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A well-defined, quantitative model for determining soil contrast was developed to improve soil survey interpretations concerning the effects of mixtures of different kinds of soils on agricultural land use. The model was evaluated by determining the levels and reasons for soil contrast on mapped soil areas representing 5 different landscapes, each dominated by a different soil order.

Several preliminary models are discussed. The final model is based on twelve soil properties including slope, drainage, depth of rooting, texture and pH. For each property, the range of possible values was divided into a small number of classes. By comparing classes, five levels of contrast (Very Similar, Similar, Somewhat Contrasting, Contrasting, Very Contrasting) were established within each property. These same five terms, plus an additional Exceedingly Contrasting class, were used to characterize the overall degree of contrast between any two soils.

Overall contrast was determined by first comparing the property values of a pair of soils and determining the degree of contrast for

each property. Then the overall contrast was set equal to either the contrast level for the most contrasting property or properties, or to the next higher contrast level if several properties varied between the two soils.

Distributions of contrast levels within soil landscapes show that areas of Inceptisols, Ultisols, Alfisols and Mollisols are characterized by a high percentage of similar soils. The Aridisol landscape sampled had the highest percentage of exceedingly contrasting soils. The Alfisols and Mollisols sampled have the highest percentage of somewhat contrasting and very contrasting soils, respectively.

Reasons for soil contrast were determined both by identifying those few properties that actually dictated the contrast level and by calculating a weighted average contribution of each of the 12 soil properties. In general, lower levels of contrast were controlled by one or two properties. At higher levels of contrast, more properties varied, and no property had as dominant an effect. Slope was the major factor controlling the contrast of similar soils. Drainage, pH, texture, and depth of rooting differences, all of which reflected differences in parent materials, were most often expressed at somewhat contrasting or contrasting levels. The most common reason for very contrasting soils was flooding, and that occurred where an alluvial soil was adjacent to an upland soil.

A Model for Determining Soil Contrast
and its Application to Five
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Typed by Rebecca R. Villamayor for Faustino Paysan Villamayor

Dedicated with love

to

Becky, my wife

and

April Joy, my daughter

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TABLE OF CONTENTS

LIST OF FIGURES

Figure		Page

LIST OF TABLES

Table		Page

A MODEL FOR DETERMINING SOIL CONTRAST AND ITS APPLICATION TO FIVE DIFFERENT SOIL ORDERS

CHAPTER 1

INTRODUCTION

A great number of soil survey reports with detailed soil maps are available to the public. Detailed soil surveys of many counties, being conducted by the U.S. Soil Conservation Service, are still in process. The U.S. Forest Service and Bureau of Land Management also conduct soil surveys on public lands. Some private companies also are conducting soil surveys.

The soil survey process involves a tremendous amount of time, money and expertise. In order to maximize the benefits from these investments, soil survey reports must be utilized effectively. Information on current uses must be kept current, and information on new applications of soil survey information must be found.

One current use for soil survey reports is to determine the suitability of soils for different land uses. The suitability of soils for a particular land use is determined by the morphological and inferred properties of the soil and by certain landscape properties such as slope and flooding. Some of the morphological and inferred properties used to rate the suitability of soils for general farming in New York, for example, include texture, drainage, permeability, stoniness, pH of the B, total water holding capacity, rooting depth and trafficability (Olson, 1981). Slope and flooding are the primary landscape properties used in the National Soils Handbook (SCS, 1983) for determining the suitability of soils for different land uses. Information on all of these properties is contained in soil survey reports, and the information has been converted into soil suitability ratings for several common land uses. Other land use ratings could be developed from the same information.

Morphological and inferred properties alone, however, may not be adequate to determine the suitability of soils for a particular land use. Other attributes of the soil landscape, such as the size and shape of individual bodies of soil, may affect land use suitability. For example, a soil can have such small area that investments in it are not feasible, or the area can be so dissected that a cultural operation such as plowing is difficult. A single body of soil shown on a map can have other soils within it that may affect its suitability. These other soils are called inclusions, and their effects depend on how different these soils are. Interactions between neighboring soils, such as movement of soil material or moisture from one soil to another, also may affect land use suitability.

Size and shape may be even more limiting if the land use being planned is situated in an area composed of an admixture of different soils. Not only are the amount and kind of inclusions within bodies of soil important, but the degree of contrast or dissimilarity between adjacent soils also must be evaluated in terms of the morphological and inferred soil properties important for the land use in question.

Consideration of the properties of the admixture of soils in addition to the properties of a single soil is a great step towards more utilization of soil survey reports, particularly soil maps. It is a step towards integrating the information about the properties of a soil taken at a single point (morphological and inferred properties) with the areal or spatial properties of entire soil bodies.

The study of the properties of the mixture of soils is important for soil genesis, too. Interactions such as movement of salts, clays and organic matter may occur between soils making up the mixture of soils. Hole and Campbell (1985) termed this as bonding. Soil genesis can be better formulated if interactions between soils in a mixture are described aside from processes such as eluviation, illuviation and pedoturbation that occur within the soil horizons.

The study of the mixture of soils is also important for making generalized soil maps out of detailed maps. The knowledge of the major soils occupying a certain area that is depicted on a detailed map can help in identifying and mapping soil associations. A soil association is a landscape that has a distinct proportional pattern of soils. It is composed of some major soils for which a soil association is named and several minor soils (Hendricks, 1985).

Hole and Campbell (1985) enumerated several applications of generalized soil maps. Among them are: the use of generalized soil maps in forming regional and/or national policies, increased comprehension of maps, and making them more suitable for publication as the number of mapping units is reduced.

An example of the use of general soil maps is in the choice of areas where most of the soils are suitable for residences, roads, schools and other facilities. The soil associations in an area can be rated in terms of suitability for these land uses. Bartelli (1966) used the following criteria: soil associations rated as having slight limitations comprise soils that occur on slopes of less than 5%, are deeper than 36" to bedrock, have water table below 30" for more than 6 months, and are not subject to flooding. Soil associations rated as moderate have shallower water tables, are subject to infrequent flooding, and occur on slopes of 5 to 12%. Soil associations rated as severe comprise soils that flood frequently, are highly unstable, occur on slopes >12%, and have hard bedrock within 20" of the surface. On-site investigations are needed, however, to determine where these facilities will be located.

The process of soil survey can be aided by the study of the mixture of soils. Prediction of the occurrence of soils in an area can be made if the soil patterns occurring in other parts of the same area or in different areas of the same landscape are known. Gile and Hawley (1972) stated that the results of studies on soil genesis and distribution of desert soils typical of the large part of the Southwest can be used for predicting uses in places similar to the study area. The number of borings to be done during soil surveys also can be determined by the mixture of soils in an area. More borings are required in areas composed of smaller delineations of soils and in areas where the differences in the properties between neighboring soil areas are small (Godelman and Pugayev, 1976).

Specific land uses may be affected by the amount of contrast or dissimilarity between soils making up a mixture. The soils present in an area can be similar in properties or they can be contrasting. Soils that have similar properties will require similar management practices, and the pattern of admixture will have little or no effect on land use. Soils that are contrasting will require different management practices. One may not be able to apply the same level of fertilizers on contrasting soils, as most likely they will require different amounts of fertilizer. On a landscape made up of contrasting soils, growth, maturity and ripening of plants can vary, which could make harvesting difficult. The yield of crops also may vary on contrasting soils (Yodis, 1967). In some cases the soils in an area are so different that farming is not feasible.

Interest in the areal or spatial properties of soils has been limited. Hole and Campbell (1985) reported on some observations pertaining to areal properties of soils in some soil survey reports. Among these areal properties are size, shape, homogeneity, relief, topographic position, arrangement, slope and boundaries of map units. They stated, however, that these areal properties of soils "usually assume incidental, rather than primary significance in conventional soil science and soil survey". But because detailed soil maps show the different areal properties of a mixture of soils, they are good tools for studying the areal properties of soils.

The methods for considering the areal properties of a mixture of soils remain to be fully worked out. One of the areal properties of the mixture of soils that needs to be studied is the degree of contrast between adjacent soils in a mixture, particularly its determination or characterization.

The National Soils Handbook (SCS, 1983) establishes two classes of contrast, referred to as similar and dissimilar soils. The criteria for distinguishing between these classes are based on the properties that determine the classification of the soils being compared. Some of the properties that were mentioned are wetness, base saturation, and content of organic matter. Similar soils are alike in most properties or share the limits of the property used to differentiate the taxa. Similar soils are allowed to differ in no more than two or three criteria that differentiate between soil taxa. They also have similar conservation needs or management requirements for a specific land use.

Dissimilar soils do not share limits of some important diagnostic properties or have different use or management requirements for major land uses in the survey area. The properties that should be considered and their allowable differences, however, are not clearly defined. The differences among dissimilar kinds of soils are either large in number or in degree or both.

These criteria are sufficiently vague that it is difficult to determine the dissimilarity of soils using them. Properties such as wetness could be further subdivided into the different drainage classes, which would give an improved basis for determining soil contrast. Further, the criteria that differentiate the taxa may not be important to the land use being planned, and this is a limitation. It may be useful, too, to have additional contrast levels between similar and dissimilar.

These limitations could be overcome by developing a model for determining soil contrast that is a better-defined, more quantitative, and multi-level system for characterizing soil contrast. Such a model would make it possible for users of soil maps to make better decisions on the effects of different mixtures of soils on land use. This study is in response to this need.

The objectives of this study, therefore, are to:

1. Develop a quantitative model for classifying the degree of contrast between adjacent soils based on some morphological and inferred properties and on properties of the landscapes they occupy;
2. Characterize the contrast of the soils occurring on some soil landscapes that are composed primarily of a certain soil order;
3. Determine the causes for the different degrees of soil contrast between soils on some soil landscapes that are composed primarily of a certain soil order;
4. Compare the contrast and reasons for contrast of soils occurring on some soil landscapes that are composed primarily of a certain soil order.

Soil maps are known to have limitations in their portrayal of the exact size, shape, boundary, and location of soil bodies on the landscape. Some of these limitations are due to scale, which makes it difficult to show small soil bodies on the maps and to draw actual soil boundaries precisely. Despite these limitations, soil maps do have "great pedologic validity" (Hole, 1978), and for that reason they were used as the primary source of data for developing and evaluating the soil contrast model. It was necessary, however, to make certain assumptions concerning the relationship between soil-landscape bodies and their depiction on soil maps. These assumptions were:

1. Areas dominated by a particular soil association were considered landscape bodies. A landscape body is a landscape unit for which the maximum lateral change of landscape characteristics is used as the boundary criteria (Schelling, 1970). The landscape body is delineated in terms of parent material and topography in the soil survey reports that were studied. The dominance of some series in a soil association of a particular soil order in the soil survey areas that were studied shows that the state factors are more or less uniform. This assumption is important so that results of the studies in one part of a landscape body can be applied to other parts of the landscape body.
2. A delineation on a map corresponds to a single soil body. A soil body in this study is either a soil phase in a consociation, the soil phase most limiting to agriculture in a complex mapping unit, or the predominant soil phase of the miscellaneous land type in the study area. A soil body can have inclusions, but these were ignored or assumed to have properties similar to those of the matrix soil.
3. Most boundaries of soil bodies as they appear on maps are not sharp but gradual, and so cannot be precisely delineated. Human errors can also occur in the delineation of soil boundaries. In this study the soil boundaries were considered precise.
4. The properties of the typical pedon of a soil series were used for all the phases of the same soil series. Phase

criteria such as slope and drainage are also used. Thus, it was assumed that all phases of a soil series have the same properties unless some properties specific for a soil phase were given.

CHAPTER 2

FUNDAMENTALS OF SOIL LANDSCAPE ANALYSIS

This chapter discusses the nature and properties of soil landscapes.

Landscape

A landscape was viewed by Hole (1978) as "a view of a discrete body of land from an aircraft by an informed observer who has delineated the boundary of the landscape largely on the basis of information obtained from ground studies in the light of pertinent literature about the area in question".

The view of a landscape as discrete assumes that boundaries separate one landscape from another. Only arbitrary boundaries, however, may be drawn based upon a number of landscape properties, since the spatial changes of all the landscape properties do not coincide (Bucher, 1927 as cited by Hartsthorne, 1939).

The dimension of landscape that can be delineated can be large or small. A large landscape can be subdivisions of a country or a continent. This landscape can be delineated using the geology of the area, agroclimatic zones, vegetation and physiographic provinces. Landscapes occupying small areas within counties can be delineated based on landforms. A landform is a land feature of particular origin, position and shape (Pasto, 1953). The different landscapes that are delineated in the Soil Survey of Broome County, New York (Giddings et al., 1971), for example, are terraces, bottomlands, valley sides with gently sloping to moderately sloping terrain, uplands with gentle to very steep slopes, and uplands with moderate to steep slopes.

Landscape Model

A landscape model as given by Hole (1978) consists of consolidated bedrock (L-skeleton), potentially mobile solids (L-plasma), water (L-liquid), air (L-gases), and such coverings of biota (L-plants and animals) as conditions permit.

Hole and Campbell (1985) defined the soils portion of the landscape as soil landscape, or soilscape. Soilscapes consist of the upper portion of the landscape plasma, which is the total mass of unconsolidated and pedologic material present.

Fridland (1976a) used the words territory and soil mantle for landscape and soil landscape, respectively. A territory can range from a small area (a state farm) to a big area (county or river basin).

Soil Mantle

The soil mantle, also called soil cover or soil continuum, is the entirety of soils occurring in a territory. The existence of many terms for soil mantle is due to the different ways of translating Fridland's work (Hole and Campbell, 1985). The soil mantle is a three-dimensional body with its horizontal and vertical extents respectively equal to the area and depth of the soils in the territory. Soil cover is a regional, spatial concept that may be applied to any territory beginning with the entire globe and finishing with any small area.

Some properties of the soil continuum have been observed. The soil cover may be regarded as a "discrete-continuous formation that is physically continuous but generally discrete" (Fridland, 1976a). It is physically continuous in that the extent of soils is disturbed only by physical interruptions such as rock outcrops and water bodies, which are not soils. The soil cover, however, is also geographically discrete, since "some classificational groups of soils are spatially limited to narrow strips, whereas others occupy extensive regions" (Fridland, 1976a). Another reason for regarding the soil cover as a discrete-continuous formation is that the boundary between soils can be gradual or sharp. The reason for the occurrence of discrete formations of soils is due to the unequal gradient in the spatial variation of soils.

The soil continuum exhibits patterns that involve regularities in the spatial distribution of soils. Fridland (1976a) uses the terms soil cover pattern and zonal-provincial arrangement of the soil cover to express this idea. The soil cover pattern is the subject of this thesis.

Soil Patterns: Soil Cover Pattern and Zonal-Provincial Arrangement of Soils

Fridland (1976a) differentiated these two kinds of patterns. The soil cover pattern is the regularity of the spatial distribution of soils over small territories that can be fully revealed with detailed soil mapping, while the zonal-provincial arrangement of soils refers to the more generalized spatial distribution shown on small-scale maps.

The soil cover pattern involves multiple repetition and near-symmetric arrangement of its component soils, whereas in the zonal-provincial arrangement of soils, the constituent components -- zones, subzones and provinces, are unique and do not tend to repeat themselves. The zones, subzones and provinces can correspond to the order, suborder and great group of the U.S. Soil Taxonomy (Soil Survey Staff, 1975). However, only those orders, suborders and great groups that reflect the regional climate are zonal in nature, whereas, the rest do tend to repeat.

The components of the soil cover pattern are genetically related. Hydraulic interactions between component soils may move materials such as clay, salts and organic matter from one soil to another. Components of the zonal-provincial arrangement of soils are only spatially related. Boundaries between components of the soil cover pattern tend to be sharp, whereas boundaries between soil zones, subzones and provinces tend to be transitional and diffuse.

The main factor responsible for the zonal-provincial arrangement of soils is climate, through its influence on other soil forming factors. The soil cover pattern, however, is governed by changes in parent material, topography and vegetation that occur within in a small area under practically uniform climatic conditions.

The soil cover pattern, then, is a pedogeographic entity controlled by the spatial arrangement of soils that are genetically linked to various degrees and that produce definite spatial patterns. Some of the attributes of spatial patterns are the size and shape of component soil bodies. The soil cover pattern is also a pedogenetic entity that is controlled by the soil forming factors that govern the genesis of individual components and the interactions between them.

Relationships Between Soil Cover Patterns and Landscapes

Landscapes can be divided into various types or units. Hole (1953), for example, divided the glaciated landscape of Richland County, Wisconsin into rough upland, smooth upland, flats, hilly upland and barren hills.

Each landscape unit can correspond to a genetic unit. Genetic units are separate areas within a landscape that have been subjected to essentially uniform action of the soil forming processes over time. Thus, at some level of detail, genetic units can be considered uniform with respect to origin (Hole and Campbell, 1985).

The geographic properties of a given landscape unit may form distinctive identifying characteristics. For example, specific landscape units may be distinct from their neighbors in terms of the size and shape of their delineations.

The delineation of landscape aids in the study of soil cover pattern, as the same pattern can be expected to occur on similar landscapes. It also decreases the number of variables which may be considered to account for the variation of soil cover pattern, as each landscape has distinguishing properties.

Effects of Soil Forming Factors on Soil Cover Pattern

The effects of the different soil forming factors on the soil landscape were stated by Fridland (1974): "The character of components shows the influence exerted by the sum-total of the factors of soil formation (bioclimatic, lithological-geomorphological and historical ones). Even so, the successions in composition of the soil mantle are connected most often with successions of bioclimatic conditions. The genetic and geometric forms of the structure of the soil mantle also depend on the entire sum of the factors of soil formation, but lithological-geomorphological conditions are expressed more clearly in them." Components refers to the kinds of soils, and composition refers to the relative proportions of soils in an area. The structure of the soil mantle refers to the different patterns of soil.

Areas with soil bodies that are round, for example, may be associated with depressional forms (sink holes). These are closed systems in which the weathering and soil formation products cannot be removed except by subsurface flow or deflation. A fan shaped form of soils in an area is characterized by alluvial fans. This form is a geochemically open system for which the products of weathering and soil formation are readily removed (Fridland, 1974).

Elementary Soil Areal

The initial indivisible component, the simplest element, of the soil cover pattern is the elementary soil areal (Fridland, 1976a) or the elementary soil body (Hole and Campbell, 1985).

The elementary soil areal (ESA) is a soil formation free from any internal pedogeographic boundaries; its size is variable. It is a kind of soil occupying space that is bounded by other ESA's or non-soil formations (Fridland, 1976a).

The concept of pedogeographic boundary was elaborated by Fridland (1976a). Any soil boundary is a boundary between classificational soil groups. However, not all soil boundaries are pedogeographic boundaries. Pedogeographic boundaries are those boundaries enclosing soils with an unlimited range in size.

An ESA can have other soils within it. These other soils have areal sizes that vary only within narrow limits, and therefore the boundaries enclosing them are not pedogeographic boundaries. They are called limiting pattern elements and are defined as "small areas of only a few square meters (rarely a few tens of meters) distinguished by specific soils, their size being limited by the intrinsic nature of the factors controlling the specificity of their soils". Examples of limiting pattern elements are root systems of trees and anthills whose sizes are controlled by limited distribution of trees and ants, respectively, in an area.

Kinds of Elementary Soil Areals

Fridland (1976a) defines three different kinds of elementary soil areals (ESA):

1. homogenous ESA's - those for which the soils within the ESA belong to a single kind of soil within the lowest rank in the classification of soils in U.S.S.R., the soil kind. The homogeneity of such an ESA is not absolute because the properties of its constituent soils may vary within the limits set by the definition of the soil kind.
2. sporadically patchy ESA's - heterogeneous ESAs that have within them limiting pattern elements of biological origin

such as root systems of trees and anthills. These limiting pattern elements do not differ very much from the background soils and are of very limited dimensions. For the ESA to be sporadically patchy, there must be at least one classification difference at least on the level of soil kind between the limiting pattern elements and the background.

3. regular cyclic ESA's - those characterized by a sequence of soil patches similar in profile structure but with highly variable thickness of horizons. Regular cyclic ESA's have hexagonal patterns on the surface brought about by periodic swelling and cracking of the soil column and frequently by the collapse of materials from upper horizons to lower ones. The dimensions of these patches are limited and vary from a few decimeters to a few meters. Examples of regular cyclic ESA's are frost action or shrink-swell of clays that cause gilgai microrelief in Vertisols. The units within a regular-cyclic ESA have very little or no pedologic contrast.

It is not clear whether ESA's are actually shown on published maps that Fridland used in the study of soil cover pattern. However, Fridland (1976a) cited a study where a survey was done at a scale of 1:2000 that permits the mapping of ESA's. Other studies that he cited used a scale larger than 1:2000. Mapping at a larger scale was made possible by mapping and studying a smaller part of a landscape and then applying the results to the rest of the landscape. The soil cover pattern of a smaller part was predicted to be true for other parts of the landscape.

Pedons, Polypedons and Elementary Soil Bodies

The concepts of pedons and polypedons need to be discussed. These concepts developed from the search for a soil individual that could be both a unit for classification and the simplest unit making up the soil cover pattern.

A pedon is the smallest volume to be called a soil. Johnson (1963) paraphrased the definition of the pedon in the 7th approximation as "a small volume of soil that extends downward to the lower limit of common rooting of the dominant native perennial plants, or the lower of the genetic horizons, whichever is the deeper, roughly hexagonal in cross section, with a surface of 1 to 10 sq. m.; with a minimum lateral dimension of 1 m. and a maximum lateral dimension of about 3 1/2 m., depending on variability in the horizons. If the horizons are intermittent or cyclic and recur at intervals of 2 to 7 m., the pedon has a diameter that is one-half the length of the cycle. If the cycle is of wavelength <2 m., or if the horizons are continuous and of uniform thickness, the diameter of the pedon is 1 m".

Pedons, however, are smaller than the bodies required for ordinary measurement of slope and the determination of other larger scale features (Knox, 1965). Similar pedons are not mutually exclusive, as there is no way to determine where to place the boundaries of the first pedon. A single pedon also cannot exhibit the ranges in characteristics that are allowed for a series (Johnson, 1963). These limitations make the pedon not a soil individual.

Polypedon is the soil individual or "the real thing that we want to identify" in the 7th approximation (Soil Survey Staff, 1960). It is referred to as "one or more contiguous pedons, all falling within the defined range of a soil series" (Johnson, 1963). It is a real physical soil body, limited by 'not-soil' or by pedons of unlike character in respect to criteria used to define the series. Its minimum size is the same as the minimum size of one pedon, 1 sq. m., but it has no prescribed maximum area. Its boundaries with other polypedons are determined more or less exactly by definition. Within a given polypedon, the individual pedons may vary slightly or a great deal. For example, if a soil series is allowed to range in slope gradient from 0 to 25% slope, then a given polypedon corresponding to the series can have this range of slope also (Johnson, 1963).

Every polypedon can be classified into a soil series, but a series normally has wider ranges of characteristics than those shown by a single polypedon (Soil Survey Staff, 1975).

The elementary soil body (ESB) is a soil body without internal pedogeographic boundaries at the lowest categorical level (the soil series of the USDA), but it is actually a subdivision of a series, i.e. a soil phase (Hole and Campbell, 1985). Habermann and Hole (1980) use all delineations on published maps of soil phases and miscellaneous land types as soil bodies.

The use of soil phases as the lowest categorical level for an ESB makes it more similar to an ESA than when soil series are used as the lowest categorical level. Soil phases are more similar to soil kinds than soil series.

A soil body is an actual pedologic entity on a landscape and can be delineated and shown on soil maps only approximately. Map units used in soil map legends cannot represent the soil body exactly due to limitations imposed by scale and legibility. Map units named for one taxon may include bodies of other soils that may be too small to map. Intricate patterns of small soil bodies must be mapped as soil complexes. Some boundaries on a soil map can also be imprecisely delineated or may have different distinctness that cannot be expressed on the maps.

The soil maps that Habermann and Hole (1980) and Hole (1978) used in their studies on soil landscape analysis have scales from 1:15,840-1:24,000. These maps have smaller scales than those used by Fridland (1:2000 and larger), and so an ESB can be said to be more impure than an ESA. Thus, the working representations of ESA and ESB vary in terms of purity, but their concepts are similar.

Soil Combination or Combinational Soil Body

The soil cover pattern is characterized by multiple spatial repetition of ESA's. Links which join or unite several ESA's in a definite manner can be identified, and the soil cover pattern is formed by the multiple repetition of the links (Fridland, 1976b).

Fridland (1976b) called the linking of several ESA's a soil combination; Hole and Campbell (1985) called it a combinational soil body (CSB).

The elementary soil areals within a combinational soil body interact with each other. Interactions resulting from throughflow, soil creep, overland flow, mass movements, wind transport and other processes of erosion, transportation and deposition can occur between ESA's within CSB's (Hole and Campbell, 1985).

The typical arrangement and interconnections of ESA's are also shown in a combinational soil body. The CSB that best represents a soil pattern is the typical one, but other minor CSB's can occur within a soil cover pattern. Fridland (1976a) further stated that "the soil cover pattern model should not be a specific, individual soil combination, but a generalized ideal form of soil combination embodying only the main features of soil cover pattern -- its composition, interrelationship of components and geometry."

The soil association, which consists of a set of soil bodies that are segments of the soil mantle covering the soil surface (Simonson, 1971), is close to the concept of soil combination. Soil associations are composed of 2 or more polypedons that occur together in a characteristic repeating pattern. Each delineation of a soil association contains the same major kinds of soils occurring in similar patterns. The links among the component soils as well as the geometric properties of the component soils, however, are not often considered in the soil association.

Kinds of Links In Combinational Soil Body

The links between ESA's occurring in a combinational soil body can be bilateral, unilateral, poorly expressed or absent (Fridland, 1976b). A bilateral link is one in which the component soil bodies mutually affect each other. An example of a bilateral link is the "duo-flow" which occurs in regions characterized by seasonal moisture deficit (Hole and Campbell, 1985). This term refers to the movement of water downslope coupled with upward flow of water through evapo-transpiration to the crest of the knoll in areas of low precipitation. The amount of precipitation is not enough to counteract the reverse flow of water and associated deposits of solutes and suspensoids.

A unilateral link is one in which the interaction between component soil bodies is only one way. An example of a unilateral link is one occurring in areas without marked water deficit where water moves downslope but no upward flow of moisture is occurring.

A poorly expressed or absent link is one in which there is little or no interaction between component soil bodies. An example is a soil combination that is due to differences in parent materials such as that of a saline soil on clayey rocks and of nonsaline soils in coarser textured parent rocks (Carter and Wiegand as cited by Fridland, 1976b). The component soil bodies in the combinational soil bodies have weak genetic linkage or none at all.

Degree of Contrast in Combinational Soil Body

The component soils are also characterized by different degrees of soil contrast. The degree of contrast refers to the differences in soil properties among the component soils. Fridland (1976a) stated that the degrees of contrast within different kinds of soil combinations have not yet been adequately elaborated. It is only assumed that soils belonging to different cultivation (or amelioration) groups require different management practices and are therefore high contrast combinations, whereas those belonging to a single cultivation group are low contrast combinations.

Kinds of Combinational Soil Body

The different kinds of soil combinations are shown in Table 2.1.

Table 2.1. Fridland's (1974) classification of soil combinations

Degree of Contrast	Nature of links between components		
	Bilateral	Unilateral	Links either poorly expressed or absent
High	Complexes	Catenas	Mosaics
Low	Spottiness	Variations	Tachets

Complexes are composed of small areas of contrasting soils that alternate regularly at intervals of a few meters or tens of meters. The uses of complexes are determined by the properties of the whole complex and not by the individual component of soils.

Catenas, sometimes called combines (Fridland, 1976a), are soil combinations with regular alternation of large areas of contrasting soils (hectares and tens of hectares). Each component soil body occupies a large area that can be devoted to a specific land use.

Spottiness and variations are similar to complexes and combines in terms of the areas of component soil bodies. However, the component soil bodies of spottiness and variation have lower contrast than those of complexes and catenas.

