratings. The term *soil potential* has been used to describe locally controlled numerical ratings that give the relative ranking of soils for a given use. This is in contrast to the national specific-use interpretative system which emphasizes criteria that apply nationwide and thus are more general than rankings based on local data that include costs to overcome limitations and costs to maintain a system.

The process of determining a soil potential requires an evaluation of the capacity of the soil to produce a crop or support a given structure or activity at a cost expressed in economic, social, and environmental units. Determination of potentials usually cannot be accomplished by soil scientists working alone. In particular, identification of corrective measures requires other disciplines.

Soil potentials for a soil survey area are of greatest value in local planning of specific tracts of land. If comparative ratings of every soil in a specific tract for a particular use are available, then a rational decision can be made whether to proceed, to change the plans, or to find another area that has soils with higher potential. The best soils in the specific tract for the particular use may be among those with low potential in the soil survey area overall, although this fact has no bearing on the relative evaluation for the specific tract.

The extent to which a given property is limiting and, in many cases, the practices that can be used to overcome the limitation are influenced by other properties of the soil. An example is the low strength of some soils in coarse-silty families. Such soils may not be limiting for dwelling foundations if the shallowest depth of free water exceeds 2 m. If, however, the shallowest depth of free water is within 25 to 50 cm of the base of the foundation, then these soils may be decidedly limiting for foundations. The process of determining soil potentials, which involves the interaction of knowledgeable local people, makes it possible to use more sophisticated criteria than is feasible for the national specific-use program.

Soil potentials are presented either as a set of qualitative, relative classes or in a numerical scale. The first step is to identify for a particular use the soil properties of significance. These properties may be the same as the basic soil interpretative attributes but are not limited to these properties. Critical values for each property are defined and may include properties that are not limiting. For example, the occurrence of free water below 60 cm may not interfere with the production of soybeans; but the critical depth may be 120 cm for the production of alfalfa. Thus, soil potentials are crop and property specific.

The second step in rating soil potential is to identify the corrective measures. Alternatives that appear to be applicable for each soil use should be listed. The most common sources of information are examples where the practices have been successfully used. Soil research and field trials may identify new practices. A single practice may not be fully effective unless it is used in combination with other practices. This may require broadening the definition of a single practice to include interrelated practices. Alternative practices can commonly be substituted. For example, dwellings can be built without basements on integral slab foundations and avoid the necessity of reinforced basement walls.

The third step in rating soil potential is to determine the cost or difficulty of overcoming soil limitations. Relative rather than absolute costs of corrective measurements are generally desirable. If the cost of overcoming the limitation is judged to be prohibitive, the soil is rated to have low potential for that use. Information on cost provides a guide to landowners and local planners.

The fourth step is to identify the limitation that would exist after the corrective measures have been installed. Certain practices are fully successful in overcoming limitations on some soils. Performance is as good as that of soils that do not have the limitations or even better. For other soils and uses, however, no corrective measures are available at an acceptable cost. For many situations, practices may substantially lessen the effects of soil properties, but problems still remain.

To express soil potentials numerically, values are assigned to those soil properties and site conditions that influence performance. Some approaches assign penalty points to limiting soil properties or site conditions, and others assign points based on favorable properties or conditions.

An illustrative formula for the Soil Potential Index (SPI) is:

$$SPI = P - CM - CL$$

P is the standard of performance or yield as locally defined. An index value of 100 for P is commonly used, but it may be any value; for example, the potential yield in kilograms per hectare may be employed. *CM* is an index of cost of the needed corrective measures. Finally, *CL* is an index of the extent to which the feasible corrective measures are not fully successful. It reflects costs for annual or periodic maintenance, for inconvenience or aggravation, or for substandard yield.

Alternatively, qualitative ratings of soil potential may be employed. An example of a three class set follows:

High potential. The soil meets or exceeds the requirements stipulated in one or more of the following statements:

(1) The soil has few limitations, or practices for overcoming the limitations are available at a reasonable cost.

(2) Crop production is profitable and at least average for the area.

(3) For a particular use, performance of the soil is satisfactory or as good as, or better than, local standards.

(4) Environmental quality, both on and off the site, is maintained at a level that is better than the average for the area.

(5) After corrective measures have been installed, any continuing soil limitations do not appreciably reduce production, performance, or environmental values.

Medium potential. The soil has a combination of properties intermediate between those qualifying for high potential and those qualifying for low potential. Production is somewhat below local standards, cost of corrective measures is high, or continuing limitations after measures have been installed detract from environmental quality or economic return.

Low potential. The soil has a combination of properties, including one or more of the following situations:

(1) Serious soil or site limitations exist and measures for overcoming them are not available or are considered locally to be too expensive.

(2) Crop production is substantially below the local average and is economically marginal or submarginal.

(3) Performance of the soil is below local standards or below the normal expectations of the land user, even under the best available management.

(4) Environmental quality, both on and off the site, is considerably degraded by the use.

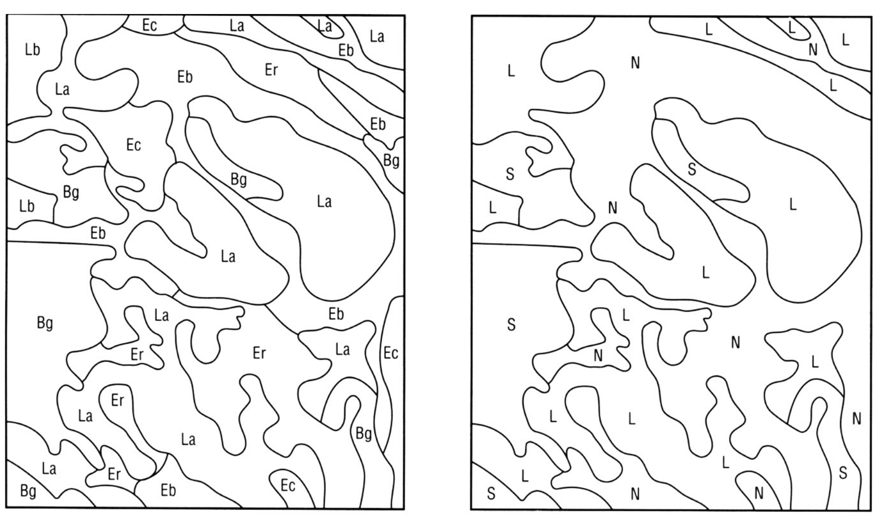
(5) Serious soil limitations continue to affect the use even after corrective measures have been installed.

A five-class system may be needed. *Very high* potential distinguishes soils that have few or no limitations affecting the land use. Only standard practices, systems, or designs are needed on these soils; no special practices involving additional cost are needed. *Very low* potential applies to soils so severely limited that they cannot be made to even marginally perform for the use.

Interpretive Soil Properties

Soil survey interpretations are provided for specific soil uses. Interpretations for each soil use are based on a set of interpretative soil properties. These properties include site generalities such as slope gradient, measurements on individual horizons (e.g., particle size distribution), temporal repetitive characteristics that pertain to the soil as a whole (e.g., depth to free water), and potential for diastrophic events (e.g., down-slope movement). Most of the interpretative soil properties are included in the description text and are on the tables associated with a particular map unit (fig. 6-1).

FIGURE 6-1



Section of a detailed soil map on the left and its interpretation on the right. The map units have been rated slight (L), moderate (N), or severe (S) for a specific use.

Abbreviated descriptions follow for the more commonly used interpretative soil properties. Formal classes have been assigned to several of the interpretative soil properties. These classes generally are not given unless they are used in field morphological descriptions. All of the classes are in the *National Soils Handbook* of the Soil Conservation Service. Local conditions may dictate other interpretative soil properties or a greater emphasis on a subdivision of some of the interpretative properties here listed.

Assignment Guidelines

In principle, the system permits the assignment of interpretative soil properties and related interpretations by map unit based on the named components, generally phases of soil series. Properties of the minor components of a map unit may be included if adequate sampling techniques are used to characterize the map units of a survey area.

Commonly, representative values are specified by layers or horizons. These layers normally reflect the mode for depths and sequences of horizons for the soil series. Only major horizons are delimited and are generally related to surface layer, subsoil, and underlying material.

Ranges are commonly attached to numerical quantities. The ranges are designated to encompass both the actual variation to be expected within the modal concept of the named soil and the expected analytical variation.

Setting

Annual air temperature.—This is the mean air temperature for the calendar year.

Elevation.—This is the range in height above sea level.

Frost-free period.—This is the average length of the longest period that is free of killing frost.

Precipitation.—This is the mean annual moisture received, including rainfall and solid forms of water.

Slope.—This is the range in slope gradient in percent (ch. 3).

Field Water Characterization

Available water capacity.—This is the volume of water that should be available to plants if the soil, inclusive of rock fragments, were at field capacity. Volumes are expressed both as a volume fraction and as a thickness of water. The standard of reference is the *water retention difference* (under 4C in Soil Survey Laboratory Staff, 1992). Reductions are made in the water retention difference for incomplete root ramification that is associated with certain taxonomic horizons and features such as fragipans, and for chemical properties that are indicative of root restriction such as low available calcium and high extractable aluminum. Corrections for the osmotic effect of high salt concentrations also may be made. The amount of available water to the expected maximum depth of root exploration, commonly either 1 or 1 1/2 m, or a physical or chemical root limitation, whichever is shallower, has been formulated into a set of classes. For the class sets, the depth of rooting that is assumed and the class limits that are stipulated differ among the taxonomic moisture regimes.

Drainage class.—This class (ch. 3) places major emphasis on the relative wetness of the soil under natural conditions as it pertains to wetness due to a water table.

Flooding.—This refers to inundation by flowing water. Frequency and duration classes are employed. These are described in chapter 3 (fig. 6-2).

Free water occurrence.—This includes the depth to, kind, and months of the year that a zone of free water is present within the soil (ch. 3).

FIGURE 6-2

Soil subject to flooding.

Hydrologic soil groups.—This is a set of classes that pertain to the relative infiltration rate of soil under conditions of maximum yearly wetness. It is assumed that the ground surface is bare and ice does not impede infiltration and transmission of water downward (ch. 3).

Ponding.—This refers to inundation by stagnant water. The duration and month(s) of the year that ponded water occur are recorded (ch.3).

Particle Size Distribution

USDA particle size classes (based on < 2mm fraction).—This is the relative proportion by weight of the particle separate classes <2 mm in diameter (textural classes) as modified by adjectival classes based on the proportion, size, and shape of rock fragments and by the proportion of organic matter if high. The classes are defined in chapter 3. Measurement is described under 1A2, 3A, and 3B (Soil Survey Laboratory Staff, 1992).

Fraction >250 mm (based on whole soil).—This quantity is expressed as a weight percent and is inclusive of unattached pieces of rock up to an unspecified upper limit, but it does not exceed the size of the pedon. The rocks more than 250 mm do not affect the Unified or AASHTO classifications, but they may have a large influence on suitability for certain soil uses (ch. 3).

Fraction 75 - 250 mm (based on whole soil).—This quantity is expressed as a weight percent of the whole soil, inclusive to an undefined upper limit which is less than the size of the pedon. Consult chapter 3 and methods 1A2 and 3B (Soil Survey Laboratory Staff, 1992). The quantity does not affect the Unified and AASHTO placements. It may, however, have a large influence on suitability for certain uses.

Percent passing sieve numbers 4, 10, 40, and 200 (based on < 75mm fraction).— These quantities are the weight percent passing sieves with openings of 4.8 mm, 2.0 mm, 0.43 mm, and 0.075 mm in diameter, respectively. The quantities are expressed as a percentage of the less than 75 mm material. The percent passing the number 4 and 10 sieves may be estimated in the field (ch. 3), or measured in the office or laboratory under methods 1A2 and 3B (Soil Survey Laboratory Staff, 1992). The material passing the 40 and 200 sieves may be measured directly in the laboratory (designation D 422-063, ASTM, 1984) or estimated from the USDA particle separate measurements made as described under 3A (Soil Survey Laboratory Staff, 1992).

Clay (based on < 2mm fraction).—This is the <0.002 mm material as the weight percent of the total <2 mm. The pipette method under 3A (Soil Survey Laboratory Staff, 1992) is the standard. For soils that disperse with difficulty, the clay percentage commonly is evaluated from the 1500 kPa retention under 4B (Soil Survey Laboratory Staff, 1992). Carbonate of clay size is included.

Fabric-Related Analysis

Moist bulk density.—This is the oven dry weight in megagrams divided by the volume of soil in cubic meters at or near field capacity, exclusive of the weight and the volume of fragments >2 mm. Method 4A1 in (Soil Survey Laboratory Staff, 1992), the so-called clod density method, is the common laboratory reference determination.

Shrink-swell potential.—These are a set of classes of reversible volume change between field capacity and oven-dryness for a composition inclusive of rock fragments. Actual shrink-swell, in contrast, is dependent on the minimum water content that occurs under field conditions. The standard laboratory method 4D (Soil Survey Staff Laboratory, 1992), involves computation of the strain from the volume decrease of bulk density clods that are oven-dried from the water content at the suction selected to estimate field capacity, (fig. 6-3).

FIGURE 6-3

Cracks in a Vertisol.

Available water capacity.—This is the volume of water that should be available to plants if the soil, inclusive of rock fragments, were at field capacity. Values are expressed both as a volume fraction and as a thickness of water per thickness of soil. The standard of reference is the water retention difference under 4C (Soil Survey Laboratory Staff, 1992). Reductions are made in the water retention difference for incomplete root ramification associated with certain taxonomic horizons and features such as fragipans, and for chemical properties indicative of root restriction such as low available calcium, and high extractable aluminum. Corrections for the osmotic effect of high salt concentrations also may be made.

Saturated hydraulic conductivity.—This class placement pertains to the amount of water that would move downward through a unit area of saturated in-place soil in unit time under unit hydraulic gradient (ch. 3). Estimates are based on models that relate laboratory measurements on soil cores to the interpretative soil properties and morphology (O'Neil, 1952; Baumer, 1986). The quantity has been referred to as *"permeability."*

Engineering Classification

Liquid limit.—This is the water content at the change between the liquid and the plastic states. It is measured on thoroughly puddled soil material that has passed a number 40 sieve (0.43 mm) and is expressed on a dry weight basis (ASTM method D 4318-83 in **ASTM, 1984).**

Plasticity index.—This is the range in water content over which soil material is plastic. The value is the difference between the liquid limit and the plastic limit of thoroughly puddled soil material that has passed a number 40 sieve (0.43 mm). The *plastic limit* is the water content at the boundary between the plastic and semisolid states. The measurement of the plastic limit is described in ASTM method D 4318-83 (ASTM, 1984).

Unified classification.—This is a classification of soil material designed for general construction purposes. It is dependent on the particle size distribution of the <75 mm, the liquid limit, and the plasticity index and on whether the soil material is high in organic matter (ASTM test D 2487, in ASTM, 1984). There are three major divisions: mineral soil material having below 50 percent particle size <0.074 mm (pass 200 mesh), mineral soil material having 50 percent or more particle size <0.074 mm, and certain highly organic soil materials. The major divisions are subdivided into groups based on the liquid limit, plastic index, and the coarseness of the material that exceeds 0.074 mm (retained on 200 mesh).

AASHTO classification.—This is a classification of soil material for highway and airfield construction (Procedure M 145-73. In Am. Assoc. of State Highway and Transportation Officials, 1984). It is based on the particle size distribution of the <75 mm and on the liquid limit and the plastic index. The system separates soil materials having 35 percent or less, which is <0.074 mm, from those soil materials having over 35 percent. Each of these two divisions are subdivided into *classification groups* based on guidelines that employ particle size, liquid limit, and volume change. A *group index* may be computed based on the liquid limit and plasticity index in addition to the percent <0.074 mm. The *group index* is a numerical quantity based on a set of formulas.

Chemical Analysis

Calcium carbonate equivalent.—The methods under 6E (Soil Survey Laboratory Staff, 1992) are the standard of reference.

Cation exchange capacity.—The methods of reference are 5A3b for soil with a pH below 5.5 and method 5A8 if the pH is 5.5 or above (Soil Survey Laboratory Staff, 1992).

Gypsum.—The quantity pertains to the <20 mm. The methods of reference are under 6F (Soil Survey Laboratory Staff, 1992).

Organic matter.—The methods of reference are under 6A (Soil Survey Laboratory Staff, 1992). Measured organic carbon is multiplied by a factor of 1.72 to obtain organic matter.

Reaction (pH).—The standard is the 1:1 water pH (method 8C1f, Soil Survey Laboratory Staff, 1992). For organic soil materials the pH in 0.01M CaCl2 is employed. Classes are in chapter 3.

Salinity.—A set of classes is employed for the concentration of dissolved salts in a water extract. The classes are expressed as electrical conductivity. The measurement of reference is made on water extracted from a saturated paste (method under 8A, Soil Survey Laboratory Staff, 1992). Units are decisiemens per meter (dS/m).