Mosaics and tachets lack a regular alternation of the component soils. The component soil bodies of tachets and mosaics have a very weak relationship and their pattern of symmetry is indistinct. Mosaics consist of markedly different soils whereas tachets consist of similar soils.

Monocombinational and Polycombinational Soil Areal

An area can have either a certain single often-repeated soil combination, which is termed a monocombinational soil areal, or a complex combination comprised of several different but genetically interrelated simple soil combinations and ESA's, which is termed a polycombinational soil areal. Polycombinational soil areals are used for larger areas and are shown on smaller scales (Fridland, 1976a). Hole and Campbell (1985) termed the monocombinational soil areal and the polycombinational soil areal a simple (primary) combinational soil body and a complex (secondary) combinational soil body, respectively.

Kinds of Soil Patterns

There are many kinds of soil patterns. Fridland (1980) presented a classification of soil cover patterns that includes six taxonomic levels. The simplest classification of soil patterns is in terms of origin, as described by Hole and Campbell (1985):

A. Materials Pattern

Materials pattern includes arrangement of bodies of geologic materials such as loess blanket (geomaterial), bodies of pedogenic materials and features such as clays and caliche (pedomaterials), bodies of plant and animal materials (biomaterials), and bodies of mineral and organic materials resulting from human activity, such as that of sanitary landfills (homomaterials).

B. Form Pattern

Form pattern includes arrangement of landforms produced by geologic agents such as volcanoes (geoform), those created by pedogenesis such as patterned ground of tundra and gilgai (pedoform), those of plant and animal origin such as termite mounds (bioforms), and patterns created by human beings, such as arrangement of terraces for rice production (homoform).

C. Local-Climate Patterns

Local-climate patterns are arrangements of soils that are influenced by modification of climate. These modifications can be brought about either by plant-animal community (bio-local-climatic patterns), human activities such as irrigation (homo-local-climatic patterns) or pedogenesis such as contrasting albedo of adjacent dark and white encrusted soils (pedo-local-climatic patterns).

Pavlik and Hole (1977) described a drumlinoid landscape as having a geoform origin and linear soils. Habermann and Hole (1980) described a pedogeomorphic feature consisting of a large soil body (78 sq. km. in area) formed by the deposition of uniform glacial till that has undergone relatively little dissection due to the formation of a fragipan in the soils.

The most common patterns that are described are geomorphic, geomaterial, and pedomorphic patterns (Pavlik and Hole, 1977; Hole, 1978; Habermann and Hole, 1980). However, combinations of these different kinds of patterns exist.

Description of Soil Pattern

Soil pattern can be described by determining the characteristics of both the elementary soil areals and the combinational soil bodies. A quadrat of a soil landscape depicted on a detailed soil map can be used for gathering data necessary to describe soil pattern.

Characteristics of Elementary Soil Areal (ESA)

A. Content

The content of an ESA refers to the specific soil phase that comprises the ESA.

B. Geometry

The geometry of an ESA refers to the size, shape and contour irregularity or dissection of a body of soil, or its equivalent delineation on a soil map. Fridland (1976a) computed the mean size of an ESA using the formula

$$MS = \frac{\sum_{i=1}^{k} Pi}{k}$$

where: Pi is the areal size of an ESA,

k is the number of ESA(s), and

MS is the mean size.

Fridland (1976a) used the following arbitrary ranges of sizes:

Very small ESA - 0 to 100 sq.m.

Small ESA - 101 to 300 sq.m.

Large ESA - 301 to 1000 sq.m.

Very large ESA - >1000 sq.m.

Habermann and Hole (1980) used these abitrary divisions:

Very coarse - 100 to 10,000 sq.km.

Coarse - 1 to 100 sq.km.

Medium - .01 to 1 sq.km.

Fine - <0.01 sq.km.

The degree of differentiation of size of ESA's (Ostrowski and Jankowski, 1969, as cited by Fridland, 1976a), can be computed using the formula

$$DD = \frac{\sum_{i=1}^{k} |Pi - P|}{kP}$$

where: DD is the degree of differentiation,

Pi is the areal size of an ESA (or contour),

P is the mean size of an ESA (or contour),

k is the number of ESA's (or contours), and

|Pi-P| is the absolute value of the difference between the areal size of each ESA and the mean size of all ESA's.

Shapes of ESA's can be equilateral, elongated, and linear, with longest/shortest axial ratios of <2, 2-5 and >5, respectively. The ESA's of all these groups can be either symmetric or asymmetric. Symmetric ESA's can be folded along a straight line with 70% overlap.

The degree of dissection expresses the tortuosity of the boundaries of elementary soil areals (Fridland, 1976). It may be defined as the ratio of the ESA boundary to the circumference of a circle that has the same area as the ESA. It is determined using the formula:

$$CD = \frac{S}{3.54\sqrt{A}}$$

where: CD is the coefficient of dissection,

S is the length of the ESA boundary (perimeter), and

A is the area of the ESA.

The higher the CD, the higher is the tortuosity of its boundaries. The value in the least dissected area is a circle equal to unity, the value of CD increasing with the increase in dissection.

C. Distinctness of Soil Boundaries

This refers to whether the soil boundaries on the ground are sharp or not. Hole and Campbell (1985) suggested the following classes of soil boundary widths to determine the degree of distinctness of soil boundaries (Table 2.2):

Table 2.2. Hole and Campbell's (1985) classes of soil boundary widths

Class	Definition
Discrete	
Very sharp	<0.3m
Sharp	0.3 - 3m
Distinct	3 - 5m
Gradual	5 - 10m
Continual	
Diffuse	10 - 25m
Transitional	>25m

Transitional boundaries can be converted into transitional soil bodies on a highly detailed soil map.

D. Nearest Neighbor Index

This refers to the percentage of the length of the boundary of an ESA that is occupied by any other soil (Fridland, 1976a). Some ESA's tend to be neighbors of an ESA more often than others, so in the description of an ESA, the more frequently occurring neighboring ESA's can be included. An upland soil, for example, would tend to be adjacent to another upland soil rather than to an alluvial soil.

Another kind of nearest neighbor index is simply the number of times a soil occurs adjacent to the boundary of an ESA, disregarding the length of the segment. This method is faster than using the % of boundary length and would not require the use of equipment for determining boundary lengths.

The neighboring soils can participate in the soil combination as background or matrix, enclaved ESA's (holes), alternating major components, and transitional components. The background or matrix ESA is the one containing the enclaved ESA's (Fridland, 1976a).

Characteristic of the Combinational Soil Body

A. Orientation

The predominant orientation of elementary soil bodies in a combinational soil body can be estimated by eye or by the use of a line transparent disk with 20 slots per 10 cm, each slot being 0.5 mm wide and 4.5 mm apart (Hole, 1978). This is placed over the soil map quadrat at 18 different orientations, starting at north and proceeding at 10 degree intervals eastward. The number of intersections of soil boundaries on the slots is counted at each orientation. The predominant orientation is the direction for which the least number of boundaries intersect the slots. Hole (1978) used this method and found that soils of drumlinoid landscapes are parallel.

B. Population Density

The number of soil bodies or delineations in a quadrat, whole or partial, can be counted. This property can characterize the density of soils. The delineations can correspond to a number of soil phases or soil series. The density of soils and the number of soil phases or soil series provide a measure of diversity of soils (Hole, 1978).

C. Composition

This indicates the proportional extents of soil taxa (Hole, 1978). An area can be dominated by several soil bodies, or all soils in an area may have equal proportion.

D. Variegation of Soil Pattern

This refers to the mean size of all delineations in an area. Yodis (1967) determined the mean size of soil types shown on a 1:10000 map by dividing the total area by the number of delineations present. The arbitrary divisions on a 1:10000 map were

very variegated - average size <2 ha.

variegated - 2 to 5 ha.

rather variegated - 5 to 8 ha.

uniform - 8 to 12 ha.

very uniform - >12 ha.

Some combinational soil bodies are characterized by relatively large polypedons. Habermann and Hole (1980) found that in the young (about 15,000 years old) soilscape of Ashtabula County, Ohio, one large soil body dominates the soilscape.

Combinational soil bodies do not contain all the properties of the soil pattern of a large area. Generalization of the soil pattern of a large area is then done. A classification of the soil pattern of a large area includes six taxonomic levels: category, formation, rank, family, subfamily and series (Fridland, 1980). The classification scheme is shown in Table 2.3.

Table 2.3. Fridland's (1980) taxonomic classification of soil mantle structure

Generalized Taxonomic Criteria	Name	Context and Diagnostic Criteria
I	Category	Micro- or mesostructures of leading importance
II	Formation	Definite classes of soil combinations of leading importance (complexes, combinations, variations, etc.)
III	Rank	Genetic-geochemical context of structure: nature and mechanism of soil-mantle differentiation, substances and energy transported between components
IV	Family	Components of the soil mantle, lithological conditions of its formation
V	Subfamily	Composition of the soil mantle (quantitative ratio of its components)
VI	Series	Genetic-geometric structure of soil mantle, its complexity, topographic conditions

Category indicates whether the soil cover pattern is predominantly composed of mesostructures or microstructures. Mesostructures are composed of bigger ESA's than the microstructures. However, there are no size criteria for either structure. Examples of mesostructures are spotty and spotty-circular, dendritic, or striped. Microstructures are spotty, striated, and polygonal.

Formation refers to the kinds of soil combinations that are important. Rank refers to the properties and processes that differentiate the soil mantle. An example of a rank is differential salinization caused by mass movement between components of soil mantle structures with irrigation water. The soil mantle is differentiated according to mineral composition and moisture content.

Family refers to components of the soil mantle, for example structures containing residually calcareous, various gravelly or bouldery soils, etc. Subfamily refers to the areas occupied by each of the components. Series is based on the genetic-geometric structure of soil mantle, e.g. spotty, dendritic series and open dendritic.

Contrast Between Adjacent Elementary Soil Bodies and the Overall Contrast of the Soil Landscape

Contrast is the degree of dissimilarity between the properties of the constituent soils of the soil cover. Soil contrast can be expressed either by using the taxonomic rank of soil boundaries or by the differences in the properties of the components of the soil cover.

A. Determination of soil contrast using the taxonomic rank of soil boundaries

Hole and Campbell (1985) developed a procedure for the determination of soil contrast using the taxonomic rank of soil boundaries. The procedure utilizes the 9 soil boundary ranks shown in Table 2.4.

Table 2.4. Hole and Campbell's (1985) ranking of kinds of soil boundaries

Rank	Description
1	boundaries separating soil phases
2	those separating soil textural types (regardless of series)
3	those separating variants of soil series
4	those separating soil series
5	those separating soil families
6	those separating subgroups of soils
7	those separating great groups of soils
8	those separating suborders of soils
9	those separating orders of soils

The soil contrast between adjacent elementary soil bodies can be reported either as the maximum categorical level or by the number of ranks at which the boundary between them serves. Both the maximum categorical level and the number of ranks at which the boundary serves can be illustrated using Table 2.5, in which ranks 1 and 2 refer to soil phases, and ranks 3, 4, and 5 refer to soil families.

In Table 2.5, the maximum categorical level at which the boundary between soils 1 and soil 2 serves is the order level, which is 9 in the soil boundary ranks. The number of ranks at which the boundary between soil 1 and soil 2 serves simultaneously is 7, as they differ in slope, erosion, texture, subgroup, great group, suborder and order.

The overall soil contrast of the soil landscape can be reported as the average taxonomic rank at which the boundaries of all soils in the area serve and by the average number of ranks at which the boundaries of all soils in the area serve.

Table 2.5. Soil data needed to determine indexes of taxonomic contrast (Hole and Campbell, 1985)

Rank	Description	Soil 1	Soil 2
1	Slope	B	C
2	Erosion	2	3
3	Texture	fine-silty	coarse-loamy
4	Mineralogy	mixed	mixed
5	Soil temperature regime	mesic	mesic
6	Subgroup	Typic	Entic
7	Great group	Arqiudoll	Haplaquept
8	Suborder	Udoll	Aquept
9	Order	Mollisol	Inceptisol

The calculation of the overall soil contrast of the soil landscape requires the determination of the proportionate length of each soil boundary in the area. The proportionate length is determined by the length of each segment divided by the total length of all the soil boundaries.

The average taxonomic rank at which the boundaries of all soils in the area serve is determined by multiplying the proportionate length of each boundary segment by its maximum categorical level and summing all of the products. The higher the average the higher also is the contrast among the soils in the soil combination. It means that diverse soils of different taxonomic classes are in the area.

The average number of ranks at which the boundaries of all soils in the area serve is determined by multiplying the proportionate lengths of each soil boundary by the number of ranks at which each boundary serves. The products for all the boundary segments are summed to get the average for the entire area being characterized.

Hole and Campbell (1985) developed another index of taxonomic contrast using quadrats. The index is based not on the proportionate length of soil boundaries but on the proportionate area or extent of each soil unit. The index of taxonomic contrast is calculated as

$$\frac{Ena - 9}{Enp} \cdot \frac{Una}{1}$$

where: Ena is the actual number of taxonomic elements in the map legend,

Enp is the potential number of taxonomic elements if the area displayed maximum contrast, and

Una is the effective number of map units in the legend.

The taxonomic elements in each rank can be determined by counting the number of unrepeated elements. Given 5 mapping units with slopes of B, C, D, B, A, respectively, the number of taxonomic elements for the slope rank is 4, disregarding the other B slope. The number of taxonomic elements is determined in the same way for all the taxonomic ranks shown in Table 2.5 and added. The sum is equal to Ena.

The determination of Enp was not discussed clearly, but it can be presumed that it can be known using the taxonomic elements of each rank for all the soils present in the soil landscape from which the sample is taken. If all the slope classes, A, B, C, D, and E, for example, are present in the soil landscape, the potential number of taxonomic elements in the slope rank is then 5. The number of potential taxonomic elements for each rank is added to obtain Enp.

Nine is subtracted from Ena so that a single delineated body will have a contrast of 0 even if there are 9 taxonomic ranks. The effective number of map units takes into account the proportionate extent. The proportionate extent of each soil unit indicates the relative areal extent and importance of each map unit in the quadrat. This is determined by dividing each percentage of the map unit by the highest percentage, then adding all quotients.

An example of 5 quadrat map units is shown below with 70% as the largest % of an area occupied by a map unit.

Map Unit	Area	%	Proportionate Extent
1	5	5	5/70 = 0.071
2	10	10	10/70 = 0.142
3	70	70	70/70 = 1.000
4	10	10	10/70 = 0.142
5	5	5	5/70 = 0.071
		Effective number of map units	= 1.426

The higher the index of taxonomic contrast, the more contrasting the soils are.

Another measure of taxonomic contrast is the degree of quantitative differentiation of soil individuals, which was introduced by Ostrowski and Jankowski (1979) and cited by Fridland (1976a), who appropriately called it the "coefficient of classificational differentiation of soil cover components" (CDSC). Tt is determined from the formula

$$CDSC = \frac{\sum_{i=1}^{n} Ei}{m} \cdot \frac{1}{n}$$

where: n is the number of taxonomic levels required for description of the soil cover components,

m is the total number of soil units, and

E is the number of soil units at every taxonomic level.

The determination of CDSC is illustrated by the example shown below.

	Types	Subtypes	Genera	Species	Varieties	Kinds
	a_6	a_5	a_4	a_3	a_2	a_1
	a_6	b_5	b_4	b_3	b_2	b_1
	b_6	c_5	c_4	c_3	c_2	c_1
E =	2	3	3	3	3	3

In this example, n = 6 (from type to kind), m = 3 (total number of soils in the combination), a, b, c are the symbols for the soils, with the subscripts referring to a soil class under each taxonomic rank in the first row. For the type level, type being equivalent to Suborder or Great group in Soil Taxonomy, E = 2 (a and b). For each of the lower taxonomic levels, E = 3 (a, b, and c).

Thus,

$$\text{CDSC} = \frac{2+3+3+3+3+3}{3} \cdot \frac{1}{6} = \frac{17}{18} = 0.94$$

The contrast is high because each soil belongs to different levels of class below the types.

Taxonomic contrast has some limitations. It may not be true that soils which are classified differently at higher levels really will be very contrasting in terms of their properties. The U.S. Soil Taxonomy (Soil Survey Staff, 1975) is not based on properties of soils important in agriculture but properties that are indicative of the mode of genesis of soils. Soils may belong to different soil orders such as Alfisols and Mollisols, yet their suitability for agriculture may be nearly the same. The Mollisol order is based mainly on color and depth requirements, which most of the time indicate a fertile soil. An Alfisol can also be fertile and deep, and can be as good as a Mollisol in terms of plant growth, but might be considered very contrasting if compared with a Mollisol because it belongs to a different soil order.

Because soil classificational units are a continuum, soils belonging to different taxa but situated near the boundary between taxa units are less contrasting than soils located on opposite sides of the classification continuum (Fridland, 1976a).

Using soil taxonomy to get a measure of soil contrast is also limited by the fact that all map units are not defined at the same taxonomic level. Some map units may have been defined only at higher categorical levels. In the Soil Survey of Jefferson County, Idaho (Jorgensen, 1979), for example, most soils are classified in family classes, but some are classified in the Great Groups, e.g. Fluvaquent and Psammaquent, and subgroups such as xeric Torrifluvent.

The index of taxonomic contrast requires the determination of potential taxonomic elements in the soil landscape, which Fridland (1976a) did not elaborate well. The determination of potential taxonomic elements requires knowledge of all soils in the area.

B. Determination of Soil Contrast using Differences in Soil Properties

Hole and Campbell (1985) stated that soil contrast can be based on actual soil properties such as average pH and content of clay, silt, or organic matter to a depth of 1 meter.

Soil properties can be limited to those that are important to the land use to which the soil will be utilized. Fridland (1976a) suggested the use of properties which differ most strongly among the soils forming the combination. This is good for soils in which differences are controlled by a small number of properties.

Three models illustrate the use of soil properties for determining soil contrast. The first model is by Godelman and Pugayev (1976). They used it to determine the contrast of soils in Central and Eastern Kamchatka. They examined the characteristics of soils in this region and decided to use properties reflecting hydromorphism, the most genetic differences between the soils, state of cultivation, thickness, and texture. Their model is shown in Table 2.6.

The contrast between adjacent soils was determined by multiplying the % contrast in each series by the proportionate length of the boundary separating the two soils. The products were then summed up, and the sum is the index of contrast of the soil combination.

The second model (Yodis, 1967) uses the following properties: texture, wetness, podzolization, and extent of erosion, as shown in Table 2.7. The textures of the upper and lower horizons are considered in the model, but not at a specified depth. The use of the model can be illustrated by finding the degree of contrast between a Sod-Podzolic-Gleyish (P_1b) soil with respect to a Sod-Gley (SG) soil. The Sod-Podzolic-Gleyish soil is a weakly podzolic (Podzolization class II) coarse clay loam (Texture class III) that is very wet (Wetness class III) and is not eroded (Erosion class I). The Sod-Gley soil is a calcareous (Podzolization class I) loamy sand (Texture class II) that is extremely wet (Wetness class IV) and is not eroded (Erosion class I).

Table 2.6. Godelman and Pugayev's, (1976) model for determining the contrast of soils in Kamchatka

A. Hydromorphism series

Ground water level (cm)	Contrast, %
0 - 20	0
21 - 40	20
41 - 60	40
61 - 80	60
81 - 100	80
100	100

B. State of cultivation series

Category of cultivation	Contrast, %
Non cultivated	0
Light	25
Weak	50
Moderate	75
Good	100

C. Thickness series

Thickness	Contrast, %
Shallow (up to 20cm)	0
Moderately thick (20-41cm)	33
Thick (41-80cm)	67
Very thick (>80cm)	100

D. Texture series

Texture	Contrast, %
Sand	0
Loamy sand	14
Sandy loam	23
Loam	42
Clay loam	56
Coarse clay	71
Clay	85
Fine clay	100

Table 2.7. Yodis' (1967) model for determining soil contrast

Soil Properties	Extent to which Properties are Evident (contrast)
Texture	I. Sands (coarse-textured soils)
	II. Loamy sands (soils of medium fine texture)
	III. Coarse and medium clay loams (fine textured soils)
	IV. Fine textured clay loams and clays (very fine-textured soils)
Wetness	I. Soils of normal wetness
	II. Soils of low and moderate wetness
	III. Very wet soils
	IV. Extremely wet soils
Podzolization	I. Calcareous
	II. Weakly podzolic
	III. Strongly podzolic
Extent of erosion	I. Non-eroded
	II. Eroded

The contrast between the two soils is 3, which is the sum of one degree contrast in wetness, one degree with respect to podzolization, one degree in texture, and no difference in the extent of erosion.

The contrast of alluvial and deluvial soils is increased by one point when compared with other soils. Deluvial soils are soils of slope bottoms that are deep, fine textured and rich in humus. They often bury natural soils. They are probably synonymous with colluvial soils (Plaisance and Cailleux, 1981). Peat soils differ from other soils by two points with respect to texture.

The degree of contrast of the entire set of soils in an area is computed according to this formula:

$$K = \frac{a(x) + b(y) + c(z) + \ldots}{20}$$

where: K is the coefficient of contrast of the pattern of the soil distribution,

a,b,c, etc. represent the areas of the soils in % of the total area,

x,y,z represent the degree of contrast of soils as compared with the largest soil in the area, and

20 is arbitrarily introduced to make the K value smaller.

The following groups are proposed:

1. Soil patterns of very high contrast, $K > 9$
2. High contrast, $K = 9\text{-}7$
3. Slightly contrasting, $K = 7\text{-}5$
4. Very low contrast, $K = 5\text{-}3$
5. Noncontrasting, $K < 3$.

The properties that were incorporated are important in agriculture; however, there are more properties that are also important that can be incorporated in the model. Podzolization appears to be related to pH and could be replaced by pH, as podzolization itself may not be important.

The third model was suggested by Godelman (1969) as cited by Fridland (1976a) for determining the contrast of Moldavian soil cover. The following characteristics were considered: genetic-classification properties, texture, and degrees of erosion and deposition. The model is shown in Table 2.8.

Table 2.8. Model used to determine the contrast of Moldavian soils (Godelman, 1969, as cited by Fridland, 1976a)

	Contrast, %
A. Genetic series	
Light gray forest soils	0
Brown forest podzolized	10
Gray forest	20
Brown forest saturated	30
Dark gray forest soils	40
Podzolized chernozems	50
Leached chernozems	60
Deep-effervescing ordinary chernozems	70
Ordinary chernozems	80
Surficially calcareous	90
Chernozems	100
B. Texture sequence	
Heavy clay	0
Medium clay	14
Light clay	28
heavy loam	42
Medium loam	56
Light loam	71
Sandy loam	86
Sand	100
C. Erosion-deposition sequence	
Heavy sedimentation	0
Moderate sedimentation	14
Slight sedimentation	28
Uneroded	42
Slightly eroded	56
Moderately eroded	71
Heavily eroded	86
Very heavily eroded and destroyed soils	100

The degree of contrast between any 2 soils can be determined based on each of these soil properties by taking their arithmetic differences. The length of the boundary of any 2 soils is also determined.

The degree of contrast with respect to every separate property such as genetic series is computed using:

$$GKm = \frac{k_1 l_1 + k_2 l_2 + k_3 l_3 + \ldots + k_n l_n}{100} \; \%$$

where: GKm is the mean genetic contrast,

$k_1, k_2, k_3, \ldots k_n$ are the degrees of contrast with respect to genetic properties,

$l_1, l_2, l_3, \ldots l_n$ are the corresponding lengths of boundaries stated as percentages of the total length of boundaries, and

1, 2, 3,...n represent the number of discrete contrast differences.

The same formula is also used for the mean contrast with respect to texture (TKm) and erosion (EKm) with different values of k.

A graph showing the length of boundaries in percent for each level of contrast and a given property is made. This graph is useful in determining the importance of a given soil property in each level of contrast.

The contrast using this model is based on a single property, which is any of the 3 properties used. Areas of soils, however, are characterized by a set of soil properties, so this method may not be useful for comparing different areas.

Contrast can also be computed based on the general agroproduction groupings of soils (Fridland, 1976a). Agroproduction groups and amelioration groups are not well defined, thus limiting the use of this model. The type and amount of amelioration are not clearly defined either.

CHAPTER 3

METHODOLOGY

The primary objective of this research was to develop a more thorough, objective scheme for characterizing soil contrast than is presently given in the National Soils Handbook. In order to test and evaluate the scheme, however, it was necessary to select several different mapped soil areas representing different kinds of soils and soil formation processes. The procedure for selecting these sampling areas is discussed in the next section. Then, using the background information discussed in the previous chapter, an initial model of soil contrast was developed. Testing of this model led to a second model, which was further revised to generate the final model of soil contrast. The procedures used in each model are discussed in this chapter, along with some discussion of the limitations that led to alterations that ultimately became the final model.

Selection of the Sample Areas and Sources of Data

Five soil survey reports, each representing a different soil order and different soil landscape, were used in the study. Using the general soil map in each soil survey report, an association composed primarily of a particular soil order was selected. The soil survey reports and the soil associations that were sampled are shown in Table 3.1.

Table 3.1. Soil survey reports and the soil associations that were sampled

County	Soil Association	Soil Order	Landscape
1. Broome Co., New york (Giddings et al., 1971)	Volusia-Mardin	Inceptisol	glaciated uplands
2. Columbia Co., Wisconsin (Mitchell, 1978)	Lapeer-Wyocena	Alfisol	glaciated uplands
3. Jefferson Co., Idaho (Jorgensen, 1979)	Grassy Butte-Matheson-Diston	Aridisol	sandy eolian uplands
4. Lexington Co., So. Carolina (Lawrence, 1976)	Cecil-Appling	Ultisol	uplands, mainly granite and gneisses
5. Adair Co., Iowa (Sherwood, 1980)	Sharpsburg-Nira	Mollisol	loess-mantled and glaciated uplands

Each general soil map was divided into 1-square-mile blocks, and each block that contained at least 3/4 square miles of the soil association selected was numbered consecutively. Three blocks were randomly selected out of all the numbered blocks of each soil association being studied. The sampling area was then defined as the entire area of all delineations that were either wholly or partially contained in the block selected.

The sheet numbers of the soil maps on which the sample areas were located were determined from the Index to Map Sheets. The sampled areas were then delineated on the soil map. The map sheet numbers containing each sampling area are given in Table 3.2.

Table 3.2. Location of sampling areas within each soil association

Area	Sample No.	Map Sheets	Scale
1. Broome Co., New York	1	12, 11, 15, 16	1:15,480
	2	40, 50, 30, 41	
	3	14, 15, 19, 18	
2. Columbia Co., Wisconsin	1	30, 31, 19, 20	1:15,840
	2	7, 18, 19, 8	
	3	74, 84, 74, 73	
3. Jefferson Co., Idaho	1	5, 9, 10	1:24,000
	2	4, 5, 9	
	3	8, 9, 15, 14	
4. Lexington Co., So. Carolina	1	15, 22	1:20,000
	2	21, 22	
	3	16, 17	
5. Adair Co., Iowa	1	20, 21, 6, 28, 13, 14	1:15,840
	2	59, 52, 53, 45	
	3	40, 33, 39, 34, 32, 41	

The first map sheet in each sample contains the original 1-sq.-mile block or most of it. The other map sheets contain the rest of the delineations which originate on the first map sheet.

Each delineation within each sampling area was digitized using a GTCO Digitizer and a microcomputer. The digitized data were used to calculate the area of each delineation and the length of boundary shared by every pair of adjacent delineations. These data were subsequently used in the analysis of data produced by the soil contrast model.

Landscape properties such as slope and flood hazard were taken from the map unit descriptions. The morphological properties of a particular soil phase were taken from the soil profile description that represented the soil series, except when properties of the particular soil phase were described separately. Variations in the morphological properties of different soil phases within a soil series were assumed to be sufficiently minor as to cause no differences in soil management practices. Data on permeability and depth to bedrock were taken from the Table of Estimated Properties included in the soil survey report.