Sodium adsorption ratio.—This is evaluated for the water extracted from a saturated soil paste. The numerator is the concentration of water soluble sodium and the denominator is the square root of half of the sum of the concentrations of water soluble calcium and magnesium (5E, Soil Survey Laboratory Staff, 1992).

Sulfidic materials.—On exposure to air the pH of soil materials that contain significant sulfides becomes very low. The requirements are defined in the latest edition of the *Keys To Soil Taxonomy*. Methods for total sulfur are under 6R (Soil Survey Laboratory Staff, 1992). Direct measurement of the pH after exposure to air is also employed.

Physical Features or Processes

Depth to bedrock.—This refers to the depth to fixed rock. Hard and soft bedrock are distinguished. Hard bedrock is usually *indurated* but may be *strongly cemented*, and excavation difficulty would be *very high* or *higher* (ch. 3). Soft bedrock meets the consistence requirements for *paralithic* contact (Soil Survey Staff, 1975).

Depth to cemented pan.—This is the depth to a pedogenic zone that is *weakly cemented* to *indurated* (ch. 3). *Thin* and *thick* classes are distinguished. The thin class is less than 8 cm thick if continuous and less than 45 cm if discontinuous or fractured. Otherwise, the thick class applies.

Mass movement.—Three kinds of rather large scale irreversible soil movement are recognized: *downslope movement* may occur if the soil is loaded, excavated below, or is unusually wet; *ice-melt pitting* may result from melting of ground ice after vegetative cover has been removed; and differential settling may occur related to wet-dry cycles.

Total subsidence.—This is the potential decrease in surface elevation as a result of drainage of wet soils having organic layers or semifluid mineral layers. The subsidence may result from several causes: loss of water and resultant consolidation; mechanical compaction; wind erosion; burning; and of particular importance for organic soils, oxidation.

Depth to permafrost.—The critical depth is determined by the active layer. utilities, footings, and so on are placed below the active layer. The minimum depth is affected by the depth of annual freezing. Permafrost depth may be strongly influenced by the soil cover.

Potential frost action.—This pertains to the likelihood of upward or lateral movement of soil by formation of ice lenses and the subsequent loss of soil strength upon thawing. Large scale collapse to form pits is excluded and considered under mass movement. Soil temperature, particle size, and the pattern of water states are used to make predictions.

Erosion

The K Factor.—The factor appears in the Universal Soil Loss Equation (Wischmeier and Smith, 1978) as a relative index of susceptibility of bare, cultivated soil to particle detachment and transport by rainfall. Measurements are made on plots of standard dimensions. Erosion is adjusted to a standard of 9 percent slope. K factors are currently measured by applying simulated rainfall on freshly tilled plots. Earlier measurements integrated the erosion for the year for cultivated plots under natural rainfall. K may be computed from the composition of the soil, saturated hydraulic conductivity, and structure.

The T Factor.—This is the soil loss tolerance which can be used with the Universal Soil Loss Equation (Wischmeier and Smith, 1978). It is defined as the maximum rate of annual soil erosion that will permit crop productivity to be sustained economically and indefinitely. The T factors are integer values of from 1 through 5 tons per acre per year. The factor of 1 ton per acre per year is for shallow or otherwise fragile soils and 5 tons per acre per year is for deep soils that are least subject to damage by erosion.

Wind erodibility groups.—This is a set of classes given integer designations from 1 through 8, based on compositional properties of the surface horizon that are considered to affect susceptibility to wind erosion. Texture, presence of carbonate, and the degree of decomposition of organic soils are the major criteria. Associated with each wind erodibility group is a wind erodibility index in tons per acre per year. The *wind erodibility index* is the theoretical, long-term amount of soil lost per year through wind erosion. It is based on the assumption that the soil is bare, lacks a surface crust, occurs in an unsheltered position, and is subject to the weather at Garden City, Kansas (Woodruff and Siddoway, 1965). Tillage frequency and practices are not specified.

Corrosivity

Uncoated steel.—The rating depends on texture, drainage class, extractable acidity (methods under 6H, Soil Survey Laboratory Staff, 1992), and either resistivity of a saturated soil paste or electrical conductivity of the saturation extract (methods under 8E and 8A, respectively, Soil Survey Laboratory Staff, 1992).

Concrete.—The ratings depend on texture, occurrence of organic horizons, pH, and the amounts of magnesium and sodium sulfate or sodium chloride in the saturation extract (methods under 8A, 8C, and 6, Soil Survey Laboratory Staff, 1992).

Interpretative Applications

In this section the process of developing soil interpretations for land uses is discussed and the kinds of soil interpretations or groupings of soils are presented.

Soil interpretations may be developed at many levels of generalization or abstraction. Traditionally, interpretations have been developed for national application. These criteria, however, may be too general for applications at the local or regional levels. The national criteria, however, may be the basis from which to narrow limits or add further criteria for the local situation.

The process of developing interpretations for a specific land use follows a scientific method as do other processes in a soil survey. The soil scientist or group preparing the criteria reviews the literature, interviews experts, makes observations of soil performance under the specific use, develops a set of criteria using the basic soil properties, tests the criteria, and finally adopts the system. The process rarely becomes static. As new technologies become available, the criteria must be reevaluated.

Soil interpretations are a paradigm of how soils respond for a specific use. They are models that use a set of rules or criteria that are based on, or fed by, the basic soil properties, modeled properties, or classes of properties. In some cases it may be necessary to model a subset or intermediate interpretation to evaluate potential frost action, corrosivity, or potential for mass movement.

The interpretations are most often developed in response to user needs, thus the development process must include input from the user and professionals from other disciplines. User feedback is crucial in the iterative process of refining a specific interpretation.

Example.—Table 6-1 contains the criteria for interpreting soils for septic tank filter fields.

Table 6-1. Interpretive Soil Properties and Limitation Classes for Septic Tank Soil Absorption Suitability

Interpretive Soil Property	Limitation Class		
	Slight	Moderate	Severe
Total Subsidence (cm)	--	--	> 60
Flooding	None	Rare	Common
Bedrock Depth (m)	> 1.8	1-1.8	< 1
Cemented Pan Depth (m)	> 1.8	1-1.8	< 1
Free Water Occurrence (m)	> 1.8	1-1.8	< 1
Saturated Hydraulic Conductivity (µm/s)			
Minimum 0.6 to 1.5 m [a/]	10-40	4-10	< 4
Maximum 0.6 to 1 m [a/]			> 40
Slope (Pct)	< 8	8-15	> 15
Fragments > 75 mm [b/]	< 25	25-50	> 50
Downslope Movement			c/
Ice Melt Pitting			c/
Permafrost			d/

[a/] 0.6 to 1.5 m pertains to percolation rate; 0.6 to 1 m pertains to filtration capacity

[b/] Weighted average to 1 m.

[c/] Rate severe if occurs.

[d/] Rate severe if occurs above a variable critical depth (see discussion of the interpretive soil property).

Table 6-2 illustrates how the criteria are applied to the map unit of Sharpsburg soils in the appendix. These tables are used to illustrate the process of developing an interpretation. (N.B.: The classes of hydraulic conductivity are those used currently in interpretations and are not coincident with the new class limits given in ch. 3.)

Table 6-2. Values of applicable interpretive properties for septic tank suitability for Sharpsburg silty clay loam, 5 to 9 percent slopes; Soil Survey of Lancaster County, Nebraska, (Brown et al., 1980).

Property	Limitation Class			Values
	Slight	Moderate	Severe	
Flooding	X			None
Bedrock Depth	X			>1.8 m
Free Water Occurrence	X			>1.8 m
Saturated Hydraulic Conductivity				
Minimum 0.6 to 1.5 m			X	1-4 μm/s
Maximum 0.6 to 1 m	X			1-4 μm/s
Slope		X		5-9
Fragments > 75 mm	X			trace

The soil scientist or group of individuals developing an interpretation first determine a list of soil properties that are known, or are thought to be, important for septic tank filter fields. Depth to water table, permeability, depth to bedrock, depth to cemented pan, depth to permafrost, slope, flooding, ponding, susceptibility to downslope movement, and susceptibility to pitting are considered important properties in this case. After determining the list of soil properties, the soil scientist or group of individuals develop limits for each property and each class (slight, moderate, severe). This iterative phase is often the most difficult. The initial set of criteria is tested in different areas of the country using a wide array of soil conditions. Results of the tests may require adjustments to the criteria and retesting. Once the limits are set they may be arrayed in the table according to degree of severity or importance.