Mapping units of undifferentiated units and soil complexes were encountered in the study. For undifferentiated units, the dominant soil phase, if specified in the map unit description, was used to represent the soil map unit. For example, the undifferentiated unit of Lordstown and Oquaga channery silt loams, 25 to 35% slopes (LoE) was represented by Lordstown, which is dominant in Western Broome County where the sample is located. In cases where the proportional extent of the component soil phases was not given, the more limiting soil phase was used to represent the map unit. Thus, the undifferentiated unit of Chenango and Howard gravelly loams, 0 to 5% slopes (ChA) was represented by Chenango gravelly loam because it has a more limiting B horizon.

For soil complexes, the most limiting soil phase was used to represent the map unit. For example, in the Malm-Matheson-Rock outcrop complex, the most limiting component is the Rock outcrop, and it was used to represent the complex.

Development of Preliminary Soil Contrast Models

A. Model I. Program Cluster

The first attempt to calculate the contrast between soils was through the use of Program Cluster by James A. Keniston of the O.S.U. Marine Science Center. This approach uses the values of selected soil properties to calculate the dissimilarity between any 2 pairs of entities, which in this study is any 2 pairs of soil map units.

The Bray-Curtis formula was used to determine the dissimilarity between 2 map units by computing the dissimilarity coeffecient, Djk.

$$Djk = \frac{\sum_{i=1}^{nv} xij - xik}{\sum_{j=1}^{nv} xij + xik}$$

where: nv is the number of variables,

xij is the value of attributes of entity j,

xik is the value of attributes of entity k, and

Dij is the dissimilarity between entity j and k.

The attributes are any of the soil properties that were incorporated in the model. The higher the value of Djk, the higher the dissimilarity, or the higher the contrast between the soils.

The attributes or the soil properties that were selected were not only those important for general agriculture but also those that vary among the soils in the study areas. Fragipan, plinthite and calcic layers, for example, were present in some soils in the five soil survey reports and so were included in determining the contrast between soils and between sample areas.

The ranges of the values of the soil properties were divided into classes, either in an increasing numerical order (depth of the A, available water holding capacity, slope), increasing fineness (texture), decreasing numerical orders (depth to bedrock, depth to shallow water, depth of mottles, depth of calcic layers, depth of fragipan) or decreasing drainage class. Other properties were characterized by presence or absence, such as plinthite and O horizon.

Each class within a range of values was coded to facilitate the entry of the data. The codes were designed so that the codes always increased as the class increased in the arrayed property data. Table 3.3 shows the classes of soil properties and their corresponding codes.

Program Cluster was used to calculate the dissimilarity coefficients for all possible pairs of map units in each sampling area. An example of the output from the program is found in Table 3.4. The list of soils corresponding to the map unit symbols in Table 3.4 is shown in Table 3.5. The original data matrix, i.e. codes corresponding to the classes for the values of each soil property of each map unit, is shown in part A. Soil properties shown in Table 3.3 that do not vary among the soils shown are not included in Table 3.4.

The transformed data matrix was created by dividing each row of numbers in the original data matrix by the maximum code value in that row. The transformed data are necessary, as the soil properties have varying maximum codes, and without transformation the higher codes would have more weight or would contribute more to the dissimilarity. The transformed data are shown in part B of Table 3.4; all codes range between 0 and 1. The index of dissimilarity between pairs of soils is shown in part C. The higher the index, the greater the differences between the soils.

Table 3.3. Classes of soil properties and their corresponding codes

Depth to Bedrock (Deb), to Mantle (Dem), to water table (Des), to calcic layer (Dec), to fragipan (Def)

Inches	Code
> 60	0
50 - 60	1
40 - 50	2
30 - 40	3
20 - 30	4
10 - 20	5
0 - 10	6

Thickness of A (Dea)

Inches	Code
0 - 10	1
10 - 20	2
20 - 30	3
30 - 40	4
40 - 50	5
50 - 60	6

Slope (Slo)

%	Code
0 - 3	1
3 - 7	2
7 - 12	3
12 - 20	4
20 - 35	5

Drainage (Drn)

Class	Code
Very poorly drained	1
Poorly drained	2
Somewhat poorly drained	3
Moderately well drained	4
Well drained	5
Somewhat excessively drained	6
Excessively drained	7

Waterholding Capacity (Awc)

Class (in.)	Code
Very low (<3)	1
Low (3-6)	2
Moderate (or medium) (6-9)	3
High (9-12)	4
Very high (>12)	5

Texture (TexA)

Class	Code
Sand	1
Loamy sand	2
Sandy loam	3
Fine sandy loam	4
Very fine sandy loam	5
Loam	6
Silt loam	7
Silt	8
Clay loam	9
Sandy clay loam	10
Silty clay loam	11
Sandy clay	12
Silty clay	13
Clay	14

Erodibility (Ero)

Class	Code
None	0
Slight	1
Moderate	2
Severe	3

O Horizon (Deo)

Class	Code
Absent	0
Present	1

Table 3.4. Data matrices and dissimilarity values for some map units of Inceptisols

A. Original data matrix

Prop	Ald	MhB	MhC	MhD	MhE	Ta
	Soil Map Units					
Des	6	4	4	4	4	4
Dem	6	5	5	5	5	0
Slo	1	2	3	4	5	1
Drn	1	4	4	5	5	5
Awc	3	2	2	2	2	3
Def	0	5	5	5	5	0

B. Transformed data matrix

Prop	Ald	MhB	MhC	MhD	MhE	Ta
	Soil Map Units					
Des	1.00	0.67	0.67	0.67	0.67	0.67
Dem	1.00	0.83	0.83	0.83	0.83	0
Slo	0.20	0.40	0.60	0.80	1.00	0.20
Drn	0.20	0.80	0.80	1.00	1.00	1.00
Awc	1.00	0.67	0.67	0.67	0.67	1.00
Def	0	1.00	1.00	1.00	1.00	0

C. Index of dissimilarity

	Ald	MhB	MhC	MhD	MhE
Ald					
MhB	0.33				
MhC	0.35	0.02			
MhD	0.38	0.06	0.04		
MhE	0.40	0.08	0.06	0.19	
Ta	0.33	0.35	0.37	0.35	0.36

Table 3.5. Soils corresponding to the map unit symbols in shown in Table 3.4

Map Unit Symbol	Soils
Ald	Alden soils, 0 to 3 percent slopes
MhB	Mardin channery silt loam, 2 to 8 percent slopes
MhC	Mardin channery silt loam, 8 to 15 percent slopes
MhD	Mardin channery silt loam, 15 to 25 percent slopes
MhE	Mardin channery silt loam, 25 to 35 percent slopes
Ta	Tioga silt loam, 0 to 5 percent slopes

The highest dissimilarity (0.4) is between MhE and Ald. Ald is a very poorly drained soil that is found in depressions and nearly level drainageways of uplands. MhE is a moderately well drained soil that is found on strongly sloping uplands. Other properties such as depth to fragipan and available waterholding capacity also differ between these two soils.

The least dissimilar pair (.02) is MhB-MhC. These are simply adjacent slope phases of the same soil series. The dissimilarity for MhC-MhD is a little higher (.04) because the Mardin series is defined such that C-slope soils are moderately well drained and steeper soils are well drained. Thus both slope and drainage differ between this pair of soils.

There are some limitations in the Program Cluster-Dissimilarity approach. First, the soil properties that were used may not all have equal effects on agricultural use. Giving them equal weights may not be valid. Erodibility, for example, is less important than drainage, as crops can be grown even on eroded soils. Second, soil properties such as depth to shallow water table and depth to mottles are correlated, and it may not be necessary or appropriate to include both. Third, the classes established within the ranges of values of the soil properties were arranged either from high to low or from low to high. It would be better if the properties could be arranged in terms of suitability for a particular purpose, e.g. agriculture, in which case the dissimilarity would give a better idea of the differences of the soils in terms of suitability. Drainage, for example, might be arranged in terms of decreasing suitability as follows:

1. well drained
2. moderately well drained or
   somewhat excessively drained
3. somewhat poorly drained
4. poorly drained or
   excessively drained
5. very poorly drained

Well drained soils are most suitable, moderately well drained and somewhat excessively drained soils have similar suitability as do poorly drained and excessively drained soils.

Texture could be arranged as follows:

sil, l

scl, cl, sicl

c, sic, sc

sl

ls, s

Silt loam and loam are most suitable, whereas loamy sand and sand are least suitable.

Although these limitations could have been remedied, the Program Cluster approach was not used due to limitations that are in the program itself. One of these limitations is that the dissimilarity indices are based solely on the data used for computing the index. A high index can be derived by the summation of small differences in properties even if there is no property with a wide difference. Such summation of small differences may make a pair contrasting based on the index that is derived but does not result in differences in soil management as much as the high index derived when at least one property has a wide difference in properties.

The program allows one to assign weights to any property that was used. However, all soil properties shown in Table 3.4 were given equal weights, i.e. 1.0, as the assigning of numerical weights is difficult because of inadequate bases for decisions.

Another limitation of the program is that the denominator, which is the sum of the values for each pair being compared, differs for every pair. It would be better if there was a common denominator for all pairs. In this way the dissimilarity index could be ranked more appropriately.

B. Model II

This model assigns various levels of soil contrast, i.e. very similar, similar, somewhat contrasting, contrasting and very contrasting to pairs of map units. The assignment of soil contrast levels is based on the amount of difference in the classes that subdivide the range of values for any given soil property. One class difference is the comparison between adjacent classes of a soil property, while two classes differences is the comparison between the 1st and 3rd classes or 2nd and 4th classes, etc.

In this model soil properties were arranged in terms of decreasing importance for agriculture, such that higher levels of soil contrast could be declared based on small differences of important soil properties. As the soil properties become less important, lower levels of contrast were assigned even to high differences in soil properties.

A new set of soil properties, limited to those important for general agriculture, was chosen for this model. Flooding, workability, pH, and depth of rooting were also included in the new set of properties. Texture and pH were measured for both A and B horizons. Properties such as depth to calcic layers, which are different among the soils but are not important to agriculture, were not included. Properties that were highly correlated with other soil properties already included were not used.

This model assumes a moderately high level of management. This assumption is important, because it means that gleyed layers need not be considered a barrier to plant roots as long as artificial drainage is technically and economically feasible.

The soil factors that were selected are those related to several land qualities that are important for plant growth. Among them are workability (affected by consistence and grade of the structural ped and by coarse fragments), available water capacity (affected by rooting depth, texture, coarse fragments), nutrient supplying capacity of the soil (texture and pH), and aeration (drainage, structural grade, and coarse fragments).

Because texture and pH differ from horizon to horizon, these properties were taken both at the surface and at a depth of 25 inches. If the rooting depth was less than 25 inches, as in soils with bedrock shallower than 25 inches, texture and pH were recorded at a depth midway between the surface and the limit of the depth of rooting.

The soil properties which were selected and their importance are as follows:

Coarse fragments of the A: Coarse fragments are soil particles that are between 2mm and 10 inches in size. A high amount of coarse fragments can cause damage to machinery. It also decreases the available waterholding capacity and water content, which can create a potential for droughty conditions. The nutrient supplying capacity of the soil may also be reduced because of coarse fragments. They also may act as physical barriers to seedling emergence and root penetration.

Depth of rooting: The effective depth of rooting is the distance from the ground surface to the top of any soil horizon that prevents significant root penetration. Very dense horizons such as fragipans or duripans, or very gravelly or cobbly horizons or abrupt texture change from one horizon to another, as loam over sand, are barriers to root penetration.

The effective depth of rooting of the soil affects the volume of soil available to plants for moisture and nutrient supply. If a physical barrier to the depth of rooting is within the depth of plowing, the use of farm implements may also be adversely affected.

Flooding: Flooding during spring before the growing season may delay cultural operations such as land preparation. Flooding can destroy standing crops by creating an anaerobic environment for the plant. It can also limit the choice of crops. The extent of the effects of flooding may depend on the occurence, frequency and duration of flooding.

Floods occuring during a non-growing season were considered less detrimental to plant growth than those occuring during the growing season. Floods occuring more frequently were considered more detrimental than those occurring less frequently. The duration of flooding, i.e. the number of days the soil remains inundated with water, was not incorporated in flooding, as it was thought that flooding of even brief duration is harmful to plants.

The occurrence of flooding was determined from the interpretive tables in the soil survey report. It was determined from the table of monthly precipitation if not indicated from these tables. Flooding during a growing season was considered possible if the month with the highest rainfall was from April to October.

The frequency classes for flooding are:

None - 0% chance of flooding in any year

Rare - from near 0 to 5% chance of flooding in any year or near 0 to 5 times in 100 years

Occasional - 5 to 50% chance of flooding in any year or 5 to 50 times in 100 years

Frequent - more than 50% chance of flooding in any year or more than 50 times in 100 years

Drainage: Drainage is important as it affects soil aeration. Aeration is impaired if the soil is saturated with water. Cultural operations are also delayed, as it takes time for a wet soil to dry up. Drainage also affects the choice of crops, the temperature of the soil, and the toxicity or deficiency of plant nutrients. A poorly drained soil implies that intensive management using artificial drainage is required to provide adequate rooting depth.

Slope: Slope is important as it affects the possibility for mechanization. Mechanization is increasingly difficult with increasing slopes. Slope also affects the susceptibility to erosion. The susceptibility increases as slope increases.

Texture: Texture affects both the chemical the physical behavior of soils. It is related to cation exchange capacity, which influences the supply of some plant nutrients. Porosity, workability, permeability, and waterholding capacity of soils are all affected by texture. Soils that are clayey and have weak structure have low permeability; soils that are sandy have high permeability. Soils with a sandy texture have low water holding capacity.

pH: pH is the only chemical property incorporated in this model. Hydrogen ions have both direct and indirect effects on plant growth. They can cause H^+ and Al^{+++} toxicities or affect the availability of other nutrients, causing either deficiencies or toxicities.

Workability: Workability determines the relative ease by which the soil can be prepared for planting. A soil with very firm or extremely firm moist consistence will be hard to plow. Workability is also related to the ease by which the peds can be dispersed, leading to soil crusting. Soils which have very weak structural grade and very friable moist consistence are more easily dispersed and more subject to crusting.

The range of values for each soil property was divided into classes according to the effect of a particular class on general agriculture. Soils with 0-15% coarse fragments are most suitable, whereas soils with >60% coarse fragments are least suitable. Soils with the greatest rooting depth are most suitable and soils with the least rooting depth are least suitable. Soils that do not flood or flood only rarely in a non-growing season are considered most suitable; those with frequent flooding during the growing season are least suitable. Well drained soils were considered most suitable for agriculture while very poorly drained soils were considered least suitable. Soils on 0-3% slopes were considered most suitable; soils on slopes >25% were considered least suitable. For texture, loam and silt loam were considered most suitable and loamy sand and sand least suitable. A near neutral pH was considered to be most suitable, while pH values that are very low or very high were considered to be least suitable. Very friable and friable moist consistence and strong structural grade are most suitable. Very firm moist consistence and weak, very weak and massive structural grades are least suitable.

Suitability codes that range from 1 to 5 were assigned for each class of each property. The code increases with decreasing suitability. These codes are shown in Table 3.6.

Table 3.6. Suitability classes of soil properties. Class 1 is most suitable, and class 5 is least suitable

Soil Properties	Class
1. Coarse fragments of the A (%)	
<15	1
15 - 30	3
30 - 60	4
>60	5
2. Rooting depth (inches)	
>40	1
30 - 40	2
20 - 30	3
10 - 20	4
<10	5

3. Flooding

	None	Rare	Occasional	Frequent
growing season	1	3	4	5
non-growing season	1	1	2	3

Soil Properties	Class
4. Drainage	
excessively drained	4
somewhat excessively drained	2
well drained	1
moderately well drained	2
somewhat poorly drained	3
poorly drained	4
very poorly drained	5
5. Slope (%)	
A (0-3)	1
B (3-8)	2
C (8-16)	3
D (16-25)	4
E (>25)	5
6. Texture of the A	
l, sil	1
scl, cl, sicl	2
c, sic, sc	3
sl	4
ls, s	5

Table 3.6. Cont'd.

7. Texture of the B (same as texture of the A)

8. pH of the A

6.6 -7.3	1
5.6 - 6.5	
7.4 - 7.8	2
4.5 - 5.5	
7.9 - 8.4	3
<4.5	
8.4 - 9.0	4
>9.0	5

9. pH of the B (same as pH of the A)

10. Workability

	Moist Consistence			
	Very friable	friable	firm	very firm
Grade				
strong	1	1	2	3
moderate	3	2	3	4
weak	4	3	4	5
very weak	5	4	5	5
massive	3	3	4	5

For coarse fragments of the A, there were only 4 classes. The 2nd class (15-30%) was assigned a suitability code of 3 because it is believed that there is more decrease in suitability with this class.

Flooding classes of none and rare during the non-growing season are both most suitable for agriculture. For drainage and pH, 2 classes may have the same suitability rating, so they are given equal codes. Somewhat excessively drained and moderately well drained soils, for example, are both considered to be in suitability class 2, and excessively drained and poorly drained soils are both placed in suitability class 4. Thus the range of suitability codes for drainage do not go in order from 1 to 7, and the range of suitability from 1 to 5 is still maintained.

The model in which these properties were tested is found in Table 3.7. In this model the properties are arranged in order of decreasing importance. Class difference is the difference in suitability rating of the soils being compared in terms of the property being considered.

Five contrast levels were assigned according to the amount of difference in class suitability. These five levels are very similar, similar, sonewhat contrasting, contrasting and very contrasting. The contrast level increases as the difference in suitability class increases. Coarse fragments of the A is very important because only one class difference between the soils being compared makes them contrasting. For rooting depth, flooding, and drainage, either one or two classes difference make the soils being compared contrasting. Three or four classes difference in the same properties make the soils very contrasting. One class difference in slope makes the soil somewhat contrasting.

Additional properties are considered in the determination of contrast if there is the same suitability in terms of coarse fragments of the A, rooting depth, flooding, drainage and slope. Starting from texture of the A, either the same suitability or one class difference is required for less important factors such as texture of the A, texture of the B, and pH of the A and B to enter into the determination of the contrast.

Table 3.7. Model II key for determining contrast levels

	Soil Contrast
A. Coarse Fragments of the A	
1. Same suitability	Go to B
2. One class difference	Contrasting
3. Two to four classes difference	Very Contrasting
B. Rooting Depth	
1. Same suitability	Go to C
2. One to two classes difference	Contrasting
3. Three to four classes difference	Very contrasting
C. Flooding	
1. Same suitability	Go to D
2. One to two classes difference	Contrasting
3. Three to four classes difference	Very Contrasting
D. Drainage	
1. Same suitability	Go to E
2. One to two classes difference	Contrasting
3. Three to four classes difference	Very Contrasting
E. Slope	
1. Same suitability	Go to F
2. One class difference	Somewhat Contrasting
3. Two classes difference	Contrasting
4. Three to four classes difference	Very Contrasting
F. Texture of A	
1. Same suitability and one class difference	Go to G
2. Two to three classes difference	Somewhat Contrasting
3. Four classes difference	Contrasting

Table 3.7. Cont'd.

G. Texture of the B

1. Same suitability and one class difference	Go to H
2. Two to three classes difference	Somewhat Contrasting
3. Four classes difference	Contrasting

H. pH of A

1. Same suitability and one class difference	Go to I
2. Two classes difference	Somewhat Contrasting
3. Three to four classes difference	Contrasting

I. pH of B

1. Same suitability and one class difference	Go to J
2. Two classes difference	Somewhat Contrasting
3. Three to four classes difference	Contrasting

J. Workability

1. Same workability and one to two classes difference	Very Similar
2. Three to four classes difference	Similar

Soils are very similar only when they have the same suitability in terms of coarse fragments of the A, rooting depth, flooding, drainage and slope and either the same suitability or one class difference in texture and pH of both A and B, and either the same suitability or up to two classes difference in terms of workability.

Similar soils occur when all codes other than workability are the same and the only difference is a three to four class difference in terms of workability.

This model was tested using some mapping units from one of the Ultisol sampling areas. AmB (Alamance) and ApB (Appling), found in

Lexington Co., So. Carolina, are very similar pairs. The suitability codes for the soil properties of this pair are:

	AmB	ApB
Coarse fragments of the A	1	1
Rooting depth	1	1
Flooding	1	1
Drainage	1	1
Slope	2	2
Texture of the A	4	4
Texture of the B	2	3
pH of the A	2	2
pH of the B	3	3
Workability	4	3

This pair has the same suitability codes for properties listed before texture of the B. Only that property and workability differ, and both differences are but a single class. Using the key in Table 3.7, this pair of soils keys out to be very similar.

An example of a somewhat contrasting pair is HeB-HeC, which consists of slope phases of the Helena series. The suitability codes for the properties of the soils in this pair are:

	HeB	HeC
Coarse fragments of the A	1	1
Rooting depth	1	1
Flooding	1	1
Drainage	2	2
Slope	2	3
Texture of the A	4	4
Texture of the B	3	3
pH of the A	3	3
pH of the B	3	3
Workability	3	3

Of all the properties, only slope differs between these two soils, and that by only one class. This keys out as somewhat contrasting. Texture of the A and B, pH of the A and B, and workability would not have been considered, even of there had been differences, as the slope difference controls the contrast classification.

AgB (Alaga) and PkD (Pickens) form a contrasting pair. The suitability codes for the properties of the soils in this pair are:

	AgB	PkD
Coarse fragments of the A	1	2
Rooting depth	1	4
Flooding	1	1
Drainage	2	2
Slope	2	4
Texture of the A	5	1
Texture of the B	4	5
pH of the A	3	3
pH of the B	3	5
Workability	4	3

There is one suitability class difference in terms of coarse fragments of the A, so only this property is considered, and the pair is declared contrasting, even though rooting depth would have classified the pair as very contrasting.

One serious limitation of this model is that properties below the one used for declaring the contrast are not considered in the determination of soil contrast. This limitation was illustrated by the AgB-PkD pair, for which properties from rooting depth to workability were not considered.

This model was considered a better model than the first one and so was not totally abandoned but revised. All the soil properties incorporated in the model are important for agriculture. Weights were assigned by ranking the soil properties and not by assigning numerical values. The former method of assigning weights is easier than the latter. The revisions (Tables 3.8 and 3.9) which were made are as follows:

1. The suitability codes corresponding to each level of coarse fragments were adjusted. Suitability codes of 2, 3 and 4 were

assigned to the classes 15-30%, 30-60% and >60%, respectively. This implies that the class of 15-30% coarse fragments is still considered suitable, as crops can still be grown. The lowest suitability was reduced to 4 instead of 5.

2. Contrast codes were used. All possible pairs of ranges for each property were identified and a contrast code was assigned to each one of them. The contrast code increases as the difference between the suitability levels increases. These codes are given in Table 3.9.

3. The levels in suitability 2 and 4 of drainage were further differentiated. Moderately well drained and somewhat excessively drained were given codes of 2m and 2s, respectively (Table 3.8), while poorly drained and excessively drained were given codes of 4p and 4e. The different levels in suitability level of 2, 3 and 4 for pH of the A and B were also further differentiated by giving new codes. This was done because the members within the same suitability code can have different contrast when both are compared to the same level of another property. For example, 2m vs 5 has a contrast code of 2 whereas 2s vs 5 has a contrast code of 3, even if both 2m and 2s have a suitability of 2.

Table 3.8. Revised list of soil properties and suitability codes

Soil Properties	Suitability Code
1. Coarse fragments of the A	
<15%	1
15 - 30%	2
30 - 60%	3
>60%	4
2. Flooding	
None, growing season and rare non-growing season	1
Occasional, non-growing season	2
Rare, growing season and frequent non-growing season	3
Ocassional, growing season	4
Frequent, growing season	5
3. Rooting depth (in)	
>40	1
30 - 40	2
20 - 30	3
10 - 20	4
<10	5
4. Slope	
A (<3%)	1
B (3-8%)	2
C (8-15%)	3
D (15-25%)	4
E (>25%)	5
5. Drainage	
well drained	1
moderately well drained	2m
somewhat excessively drained	2s
somewhat poorly drained	3
poorly drained	4p
excessively drained	4e
very poorly drained	5

Table 3.8. Cont'd.

6. Texture of the A horizon

l, sil	1
scl, cl, sicl	2
c, sic, sc	3
sl	4
ls, s	5

7. Texture of the B horizon

l, sil	1
scl, cl, sicl	2
c, sic, sc	3
sl	4
ls, s	5

8. pH of the A

6.6 -7.3	1
5.6 - 6.5	2a
7.4 - 7.8	2b
4.5 - 5.5	3a
7.9 - 8.4	3b
<4.5	4a
8.4 - 9.0	4b
>9.0	5

9. pH of the A

6.6 -7.3	1
5.6 - 6.5	2a
7.4 - 7.8	2b
4.5 - 5.5	3a
7.9 - 8.4	3b
<4.5	4a
8.4 - 9.0	4b
>9.0	5

10. Workability

	MOIST CONSISTENCE			
Structural Grade	Very Friable	Friable	Firm	Very Firm
strong	1	1	2	3
moderate	3	2	3	4
weak	4	3	4	5
very weak, single grain	5	4	5	5
massive	3	3	4	5

Table 3.9. Contrast codes for different pairs of suitability within each soil property

Soil Properties	Contrast Codes
1. Coarse fragments of the A	
a) Same suitability, 3 vs 4	1
b) 2 vs 3	2
c) 1 vs 2	3
d) 1 vs 3, 1 vs 4	4
2. Flooding	
a) Same suitability	1
b) 1 vs 2, 2 vs 3, 4 vs 5	2
c) 1 vs 3, 3 vs 4, 2 vs 4	3
d) 1 vs 4, 1 vs 5	4
3. Rooting depth	
a) Same suitability	1
b) One class difference	2
c) Two classes difference	3
d) Three classes difference	4
e) Four classes difference	5
4. Slope	
a) Same suitability	1
b) 4 vs 5, 1 vs 2, 2 vs 3, 3 vs 4	2
c) 2 vs 4, 1 vs 3, 3 vs 5, 1 vs 4	3
d) 1 vs 5, 2 vs 5	4
5. Drainage	
a) Same suitability	1
b) 1 vs 2m or 2s	2
c) 1 vs 3	3
d) 1 vs 4p	4
e) 1 vs 4e	4
f) 1 vs 5	5
g) 2m vs 3	2
h) 2s vs 3	3
i) 2m vs 4p	3
j) 2s vs 4p	3
k) 2m vs 4e	4
l) 2s vs 4e	2
m) 2m vs 5	4
n) 2s vs 5	5
o) 3 vs 4p	2
p) 3 vs 4e	3
q) 3 vs 5	3
r) 4p vs 5	2
s) 4e vs 5	5

Table 3.9. Cont'd.

6. Texture of the A horizon	
a) Same suitability	1
b) One class difference	2
c) Two classes difference	3
d) Three classes difference	4
e) Four classes difference	5
7. Texture of the A horizon	
a) Same suitability	1
b) One class difference	2
c) Two classes difference	3
d) Three classes difference	4
e) Four classes difference	5
8. pH of the A horizon	
a) Same suitability	1
b) 1 vs 2a	2
c) 1 vs 2b	2
d) 1 vs 3a	3
e) 1 vs 3b	2
f) 1 vs 4a	5
g) 1 vs 4b	3
h) 1 vs 5	4
i) 2a vs 3a	2
j) 2a vs 3b	2
k) 2a vs 4a	3
l) 2a vs 4b	2
m) 2a vs 5	3
n) 2b vs 3a	2
o) 2b vs 3b	2
p) 2b vs 4a	4
q) 2b vs 4b	2
r) 2b vs 5	3
s) 3a vs 4a	2
t) 3a vs 4b	3
u) 3a vs 5	4
v) 3b vs 4a	3
w) 3b vs 4b	2
x) 3b vs 5	2
y) 4a vs 5	4
z) 4b vs 5	2
9. pH of the B horizon	
Same as pH of the A.	
10. Workability	
a) Same suitability and one class difference	1
b) Two classes difference	2
c) Three to four classes difference	3

4. Weights for each property were also assigned. Higher weights were given to more important properties. The weights were determined by a calibration process that involved plotting a contrast score (see number 5 below) for each pair of soils against the difference in an independently derived agricultural potential rating ($\triangle$APR) for the same pair of soils. These agricultural potential ratings result from an extension of the soil potential ratings process (SCS, 1983). For individual crops, soil potentials were calculated by subtracting from the gross output from a soil the sum of all the inputs required to achieve the stated output. The agricultural potential rating is a composite rating based on all the crops for which soil potential ratings were determined. The procedure illustrated in Table 3.10 was to select the net return for the most profitable crop on each soil, array these values from high to low, and convert them to an arbitrary scale of 100 or 150 points.

The $\triangle$APR of any two soils being compared is the difference between their absolute APR's. For calibration purposes, the $\triangle$APR's of a set of soils in Marion County, Oregon (Williams, 1972) were used as an independent measure of soil quality against which soil contrast scores were tested and evaluated. The APR's of the soils in Marion County, Oregon, were taken from Fastner, 1985.

It was postulated that the contrast score would increase with an increase in $\triangle$APR. Therefore several attempts were made to find the combination of weights that gave the best relationship between contrast and $\triangle$APR.

Table 3.10. Net returns and overall agricultural potential ratings for four soils common in Linn County, Oregon (Steiner et al., 1984)

Soil	Net Returns				Most Profitable Crop	APR*
	Winter Wheat	Annual Ryegrass	Permanent Pasture	Irrigated SweetCorn		
Amity	286	252	100	305	305	107
Bellpine (3-12%)	260	116	60	229	260	91
Dayton	36	241	78	85	241	85
Willamette (0-3%)	424	252	120	404	424	149

*The maximum net return was $427 for irrigated sweet corn on Chapman soils.

5. Contrast scores were determined by multiplying the contrast code for each soil property by a weighting factor according to the importance of each property, and adding all the products. The process of determining contrast scores can be illustrated using the WiA (Willamette) and SkB (Salkum) soils in Marion County, Oregon.

A. Assign suitability codes for each property of each soil based on the values in Table 3.8. These data are given in Table 3.11.

B. Compare suitability codes and assign corresponding contrast codes for each property according to the criteria in Table 3.9. These results are given in Table 3.12.

C. Assign weights to each soil property. The weighting factors used for this example are shown in Table 3.13.

Table 3.11 Soil properties and suitability codes (parenthesized) for WiA and SkB

Soil Properties	WiA	SkB
Coarse fragments of the A	<15% (1)	<15% (1)
Flooding	None (1)	None (1)
Depth of rooting	>40 in (1)	>40 in (1)
Slope	<3% (1)	3 - 8% (2)
Drainage	well drained (1)	well drained (1)
Texture of the A	sil (2)	sicl (2)
Texture of the B	sicl (2)	sic (3)
pH of the A	slightly acid, pH 6.1 (2a)	strongly acid, pH 5.2 (3a)
pH of the B	slightly acid, pH 6.2 (2a)	very strongly acid, pH 5 (3a)
Workability	moderate structure, friable (2)	weak structure, friable (3)

Table 3.12. Contrast codes (from Table 3.9) corresponding to the differences in properties of WiA and SkB

Soil Properties	Suitability Comparison	Contrast Code
Rock fragments	Same suitability	1
Flooding	Same suitability	1
Rooting depth	Same suitability	1
Slope	2 vs 3	2
Drainage	Same suitability	1
Texture of the A	One class difference	2
Texture of the B	One class difference	2
pH of the A	2a vs 3a	2
ph of the B	2a vs 3a	2
Workability	One class difference	1

D. Calculate the contrast score by multiplying each contrast code by its corresponding weight and sum the products. This process is illustrated in Table 3.13. The results show a final contrast score of 40. For WiA and SkB soils, the △APR was also 40 (WiA=100 and SkB=60). The specific weighting factors used in this example were just right to generate perfect agreement between the contrast score and the difference in agricultural potential rating.

Table 3.13. Calculation of contrast score for WiA and SkB.

	Contrast Codes	Weights	Products
Rock fragments of the A	1	3	3
Flooding	1	3	3
Rooting depth	1	4	4
Slope	2	4	8
Drainage	1	4	4
Texture of the A	2	3	6
Texture of the B	2	3	6
pH of the A	2	1	2
pH of the B	2	1	2
Workability	1	2	2
		Total =	40

This general procedure was repeated, using the same weighting factors, for all possible pairs of WiA (Willamete) with the rest of the soils in the set of Marion County soils used for calibration. The results of comparing the contrast scores with their corresponding △APR's are shown in Fig. 3.1.

The relationship is generally linear with r=0.632, but there is a rather wide range of soil contrast scores, particularly for △APR of 40 and higher. The soil contrast score, for example, corresponding to a potential rating difference of 67 ranges from 45 to 72.

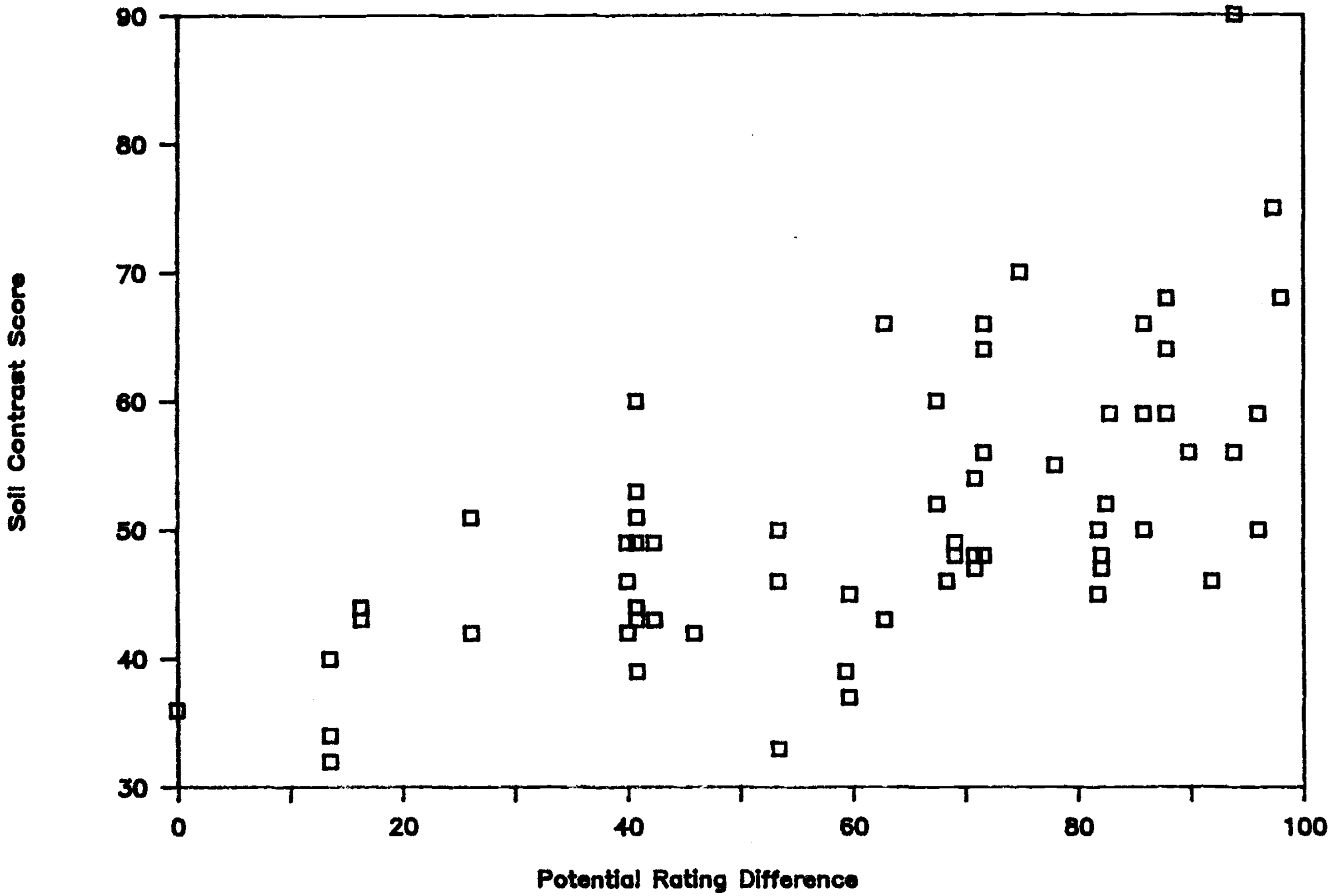

Fig. 3.1. Relationship between agricultural potential rating difference and soil contrast score of all soils being compared with WiA

For this reason, further revisions in the model were made in an attempt to improve the relationship between contrast score and $\triangle$APR. These revisions included:

1. Excessively drained, somewhat excessively drained and well drained soils were all given a suitability code of 1. This was done as the problem in drainage is the inability of the soil to get rid of excess water, which is not a problem in excessively drained, somewhat excessively drained and well drained soils. Because permeability is important to drainage feasibilty, it was also incorporated. A somewhat poorly drained soil with moderately slow or greater permeability is more suitable than the same drainage class with slow or very slow permeability. Moist consistence of the B and available water capacity were also included among the soil properties, merely to see if a better calibration could be obtained.
2. Coarse fragments of the B were added to account for their effects throughout the soil profile.
3. The determination of workability was expanded to consider further interactions among texture, moist consistence, and structural grade.
4. The soil properties were arranged not only in decreasing suitability but also in other orders such as decreasing fineness (texture of the A and B), increasing firmness (moist consistence of the B), and increasing pH. This step eliminated the need to assign suitability levels, which was sometimes difficult, as crops have different requirements.

5. New codes were assigned for each level of each property, as shown in Table 3.14. These codes were adjusted so that greater degrees of differences between levels could be expressed. For coarse fragments, for example, the difference between <15% and 15-30% is less (difference of 1) than the difference between 15-30% and 30-60% (difference of 7). 15-30% coarse fragments can be a critical level such that a higher level will have a big effect on soil management. The effect of increasing levels of a soil property, therefore, is not necessarily linear.

The method of sampling the soils used in the calibration was also revised. Instead of having all soils compared with WiA, all soils in Marion County, Oregon were divided into the following ranges of APR: 83.7-100, 60-83.7, 54.1-60, 37.2-54.1, 22- 37.2 and 0-22. Two samples were selected from each range.

Using these revisions, the calibration process was repeated for all possible pairs of soils that were randomly selected from each range by subtracting the codes for each property, multiplying the absolute difference by a weighting factor for each soil property, and adding the products to determine the contrast score. This procedure is illustrated in Table 3.15 using two soils, Ch (Chehalis) and JoB (Jory). The contrast score of each pair was plotted against its corresponding $\triangle$APR. The result is shown in Fig. 3.2.

The relationship in Fig. 3.2 ($r = 0.219$) is not very good at all, so the calibration process was repeated several times, each time adjusting the weighting factors used. In each case, however, a wide range of contrast scores for each difference in agricultural potential rating was observed. The failure to discover a combination of soil properties, suitability codes, and weighting factors that would give an acceptable relationship between soil contrast score and the potential rating differences as shown in Fig. 3.2 gives doubt as to the validity of this model, so it was not considered further.

Table 3.14. Soil properties and their new assigned codes

Soil Properties				
			Code	
A. Coarse fragments of the A and B (%)				
<15			1	
15 - 30			2	
30 - 60			7	
>60			10	
B. Flooding				
	None	Rare	Occasional	Frequent
Growing season	1	6	8	10
Non-growing season	1	2	2	3
C. Depth of rooting (inches)				
>40			1	
30 - 40			2	
20 - 30			5	
10 - 20			8	
<10			10	
D. Slope (%)				
A (0-3)			1	
B (3-8)			2	
C (8-15)			4	
D (15-25)			7	
E (>25)			10	

Table 3.14. Cont'd.

E. Drainage	
Excessively drained	1
Somewhat excessively drained	1
Well drained	1
Moderately well drained	2
Somewhat poorly drained, moderately slow or more rapid permeability	2
Somewhat poorly drained, moderately slow to very slow permeability	5
Poorly drained, moderately slow permeability	7
Poorly drained, slow to very slow permeability	7
Very poorly drained	10
F. Moist Consistence of the B	
Loose	1
Friable	2
Firm	5
Very firm	8
Extremely firm	10
G. Texture of the A and B	
c, sic, sc	1
sicl, cl, scl	2
sil, l	3
sl	7
ls, s	10
H. pH of the A and B	
<4.5	1
4.5 - 5.5	2
5.6 - 6.5	4
6.6 - 7.3	6
7.4 - 7.8	7
7.9 - 8.4	8
8.5 - 9.0	9
>9.0	10

Table 3.14. Cont'd.

I. Workability, in suitability level

Sand	Sand, Loamy sand	1
Loamy sand	weak, very friable	2
Sandy loam	all others	1

	Structure Grade	Moist Consistence: very friable	friable	firm	very firm
Loam	strong	2	1	1	2
Silt loam	moderate	2	2	1	2
	weak	3	2	2	3
	massive	3	3	3	3
Silty clay loam					
Clay loam	strong		2	2	3
Sandy clay	moderate	3	3	2	3
loam	weak	4	3	3	4
	massive	4	4	4	4
Silty clay loam					
Sandy clay	strong	4	3	3	3
Clay	moderate	4	4	3	4
	weak	5	4	4	4
	massive	5	5	5	5

Suitability Level	Contrast Code
1	1
2	3
3	5
4	7
5	10

J. Available Water-holding Capacity (in)

>12	1
9 - 12	3
6 - 9	5
3 - 6	7
<3	10

Table 3.15. Soil properties, contrast codes, and calculation of contrast for a Ch-JoB pair

	Ch	JoB	Diff.	Weights	Products
Rock fragments of the A	1	1	0	3	0
Rock fragments of the B	1	1	0	3	0
Flooding	2	1	1	4	4
Depth of rooting	1	1	0	4	0
Slope	1	2	1	3	3
Drainage	1	1	0	4	0
Moist consistence of B	2	2	0	2	0
Texture of the A	2	2	0	4	0
Texture of the B	2	1	1	3	3
pH of the A	6	4	2	2	4
pH of the B	4	2	2	2.5	5
Workability	3	3	0	2	0
Available waterholding capacity	5	3	2	3	6
		Contrast Score			25

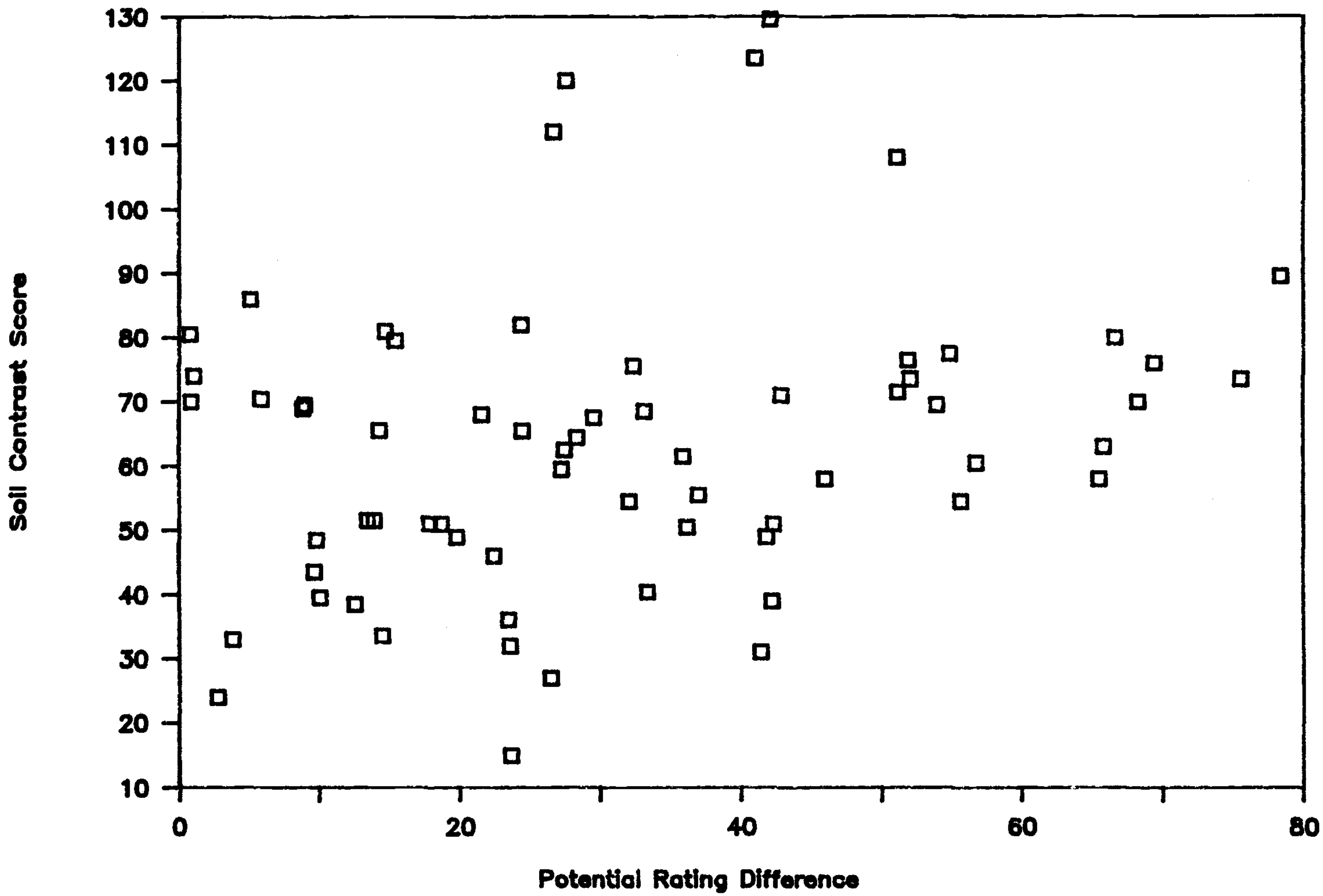

Fig. 3.2. Regression between agricultural potential rating difference and soil contrast score using soils selected by random sampling

The Final Model

Experience gained through experimentation with the previous models provided the basis for the development of the final model. This model uses a selected set of soil properties, divides the range of values for each property into classes, assigns contrast scores to each class, incorporates a weighting of soil factors, and combines information from all properties evaluated into a single statement of contrast between any two soils. The details of this model are spelled out in the sections to follow.

A. Soil Properties Included in the Model

The final model utilizes the soil properties shown in Table 3.16. The importance of all the properties except EP, SP and DPD has been discussed in the previous models. Erosion phase (EP) is an important property because eroded soils have shallower effective rooting depth and may limit the supply of water and nutrients to the plant. The removal of the topsoil also exposes soil layers that are low in organic matter and have less favorable physical properties, such as high bulk density and firm moist consistence.

Salinity phase (SP) was added because this property is important for soils belonging to the Aridisol order. The presence of excess salts is detrimental to the plants because it limits the absorption of water and nutrients.

Table 3.16. List of soil properties used in the final model

Soil Properties	Symbol
Coarse fragments of the A	CfA
Coarse fragments of the B	CfA
Flooding	Fld
Depth of Rooting	DRt
Slope	Slo
Drainage, permeability and depth to least permeable layer	DPD
Erosion phase	EP
Salinity phase	SP
Texture of the A	TexA
Texture of the B	TexB
pH of the A	pHA
pH of the B	pHB

DPD is an index that expresses interactions among drainage, permeability and depth to least permeable layer. Drainage and permeability usually can be determined from the map unit description in the soil survey report. In cases where permeability is not given in the map unit description, the lowest permeability in the Table of soil properties can be used. The permeability class using this value can be derived using these ranges:

Permeability (in/hr)	Class
<0.06	very slow
0.06 - 0.2	slow
0.2 - 0.6	moderately slow
0.6 - 2.0	moderate
2.0 - 6.0	moderately rapid
6.0 - 20	rapid
>20	very rapid

B. Establishing Classes and Assigning Contrast Codes for each Class of each Property

The range of values of each soil property was divided into several classes. For some properties, e.g. depth of rooting, slope, pH, salinity, and erosion, the classes used were those used for soil classification and mapping. Established classes of coarse fragments were modified slightly by subdividing the <15% coarse fragments class into 2 classes, non-stony to 5%, and 5-15%. This division was necessary in order to adequately express soil differences important for agricultural management and crop growth. For the remaining properties (flooding, DPD and texture), new classes were created specifically for this study (Table 3.17).

In general the first class of each property is the most suitable class. Differences in soil texture, however, do not correspond to suitability for crop growth. Consequently, classes of soil texture were arranged from the highest to the lowest amount of clay. Similarly, pH classes were arranged from extremely acid to very strongly alkaline.

Each class of each soil property was assigned a numerical code between 0 and 10 (Table 3.17). The 1st class was assigned a class code of 0 and the last class was assigned a class code of 10.

For soil properties that include 5 classes, except salinity phase, the class code range was equally divided, i.e. with an increment of 2.5 for each class. Soil properties with the number of classes unequal to 5 were assigned class codes with an unequal increment.

The determination of DPD suitability classes was done using the data on drainage, permeability and depth to least permeable layer. For example, a soil has an exceedingly high suitability for agriculture if it is well drained and has permeability greater than or equal to moderate, or if it is well drained, has moderately slow permeability, and a depth to least permeable layer of at least 20 inches. Because drainage is more feasible in a permeable soil than in a slowly permeable soil, soils whose slowly permeable horizons are deeper in the profile are more suitable than those whose least permeable horizons are shallow or near the surface.

The values of each soil property in the model were determined for each soil present in the sample areas for all 5 soil orders studied. The class codes corresponding to the properties of each soil were also determined according to the criteria in Table 3.17. This process is illustrated in Table 3.18 using Ms (Middlebury) and ChC (Chenango) soils from Broome County, New York.

Table 3.17. Classes and class codes for each soil property

Classes	Code
Coarse Fragments of the A and B	
Non-stony - 5%	0
5 - 15% (no adjective)	2.5
15 - 30% (adj. like gravelly)	5.0
30 - 60% (adj. like very gravelly)	7.5
>60% (adj. like extremely stony)	10.0
Flooding	
None	0
Rare during a growing season	1
Occasional during a non-growing season	3
Frequent during a non-growing season	4
Occasional during a growing season	8
Frequent during a growing season	10
Depth of Rooting	
>40 in.	0
30 - 40 in.	2.5
20 - 30 in.	5.0
10 - 20 in.	7.5
<10 in.	10.0

Table 3.17. Cont'd.

Slope

<3% (A)	0
3-8% (B)	2.5
8-15% (C)	5.0
15-25% (D)	7.5
>25% (E,F)	10.0

DPD

	DRAINAGE				
	WD	MWD	SPD	PD	VPD
PERMEABILTY					
Moderate	EH	VH	H	H	M
Moderately slow					
>40 in.	EH	VH	H	M	L
30-40 in.	EH	VH	H	M	L
20-30 in.	EH	H	M	M	L
10-20 in.	VH	H	M	L	L
<10 in.	VH	H	L	L	L
Slow					
>40 in.	H	H	M	M	M
30-40 in.	H	H	M	L	L
20-30 in.	H	M	L	L	L
10-20 in.	H	M	L	L	VL
<10 in.	M	M	L	VL	VL
Very Slow					
>40 in.	H	M	M	L	L
30-40 in.	H	M	L	L	VL
20-30 in.	M	L	L	VL	VL
10-20 in.	M	L	VL	VL	U
<10 in.	M	L	VL	U	U

EH (Exceedingly High)	0
VH (Very High)	1.5
H (Good)	3.0
M (Fair)	4.5
L (Poor)	6.0
VL (Very Poor)	8.5
U (Unsuitable)	10.0

Table 3.17. Cont'd.

Erosion phase		
No erosion		0
Moderately eroded		3
Severely eroded		10.0
Salinity phase		
<2 mmhos/cm	non-saline	0
2-4 mmhos/cm	very slightly saline	2
4-8 mmhos/cm	slightly saline	3.5
8-16 mmhos/cm	moderately saline	8
>16 mmhos/cm	saline	10
Texture of the A and B		
c, sic, sc		0
sicl, cl, scl		2.5
sil, l		5.0
sl		7.5
ls, s		10.0
pH of the A and B		
<4.5 (Extremely acid)		0
<4.5-5.0 (Very strongly acid)		1
5.1-5.5 (Strongly acid)		2
5.6-6.0 (Medium acid)		3
6.1-6.5 (Slightly acid)		4
6.6-7.3 (Neutral)		5.5
7.4-7.8 (Slightly alkaline)		6
7.9-8.3 (Moderately alkaline)		7.5
8.4-9.0 (Strongly alkaline)		8.5
>9.0 (Very strongly alkaline)		10.0

Table 3.18. Soil property data and corresponding class codes for 2 soils from the Broome County, New York sample areas

Soil Properties	Ms		ChC	
	Value	Code	Value	Code
Coarse fragments of A	none	0	gravelly	5
Coarse fragments of B	none	0	very gravelly	7.5
Flooding	occasional during growing season	8	none	0
Depth of rooting	45"	0	>40"	0
Slope	A	0	C	5
DPD		1.5		0
Drainage	moderately well drained		well drained	
Permeability	moderate		moderate	
Depth to least permeable layer	5"		29"	
Erosion phase	non-eroded	0	non-eroded	0
Salinity phase	nonsaline	0	nonsaline	0
Texture of A	sil	5	loam	5
Texture of B	sil	5	sandy loam	7.5
pH of the A	slightly acid	4	medium acid	3
pH of the B	slightly acid	4	medium acid	3

C. Determination of Contrast Levels based on Class Differences

After different classes and their corresponding codes were set up, a contrast level between any two classes within each property was assigned. The contrast levels and their symbols are as follows: Very Similar (VS), Similar (S), Somewhat Contrasting(SC), Contrasting (C), and Very Contrasting (VC). These contrast levels expressed the amount of difference in each single property between any two soils being compared. For properties whose ranges were divided into five classes, soils having the same class are very similar, soils with one class difference are similar and so on up to the highest level of contrast, which has a difference of 4 classes.

A very similar contrast means that, for the property under consideration, the 2 soils being compared have the same class. Very contrasting means that the values of the property for the 2 soils are at opposite ends of the range possible, and the soils will require the most different soil management practices, e.g. a soil that is extremely gravelly versus another soil that has <5% gravel.

For some properties, two or three combinations of class comparisons can occur in one contrast level. An example of this is DPD, for which EH vs M and EH vs L have the same contrast level, i.e. contrasting.

Table 3.19 displays the contrast levels for all possible class comparisons within each property included in the soil contrast model. This table also shows for each pair of classes the numerical difference in the class codes (from Table 3.17). These absolute differences are summarized in Table 3.20, which facilitates rapid determination of the contrast level for each property used in comparing any two soils. One simply has to record the data, as in Table 3.18, note in addition the difference in class code for each property, use Table 3.20 to find the appropriate column that includes this difference in class code for each property, and record the contrast level as the appropriate column heading.

Table 3.20 shows that the same values of absolute difference can correspond to different contrast levels. For example, an absolute difference of 5 for flooding represents a contrasting situation, whereas a 5 for coarse fragments of A and B represents only a somewhat contrasting situation, and 5 for erosion phase represents soils that are similar with regard to this property. Thus, the absolute differences are used just to provide a convenient way to determine the contrast level of each property. The absolute differences should not be compared with each other, as the same absolute difference can give different contrast levels depending on the property.