Testing and reevaluation.—The interpretative paradigm is under continuous scrutiny by user feedback, ranging from local homeowners' associations and units of government to national environmental agencies and organizations. Soil scientists continue the testing of interpretations through observations and discussions with local user groups during the soil survey process.

National Inventory Groupings

Technical soil groupings have been developed as criteria for the application of national legislation concerned with the environment and with agricultural commodity production. Groupings may pertain to agricultural productivity and diversity, erosion potential, surface and ground water quality, maintenance of wetlands, or other groups to meet national needs. Four national groupings are described as examples: *prime farmlands*, *unique farmlands*, *hydric soils*, and *highly erodible lands*. Specific criteria in the *National Soils Handbook* may be studied to demonstrate how various taxonomic and nontaxonomic map unit criteria, coupled with interpretative soil properties, have been employed to construct definitions for national inventory purposes.

Prime farmland. This is land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops. It must also be available for these uses. It has the soil quality, growing season, and moisture supply needed to produce economically sustained high yields of crops when treated and managed according to acceptable farming methods, including water management. In general, prime farmlands have an adequate and dependable water supply from precipitation or irrigation, a favorable temperature and growing season, acceptable acidity or alkalinity, acceptable salt and sodium content, and few or no rocks. They are permeable to water and air. Prime farmlands are not excessively erodible or saturated with water for a long period of time, and they either do not flood frequently or are protected from flooding.

Unique farmland. This is land other than prime farmland that is used for the production of specific high value food and fiber crops. It has the special combination of soil quality, location, growing season, and moisture supply needed to produce economically sustained high quality and/or high yields of a specific crop when treated and managed according to acceptable farming methods. Examples of crops are tree nuts, olives, cranberries, citruses and other fruits, and vegetables.

Hydric soils. These are soils that are saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions in the upper part. They make up part of the criteria for the identification of wetlands.

Highly erodible land. These lands have been defined in order to identify areas on which erosion control efforts should be concentrated. The definition is based on Erosion Indexes derived from certain variables of the Universal Soil Loss Equation (Wischmeier and Smith, 1978) and the Wind Erosion Equation (Woodruff and Siddoway, 1965). The indexes are the quotient of tons of soil loss by erosion predicted for bare ground divided by the sustainable soil loss (T factor).

Land-Use Planning

Land-use planning is the formulation of policies and programs for guiding public and private land use in areas of any size where different uses compete for land. The word "land" in this context implies attributes of place and other factors besides soil. Planners must consider place, size of area, relation to markets, social and economic development, skill of the land users, and other factors. Soil surveys can help in land-use planning by serving as an introduction to the soil resources of the area and by providing a source of information for the evaluation of the environmental and economic effects of proposed land uses. Soil surveys can be interpreted for land-use planning through groupings or ratings of soils according to their limitations, suitabilities, and potentials for specified uses.

Local planning.—Local government units such as those of cities, towns, and counties do local planning. The planning applies to complexes of farms and ranches, to housing developments, shopping centers, industrial parks, and to entire communities or political units.

Local planners use interpretations of soils and other information to develop recommendations on alternatives for land use, patterns of services, and public facilities. Planners may need interpretative maps at different scales depending on the objective. Interpretations of small areas for local planning rate limitations, identify management or treatment needs, and predict performance and potential of individual kinds of soils identified on detailed soil survey maps. Interpretations of areas that include entire governmental units evaluate the soils for all competing uses within the planning area. These maps are smaller in scale, and the units are associations of soil series or of higher taxa. Local planners commonly need ratings of the whole association for alternative uses. Special maps showing the location of areas having similar potentials or limitations for certain uses may be helpful for planners. Information about the amounts and patterns of soils having different potentials within each association can be given in tables or in the text of a soil survey report.

Regional Planning.—Certain problems pertain to areas that cover several political units. For these situations, regional planning is appropriate. The principal functions of regional planning are the collection, analysis, and dissemination of planning and engineering information, preparation of long-range plans, and coordination among the agencies involved.

Most soil maps for regional planning are small scale maps generalized from detailed soil survey maps. Soil interpretations show the differences between the map units in terms of suitabilities and limitations for the principal competing uses. The distribution of map units having similar behavior for a given use are commonly shown on special maps. An accompanying text describes the units, explains the basis for the ratings, and may also describe the effect of the pattern of associated soils on the use of specific parcels. Regional planners commonly need more specific information about the suitability of small parcels than can be obtained from generalized soil maps. For example, they may find an area that is generally good for recreation, but they also need to know that a potential site for a reservoir has soils suitable for storing water before the regional plan can be completed.

Farmland

Soil surveys in agricultural areas identify the soil characteristics that determine the suitability and potential of soils for farming. Interpretations for farming involve placement of the soils in management groups (land capability system) and identification of the important soil properties that pertain to crop production, application of conservation practices, and other aspects of agriculture. The other aspects of agriculture include yield potential, susceptibility to erosion, depth to layers that restrict roots, available water capacity, saturated hydraulic conductivity, the annual pattern of soil-water states (including soil drainage class, inundation, and free water occurrence), qualities that describe tilth, limitations to use of equipment (including slope gradient and complexity, rock fragments, outcrops of bedrock, and extremes in consistence), salinity and sodium adsorption ratio, presence of toxic substances, deficiency of plant nutrients, capacity to retain and release plant nutrients, capacity to retain soluble substances that may cause pollution of ground water, capacity to absorb or deactivate pesticides, and pH as related to plant growth and the need for liming.

The fate of added nutrients and pesticides, as related to farm management and cropping systems, is an important consideration in nonpoint water pollution. The identification of critical soil properties as related to resource management systems is crucial in the wise use of the land. The *Land Capability System* shows the suitability of soils for agricultural uses (Klingebiel and Montgomery, 1961). The system classifies soils for mechanized production of the more commonly cultivated field crops—corn, small grains, cotton, hay, potatoes, and field-grown vegetables. It does not apply directly to farming systems that produce crops, such as some fruits and nuts that require little cultivation, or to crops that are flooded, such as rice and cranberries. It also cannot be used for farming systems that depend on primitive implements and extensive hand labor.

Soil productivity is the output of a specified plant or group of plants under a defined set of management practices. It is the single most important evaluation for farming. In general, if irrigation is an optional practice, yields are given with and without irrigation. Productivity can be expressed in quantity of a product per unit land area, such as kilograms or metric tons per hectare. For pasture, productivity can be expressed as the carrying capacity of standard animal units per unit area per season or year—or as live-weight gain. Productivity may be expressed as a rating or index related to either optimum or minimum yields, or it may be indexed to a set of soil qualities (properties) that relate to potential productivity. Productivity indices have the advantage of being less vulnerable to changes in technology than are expressions of productivity based on yields.

Productivity ratings express the predicted yields of specified crops under defined management as percentages of standard yields. They are calculated as follows:

$$\text{Productivity rating} = \frac{\text{predicted yield per unit area x 100}}{\text{standard yield per unit area}}$$

Such a rating provides a scale for comparing the productivity of different kinds of soils over large areas. Ratings lend themselves to numerical treatment. Productivity ratings permit comparison of the productivity of crops having yields that differ markedly in numerical values. For example, a certain soil has a yield of corn for silage of 60,000 kg/ha and of 9,000 kg/ha for grain corn. These entities represent similar levels of production so the productivity ratings would be similar. Selection of the standard yield of a crop depends on the purpose of the rating. For national comparison, the standard yields should be for a high level of management on the best soils of the region for the crop. If potential production is of interest, yields under the best combination of practices are used.

Productivity ratings for individual crops can be combined to obtain a general rating for the soil over its area of occurrence. The individual ratings are weighted by the fraction of the area occupied by each crop, and a weighted average is calculated that characterizes the general productivity of the soil.

Productivity indices tied to soil properties are used as a relative ranking of soils. Soil properties important to favorable rooting depth and available water capacity normally are chosen. Some productivity models rely on a few critical soil properties such as pH and bulk density to rate soils (Kiniry et al., 1983). The EPIC model is a comprehensive productivity calculator that integrates many soil and climatic processes (Williams et al., 1989). Giving a relative ranking to soils, as well as calculating the impact of cropping systems on soil erosion and productivity, is worthwhile.