Table 3.20 also shows how the various soil properties were weighted. For most properties, maximum differences in the range of values warranted a very contrasting designation. For erosion phase and salinity phase, however, the maximum contrast levels are SC and C, respectively. This recognizes that crops can still be grown even on severely eroded soil, so this property was not given as much weight. Likewise salinity phase was given a maximum contrast level of contrasting because it can be ameliorated, and some crops can still be grown on saline soils. Soil pH could have been given lower weights also, but since an extremely acid soil and a very strongly alkaline soil are not likely to occur side by side, the practical reality is that pH contrast level will rarely, if ever, exceed somewhat contrasting.

One other aspect of Table 3.20 is that numerical contrast codes as shown in parenthesis beside the symbol for each contrast level. These codes are used in subsequent steps to determine the overall contrast between any 2 soils.

Table 3.21 presents a complete example of the determination of contrast levels and the assigning of contrast codes for all properties used to compare a given pair of soils.

Table 3.19. Contrast levels and absolute differences in codes for pairs of classes within each soil property

	Contrast Level	Absolute Difference in Codes
Coarse fragments of the A and B		
Same class	VS	0
Non-stony - 5% vs 5-15%	S	2.5
Non-stony - 5% vs 15-30%	SC	5.0
Non-stony - 5% vs 30-60%	C	7.5
Non-stony - 5% vs >60%	VC	10
5-15% vs 15-30%	S	2.5
5-15% vs 30-60%	SC	5.0
5-15% vs >60%	C	7.5
15-30% vs 30-60%	S	2.5
15-30% vs >60%	SC	5.0
30-60% vs >60%	S	2.5
Flooding		
Same class	VS	0
None vs rare at growing season	S	1
None vs occasional at non-growing season	S	3
None vs frequent at non-growing season	SC	4
None vs occasional at growing season	VC	8
None vs frequent at growing season	VC	10
Rare at growing season vs occasional at non-growing season	S	1
Rare at growing season vs frequent at non-growing season	SC	3
Rare at growing season vs occasioanl at growing season	C	7
Rare at growing season vs frequent at growing season	VC	9
Occasional at non-growing season vs frequent at non growing season	S	1
Occasional at non-growing season vs occasional at growing season	C	5
Occasional at non-growing season vs frequent at growing season	VC	7
Frequent at non-growing season vs occasional at growing season	SC	4
Frequent at non-growing season vs frequent at growing season	C	6
Occasional at growing season vs frequent at growing season	S	2

Table 3.19. Cont'd.

Depth of Rooting		
Same class	VS	0
>40 in. vs 30 - 40 in.	S	2.5
>40 in. vs 20 - 30 in.	SC	5
>40 in. vs 10 - 20 in.	C	7.5
>40 in. vs <10 in.	VC	10
30 - 40 in. vs 20 - 30 in.	S	2.5
30 - 40 in. vs 10 - 20 in.	SC	5.0
30 - 40 in. vs <10 in.	C	7.5
20 - 30 in. vs 10 - 20 in.	S	2.5
20 - 30 in. vs <10 in.	SC	5.0
10 - 20 in. vs <10 in.	S	2.5
Slope		
Same class	VS	0
<3% vs 3-8%	S	2.5
<3% vs 8-15%	SC	5.0
<3% vs 15-25%	C	7.5
<3% vs >25%	VC	10.0
3-8% vs 8-15%	S	2.5
3-8% vs 15-25%	SC	5.0
3-8% vs >25%	C	7.5
8-15% vs 15-25%	S	2.5
8-15% vs >25%	SC	5.0
15-25% vs >25%	S	2.5
DPD		
Same code	VS	0
EH vs VH	S	1.5
EH vs H	SC	3.0
EH vs M	C	4.5
EH vs L	C	6.0
EH vs VL	VC	8.5
EH vs U	VC	10.0
VH vs H	S	1.5
VH vs M	SC	3.0
VH vs L	C	4.5
VH vs VL	VC	7.0
VH vs U	VC	8.5
H vs M	S	1.5
H vs L	SC	3.0
H vs VL	C	5.5
H vs U	VC	7.0
M vs L	S	1.5
M vs VL	SC	4.0
M vs U	C	5.5
L vs VL	S	2.5
L vs U	SC	4.0
VL VS U	S	1.5

Table 3.19. Cont'd.

Erosion Phase		
Same class	VS	0
No erosion vs moderately eroded	S	3
No erosion vs severely eroded	SC	10
Moderately eroded vs severely eroded	S	7
Salinity Phase		
Same class	VS	0
Non-saline vs very slightly saline	S	2
Non-saline vs slightly saline	S	3.5
Non-saline vs moderately saline	SC	8
Non-saline vs saline	C	10
Very slightly saline vs slightly saline	S	1.5
Very slightly saline vs moderately saline	SC	6
Very slightly saline vs saline	SC	8
Slightly saline vs moderately saline	S	4.5
Slightly saline vs saline	SC	6.5
Moderately saline vs saline	S	2
Texture of the A and B		
Same class	VS	0
c, sic, sc vs sicl, cl, scl	S	2.5
c, sic, sc vs sil, l	SC	5.0
c, sic, sc vs sl	C	7.5
c, sic, sc vs ls, s	VC	10.0
sicl, cl, scl vs sil, l	S	2.5
sicl, cl, scl vs sl	SC	5.0
sicl, cl, scl vs ls, s	C	7.5
sil, l vs sl	S	2.5
sil, l vs ls, s	SC	5.0
sl vs ls, s	S	2.5

Table 3.19. Cont'd.

<u>pH of the A and B</u>		
Same class	VS	0
<4.5 vs 4.5-5.0	S	1
<4.5 vs 5.1-5.5	S	2
<4.5 vs 5.6-6.0	SC	3
<4.5 vs 6.1-6.5	SC	4
<4.5 vs 6.6-7.3	C	5.5
<4.5 vs 7.4-7.8	C	6
<4.5 vs 7.9-8.3	C	7.5
<4.5 vs 8.4-9.0	VC	8.5
<4.5 vs >9.0	VC	10.0
4.5-5.0 vs 5.1-5.5	S	1
4.5-5.0 vs 5.6-6.0	S	2
4.5-5.0 vs 6.1-6.5	SC	3
4.5-5.0 vs 6.6-7.3	SC	4.5
4.5-5.0 vs 7.4-7.8	SC	5
4.5-5.0 vs 7.9-8.3	C	6.6
4.5-5.0 vs 8.4-9.0	C	7.5
4.5-5.0 vs >9.0	VC	9
5.1-5.5 vs 5.6-6.0	S	1
5.1-5.5 vs 6.1-6.5	S	2
5.1-5.5 vs 6.6-7.3	SC	3.5
5.1-5.5 vs 7.4-7.8	SC	4
5.1-5.5 vs 7.9-8.3	C	5.5
5.1-5.5 vs 8.4-9.0	C	6.5
5.1-5.5 vs >9.0	C	8
5.6-6.0 vs 6.1-6.5	S	1
5.6-6.0 vs 6.6-7.3	S	2.5
5.6-6.0 vs 7.4-7.8	SC	3
5.6-6.0 vs 7.9-8.3	SC	4.5
5.6-6.0 vs 8.4-9.0	C	5.5
5.6-6.0 vs >9.0	C	7
6.1-6.5 vs 6.6-7.3	S	1.5
6.1-6.5 vs 7.4-7.8	S	2
6.1-6.5 vs 7.9-8.3	SC	3.5
6.1-6.5 vs 8.4-9.0	SC	4.5
6.1-6.5 vs >9.0	C	6
6.6-7.3 vs 7.4-7.8	S	0.5
6.6-7.3 vs 7.9-8.3	S	2
6.6-7.3 vs 8.4-9.0	SC	3
6.6-7.3 vs >9.0	SC	4.5
7.4-7.8 vs 7.9-8.3	S	1.5
7.4-7.8 vs 8.4-9.0	S	2.5
7.4-7.8 vs >9.0	SC	4
7.9-8.3 vs 8.4-9.0	S	2.5
8.4-9.0 vs >9.0	S	1.5

Table 3.20. Values of absolute difference in contrast codes corresponding to each contrast level for each soil property

Soil Properties	CONTRAST LEVELS				
	VS(1)	S(2)	SC (3)	C (4)	VC (5)
Coarse fragments of A and B	0	2.5	5	7.5	10
Flooding	0	1-3	4	5-7	8-10
Depth of rooting	0	2.5	5	7.5	10
Slope	0	2.5	5	7.5	10
DPD	0	1.5-2.5	3-4	4.5-6.0	7-10
Erosion phase	0	3.0-7.0	10	-	-
Salinity phase	0	1.5-4.5	6-8	10	-
Texture of the A and B	0	2.5	5	7.5	10
pH of the A and B	0	1.0-2.5	3-5	5.5-8.0	8.5-10

Table 3.21. Example for determining the contrast level for each property used to compare two soils

Property	Ms Value	Ms Code	ChC Value	ChC Code	Abs. Diff.	Contrast Level*	Contrast Code**
CfA	none	0	gravelly	5	5	SC	3
CfB	none	0	very gravelly	7.5	7.5	C	4
Fld	occasional during growing season	8	none	0	8	VC	5
DRt	>40"	0	>40"	0	0	VS	1
Slo	A	0	C	5	5	SC	3
DPD	VH	1.5	EH	0	1.5	S	2
EP	non-eroded	0	non-eroded	0	0	VS	1
SP	non-saline	0	non-saline	0	0	VS	1
TexA	sil	5	l	5	0	VS	1
TexB	sil	5	sl	7.5	2.5	S	2
pHA	slightly acid	4	medium acid	3	1	S	2
pHB	slightly acid	4	medium acid	3	1	S	2

*Determined from Table 3.20 as the column containing the absolute difference for each property.
**Determined from Table 3.20 as the parenthesized value corresponding to each contrast level.

D. Determination of Overall Soil Contrast

The overall level of contrast of a pair of soils was determined by examining the array of contrast codes for the entire set of properties evaluated. In the case where a single property had a higher contrast code than all the others, the contrast level for the pair was made the same as that of the most contrasting property. This would be the case in the example in Table 3.21, for which flooding alone has a contrast code of 5. On that basis alone the two soils would be declared as very contrasting soils.

Where several properties shared the highest contrast level present in the array of contrast codes, the contrast level for the pair was either the same as the highest level or bumped to the next higher level. An example of the former case is a pair classified as similar even though three properties all had contrast codes of 2. Examples of the latter case include declaring as somewhat contrasting a pair having $\geq$ four 2's, or declaring as contrasting a pair having two 3's and $\geq$ four 2's. This recognizes the fact that 2 soils may have a high degree of contrast not only because of one or two dominant properties but also because a large number of properties co-vary at the same level of contrast. This cumulative effect of several varying properties is the reason for declaring a higher level of contrast. The specific combinations of contrast codes used to declare the overall degree of contrast are given in Table 3.22. Two other worked examples are shown in Tables 3.23 and 3.24.

Table 3.22. Guide for determining overall soil contrast

VERY SIMILAR

All properties considered in the model have the same values. Pairs of miscellaneous landtypes were also very similar in that crops could not be grown on either member of the pair.

SIMILAR

1. $\leq$ three 2's

SOMEWHAT CONTRASTING

1. $\geq$ four 2's
2. One 3 with any number of 2's
3. Two 3's with $\leq$ three 2's

CONTRASTING

1. Two 3's with $\geq$ four 2's
2. $\geq$ three 3's with any number of 2's
3. One 4 with $<$ three 3's and with any number of 2's
4. Two 4's with $\leq$ one 3 and with any number of 2's

VERY CONTRASTING

1. One 4 with $\geq$ three 3's and any number of 2's
2. Two 4's with $\geq$ two 3's and with any number of 2's
3. $\geq$ three 4's with any number of 3's and 2's.
4. $\geq$ one 5

EXTREMELY CONTRASTING

Any pairs with miscellaneous land types such as rockland, marsh, and alluvial land. This is a comparison between a soil where crops can be grown and a miscellaneous land type where crops cannot be grown.

Table 3.23. Determination of overall soil contrast for a pair of MhB-VoC soils*

SOIL PROPERTIES	CONTRAST LEVEL
Coarse fragments of the A	1
Coarse fragments of the B	1
Flooding	1
Depth of rooting	1
Slope	2
Drainage	2
Erosion phase	1
Salinity phase	1
Texture of the A	1
Texture of the B	1
pH of the A	1
pH of the B	1

* The contrast level of this pair is similar becuase there are only two properties with similar (2) contrast level. MhB and VoC are Mardin and Volusia soils, respectively, found in Broome County, New York.

Table 3.24. Determination of overall soil contrast for a pair of 368-369 soils*

SOIL PROPERTIES	CONTRAST LEVEL
Coarse fragments of the A	1
Coarse fragments of the B	1
Flooding	1
Depth of rooting	1
Slope	1
Drainage	2
Erosion phase	1
Salinity phase	1
Texture of the A	2
Texture of the B	2
pH of the A	2
pH of the B	2

*The contrast level of this pair is somewhat contrasting becuase there are five properties with similar (2) contrast level. 368 and 369 are Macksburg and Winterset soils, respectively, found in Adair County, Iowa.

The final model has several advantages over models based on taxonomic contrast. Among these advantages are:

1. The model is based on properties important for general agriculture, which is the purpose of the model. Taxonomic contrast is based on properties that reflect the genesis of the soils, such as the presence of diagnostic horizons, which may not be important to general agriculture.
2. The model computes the contrasts quantitatively and assigns a qualitative description for the contrast. Contrast using the model can be expressed qualitatively as very similar, similar, somewhat contrasting, contrasting, very contrasting and exceedingly contrasting based on well-defined criteria that incorporate both the number of varying properties and their degrees of difference.
3. Taxonomic contrast is difficult to compute, as one needs to determine the classification of all soils available in the landscape area where the sample is located. Cases where classification of soil bodies such as miscellaneous land types are not given make such computations difficult.
4. The final model allows for the characterization of the contrast of specific pairs of soils based on the properties incorporated in the model. Taxonomic contrasts are designed more to represent the over-all contrast of an area and are not as appropriate for comparisons between specific soils.
5. The final model is also more useful than the contrast models developed in Russia as it is based on known properties important for general agriculture.

CHAPTER 4

LEVELS OF CONTRAST AND REASONS FOR CONTRAST BETWEEN SOILS WITHIN A LANDSCAPE BODY

The final model was applied to all 3 sample areas from each soil association representing the five soil orders selected for testing. Each map unit in a sample area was coded, and the levels of contrast for all possible pairs were computed. A list of all the possible pairs and their contrast levels was derived.

Not all possible pairs are pairs of soils that actually occur next to each other in the landscape. A pair of adjacent soils with A and E slopes, for example, rarely occurs. Only those soils that actually occurred in adjacent landscape positions, as determined from the maps, were used to test and evaluate the model.

All of the raw data used in the analyses that follow are presented in the appendix. Only data necessary to support the interpretations are incorporated in the text of this chapter.

General Procedures

A. Levels of Contrast

Two methods were used to determine the levels of contrast in each sample area. The first method involved determining the total number of times an adjacent pair of soils belonging to each different contrast level occurred. A pair was counted even if the boundary length was very short. An example of this method is shown in Table 4.1. The soils corresponding to the map unit symbols are shown in Table 4.8.

Table 4.1. Frequency of occurrence of pairs of adjacent soils and their associated contrast levels for Inceptisol sample 1

A. Frequency of occurrence of map unit pairs

	ArD	LdD	LoE	MhB	MhC	MhD	MhE	Ms	TuD	VoB	VoC	VoD	Wd
Ad					2EC	2EC		2EC		2EC	2EC	1EC	
ChC					1C			1VC			1C		
LdC	1SC	4S	1SC	2C	3C				1SC	2SC			
LdD	1S		1S	1C	4C	1SC				4C			
LoE					1C								
MhB					2S		1C			3S	2S		
MhC						5S	1SC	2VC		12S	6S		1VC
MhD							2S	1VC		3SC	6SC	2SC	
MhE											2SC	1SC	
MrF											1SC		
Ms										1VC	1VC		
TuD										1SC	1C		
VoB											7S	1SC	1VC
VoC												3S	1VC

B. % of total number of occurrences of each contrast level

Contrast Level	Number of Occurrence	% of Total
Very Similar (VS)	0	0
Similar (S)	48	43.24
Somewhat Contrasting (SC)	24	21.62
Contrasting (C)	19	17.11
Very Contrasting (VC)	9	8.10
Exceedingly Contrasting (EC)	11	9.90

The second method involved determining the lengths of the lines serving as boundaries between adjacent pairs of soils with a given contrast level. Each pair of soils may have one or more segments, in which case all the lengths of the segments for each pair were added. The total boundary lengths for pairs belonging to very similar, similar, somewhat contrasting, contrasting, very contrasting and exceedingly contrasting levels were also determined. The proportion of the total boundary length taken up by each contrast level was computed as shown in Table 4.2.

Table 4.2. Percentage of the grand total boundary length occupied by each contrast level. Data from Inceptisol sample 1

Contrast Level	Total Boundary Length	% of Grand Total
Very Similar	0	0
Similar	47.0604	53.97
Somewhat Contrasting	21.4611	24.61
Contrasting	12.9364	14.83
Very Contrasting	5.7355	6.57
Exceedingly Contrasting	0	0
TOTAL	87.1934	100.00

B. Reasons for Contrast

The reasons for contrast are those properties that are most different when comparing two soils. Two separate procedures were used to characterize the reasons for soil contrast. Trends in the reasons for contrast which were not evident from one procedure often were apparent from the other procedure.

The first method involved the calculation of a weighted average contribution of each property to the overall contrast of adjacent soils throughout a sample area. The procedure is illustrated in Table 4.3. For each contrast level, the first step was to calculate the total boundary length by adding the length of all boundary segments that separate adjacent pairs of soils throughout the sample area. The proportion of boundary length taken up by each pair was then computed by dividing the length of boundary between each pair in the contrast level by the total boundary length. Then the contrast codes for every property in each pair were reduced by one. This was done so that subsequent multiplication of a code by the proportional length would yield a value of 0 whenever a property was identical in the two soils of a pair. All the non-zero codes for a pair were

Table 4.3. Sample of the weighted average method for determining the reasons for contrast. Data from Aridisol sample 1

Similar Pairs	Boundary Length	Proportion of TOTAL	PROPERTIES: Slope Code	Slope Prod.	Erosion Phase Code	Erosion Phase Prod.	Texture of B Code	Texture of B Prod.
70-30	6.158675	0.231	0	0	1	0.231	1	0.231
70-69	0.736173	0.028	1	0.028	0	0	0	0
30-69	6.820602	0.256	1	0.256	0	0	1	0.256
127-129	12.901473	0.485	1	0.485	0	0	0	0
TOTAL	26.616923		Subtotal	0.769		0.231		0.487
			Grand total	= 1.487				
% Contribution = $\frac{\text{Subtotal x 100}}{\text{Grand total}}$				51.71		15.53		32.75

Product = Code x Proportion of Boundary Length

multiplied by the proportional boundary length of that pair, yielding the values in the product columms in Table 4.3. The totals for each product column were obtained, and the column totals were added to give the grand total. The percent contribution of a property could then be calculated as the column total for that property divided by the grand total.

From Table 4.3 we can see that one half of the contrast among similar soils in an Aridisol sample is due to slope. The other half is due to texture of the B and erosion phase.

The means of the contribution of each soil property at each contrast level from all three sample areas were calculated as shown in Table 4.4. These means were plotted as in Fig. 4.1.

Table 4.4. Soil properties contributing to the contrast of pairs of contrasting soils. Data from Inceptisol soils*

Sample	CfA	CfB	Fld	DRt	Slo	DPD	TexB	pHA	pHB
1	0	15.11	0	16.26	19.17	46.57	0.80	1.26	0.80
2	3.87	12.66	0	12.66	18.99	44.86	1.93	2.50	2.50
3	20.28	10.80	0	10.80	26.12	11.39	0	0.25	20.28
Mean	8.05	12.86	0	13.24	21.43	34.27	0.91	1.34	7.86

*Soil properties corresponding to the symbols are found in Table 3.16

The second method was nothing more than a discrete counting of the number of distinct pairs of soils that occurred for each specific combination of soil properties that defined a given level of soil contrast (Table 4.5). Very contrasting soils were further differentiated according to the property or properties second in importance to the dominant one (Table 4.6)

The occurrence of a large number of pairs for a given soil property/contrast level combination indicates that that soil property is a very important reason for the contrast between the soils. From Table 4.5 it is evident that DPD and Slo are the two most important reasons for contrasting soils in the Inceptisol samples, whereas Fld, DRt and DPD are soil properties that contribute highly to the contrast of very contrasting soils (Table 4.6).

Methods 1 and 2 are different not only in terms of the method of determining the properties that contribute highly to the contrast of soils but also in terms of the properties which are considered. Method 1 includes all properties that differ between a pair of soils, regardless of whether or not they controlled the overall contribution. Method 2, however, includes only properties whose contrast codes figure directly in the determination of contrast level.

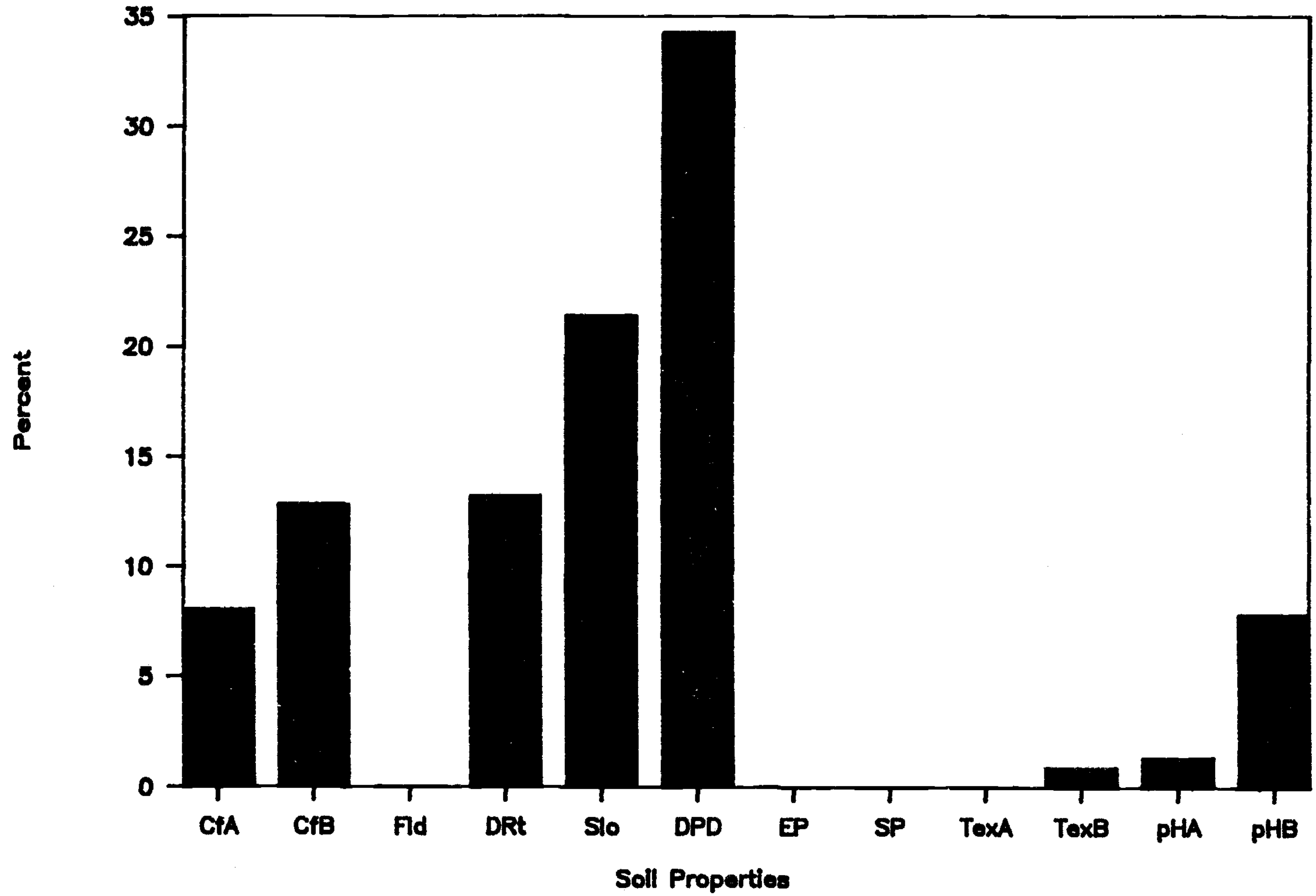

Fig. 4.1. An example of method 2 for determining reasons for contrast using very contrasting soils in Inceptisol

Table 4.5. Sample determination of the reasons for contrasting pairs using method 2. Data from Inceptisol soils

	Samples I	Samples II	Samples III
Contrasting			
One 4 with < three 3's			
DPD	8	5	1
Slo	1	1	3
Two 4's with ≤ one 3			
DRt, DPD	2	0	0
Two 3's with ≥ four 2's			
CfA, pHB	0	0	1
≥ three 3's			
Slo, pHB, CfA	0	0	1

Table 4.6. Sample determination of the reasons for very contrasting pairs using method 2. Data from Inceptisol soils

	Samples I	Samples II	Samples III
Very Contrasting			
One 5 with ≤ one 4			
Fld, DRt	4	3	1
Fld, CFB	1	0	0
One 5 with ≥ two 4's			
Fld, DRt, Slo	1	0	1
Fld, DRt, Drn	2	7	4

Soil Orders

A. Inceptisol

The legend for all the map units in all three samples of the Inceptisols is shown in Table 4.7. The area in acres, the number of delineations, and the soil order of each mapping unit are shown in Table 4.8. Mardin and Volusia soils dominate all three sample areas, and Lordstown is a major component of sample areas 1 and 2.

Table 4.7. Legend for all map units in the Inceptisol samples

Symbol[1]	Name
Ad	Alluvial land
AcA*	Alden and Chippewa soils, 0 to 3 percent slopes
ArD	Arnot Channery silt loam, 0 to 25 percent slopes
ChC*	Chenango and Howard gravelly loams, 5 to 15 percent slopes
LdB	Lordstown Channery silt loam, 0 to 5 percent slopes
LdC	Lordstown Channery silt loam, 5 to 15 percent slopes
LdD	Lordstown Channery silt loam, 15 to 25 percent slopes
LoE*	Lordstown and Oquaga Channery silt loams, 25 to 35 percent slopes
MhB	Mardin Channery silt loam, 2 to 8 percent slopes
MhC	Mardin Channery silt loam, 8 to 15 percent slopes
MhD	Mardin Channery silt loam, 15 to 25 percent slopes
MhE	Mardin Channery silt loam, 25 to 35 percent slopes
MrF*	Mardin and Cattaraugus soils, 35 to 60 percent slopes
Ms	Middlebury silt loam, 0 to 5 percent slopes
MuD*	Morris and Tuller very stony soils, 3 to 25 percent slopes
Ta	Tioga silt loam, 0 to 5 percent slopes
Tg	Tioga gravelly silt loam, fan
VoA	Volusia Channery silt loam, 0 to 3 percent slopes
VoB	Volusia Channery silt loam, 3 to 8 percent slopes
VoC	Volusia Channery silt loam, 8 to 15 percent slopes
VoD	Volusia Channery silt loam, 15 to 25 percent slopes
Wd	Wayland silt loam, 0 to 3 percent slopes

[1] The first capital letter is the initial of the soil name. The second capital letter is a guide to the slope class. Soil symbols without a slope letter are those miscellaneous land types or soils where slope is not significant to land use and management.

* These map units are undifferentiated units. All but MuD are represented by the first member of the unit in the computation of contrast level with each adjacent pair. The members that are used to represent the undifferentiated unit are considered more limiting to agriculture or dominant where the sample was taken.

Table 4.8. Area in acres, number of delineations, and soil order of each map unit in the Inceptisol samples

	Area (Number of Delineations)			Soil Order
	I	II	III	
Ad	48.656 (2)	69.372 (4)	20.399 (1)	Inceptisol
AcA	0	0	13.057 (3)	Inceptisol
ArD	9.763 (1)	0	0	Inceptisol
ChC	4.286 (1)	0	0	Inceptisol
LdB	0	9.684 (2)	0	Inceptisol
LdC	199.864 (3)	61.674 (3)	0	Inceptisol
LdD	122.276 (4)	107.631 (1)	0	Inceptisol
LoE	45.323 (1)	20.002 (2)	0	Inceptisol
MhB	85.645 (3)	8.295 (2)	129.816 (4)	Inceptisol
MhC	190.418 (9)	420.801 (19)	288.088 (13)	Inceptisol
MhD	68.539 (7)	100.091 (7)	122.752 (6)	Inceptisol
MhE	35.282 (1)	50.522 (6)	29.249 (2)	Inceptisol
MrF	0	4.762 (1)	0	Inceptisol
Ms	24.566 (1)	11.827 (2)	48.617 (3)	Inceptisol
MuD	45.124 (1)	0	0	Inceptisol
Ta	0	26.471 (2)	8.930 (1)	Inceptisol
Tg	0	18.058 (1)	0	Inceptisol
TuD	2.897 (1)	0	0	Inceptisol
VoA	0	4.445 (1)	0	Inceptisol
VoB	255.862 (4)	133.071 (9)	77.548 (11)	Inceptisol
VoC	186.965 (5)	1499.494 (8)	1865.686 (6)	Inceptisol
VoD	9.723 (2)	31.392 (3)	185.894 (8)	Inceptisol
Wd	3.016 (1)	3.770 (1)	0	Inceptisol
TOTAL	1338.206 (47)	2511.989 (74)	2790.036 (58)	
No. of Map Units	17	18	11	

The parent materials of the soils vary. Mardin and Volusia are Fragiochrepts and Fragiaquepts, respectively, formed in dense glacial till on gently rolling uplands. Mardin is moderately well drained to well drained and occurs on somewhat more convex positions. The depth to the fragipan is 18 to 22 inches. Volusia is somewhat poorly drained and tends to occupy lower landscape positions. The depth to the fragipan is 15 to 18 inches. Lordstown is a Dystrochrept derived from loamy till influenced by underlying gray sandstone. It occupies gently sloping to steep sites and does not have a fragipan, but bedrock is at a depth of 20 to 40 inches. Arnot (Dystrochrept) and Tuller (Haplaquept) are closely associated with Lordstown. They occur mainly on flat ridgetops and are shallow to bedrock. Alden soils (Haplaquept) are found in seeps and depressions.

Chenango is formed in glacial outwash deposits which are generally loamy textured and are commonly underlain by stratified sand and gravel. Tioga silt loam (Ta), Tioga gravelly loam (Tg), Middlebury and Wayland soils are formed from water-laid materials or recent alluvium. Tg, however, is formed from gravelly alluvium deposited on alluvial fans. Wayland, Tioga silt loam, Middlebury and Tioga gravelly silt loam are present on fans and along small streams.

The values of the properties that are included in the model and their class codes are shown in Appendix 1.1. The matrices showing the occurrence of adjacent map units for each sample are shown in Appendix 1.2. The most common pairs of map units were selected from the matrices and are shown in Table 4.9. They include pairs involving soil phases of the same series such as Mardin, Volusia and Lordstown and soil phases of different soil series.

Table 4.9. Contrast level and frequency of occurrence of the most common pairs in the Inceptisol samples

Pairs	Contrast Level	Number of Pairs I	II	III
MhC-VoB	S	12	0	0
MhC-VoC	S	6	12	22
VoC-VoD	S	9	5	9
VoB-VoC	S	7	8	9
MhD-VoC	SC	6	8	7
MhC-MhD	S	5	6	9
MhE-VoC	SC	0	6	0
MhB-VoC	S	0	0	8
MhD-VoB	SC	0	0	7
MhC-VoD	S	0	0	7
LdC-LdD	S	4	5	0
LdC-MhC	C	4	0	0
MhC-Ta	VC	0	5	0
LdB-VoB	C	4	0	0

Levels of Contrast

Data on levels of contrast are shown in Table 4.10 and Fig. 4.2 (method 1), and Table 4.11 and Fig. 4.3 (method 2). The boundary length and the contrast level for each property of a pair of soils is shown in Appendix 1.3. Both methods show that similar was the most frequent contrast level, followed by somewhat contrasting. The percentages of contrasting, very contrasting and exceedingly contrasting soils were almost equal and relatively low.

Area 3 has the highest percentage of similar soils. Area 3 also has the smallest area of Ad, the largest areas of VoC and VoD, and no Ld soils (Table 4.8). Of all these characteristics, the presence of the largest area of VoC and VoD contributed the most to the high percentage of similar soils in area 3.

The percentage of similar soils in area 2 using percent boundary length was about 16 percentage points larger than that using percent

Table 4.10. Percent of adjacent pairs in the Inceptisol samples belonging to different contrast levels

Contrast Level	Percent of Pairs			Mean
	I	II	III	
S	43.24	38.36	52.84	44.81
SC	21.62	19.49	23.57	21.56
C	17.11	8.17	8.13	11.13
VC	8.10	14.46	7.31	9.95
EC	9.90	19.49	8.10	12.49

Table 4.11. Distribution of contrast levels of Inceptisol samples based on percent of boundary length

Contrast Level	Percent of Boundary Length			Mean
	I	II	III	
S	50.66	54.92	66.33	57.30
SC	23.10	19.77	18.46	20.40
C	13.92	5.68	5.07	8.22
VC	6.17	8.58	3.05	5.90
EC	6.12	11.03	7.07	8.00

of the pairs. This is due to the higher percentage of very contrasting and exceedingly contrasting soils in the same sample using percent of the pair than percent of boundary length. Area 2 has two delineations of map unit Ad, with a total perimeter of 26.21 inches, that traverse more than 2/3 of the sample area, and they run right through the center of the entire area. Ad is a miscellaneous land type, so any pair associated with it would be classified as exceedingly contrasting.

The boundaries between Ad and other soils are composed of many short segments, such that the percent of exceedingly contrasting soils based on percent of pair is higher than the one based on

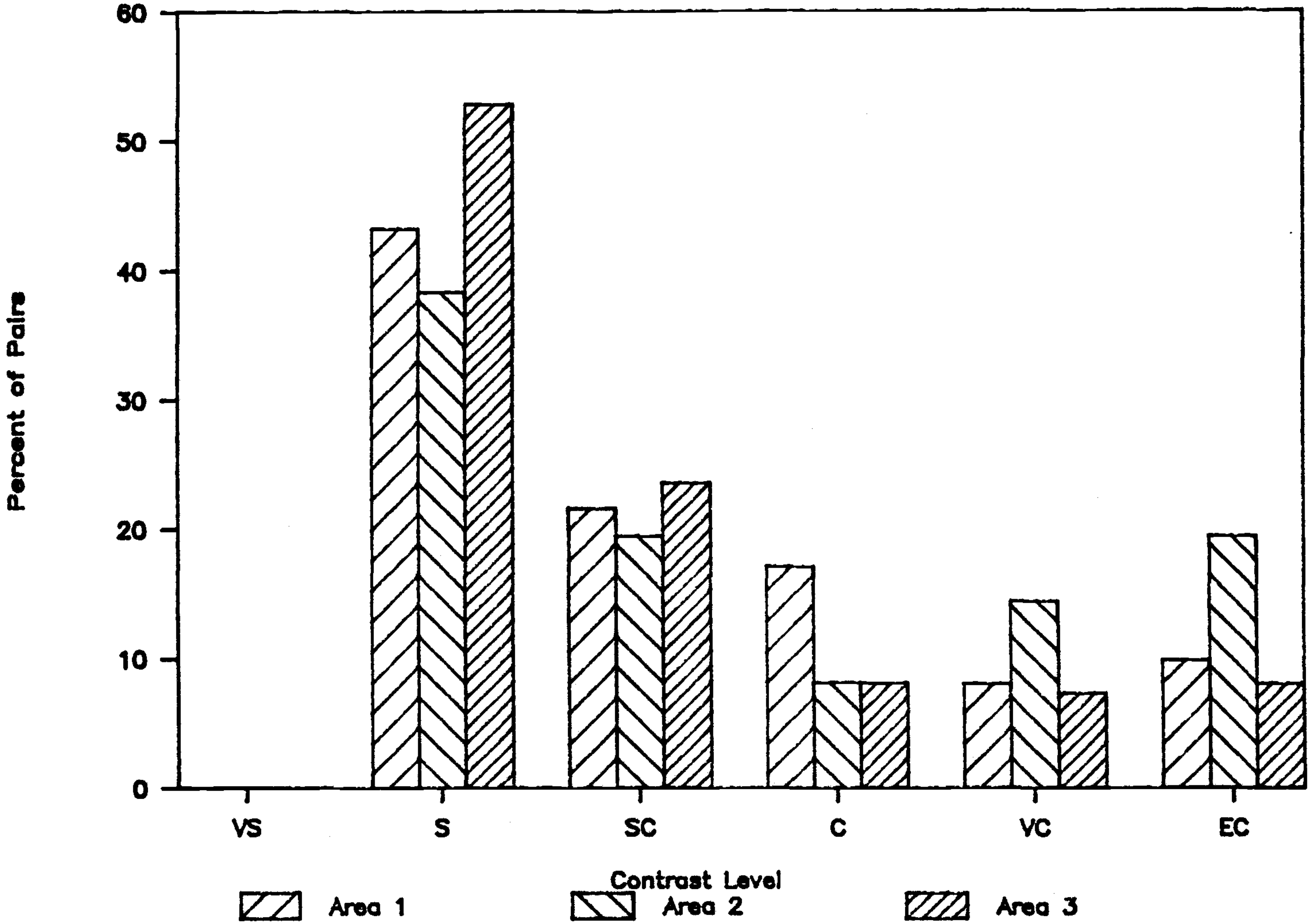

Fig. 4.2. Distribution of the percent of pairs among the different soil contrast levels in the Inceptisols

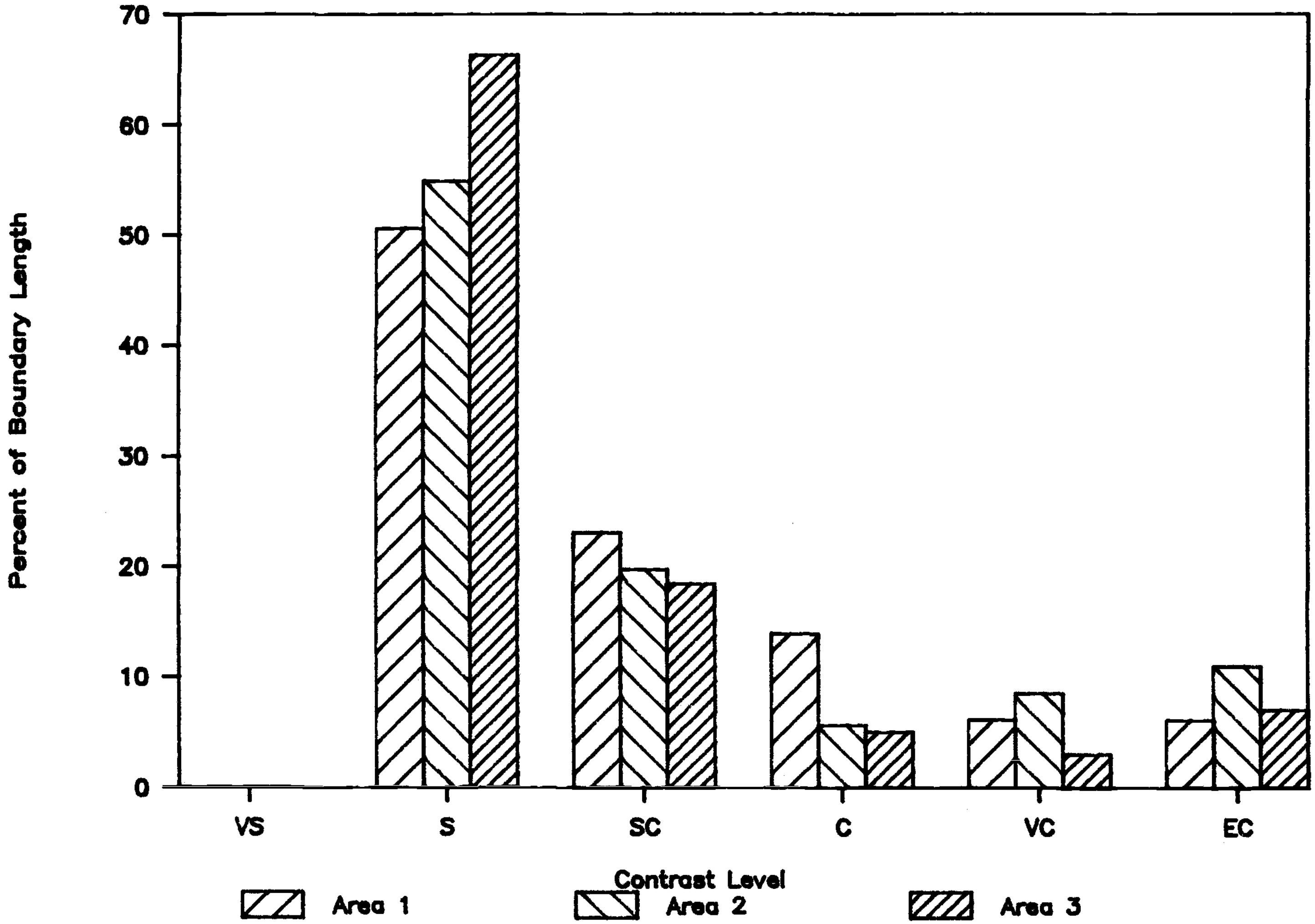

Fig. 4.3. Distribution of the percent of boundary length among the different soil contrast levels in the Inceptisols

percent of boundary length. These segments did not result in an increase in the percent of exceedingly contrasting soils based on percent of boundary length because the percentage of similar soils using this method also increased. This latter increase can be attributed to a long perimeter of enclosed soils. Sample area 2 has a total length of 51.92 inches of enclosed soils. Of this total length, 41.65 inches is the perimeter of MhC, an enclosed soil within VoC, and these two form a similar pair of soils.

The low percentage of similar soils in area 2 using percent of pairs was also affected by the high percentage of very contrasting soils in this area. Area 2 has all the alluvial soils that are responsible for very contrasting soils in all samples, and is therefore the area with the greatest amount of very contrasting soils.

Area 1 has the highest percentage of contrasting soils using both methods. Area 1 has the largest area of Lordstown that forms contrasting soils with MhC and VoB. As shown in Table 4.9, these pairs are two of the most common pairs.

Thus, the Inceptisol sample areas are dominated by similar soils followed by somewhat contrasting soils. The percentage of very contrasting and exceedingly contrasting soils are about the same. The presence of a miscellaneous land type increased the percent of exceedingly contrasting soils when counting only the number of adjacent pairs, but using percent of boundary length it did not. Increases in the percent of similar soils due to complexity of soil pattern offset whatever increase there was in the percent of exceedingly contrasting soils.

The reasons that are stated above for the variation of the percentage of contrast levels in each area using both methods are apart from the fact that the percentage of contrast levels are correlated. The percentage of all contrast levels add up to 100%. A change in the percentage of one or more levels will cause a corresponding change in all other contrast levels.

Reasons for Contrast

Data on the reasons for contrast are shown in Table 4.12 and in Figs. 4.4-4.7 (Method 1) and Table 4.13 (Method 2).

The contributions of CfA and pHB were noticeably higher and the contribution of DPD lower in sample area 3 than in samples 1 and 2 (Table 4.12). Sample 3 contained a delineation of AcA, which is an undifferentiated unit composed of Alden and Chippewa soils. These soils have no coarse fragments in the A horizon, and they developed on medium lime glacial till, and so are slightly acid.

The occurrence of AcA in sample 3 did not increase the contribution of DPD even though AcA is very poorly drained and Vo is somewhat poorly drained. The permeability of both soils is the same, and because the least permeable layer is deeper in AcA than Vo, the overall DPD contrast level is still very similar.

Table 4.12. Weighted average contribution of each soil property to each level of contrast in the Inceptisol sampling area*

Sample		CfA	CfB	Fld	DRt	Slo	DPD	TexB	pHA	pHB
S	1	0	1.29	0	1.29	61.80	35.60	0	0	0
	2	0	0	0	0	45.54	54.45	0	0	0
	3	0	0	0	0	53.38	46.61	0	0	0
	Mean	0	0.43	0	0.43	53.57	45.55	0	0	0
SC	1	0	7.40	0	5.59	35.57	48.80	0	2.61	0
	2	0	0.49	0	1.08	43.49	53.18	0	0	0
	3	0	0	0	0	44.82	53.09	0.69	0.69	0.69
	Mean	0	0.16	0	2.22	41.29	51.69	0.23	1.10	0.23
C	1	0	15.11	0	16.26	19.17	46.57	0.80	1.26	0.80
	2	3.87	12.66	0	12.66	18.99	44.86	1.93	2.50	2.50
	3	20.28	10.80	0	10.80	26.12	11.39	0	0.25	20.28
	Mean	8.05	12.86	0	13.24	21.43	34.27	0.91	1.34	7.86
VC	1	11.70	12.43	23.41	15.35	8.91	11.34	3.40	5.85	7.56
	2	9.94	11.38	22.76	17.07	8.95	16.22	2.05	5.69	5.93
	3	10.89	10.89	21.78	16.33	10.97	13.63	4.59	5.44	5.44
	Mean	10.84	11.57	22.6 5	16.25	9.61	13.73	3.35	5.66	6.31

* EP, SP and TexA were not included as they did not contribute to the contrast.

Table 4.13. Number of discrete pairs of Inceptisol soils for each controlling soil property within each contrast level

Contrast Level	Number of Discrete Pairs I	II	III
Similar			
One 2			
Slo	6	7	2
	LdC-LdD	LdB-LdC	
	LdD-LoE	MhD-MrF	
	MhB-MhC	VoB-VoC	
	MhD-MhE	VoC-VoD	
DPD	1	1	2
	MhB-VoB	MhC-VoC	
Two 2's			
Slo, DPD	3	3	3
	MhB-VoC	MhC-MhD	
	MhC-VoB	MhC-VoD	
Three 2's			
CfB, DRt, DPD	1	0	0
	LdD-ArD		
Somewhat Contrasting			
Four 2's			
CfB, DRt, DPD, Slo	1	0	0
	LdC-ArD		
One 3			
Slo	3	7	3
	LdC-LoE	MhC-MhE	
	MhC-MhE	VoA-MhC	
	VoB-VoD	VoA-VoC	
	LdB-LdD	VoB-VoD	
	MhB-MhD		
DPD	5	5	3
	MhD-LdD	MhD-VoD	
	MhD-VoC	MhE-LoE	
	MhE-VoD	MhE-LdD	
	TuD-LdC	MhD-LoE	
CfA	0	1	0
	Ms-Tg		
Two 3's with $\leq$ three 2's			
Slo, DPD	4	2	1
	MhD-VoB	VoB-TuD	
	MhE-VoC	VoC-MrF	

Table 4.13. Cont'd.

Contrasting			
One 4 with < three 3's			
DPD	8	5	1
	MhB-LdC	Ta-Wd	
	MhB-LdD	VoB-LdC	
	MhC-LdD	VoC-LdD	
	MhC-LoE	VoC-LoE	
Slo	1	1	3
	MhB-MhE	VoB-MrF	
	MhE-VoB	AlD-VoC	
Two 4's with ≤ one 3			
DRt, DPD	2	0	0
	VoC-ChC	MhC-ChC	
Two 3's with ≥ four 2's			
CfA, pHB	0	0	1
	AcA-VoB		
≥ three 3's			
Slo, pHB, CfA	0	0	1
	AcA-VoC		
Very Contrasting			
One 5 with ≤ one 4			
Fld, DRt	4	3	1
	MhC-Wd	VoC-Wd	
	VoB-Wd	MhC-Ms	
Fld, CfB	1	0	0
	Ms-ChC		
One 5 with ≥ two 4's			
Fld, DRt, Slo	1	0	1
	MhD-Ms		
Fld, DRt, DPD	2	7	4
	Ms-VoB	Ta-VoC	
	Ms-VoC	Ta-VoB	
	MhC-Tg	VoC-Tg	
	MhC-Ta		
Fld, DRt, DPD, Slo	0	0	1
	Ms-VoD		

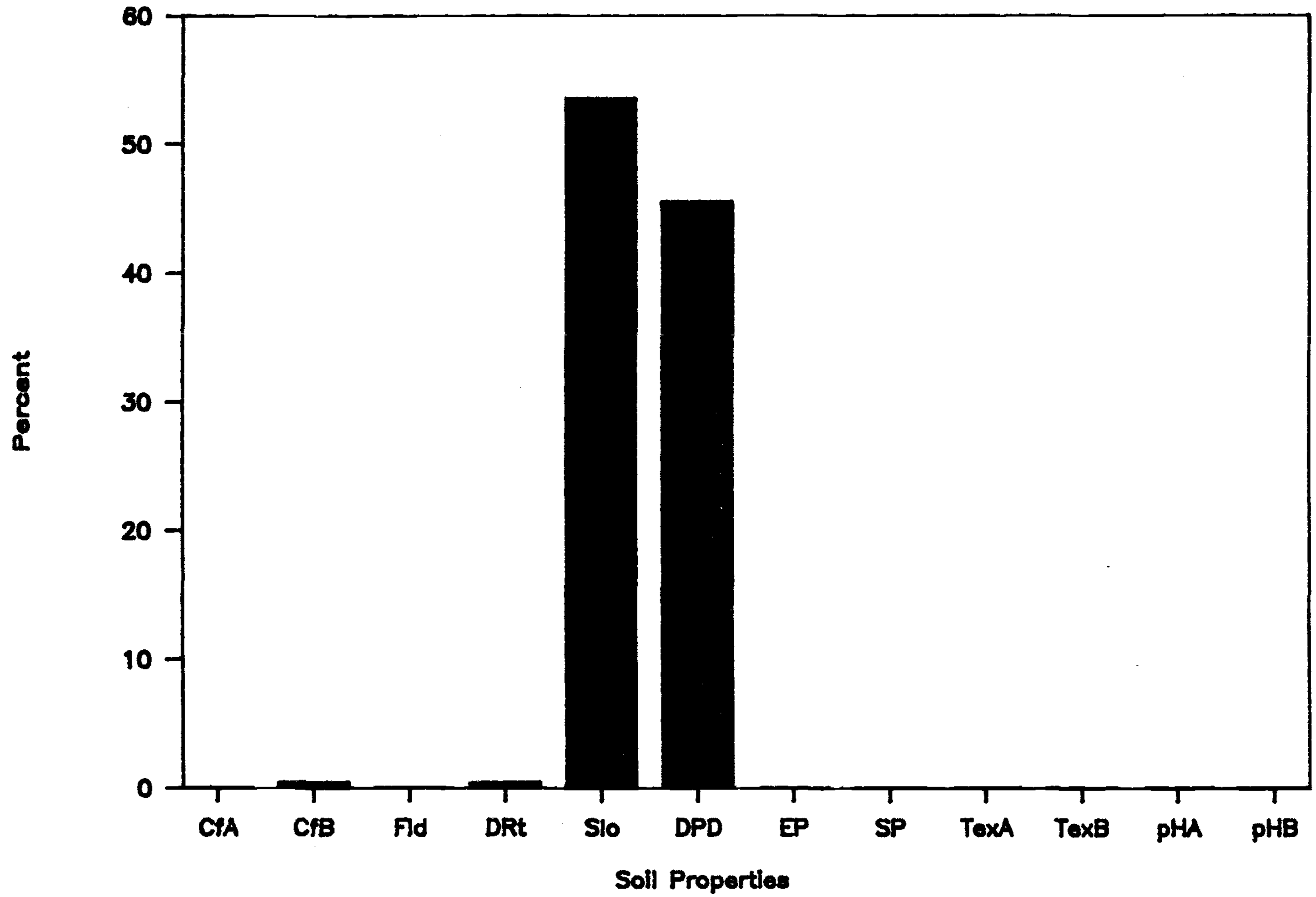

Fig. 4.4. Contribution of soil properties to the contrast of similar soils in the Inceptisols

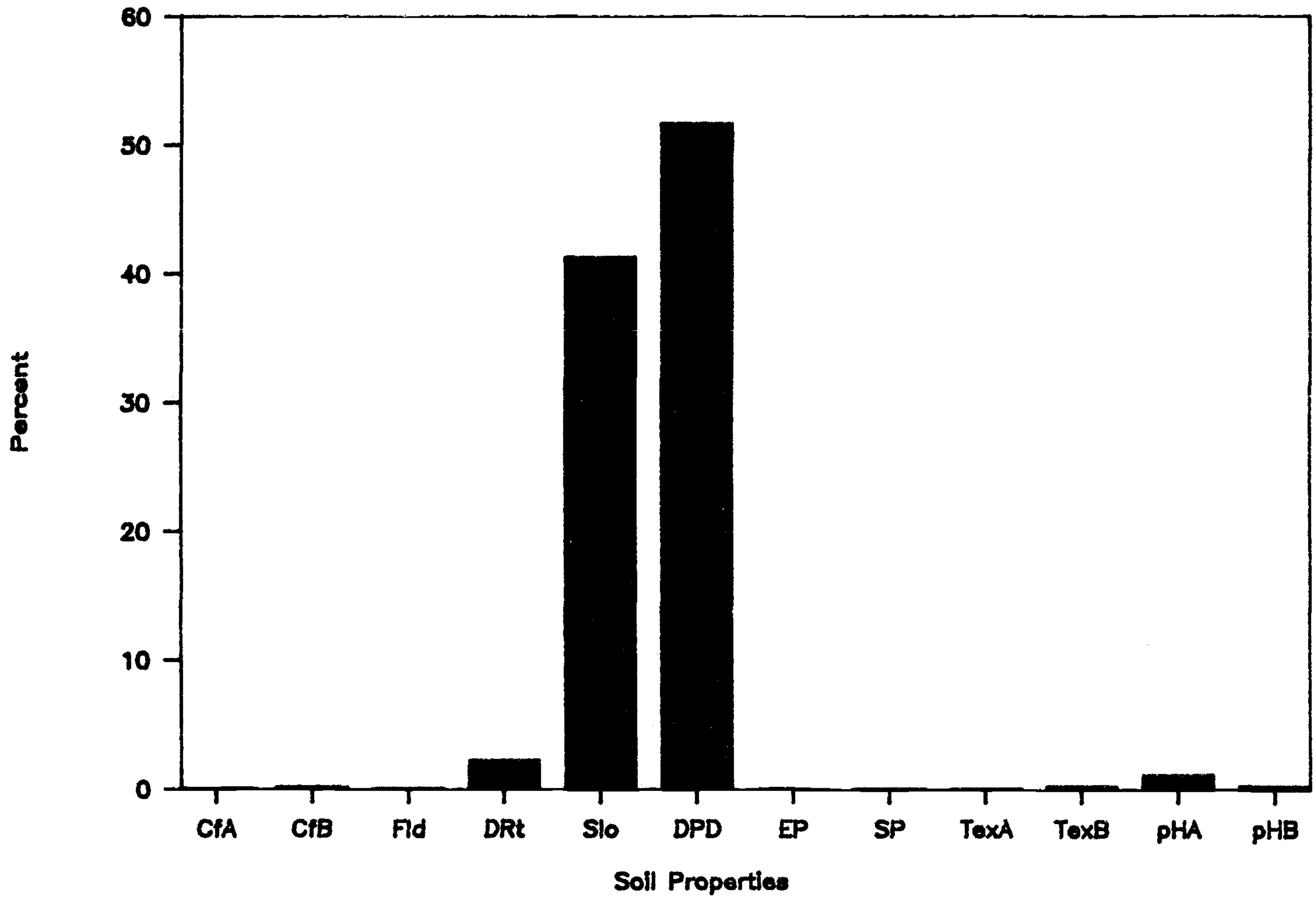

Fig. 4.5. Contribution of soil properties to the contrast of somewhat contrasting soils in the Inceptisols