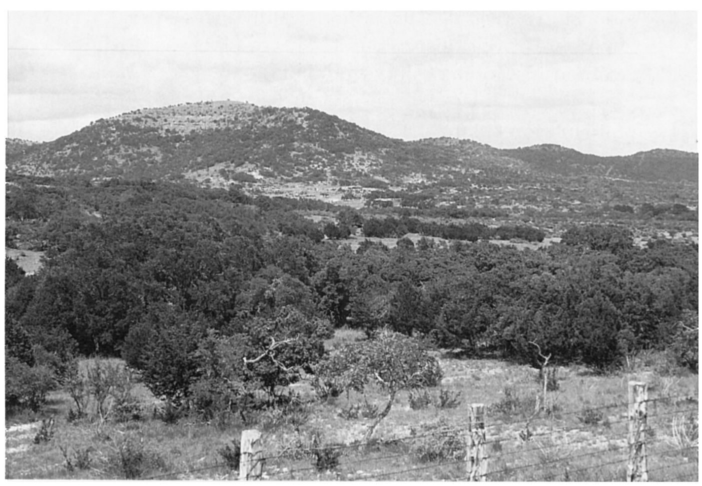
The soil fertility capability classification (FCC) system is a technical Soil Classification system that focuses quantitatively on the physical and chemical properties of the soil that are important to fertility management (Sanchez et al., 1982). Information required by the system is obtained from pedon descriptions and associated field data, laboratory characterization data, and *Soil Taxonomy*. The system is applicable to upland and wetland rice crops, pasture, forestry, and agroforestry needs under high- or low-input systems. The system does not rank soil, but rather it states the soil properties important to management decisions which will differ by crop type and management system. The system provides management statements for the classified soil and lists the general adaptability of various crops.

Resiliency of soils is an interpretation that relates to the ability of a soil to rebound from depletion of plant nutrients or organic matter or to rebound from the degradation of physical or chemical properties. The resiliency ratings are based on estimates of the natural fertility of the soil, available water capacity, favorable rooting depth, particle size distribution, and distribution of salts in the profile, if present. Resiliency ratings are important in evaluating alternative management systems that are based on lower chemical inputs. Traditional practices that use high inputs of chemical fertilizers and pesticides often mask properties of the soils that are important to crop production. Resiliency of soils is also important in evaluating long-term affects of management systems on soils.

Rangeland

Rangeland has a native vegetation of grasses, grasslike plants, forbs, and shrubs. In many areas, introduced forage species are also managed as rangeland. The vegetation is suitable for grazing and browsing by animals. Rangeland includes natural grasslands, savannahs, many wetlands and deserts, tundra, and certain shrub and forb communities. Soil-range site correlation within a soil survey gives the suitability of the soil to produce various kinds, proportions, and amounts of plants (fig. 6-4). This knowledge is important in developing management alternatives needed to maintain site productivity. Rangeland interpretations are given as range sites.

FIGURE 6-4



Two range sites on different soils.

Range sites are ecological subdivisions into which rangeland is divided for study, evaluation, and management. A range site is, therefore, a distinctive kind of rangeland that differs from other kinds of rangeland in its ability to produce a characteristic natural plant community. It is typified by an association of plant species that differs from that of other range sites in the kind or proportion of species or in total annual production. The natural plant community, in the presence of natural disturbances—fire, insects, drought—and the absence of abnormal disturbances and physical site deterioration, is the climax plant community for the range site.

A range-site description commonly contains the following information:

1. Landscape factors that describe the geographic location, physiography, and associated stream and nonstream water features of the site;
2. Climate factors that consider the soil moisture and temperature regimes, ambient climate, and moisture and temperature distribution patterns;
3. Soil factors that are most important in developing soil-vegetation relationships and that affect plant growth—the major soil families, geologic formation, features of the soil surface, surface horizon and texture, soil depth, major root zone thickness and its available water capacity, kind and amount of accumulations, profile rock fragments, reaction, salinity, sodicity, soil-water states, water table, and flooding;
4. Vegetation factors that describe the various kinds of tree, shrub, forb, grass, and grasslike, components of the plant community:

   The vegetative factors are the percent of cover and the composition and production of the plant community. Percent composition is expressed as a range of percent for each plant species identified by air-dry weight. Production is the total annual yield of air-dry forage, expressed as a range of values that reflect long-term weather variations. Yields are usually based on measured values;
5. Species list of wildlife that are associated with the site or are expected to use the site in the climax situation and will directly influence plant community dynamics;
6. Community dynamics that describe known or expected time relationships attributed to natural disturbances—periods between wild fires, cyclic insect infestations, or other disturbances to the composition of the plant community;
7. Site interpretations that give the potential importance of the site for each of its major uses and the feasibility of restoring depleted areas by seeding suitable species.
8. Listing of soils grouped into the site by soil survey area, map unit symbol, and soil name and phase.

Forest land

Forest land is dominated by native or introduced trees with an understory that consists of many kinds of woody plants, forbs, grasses, mosses, and lichens. Some forest communities produce, at least occasionally, enough understory vegetation suitable for forage to permit grazing.

Soil-forest site correlation within a soil survey gives the suitability of the soil to produce wood products. If forest land is important in a soil survey, the estimated productivity of the common trees is given for each individual soil. The understory vegetation is described at the expected canopy density most representative of forest stands having a normal production of wood. Determination of the soil productivity for forest products requires close collaboration between foresters and soil scientists.

Wood production or yield is commonly expressed as the *site index* or as some other measure of the volume of wood produced annually. Site index is the average height of dominant and codominant trees of a given species at a designated age. Measurements of site index are usually extended to a number of like soils where data are unavailable. The site index is correlated to each soil and may be further interpreted in terms of cubic meters per hectare.

Soils may be grouped using the *ordination system*. The symbols that make up the system indicate productivity potential and the major limitations for the use and management of individual soils or groups of like soils. The first part of the ordination symbol is the class designator. This is a number that denotes potential productivity in terms of the nearest whole cubic meter of the wood growth per hectare per year for the soil based on the site index of an indicator tree species. For a number of species, data are available for converting site index to average annual wood growth. The second part of the ordination symbol, or subclass, indicates soil or physiographic characteristics that limit management—stoniness or rockiness, wetness, or restricted rooting depth. A third component of the ordination symbol, or *group*, is sometimes employed to distinguish groups of soils that respond similarly to management. When the group symbol is used, soils that have about the same potential productivity are capable of producing similar kinds of trees and understory vegetation and have similar management needs.

Soils may be rated for such factors as susceptibility to mechanical compaction or displacement during forestry operations, limitations that result from burning, hazards from soil-borne pests and diseases and limitations imposed by specific soil properties such as wetness. The management of trees begins with an understanding of the soil on which the trees grow or are to be grown. Soil surveys include information that can be used effectively in the management of forest land; for example,

Erosion hazard. This is the probability that erosion damage may occur as a result of site preparation and the aftermath of cutting operations, fires, and overgrazing.

Equipment limitations. These are limits on the use of equipment either seasonally or year-round due to soil characteristics such as slope, surface rock fragments, wetness, and surface soil texture.

Seedling mortality. This rating considers soil properties that contribute to the mortality of naturally occurring or planted tree seedlings such as droughtiness, drainage class, and slope-aspect. It does not consider plant competition.

Windthrow hazard. This is based on soil properties that affect the likelihood of trees being uprooted by wind as a result of insufficient depth of the soil to give adequate root anchorage. Depth of the soil may be affected by a fragipan, bedrock, gravel, or a high water table. Differences in root systems related to tree species are not considered. The rating is usually independent of the probability of high winds unless the soil is typically on landscape positions susceptible to high winds.

Plant competition. This is the likelihood of invasion or growth of undesirable plants in openings in the tree canopy. Soil properties such as depth to the seasonal water table and available water capacity have the most affect on natural regeneration or suppression of the more desirable plant species.

Trees to plant. This is a list of one or more adapted species for producing tree crops.

Windbreaks

Windbreaks are made up of one or more rows of trees or shrubs. Well-placed windbreaks of suitable species will protect soil resources, control snow deposition, conserve moisture and energy, beautify an area, provide wildlife habitat, and protect homes, crops, and livestock. The plant species used in windbreaks are not necessarily indigenous to the areas that are planted. Each tree or shrub species has certain climatic and physiographic limits and, within these limitations, a particular species may be well or poorly suited because of soil characteristics. Correlation of soil properties and adaptable windbreak species, therefore, is essential.

A listing of adaptable species is given for each kind of soil where windbreaks will serve a useful purpose—such as open field-planting, interplanting in existing woodland, and for environmental modifications like wind or water barriers and wildlife habitat. The plant species identified for these purposes are stratified by height classes at twenty years of age.

Recreation

Interpretations in heavily populated areas are made for golf fairways, picnic sites, and playgrounds; in sparsely populated areas for paths, trails, and campsites. Interpretations for ski slopes and snowmobile trails are made in some places. Ratings are usually made on the basis of restrictive soil interpretative properties such as slope, occurrence of internal free water, and texture of surface horizons.