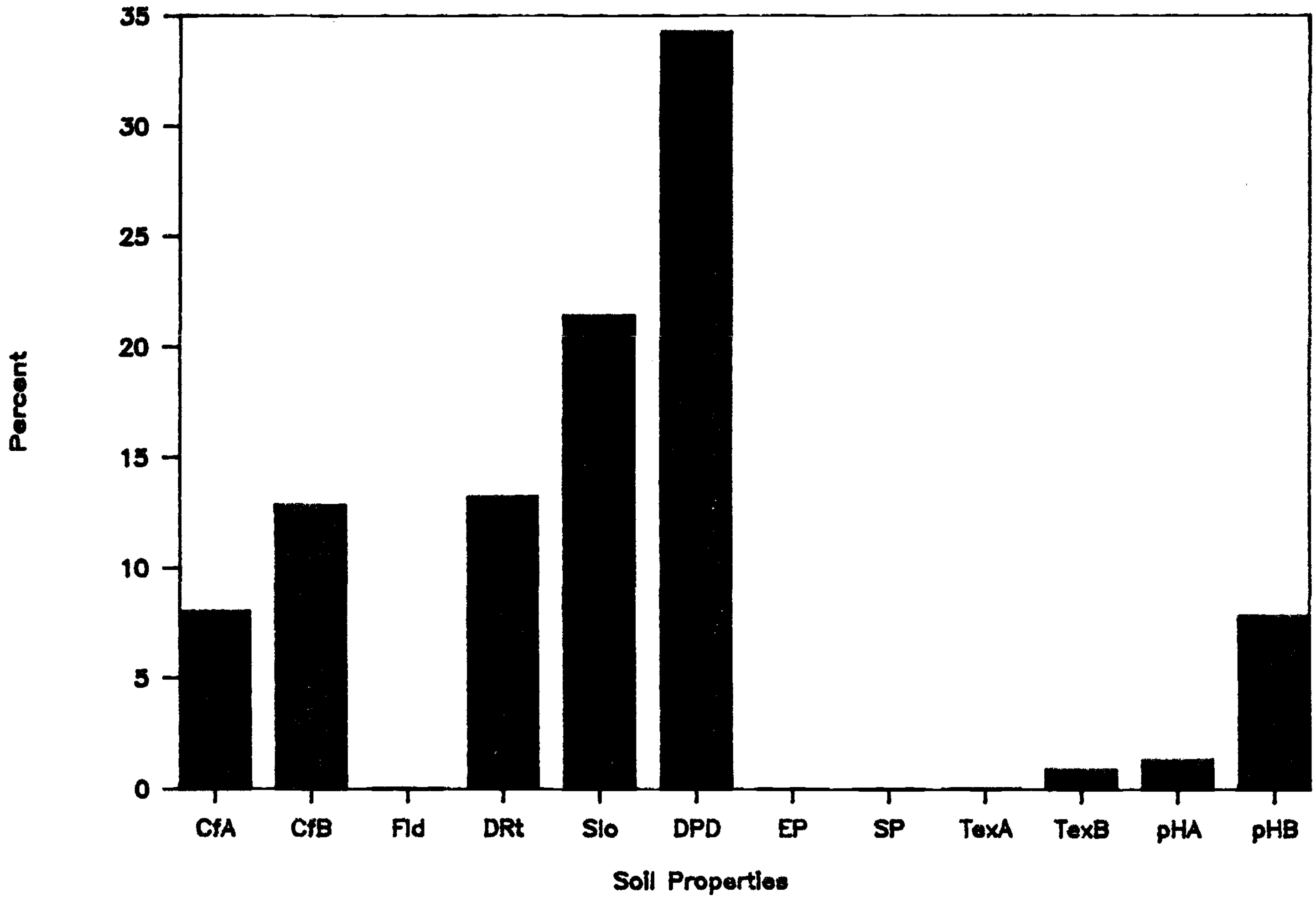

Fig. 4.6. Contribution of soil properties to the contrast of contrasting soils in the Inceptisols

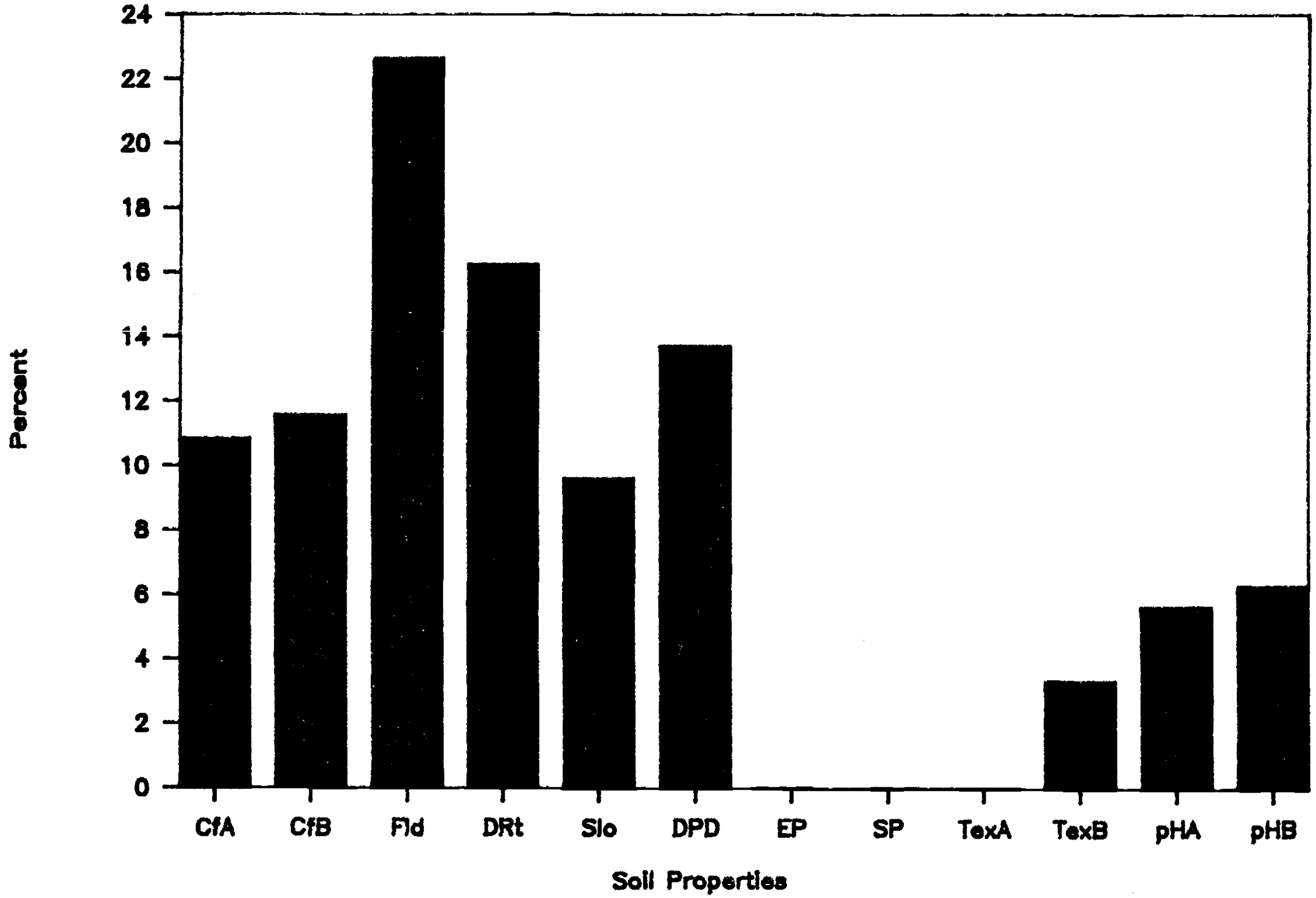

Fig. 4.7. Contribution of soil properties to the contrast of very contrasting soils in the Inceptisols

Similar Soils

Slo and DPD are the only two factors that contribute significantly to the contrast of similar soils (Fig 4.4). Other factors have only very minor influence or no influence at all.

Most of the similar pairs are slope phases of the same series, and the slope phases differ by only 1 class. An F slope is considered to have the same limitation as an E slope, so the MhD-MrF pair is similar even though there are 2 classes difference in slope. An F slope is always treated as an E slope.

The internal drainage of Mardin (Mh) soils ranges from well drained to moderately well drained. MhB and MhC are moderately well drained whereas MhD and MhE are well drained. For this reason, the MhC-MhD pair differs both in slope and in DPD.

Volusia (Vo) soils are somewhat poorly drained, so their pairing with MhB and MhC produce similar soils having one class difference either in DPD alone or in both DPD and Slo.

One pair, i.e. LdD-ArD, involved one class difference each in CfB, DRt and DPD. Arnot (ArD) is a moderately well drained soil that is shallower to bedrock and has no coarse fragments in the B horizon, whereas Lordstown (LdD) is well drained, moderately deep and has a very channery B horizon influenced by the underlying sandstone.

Only Mh, Vo, Ld and Ar soils occurred as adjacent pairs of different soil series. Mh soils occur on the upper parts of the slopes that grade toward the footslopes or hillsides where Vo soils are found, hence their association with Volusia. Ar soils are associated with Ld. Arnot soils occupy the flat ridgetops and Lordstown soils occupy the sloping areas adjoining the ridgetops.

All pairs of similar soils are pairs of upland or non-alluvial soils. Both members of the pairs are either with or without fragipan, i.e. the soils cannot be similar if one member of a pair has a fragipan and the other member does not.

Somewhat Contrasting Soils

Slo and DPD are still the dominant contributors to the contrast of somewhat contrasting soils. However, DPD contributes a little more than Slo. Other properties contribute slightly to the contrast (Fig. 4.5)

Most of the pairs with slope alone as the reason for contrast are again adjacent soil phases of the same series with 2 classes difference in slope.

MhD and MhE were involved in 7 out of 8 pairs for which DPD alone was the main contributor to contrast. These soil phases are well drained, but the permeability is slow at 15 inches. The slow permeability of the soil can cause a large amount of run-off during heavy precipitation, as water cannot infiltrate and move downward in the soil at sufficiently rapid rates. Run-off increases, and so does the hazard of erosion. At the time of the survey, however, these soils were not moderately or severely eroded, so no erosion phases were defined in the legend.

Most of the pairs of somewhat contrasting soils are pairs of upland soils. MhD and MhE, when paired with VoD soils, which are somewhat poorly drained but have the same permeabilty and depth to least permeable layer, produce somewhat contrasting soils because of 2 class differences in drainage. MhD and MhE also form somewhat contrasting pairs with Lordstown, but the difference in this case is due to moderate permeability.

One pair, however, involved 2 alluvial soils, i.e. Middlebury (Ms)-Tioga (Tg). Ms soils are found on floodplains, whereas Tg soils are on alluvial fans. The alluvium from which Tg formed contained gravel and channers that were deposited where streams emerge from steep uplands onto a level plain. Ms soils were derived from alluvium free from coarse fragments. This difference in coarse fragments causes the Ms-Tg pair to be classified as somewhat contrasting.

Four pairs involved two classes difference in both Slo and DPD. Three of these involved adjoining phases of Mardin and Volusia soils, and the differences between these soils have been discussed. The fourth involved Tuller, a soil that has the same drainage and depth to least permeable layer as Volusia, but has moderate rather than slow permeability. The moderate permeability of TuD makes it more feasible for drainage than VoB.

The slope of Tuller soils ranges from 0-25%, but generally the slope is less than 8%. Tuller soils tend to occur in shallow, seepy spots within larger areas of well drained soils. Where TuD adjoins VoB, Tuller occupies a seepy spot at the junction between the steeper Lordstown soils and the more gently sloping Volusia soils.

<u>Contrasting</u>

More properties noticeably contribute to the contrast of contrasting soils than for similar or somewhat contrasting soils. At the same time, the dominant property, DPD, decreases from 51% in the somewhat contrasting soils to 34%. Other properties that make obvious contributions to the contrast include Slo, DRt, CfB, CfA and pHB. The contribution of TexA and pHA was slight (Fig. 4.6).

Most contrasting soils for which DPD is the single property determining the overall contrast include Lordstown (Ld) paired with either Mardin (Mh) or Volusia (Vo). Both Mardin and Volusia have more restricted drainage than Lordstown, and both have slowly permeable fragipans at relatively shallow depth, hence the reason for the contrast level.

Alden (AcA)-Volusia (VoB) is a contrasting pair of upland soils for which CfA and pHB are the properties that contribute highly to the contrast. Alden soil is found in depressions and is along the drainageways in the uplands. It has no coarse fragments of the A. Alden developed from medium lime till and so it has a neutral pH in the B. VoB surrounds AcA and is developed from acid till. VoB soil has coarse fragments in the A and is strongly acid in the B horizon.

Pairs of Vo and Ld, which did not occur even once in similar and somewhat contrasting pairs, are among the contrasting pairs. These pairs occur where the more steeply sloping Lordstown soil landscapes adjoin the more gently rolling Volusia soil landscapes with no intervening seepage areas of Tuller soils. Notice that where contrasting pairs of Volusia and Lordstown soils occur, there is also a difference in slope, but it is not enough of a difference to declare as a controlling factor.

Tioga (Ta) and Wayland (Wd) are alluvial soils that are contrasting due to DPD. Both soils are on floodplains, but Ta is well drained and Wd is poorly drained. Ta is coarser textured and occupies convex knolls or natural levees on the floodplains. Wd is finer textured and occupies depressions or slackwater areas further away from the main channel.

Chenango and Howard (ChC) soils are gravelly alluvial soils found on valley floors and terraces, alluvial fans, and kames and eskers. They form contrasting pairs with Mardin and Volusia soils where the till blanket abuts the valley landforms. These pairs also occur where kames and eskers are superimposed on top of the till blanket. Chenango and Howard soils have no limitations to root development, and they are well drained soils, hence the reason for the degree of contrast. The alluvial soils never flood, so this does not affect the contrast level.

Very Contrasting

Every pair of soils classified as very contrasting was done so because one member of the pair was subject to flooding and the other was not. Beyond that, however, several other properties covary with flooding, so that although flooding does make the highest contribution to soil contrast, DRt, DPD, CfB and CfA all contribute significantly, and pHB, pHA and TexB all contribute to a lesser extent (Fig. 4.7).

All but one pair of very contrasting soils were combinations of an alluvial soil with either Mardin or Volusia. Alluvial soils were not paired with Lordstown in any of the sample areas.

None of the alluvial soils have fragipans, hence there is no physical limitation to root penetration. That is why DRt is such a common covariate with flooding. Some of the alluvial soils (Ta and

Tg) are well drained, and Wd is poorly drained. Because Mardin and Volusia are moderately well drained and somewhat poorly drained, these differences account for DPD being a common covariate. Alluvial soils are all nearly level, and slope is a covariate where moderately steep slopes directly abut the alluvial landforms. Even where slope does not covary at contrast level 4, the alluvial soils are paired with an upland soil with a C slope three times more often than with a B slope. Thus, the boundary that separates very contrasting soils also separates soils that usually have 2 classes difference in slope.

One pair, i.e. Ms-ChC, is a combination of two alluvial soils. In this case the ChC soils occupy terraces not affected by flooding. ChC also has a very gravelly subsoil, whereas Ms has no coarse fragments in its entire profile.

Summary of Levels of and Reasons for Contrast

Inceptisols are characterized by a high percentage of similar soils (65-77%). The remaining percentage is divided approximately equally between the remaining soil contrast levels. Large areas of VoC and VoD, which are similar soils, account for the high percentage of similar soils.

The properties important for each contrast level are shown in Table 4.14. This table, and Figures 4.4 to 4.7, show very clearly that only one or two properties control the contrast at low levels, but as the contrast level increases, the number of varying properties also increases, and the influence of any single property decreases.

Similar soils occur primarily where slope phases of the same series are juxtaposed. In this one area of Inceptisols, phases of

Table 4.14. Summary of soil properties important in each contrast level of the Inceptisols

Soil Contrast Level	Soil Property
Similar	Slo, DPD
Somewhat Contrasting	Slo, DPD
Contrasting	Slo, DRt, CfB, CfA, pHB
Very Contrasting	Fld, DRt, DPD, CfB, CfA

the upland Mardin, Volusia, and Lordstown soils were the most common similar soils.

Soil phases of the same series can also have one class difference in DPD in addition to Slo if the slope phases in the series have different drainage classes. This was the case with the Mardin series, for which steeper slopes are well drained but gentler slopes are moderately well drained.

Slope and DPD were also the most common reasons for somewhat contrasting soils. The same three upland soils that were often involved in similar soils were also involved in somewhat contrasting soils, only there are two classes difference in slope. Alluvial soils can also be somewhat contrasting if one is found on the floodplain and the other is found on alluvial fans. This difference in landform is associated with a difference in parent material that causes the contrast.

Soils derived from glacial till can give rise to contrasting soils depending on the nature of the glacial till. Glacial till that contains limestone forms soils with a neutral subsoil. This soil can form a contrasting pair if it is adjacent to a soil having a strongly acid subsoil.

Contrasting soils occur when two widely different parent materials are in contact with each other. In this case dense channery glacial till abutting coarse gravelly alluvium, either on terraces or fans or on eskers and kames resulted in contrasting soils. Soils in till have dense fragipans that restrict rooting, whereas soils in alluvium do not. Soils formed on eskers or kames are well drained and can have deep DRt despite their being very gravelly in the subsoil.

Pairs of alluvial soils can also be contrasting if one is situated on a natural levee and the other is in a depression. In this case drainage differences, expressed in the DPD interaction, control the contrast.

Most pairs of very contrasting soils are controlled by flooding. Most are pairs of alluvial soils and upland soils. DRt and DPD are the soil properties most commonly associated with flooding.

B. Ultisol

The legend for all the map units in all three samples of the Ultisols is shown in Table 4.15. The area in acres, the number of delineations, and the soil order of each mapping unit are shown in Table 4.16.

About 4/5 of all the map units and 98% of the area in all the samples are Ultisols. The remaining 1/5 is composed of Inceptisols, Alfisols and Entisols. All the map units in sample 3 are Ultisols. Sample 1 has two Alfisols (EnB and MeC) and an Entisol (To). Sample 2 has an Inceptisol (Ch), an Alfisol (EnB), and an Entisol (To).

Table 4.15. Legend for all map units in the Ultisol samples

Symbol	Name
ApB	Appling sandy loam, 2 to 6 percent slopes
ApC	Appling sandy loam, 6 to 10 percent slopes
ApD	Appling sandy loam, 10 to 15 percent slopes
BnC	Blaney sand, 2 to 10 percent slopes
CeB	Cecil fine sandy loam, 2 to 6 percent slopes
CeC	Cecil fine sandy loam, 6 to 10 percent slopes
CeD	Cecil fine sandy loam, 10 to 15 percent slopes
Ch	Chenneby silty clay loam
DoB	Dothan loamy sand, 2 to 6 percent slopes
EnB	Enon silt loam, 2 to 6 percent slopes
FaB	Fuquay loamy sand, 0 to 6 percent slopes
FaC	Fuquay loamy sand, 6 to 10 percent slopes
GeB	Georgeville very fine sandy loam, 2 to 6 percent slopes
GeC	Georgeville very fine sandy loam, 6 to 10 percent slopes
HeB	Helena sandy loam, 2 to 6 percent slopes
HeC	Helena sandy loam, 6 to 10 percent slopes
MeC	Mecklenburg silt loam, 6 to 10 percent slopes
Pec	Pelion Loamy sand, 6 to 10 percent slopes
To	Toccoa fine sandy loam
TrB	Troup sand, 0 to 6 percent slopes

Table 4.16. Area in acres, number of delineations, and soil order of each map unit in the Ultisol samples

	Area (Number of Delineations)			Soil Order
	I	II	III	
ApB	585.676 (3)	746.256 (5)	183.225 (1)	Ultisol
ApC	41.032 (1)	291.031 (4)	201.547 (3)	Ultisol
ApD	0	372.644 (1)	0	Ultisol
CeB	116.386 (4)	149.612 (2)	547.353 (3)	Ultisol
CeC	187.160 (5)	7.870 (1)	153.548 (3)	Ultisol
CeD	57.483 (1)	0	216.773 (4)	Ultisol
Ch	0	48.257 (1)	0	Inceptisol
DoB	18.645 (1)	0	22.580 (1)	Ultisol
EnB	195.806 (1)	5.096 (1)	0	Alfisol
FaB	0	415.418 (1)	0	Ultisol
FaC	0	5.870 (1)	0	Ultisol
GeB	66.774 (1)	0	0	Ultisol
GeC	47.354 (1)	0	0	Ultisol
HeB	100.451 (5)	0	0	Ultisol
HeC	284.386 (4)	17.870 (1)	0	Ultisol
MeC	59.354 (1)	0	0	Alfisol
PeC	0	13.225 (1)	0	Ultisol
To	136.515 (1)	7.806 (1)	0	Entisol
TrB	0	21.354 (1)	0	Ultisol
TOTAL	1897.028 (29)	20892.093 (21)	1325.029 (15)	
No. of map units	13	13	6	

The soil association from which the samples were taken is the Appling-Cecil association. This implies that Appling and Cecil are the major soils in this area. Only sample 3, however, is dominated by Appling and Cecil. Sample 1 is dominated by Appling and Helena, although Cecil occupies almost the same area as Helena, i.e. it has a total area of 361.031 acres whereas Cecil has a total area of 384.837 acres. Sample 2 is dominated by Appling and Fuquay, and the area of Cecil is only about 1/3 of the area of Fuquay. Thus, the soil association is appropriately named for sample 3 and sample 1 but not for sample 2, based on the area of major soils.

The variation in soil composition between the samples can be related to the physiographic provinces in the area. Lexington County is divided into two physiographic provinces, the Piedmont Plateau and the Sandhills. The "Fall Line", which forms the boundary between these two physiographic provinces, trends easterly across the county and is roughly parallel and just north of U.S. Highway 1. About 1/4 of the county is in the Piedmont Plateau to the north of the Fall Line. The remaining 3/4 of the county is in the Sandhills to the south of the Fall Line. Sample 3 occurs well north of the Fall Line, and all the soils except Do are Piedmont Plateau soils. Samples 1 and 2 are near the Fall Line, and there is more interfingering of soils from the Sandhills physiographic province.

The Piedmont Plateau is characterized by a dendritic pattern of streams. The main divides form broad, gently sloping to moderately sloping ridgetops with erodible surfaces. The larger streams that dissect the area have narrow floodplains, and the smaller tributaries have no floodplains at all.

The parent materials of soils in the Piedmont Plateau and the Sandhills vary. One third of the soils in the Piedmont Plateau have parent materials of saprolite of gneissic granite, which contains minerals such as quartz, mica and feldspar. Appling and Cecil soils developed in these materials. Some areas of granite and gneiss have inclusions of diorite and gabbro, and this mixture of acidic and basic rocks serves as the parent material of Enon and Helena.

Part of the remaining two thirds of the soils in the Piedmont Plateau formed in saprolite that weathered from rocks known locally as "Carolina slates". These are metamorphosed shales, dominantly argillite, fine grained sandstone and muscovite mica. The Georgeville series formed from these rocks.

Soils on stream floodplains formed in silty, loamy or sandy sediment that washed from the Piedmont Plateau. Soils of the Chenneby and Toccoa series are formed on floodplains.

The parent material in the Sandhills consists of marine-deposited sediments with varying proportions of quartz sand, kaolinitic clays and silt. Troup and Blaney series were derived from materials containing mainly sand and only small or variable amounts of clay and silt. The Pelion series formed in materials in which clay is dominant along with only small amounts of sand and silt. Dothan and Fuquay formed in materials with nearly equal percentages of sand, clay, and silt.

Appling and Cecil soils are gently sloping to strongly sloping, deep, well drained soils that are slowly permeable and contain plinthite at 30-55 inches. Helena is a gently sloping to sloping, deep, moderately well drained soil that is slowly permeable. Other characteristics of the soils that occur in these sampling areas are in Appendix 2.1.

Data for the most frequently occurring pairs, which were selected from the matrix in Appendix 2.2, are summarized in Table 4.17. These data show that pairs whose component soils both occur on the Piedmont Plateau, such as Ap-Ce, Ap-He, Ce-He, are the most numerous. Pairs in which one soil is from the Piedmont Plateau and one is an alluvial soil (ApB-Ch, HeC-To and ApC-Ch), and pairs of Piedmont Plateau and Sandhill soils (ApC-FaB) do occur but with lesser frequency. Ap-He pairs are more frequent in Ultisol 1, whereas Ap-Ce pairs are most common in Ultisol 2 and Ultisol 3.

Table 4.17. Contrast level and frequency of occurrence of the most common pairs in the Ultisol samples

Pairs	Contrast Level	Number of Pairs I	II	III
ApB-ApC	S	3	7	4
ApB-ApD	SC		3	
ApB-CeB	S		2	3
ApB-CeC	SC	3		
ApB-CeD	SC			4
ApB-Ch	VC		2	
ApB-HeB	C	5		
ApB-HeC	C	5		
ApC-ApD	S		3	
ApC-CeB	SC		4	
ApC-CeC	S		1	
ApC-CeD	SC			4
ApC-Ch	VC		3	
ApC-FaB	C		3	
ApD-CeB	SC		2	
CeB-CeC	S			5
CeB-CeD	SC			5
CeB-HeB	C	3		
CeB-HeC	C	3		
CeC-CeD	S			5
CeC-HeC	C	4		
HeB-HeC	S	4		
HeC-To	VC	3		

Levels of Contrast

The data on the different contrast levels of the Ultisols are shown in Table 4.18 and Fig. 4.8 (Method 1) and Table 4.19 and Fig. 4.9 (Method 2). The boundary length and contrast code for each property are shown in Appendix 2.3.

Area 3 has the highest percentage of similar soils of all the areas. In area 3 all soils except Dothan are on the Piedmont Plateau, and the uniformity of parent materials causes more similar soils. Alluvial soils are also absent in area 3.

Area 2 is also characterized by a high percentage of similar soils, but of lesser percentage than area 3. It has a higher percentage of contrasting and very contrasting soils compared to area 3. This is due to a large area of ApB (35% of the total area) that that forms contrasting soils with Helena, Fuquay and Enon. Alluvial soils in this sampling area form very contrasting pairs with Appling and Cecil.

Area 1 is characterized by a large total area of Helena (Table 4.16) that forms contrasting soils with Cecil and Appling. As Helena is derived from acidic and basic rocks, it is probable that area 1 is characterized by an inclusion of volcanic rocks such as gabbro and diorite.

Both methods of analysis resulted in distributions of the same general form, although there are some obvious differences in the absolute values of the percentages in each contrast level. The values of the perrcentages of somewhat contrasting and contrasting soils, for example, using frequency of pairs are higher than those using percent of boundary length, whereas the percentage of similar

Table 4.18. Percent of adjacent pairs in the Ultisol samples belonging to different contrast levels

Contrast Level	Percent of Pairs			Mean
	I	II	III	
Similar	25.0	30	53.1	36.0
Somewhat Contrasting	17.6	26	43.7	29.1
Contrasting	44.1	26	3.2	24.4
Very Contrasting	13.3	18	0	10.4

Table 4.19. Distribution of contrast levels of Ultisol samples based on percent of boundary length

Contrast Level	Percent of Boundary Length			Mean
	I	II	III	
Similar	28.86	53.30	71.01	51.0
Somewhat Contrasting	12.51	20.64	26.85	20.0
Contrasting	42.93	11.76	2.12	18.90
Very Cotrasting	15.68	14.29	0	9.9

soils is greater using % of boundary length. The percentage of very contrasting pairs did not vary much (Fig. 4.8).

The difference in results between these two methods is influenced by the length of boundaries between soils. Area 3, for example, has large delineations of ApB, ApC, CeB, CeC and CeD (Table 4.16) that form similar pairs with each other. The long boundary lengths between these pairs contributes more to the percent of similar soils than that of the number of adjacent pairs.