Interpretations for recreation must be applied cautiously. Many recreational areas in the United States have only Order 3 or more general soil surveys. Map units for such soil surveys are commonly associations or complexes of soils that may differ markedly in their limitations and suitabilities. Furthermore, general suitability of the map unit must take into consideration not only the qualities of the individual kinds of soil but also the soil pattern and potential interactions. Suitability may depend on a combination of several kinds of soil in a pattern appropriate to the intended use. Finally, factors other than soils are important in recreational planning. Aesthetic considerations, location, accessibility, land values, access to water and to public sewer lines, presence of potential impoundment sites, and location relative to existing facilities may be important even though none of these factors is evaluated for map units.

Wildlife Habitat

Soils influence wildlife primarily through control over the vegetation. Description of the soil as wildlife habitat has two parts. In one part, the suitability class for different vegetation groups is recorded. These vegetation groups are called habitat elements. Each habitat element is a potential component of the environment of wildlife. Hardwood trees and shallow water areas are examples of habitat elements. In the other part of the description, soils are rated separately for several kinds of wildlife, including animals adapted to openland, woodland, wetland, and rangeland (fig. 6-5). Current land use and existing vegetation are not considered, because these factors are subject to change and cannot be determined from a soil map. Wildlife population is also disregarded because of the mobility of wildlife and the possibility of a changing population over the year. The ratings show where management for wildlife can be applied most effectively and which practices are appropriate. The ratings may also show why certain objectives may not be feasible; for example, the production of pheasants. Some soil surveys include explicit management recommendations. These may be particularly

FIGURE 6-5

Ducks in a rice field

Construction Materials

Soil survey interpretations estimate suitability of the soil as construction material and show where to locate material that can be mined. Material that compacts readily and has high strength and low shrink-swell potential is preferred as base material under roads and foundations. Gravel and sand are used for concrete, road surfacing, filters in drainage fields, and other uses. Organic soil material is used widely as horticultural mulch, potting soil, and soil conditioner. Mineral soil material of good physical condition, is generally rich in organic matter and is applied to lawns, gardens, roadbanks, and the like. Soils can be rated as probable sources of these materials. The quality of a particular site, however, usually cannot be specified.

Building Sites

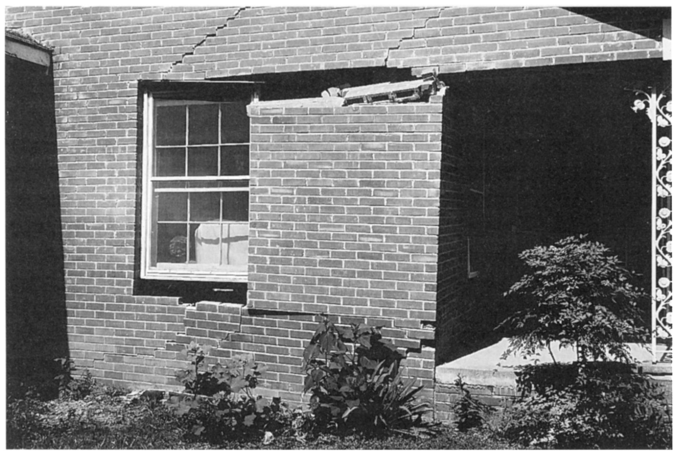
Interpretations are made for the construction of small buildings; for the installation of roads, streets, and utilities; and for the establishment of lawns and the landscaping of the grounds around the building. Such soil uses involve high capital expenditures in relatively small areas. Usually, onsite evaluation is necessary.

Soil survey interpretations are useful for comparing alternative sites, in planning onsite investigations and testing, and in land-use planning. Soil maps can assist in selecting building sites that are near areas suitable for utilities, parks, and other needs.

The preparation of building sites may alter soil properties markedly. To this extent, some interpretative soil properties for the undisturbed sites must be applied cautiously. Upper horizons may have been removed and locally translocated, which might either increase or decrease the depth to horizons important to behavior. The pattern of soil-water states may be changed. Areas may have been drained and, therefore, are not as wet as indicated. On the other hand, irrigation may be employed to establish and maintain vegetation leading to a more moist soil and possible deep movement of water. Pavements, roofs, and certain other aspects of construction increase runoff and may cause inundation at lower elevations where the soil survey does not indicate such a hazard.

Building construction: Construction and maintenance of buildings belongs primarily to architecture and engineering. Additionally, large multistory structures are generally supported by footings placed below the depth of soil survey examination. Soil survey interpretations are not, therefore, a definitive source of information for building construction. Important interpretative soil properties for small buildings and accessory installations such as roads and utilities include slope, inundation, mass movement, potential frost action, depth to bedrock and to cemented pans, shrink-swell, rock fragments >75 mm, erodibility, subsidence, and soil strength (fig. 6-6).

FIGURE 6-6



Damaged house.

Roads, streets, and utilities: The performance of local roads and streets, parking lots, and similar structures is often directly related to the performance of the underlying soil, (fig. 6-7). Pipelines and conduits are commonly buried in soil at shallow depth. The properties of the soil may affect cost of installation and rate of corrosion. Soil material is used directly as topsoil, roadfill, and aggregate for concrete. Soil interpretations can predict some

FIGURE 6-7

Damaged sidewalk.

suitabilities and limitations of different kinds of soil for these uses, although soil interpretations cannot predict performance of highways, major streets, and similar structures. For such construction, onsite testing is necessary. Use of soil surveys information, however, may reduce the number of borings and engineering tests.

Soil information in conjunction with engineering testing can identify those soils that can be stabilized in place for a road base and establish where gravel or crushed stone will be needed. Soil surveys can be helpful in deciding methods of stabilizing cuts and fills. Soil properties may affect the cost of installation and length of service of buried pipelines and conduits. Shallow bedrock, for instance, greatly increases the cost of installation. Rate of corrosion is related to wetness, electrical conductivity, acidity, and aeration (fig. 6-8). Differences in properties between adjacent horizons, including aeration, enhances corrosion in some soils. Soil properties affect the cathodic protection provided by sacrificial metal buried with pipes. Rock fragments can break protective coatings on pipes. Shrinking and swelling of some soils may preclude the use of certain kinds of utility pipe.

FIGURE 6-8

Corrosion of buried pipe.

Soil survey interpretations may be particularly useful in the prediction of problems likely to be encountered along proposed routes. Hydrologic information and other data combined with interpretative soil properties, such as the hydrologic group, can be helpful for the estimation of potential runoff for design of culverts and bridges. The probability of bedrock and unstable soils that require removal or special treatment can be determined from soil surveys.

Lawns and landscaping: Soil survey interpretations give general information about planning, planting and maintaining grounds, parks, and similar areas. Particularly important is the suitability of the soil for turf, ornamental trees and shrubs, the ability to withstand trampling and traffic, the suitability for driveways and other surfaced areas, and the ability to resist erosion. A number of soil chemical properties may be critical, especially for new plantings. Interpretations for particular plants and the treatments for a specific site require other disciplines.

Many lawn and ornamental plantings are made in leveled areas on exposed subsoil or substratum or on excavated material that has been spread over the ground. Interpretations can be made as to the suitability of such soil materials for lawns and other plantings, the amount of topsoil that is necessary, and other treatments required for satisfactory establishment of vegetation. Highway departments use soil interpretations to establish and maintain plantings on subsoil material in rights-of-way.

Waste Disposal

Waste disposal is divided on the basis of whether the practice places the waste in a relatively small area or distributes the waste at low rates over larger areas of soil.

Localized placement. Waste in this context includes a wide range of material from household effluent, through solid waste, to industrial wastes of various kinds. Effluent from septic tanks is distributed in filter fields. Liquid wastes are stored and treated in lagoons constructed in soil material. Solid wastes are deposited in sanitary landfills and covered with soil material.

The criteria for septic tank absorption fields is given in table 6-1. Extremes in saturated hydraulic conductivity and free water at a shallow depth limit the use of soil for septic tank absorption fields. Sewage lagoons require a minimum saturated hydraulic conductivity to prevent rapid seepage of the water, a slope within certain limits, and slight or no possibility of inundation or the occurrence of free water at shallow depths.

Soils are used to dispose of solid wastes in landfills, either in trenches or in successive layers on the ground surface. For trench disposal, properties that relate to the feasibility of digging the trench—depth to bedrock, slope—and factors that pertain to the likelihood of pollution of ground water—shallow zone of free water, inundation occurrence, and moderate and high saturated hydraulic conductivity—have particular importance. For disposal on the soil surface, saturated hydraulic conductivity, slope, and inundation occurrence are important.

Low-intensity distribution. Soil is used to render safe, either solid or liquid, waste that is spread on the ground surface or injected into the soil. Manures, sewage sludge, and various solids and waste waters are included, the latter particularly from factories that process farm products. In general, the physical process of distribution of the waste is limited by steep slopes, rock fragments > 75 mm and rock outcrops, and wetness. The rate at which wastes can be applied without contamination to ground water or surface water is called *loading capacity*. Low infiltration values limit the rate at which liquid wastes can be absorbed by the soil. Similarly, low saturated hydraulic conductivity through most of the upper meter limits the rate at which liquid wastes can be injected. Shallow depth of a hardpan or bedrock or coarse particle size reduces the amount of liquid waste that a soil can absorb in a given period. The time that wastes can be applied is reduced by the soil being frozen or having free water at shallow depths. Low soil temperatures reduce the rate at which the soil can degrade the material microbiologically.

Soils differ in their capacity to retain pollutants until deactivated or used by plants. Highly pervious soils may permit movement of nitrates to ground water. Similarly, saturated or frozen soils allow runoff to carry phosphates absorbed on soil particles or in waste deposited on the soil directly to streams without entering the soil. Soils that combine a limited capacity to retain water above slowly permeable layers and a seasonal water excess may allow water that is carrying pollutants to move laterally at shallow depths. Such water may enter streams directly.

Large quantities of waste may change the soil. Heavy loading with liquid waste may reduce the oxygen supply so that yields of certain crops are depressed. On the other hand, heavy loadings can provide beneficial irrigation and fertilization for other kinds of soil and crop combinations. Animal wastes improve most soils, but the effects differ according to the kind of soil.

The first step in making interpretations of soils for disposal of wastes is usually to determine how disposal systems for each kind of waste have performed on specific kinds of soil in the area. Experience may have been acquired in practical operations or by research. Soil scientists and specialists in other disciplines determine what properties are critical and how to appraise the effects of the properties. Limiting values of critical properties can be determined through experience and may be used in making interpretations where data on soil performance are scarce or lacking.

Water Management

Water management in this context is concerned with the construction of relatively small or medium impoundments, control of waterways of moderate size, installation of drainage and irrigation systems, and control of surface runoff for erosion reduction. These activities may involve large capital expenditures. Onsite evaluation commonly should be conducted, particularly of soil properties at depth. The usual Order 2 or Order 3 soil survey can be helpful in the evaluation of alternative sites, but onsite investigations are required to design engineered projects.

Ponds and reservoirs. Soil information is used in predicting the suitability of soils for ponds and reservoir areas. Impoundments contained by earthen dikes and fed by surface water have somewhat different soil requirements than those that are excavated and fed by ground water. Separate interpretations are commonly made.

Seepage potential of the soil, as determined by the minimum saturated hydraulic conductivity and the depth to pervious soil material, is an important factor for design of ponds and reservoirs. Slope also is of importance because it affects capacity of the reservoir. The *hydrologic group* of the soil (ch. 3) pertains to the prediction of runoff into a pond or reservoir.

Embankments, dikes, and levees. These are raised structures made of disturbed soil material constructed to impound water or to protect land from inundation. The soils are evaluated as sources of material for the construction. Particle size distribution and placement in the Unified system are important considerations. The interpretations do not consider whether the soil in place can support the structure. Performance and safety may require onsite investigation to depths greater than are usual in a soil survey.

Irrigation. Important considerations for the design of irrigation systems are feasible water application rates, ease of land leveling and the resultant effect on the soils, possibility of erosion by irrigation water, physical obstructions to use of equipment, and susceptibility to flooding. To meet these considerations, an Order 1 soil survey may be needed to include both deeper than customary observations and measurements of infiltration rates. Soil properties that may be the basis for the interpretations are saturated hydraulic conductivity, available water capacity, erodibility, slope, stoniness, effective rooting depth, salinity, sodium adsorption ratio (SAR), gypsum, and properties that may affect the level of response of crops (fig. 6-9).

FIGURE 6-9

Irrigation of grain sorghum.

Interpretations for irrigation in arid and semiarid regions may be more complex than for humid regions, because irrigation changes the soil-water regime more in arid and semiarid areas. Salinity and the SAR of the soils can be particularly significant, as can the quality of the irrigation water. In arid and semiarid areas, small differences in slope and elevation can lead to an accumulation of salt-laden drainage water in low places or the creation of a high water table if a proper drainage system is not provided.

Drainage. The term refers to the removal of excess water from soils for reclamation or alteration. Drainage construction criteria are established by engineers. The criteria include spacing and depth of subsurface drains, depth and width of open ditches and their side slopes, and allowable gradient. Properties of soils important to drainage include water transmission, soil depth, soil chemistry, potential frost action, slope, and presence of rock fragments greater than 75 mm.

Areal Application of Interpretations

The objective of most soil surveys is to provide interpretations for areas delineated on soil maps. This section considers the relationship of interpretations to map unit terminology and conventions, the interpretative basis of map unit design, and the uncertainty of interpretative predictions for specific areas within the map unit.

Map Units

The purpose of this section is to consider the relationships between the terminology and conventions employed to define and describe map units (ch. 2) and soil interpretations. The components of map units are the entities for which interpretations are provided. The application of interpretative information to areas of land must be through map unit descriptions and depends on an understanding of the map unit concept as it applies to interpretations.

Consociations, Associations, and Complexes.—For map units that are consociations, the interpretations pertain to a single, named soil and are applicable throughout the delineation. For *associations* and *complexes* the map unit is named for more than one component. For these kinds of map units the interpretations may be given for each named component or may be given for the map unit as a whole, depending on the objective. Information is commonly provided in the description of the map unit about the geographic occurrence of the named components of the map unit on the landscape. From this information, interpretations for each of the named components of the map unit may be applied to the portion of the landscape on which it occurs. Such an application requires, however, additional information beyond what the soil map alone can provide. The illustrative map unit of Bakeoven and Condon soils (app. I) is a complex of two phases of different soil series. The interpretations are applicable to each of the two phases considered separately. To apply these different interpretations separately requires knowledge of the location of each soil within the map unit delineation. The map unit description will provide information as to the location and extent of each named component of the map unit.

Map units differ in specificity of the named soils and hence in the broadness of the ranges for various interpretative soil properties. Phases of soil series, for example, are more specific soil concepts than are phases of a higher categorical level. Consequently, in general, the interpretative information for a phase of a soil series has narrower ranges.

Similar Soils.—These are soils that differ so little from the named soil in the map unit that there are no important differences in interpretations. These soils are not named components in the map unit. Recognition is limited to a brief description of the feature or features by which the soil in question differs from the soils in the map unit named. The following statement from the map unit of Sharpsburg soils (app.I) illustrates the point: —In places, the upper part of the material is silty clay. In a few areas, the underlying material contains a few lime concentrations."

Dissimilar Soils.—Map units are permitted to have certain proportions of included soils that differ sufficiently from the named soil to affect major interpretations. These soils are referred to as *dissimilar* (ch. 2). Usually the dissimilarities are such that the soils behave differently. Dissimilar soils are named in the map unit description if they are part of the name of another map unit in the soil survey area. Otherwise, the dissimilar soil is briefly described in a generic fashion: —medium-textured soil with bedrock at less than 50 cm.— Location of the dissimilar soils relative to landscape position may be given. Inferences as to the influence of the dissimilar soils on behavior of the map unit may be obtained from their interpretative properties and their location in the landscape. The map unit descriptions may state how the dissimilar soils affect soil behavior. Tabular soil properties and related interpretations do not include properties and interpretations of dissimilar soils. Yield estimates are, in principle, influenced by the occurrence of dissimilar soils if based on field-scale measurement; however, if yields are significantly affected, the —dissimilar— soil would likely be a named component of the map unit.

For map units that are *consociations*, the interpretations pertain to a single, named soil and soils similar to the named soil. Thus, they have a higher possibility of being applicable throughout the delineation than map units named by more than one taxon. For *associations* and *complexes*, map units with more than one component, the possibility of different kinds of interpretations are higher than consociations unless the soils are similar. In these units the interpretations may have to be presented on a probability or possibility basis. Where the soils are related to specific landforms or parts of land forms, interpretations can be related to soils and landforms.

Areal Extension of Interpretations

This may be accomplished by interpreting phases of soil series, as has been historically done, or by modifying the interpretative criteria or models to include the probability of occurrence of properties that affect a certain use. Both of the descriptive approaches that follow require the use of geographic information systems and computer technology to perform the necessary calculations and projections of soil properties areally.

- Phases of soil series have been the principal vehicle to make soil interpretations. Interpretations for the phases of soil series can be extended to map units if adequate information is available to predict the composition of the map delineation. Information on the composition of a map unit and its delineations and a measure of reliability is required. This includes information on composition and properties for included soil series or taxa in a delineation. Interpretations may then be presented in a set of probability statements such as the area has a 60-percent chance of severe limitations for septic tank filter fields because of free water at depths of less than 50 cm. These interpretations could be subdivided further if information is available for soils and landforms in the mapped area. For example, there is a 30-percent chance of moderate limitations on slight rises or knolls for septic tank filter fields because of free water at depths of 50 to 100 cm and a 90-percent change of severe limitations in swales due to free water at depths of less than 50 cm.
- Probabilities for soil properties require that criteria be developed for interpretations that are based on probabilities for occurrence of a limitation. Instead of a criterion that places a severe limitation on soil depth if depth is less than 50 cm, for example, a criterion might be constructed to place a severe limitation if more than 75 percent of an area has soil depth less than 50 cm. In the application of the interpretative model, information on the distribution of basic soil properties is needed for map units and their delineations. Using the data on composition of phases of soil series in a map unit, information on soil properties could be projected from properties of the phase of a soil series.
- Information on the basic soil properties within a map delineation could be collected using a statistical sampling scheme. To do so would require a more intensive field sampling scheme than if properties are projected based on phases of soil taxa and may be feasible for surveys done at a very large scale.

Information presented on a probability basis is essential if risk assessment procedures are to be employed in the interpretation of soils for specific land uses. Coupled with a climatic data base, a probability base presents a powerful method from which to predict soil responses and to develop resource management scenarios.

Areal Generalization

The level of generalization for the application of soil maps and the soil attribute information in soil surveys depends on the scale of the soil map, the taxonomic level used to define the map units, and the combinations of both map scale and taxonomic level. Hole and Campbell (1985) present a detailed discussion of generalizing soil survey information. In the following discussion, these methods of generalization will be discussed. Examples of applications at 3 levels of abstraction are included in the discussion.

Map unit information is commonly generalized from the relatively large scale maps in the soil survey reports to smaller scale maps, but phases of soil series are used to name map units. This is done by combining map units according to landscapes or landforms, physiography, use, vegetation, and geology or climate in order to create smaller scale maps. Such smaller scale maps as the general soil maps in published surveys, historically, use associations of soil series to name the map units.

Generalization of detailed soil maps can also be accomplished by naming or representing the map units at higher levels in the taxonomic system. Detailed surveys commonly use phases of soil series to name map units. This information, however, can be generalized in successive levels by using families, Great Groups, or Suborders to name the map units. This method is rarely used without an accompanying change in map scale.

In addition, generalizations may be made by changing both map scale and level of taxonomic representation. For example, a detailed soil survey (1:24,000 scale) has map units named by phases of soil series. Conversely, a very general map may have small scale such as 1:7,500,000 and map units named at the suborder or order level (highest taxonomic level). Intermediate combinations are possible and must be determined by the purpose for generalizing the information. It may be desirable to have a map scale of 1:7,500,000, but name the map units as associations for phases of soil series. To accomplish this, a method of determining map unit composition from the detailed map must be developed, or the composition is projected from a statistical sampling scheme after Reybold and TeSelle (1989).

Interpretive precision is deliberately sacrificed by cartographic or taxonomic generalization. This is done in order to get a summary map that can provide more general information about larger areas. Once cartographic generalization has taken place, the geographic precision has been sacrificed. For example, a 1:63,360 map that shows associations of phases of soil series is generalized from a detailed soil survey. In this case, the range of properties of each component of a map unit is relatively small. Probability statements for limitations, management needs, and performance of each component can be as specific for the 1:63,360 scale map as for the 1:24,000 scale map; although, the map units for the smaller scale map will have more components, thus diminishing geographic precision for the soil interpretations.

Conversely, on a 1:63,000 map that shows associations of phases of suborders (generalization of scale and taxonomic level), the range of properties of each constituent is large. Limitations and potentials of each constituent can be predicted only in general terms, and interpretations of their effects on use, management, and performance of the map unit must be correspondingly general.

The area of the delineations of interpretative maps should not exceed the area of concern for soil behavior interpretation. Three areas of concern have been given the names *operating units*, *communities*, and *regions*. These terms imply relative size of the delineations for which soil interpretations are needed, not to the area represented by the map as a whole.

Operating Units.—These are areas of land that usually are managed as a whole. The most common examples are farms and ranches. The operating units usually range in size from a few hectares to several thousand hectares. In addition to being used by the operators directly, soil maps for such areas are used by farm advisors, credit agencies, planners, and others who are interested in the suitabilities and limitations of soils in individual or contiguous operating units.

The map units usually consist of series or associations of soil series. At least two steps are required to interpret the map units. First, the individual kinds of soil are interpreted and rated for a given use. Then the interaction among the soils and the combined effects of all of the soils on the use, management needs, and expected performance of the mapped area are estimated to arrive at a prediction for the map unit overall. Generally, something is known about the local soil pattern from study locations. This information is used in evaluating portions of map unit delineations that are dominated by particular taxa. For soil maps prepared by generalizing Order 1 or Order 2 soil surveys, local associations of soil series can be easily identified and treated as components of map units.

Local planners use these maps and interpretations to develop recommendations on alternatives for land use, patterns of services, and public facilities. Local planners commonly need ratings of the whole association for alternative uses. Special maps showing the location of areas having similar potentials or limitations for certain uses may be helpful for planners. Information about the amounts and patterns of soils having different potentials within each association can be given in tables or in the text.

Communities.—These areas encompass communities, secondary or tertiary watersheds of major local streams, and other large areas. Map delineations may range from as few as 10 to as many as 1,000 square kilometers. The maps are used for regional planning and other purposes that require consideration of areas larger than individual operating units. In developing countries, maps of this kind are used to identify large areas that are suitable for a specific use. The map units are commonly associations of soil families, subgroups, or great groups. The map unit composition is usually quite heterogeneous. Soil properties, consequently, may have a wide range in most delineations. Soil behavior predictions must be general. The basis for the predictions may be intensive studies of relatively small tracts of land that represent extensive map units.

Soil behavior can be predicted directly from the taxonomic-based characteristics of named soils. An area might be identified as "Argiustoll-Argiaquoll-Haplustoll association on dissected, undulating loess-mantled plains." For each great group, the characteristics that pertain to soil behavior predictions are recorded and evaluations are made. The use, management, and performance of the map unit as a whole is evaluated based on the proportions and geographic patterns of the great groups. The appraisal for the map unit is necessarily general because much of the local detail is unknown.

Regions.—These areas commonly cover continents, large nations, or groups of nations. Soil maps usually have a scale of 1:250,000; although the scale may be as small as 1:1,000,000. The map units are generally associations of soil taxa ranging from the soil series to order levels of taxonomy. These small scale field maps are commonly generalized from soil survey maps at scales of 1:24,000 or larger. The objective of the generalization is to consolidate the soil information of the large areas. For areas that do not have detailed soil surveys, soil maps are made by reconnaissance methods. The information about soils commonly is least abundant and the delineations least precise for Order 5 maps and for schematic maps made without direct field investigations. The units on many maps of regions are associations of suborders, which indicate many soil properties that are important for broad interpretations. The pattern of soil-water states, for example, can be identified or inferred for suborders such as Udults, Ustults, Xerults, and Aquults. The soil temperature can be identified for some suborders, such as Tropepts and Boralfs. This information can be converted to certain broad interpretations—the kinds of plants that would grow well, for instance.

If such information as relief, physiography, and parent material is contained in the definition of a map unit, then additional interpretations are feasible. For example, the map unit designation

"Tropepts and Udults on maturely dissected basalt plateaus" implies information about soil temperature and the pattern of water states, land surface configuration, extractable acidity at depth, and relative fertility of some of the principal soils. Numerous soil behavior predictions about the map unit can be derived from such information.

Behavior prediction at this level must depend heavily on inference. The predictions should be at a level of generalization consistent with the confidence in the original data and in the inferences drawn from them. Soil behavior inferences for map units generalized from more detailed soil maps are more reliable than inferences based on map units formulated without a soil survey.

Illustrative Map Units

Three map units from published soil surveys are illustrated in the appendices: A single soil series (*consociation*), two soil series as a complex, and a single taxa above the soil series. Tabular information is given for the map units for which the named soils are soil series. Class limits are in either chapter 3 or chapter 6 or are given directly.