The percent of pairs method can substitute for the percent of boundary length if one is just interested in the order of abundance of soil pairs belonging to each contrast level. It is not useful,

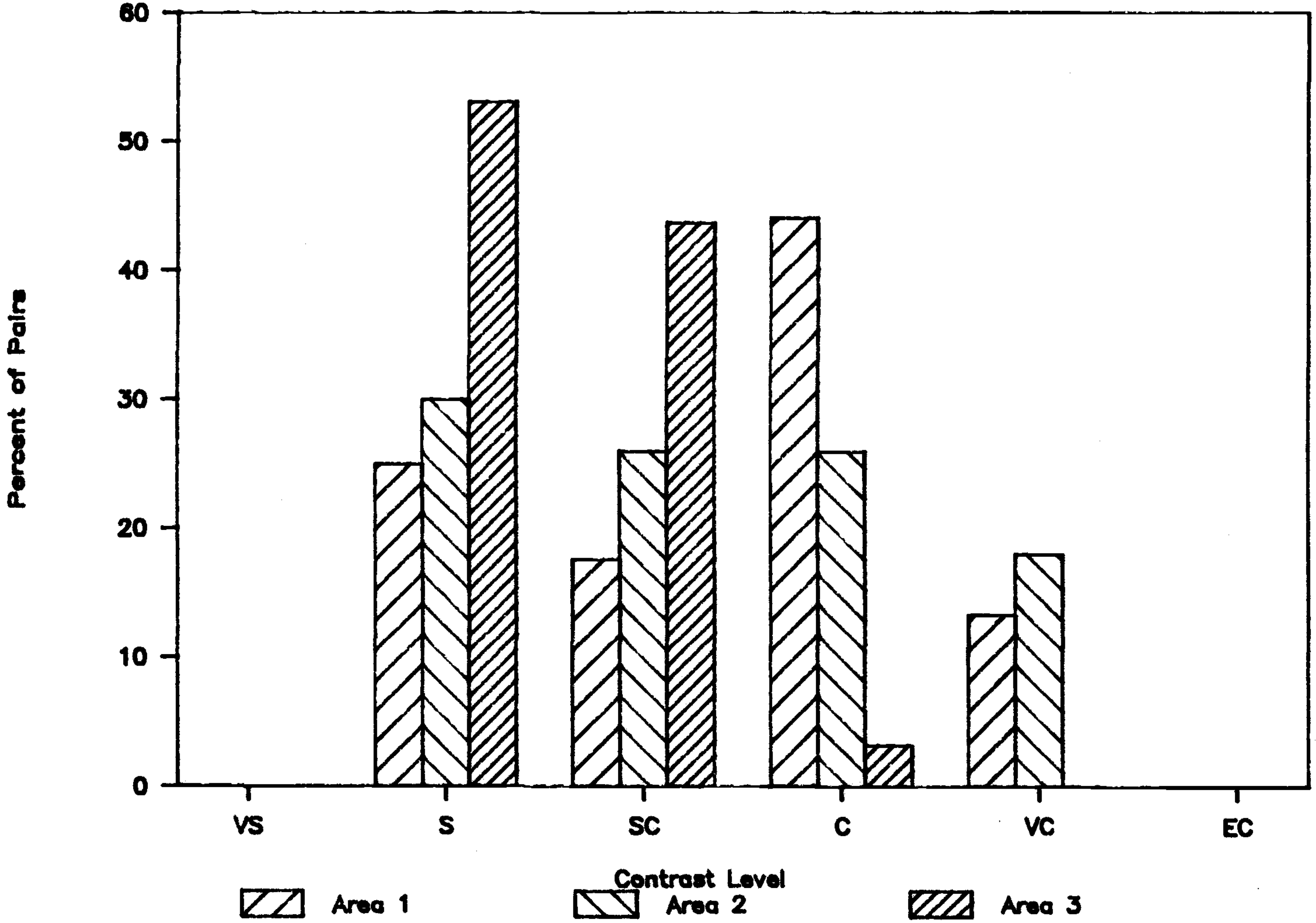

Fig. 4.8. Distribution of the percent of pairs among the different soil contrast levels in the Ultisols

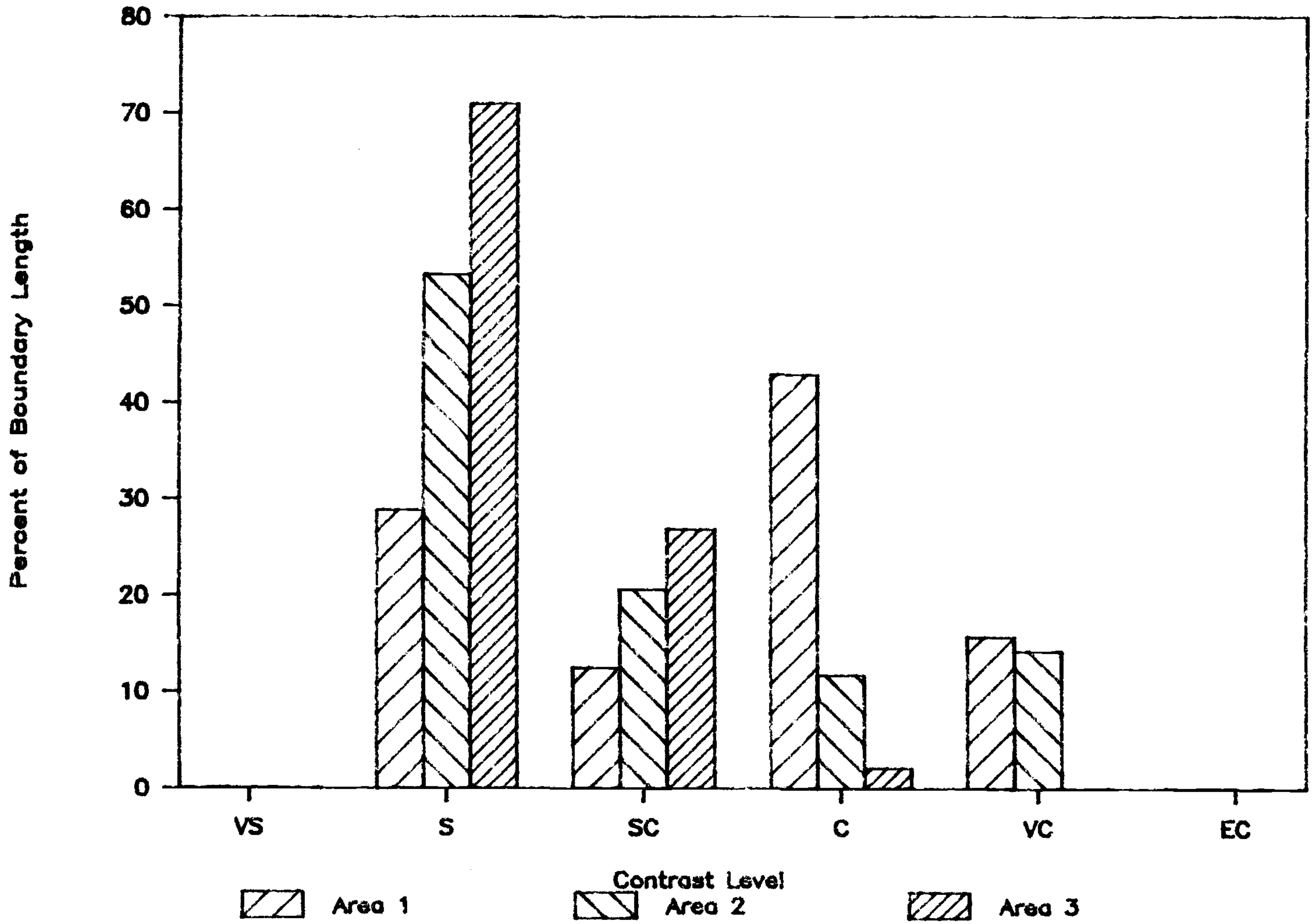

Fig. 4.9. Distribution of the percent of boundary length among the different soil contrast levels in the Ultisols

however, in determining the percentage of each contrast level, as results vary widely with percent boundary length in some contrast levels.

Reasons for Contrast

The reasons for contrast are shown in Table 4.20 and Figs. 4.10-4.13 (Method 1) and Table 4.21 (Method 2).

The areas that were randomly selected are not good replicates of each other. They differ in both the number of soils and the kind of soils present. The lack of replication causes fewer kinds of reasons for a homogenous sample such as area 3. Area 3 has the least number of soil properties contributing to the contrast of somewhat contrasting and contrasting soils (Table 4.20). The lack of replication also leads to different kinds and percentages of each reason for contrast.

Area 3 varies greatly from samples 1 and 2 as far as contribution of a soil property to contrast is concerned. For contrasting levels of soils, for example, DPD contributes nothing in sample 2, and TexB contributes 50%, whereas in sample 1, DPD and TexB contribute 40% and 10%, respectively, to the contrast.

Table 4.20. Weighted average contribution of each soil property to each level of contrast in the Ultisol sampling areas

Sample		Fld	DRt	Slo	DPD	TexA	TexB	pHa	pHB
S	1	0	0	65.54	0	6.24	11.83	16.37	0
	2	0	0	66.56	0	0	16.71	16.71	0
	3	0	0	43.93	0	0	28.03	28.03	0
	Mean	0	0	58.67	0	2.08	18.85	20.37	0
SC	1	0	13.74	30.98	0	5.99	27.23	2.29	19.74
	2	0	0	70.35	5.90	1.43	11.92	8.97	1.43
	3	0	0	69.83	0	0	15.08	15.08	0
	Mean	0	4.58	57.05	1.97	2.47	18.08	8.78	7.06
C	1	0	3.16	7.42	40.24	21.20	10.25	22.01	15.69
	2	0	8.41	7.42	23.92	10.30	21.91	14.29	13.43
	3	0	0	0	0	16.66	50.00	16.66	16.66
	Mean	0	3.85	5.05	21.38	16.05	27.38	17.65	15.26
VC	1	31.86	0.19	15.53	7.65	2.55	23.90	10.32	7.96
	2	32.58	0	15.39	12.74	13.02	11.25	6.60	8.42
	3	0	0	0	0	0	0	0	0
	Mean	21.48	0.06	10.31	6.80	5.19	11.72	5.64	5.46

Table 4.21. Number of discrete pairs of Ultisol soils for each controlling soil property within each contrast level

Contrast Level	Number of Discrete Pairs I	II	III
Similar			
One 2			
Slo	5 ApB-ApC ApC-ApD CeB-CeC CeC-CeD	4 FaB-FaC GeB-GeC HeB-HeC	3
pHA	1 CeC-GeC	0	0
TexA	1 ApB-DoB	0	0
Two 2's			
TexB, pHA	1 ApB-CeB	2 ApC-CeC	1
Slo, pHA	1 CeC-GeB	0	0
Three 3's			
Slo, TexB, pHA	3 ApB-CeC ApC-CeD	2 ApC-CeB ApD-CeC	3
Somewhat Contrasting			
One 3			
Slo	3 ApB-ApD CeB-CeD	2 ApD-CeB	2
Two 3's with $\leq$ three 2's			
DPD, TexB	0 ApB-FaB	2 ApC-FaC	0
$\geq$four 2's			
DRt, Slo, TexB, pHB	1 EnB-MeC	0	0
Contrasting			
Two 3's with $\geq$ four 2's			
DRt, pHB	1 EnB-GeB	0	0
DPD, TexB	0 ApC-FaB	1	0

Table 4.21. Cont'd.

One 4 with < three 3's			
DPD	11	4	0
	ApB-EnB	CeC-EnB	
	ApB-HeB	CeC-HeB	
	ApB-HeC	CeC-HeC	
	ApC-HeB	CeD-HeB	
	ApC-PeC	CeD-HeC	
	CeB-HeB	DoB-HeB	
	CeB-HeC	DoB-HeC	
	GeB-MeC		
TexB	0	3	1
	ApC-BnC	CeB-FaB	
	ApC-TrB		
Very Contrasting			
One 5 with ≤ one 4			
TexB	0	1	0
	CeB-TrB		
Fld	0	3	0
	ApB-Ch	ApC-To	
	ApC-Ch		
Fld, TexB	2	1	0
	CeB-To	CeC-To	
Fld, Slo	0	1	0
	ApD-To		
One 5 with ≥ two 4's			
Fld, Slo, Tex	1	0	0
	CeD-To		
Fld, DPD, TexB	2	0	0
	HeC-To	MeC-To	

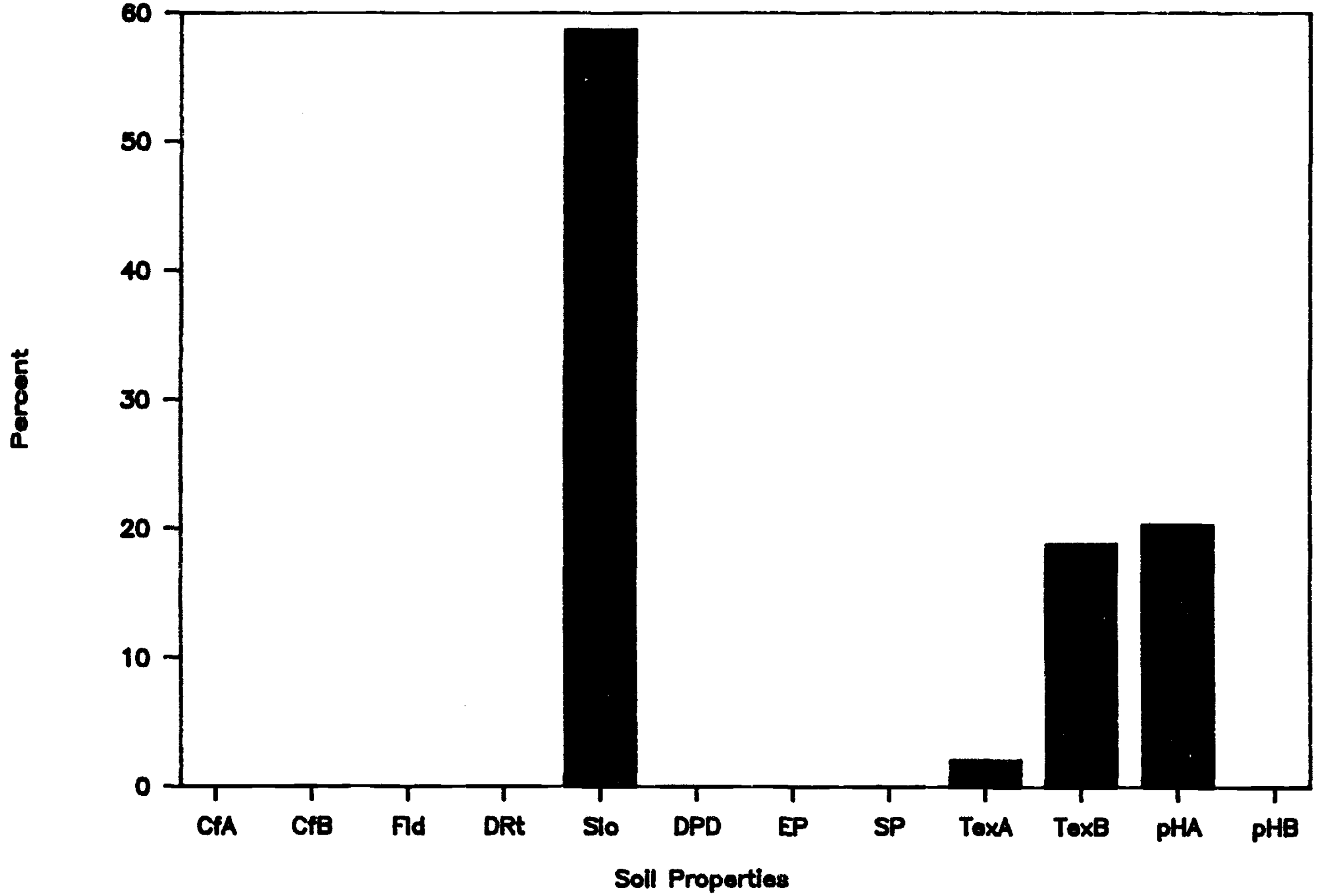

Fig. 4.10. Contribution of soil properties to the contrast of similar soils in the Ultisols

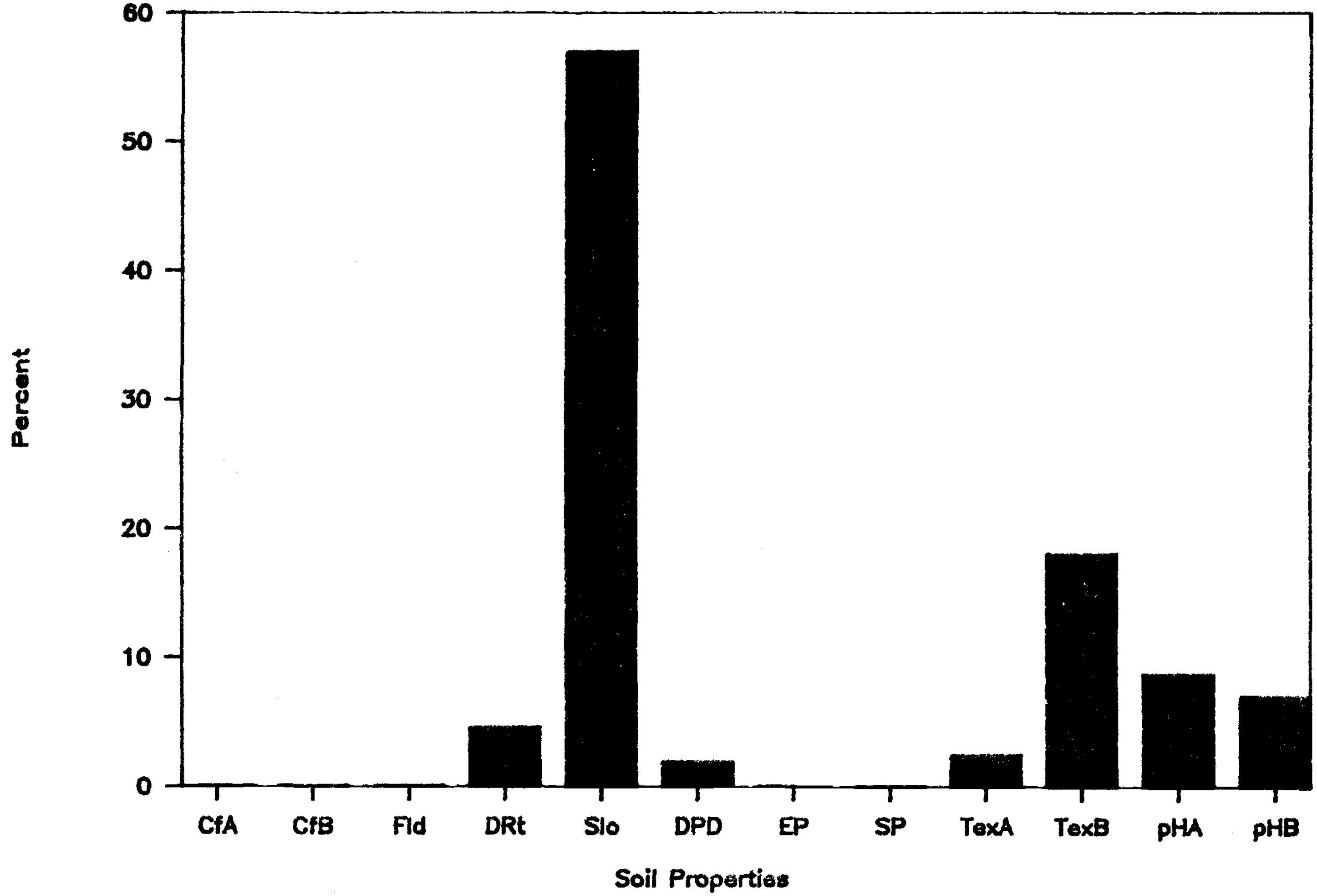

Fig. 4.11. Contribution of soil properties to the contrast of somewhat contrasting soils in the Ultisols

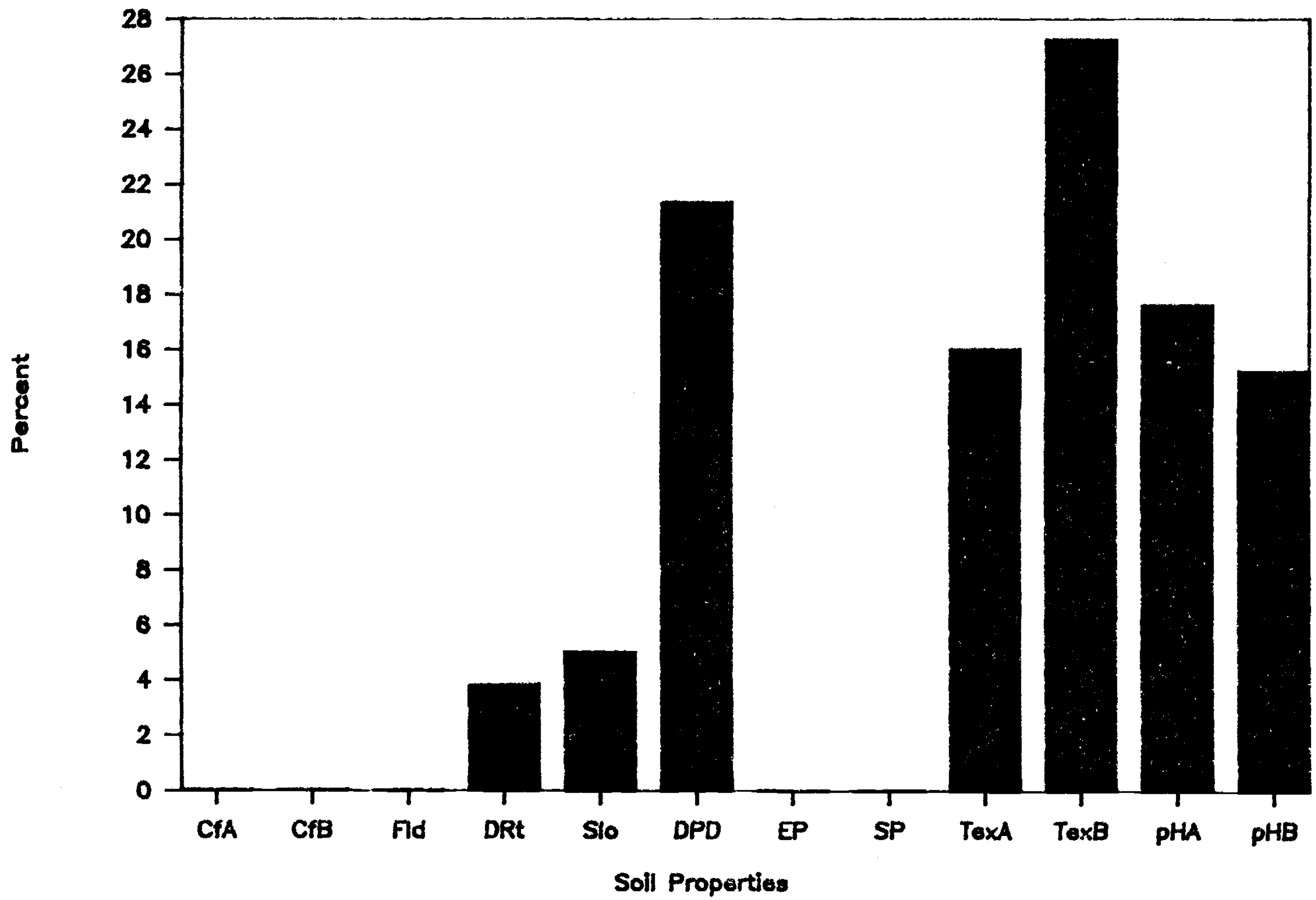

Fig. 4.12. Contribution of soil properties to the contrast of contrasting soils in the Ultisols

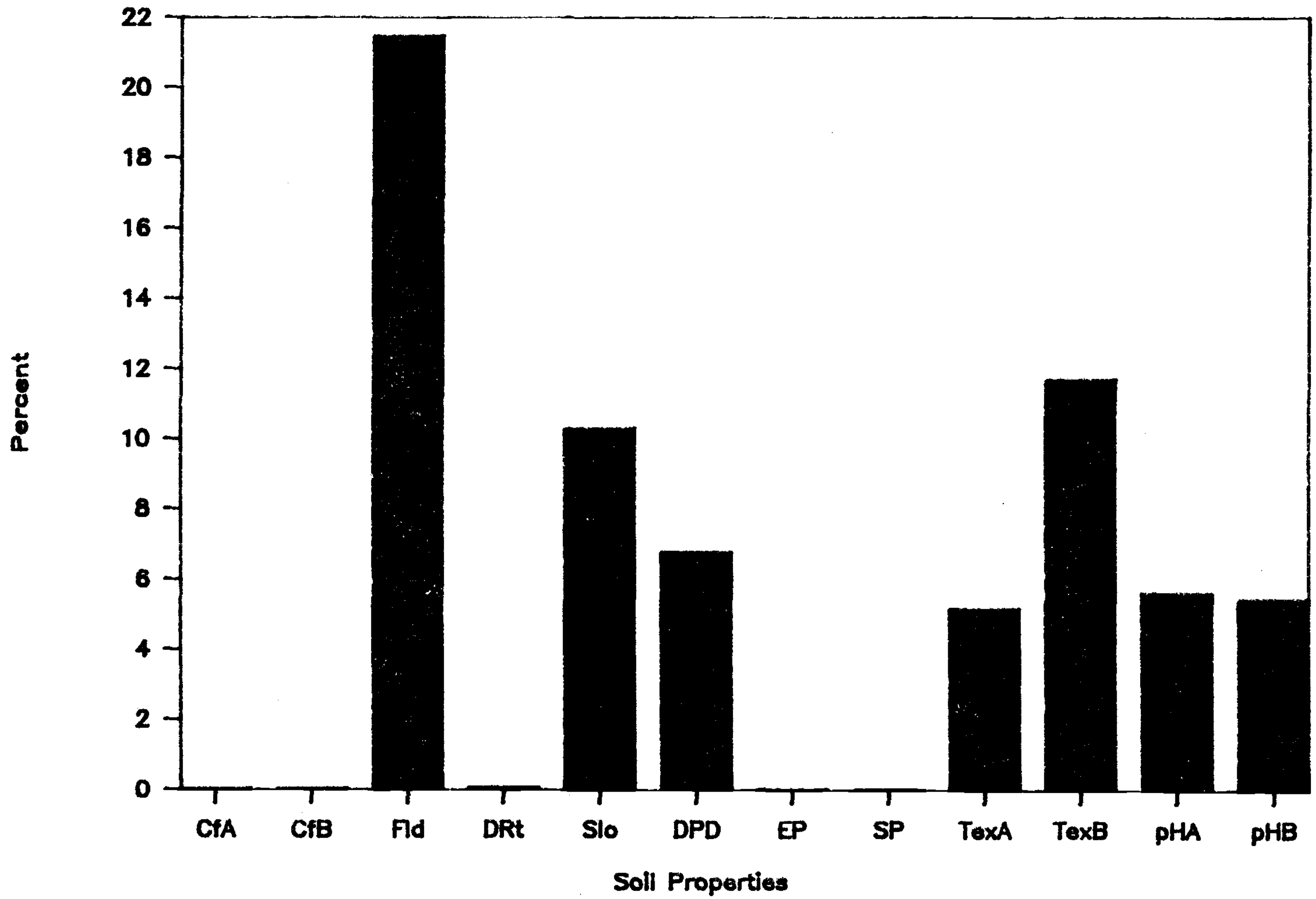

Fig. 4.13. Contribution of soil properties to the contrast of very contrasting soils in the Ultisols

Similar Soils

Slope is by far the single most important reason for differences between similar soils. Texture of the B and pH of the A are involved in some pairs of similar soils, and texture of the A has a very minor influence.

There are 16 kinds of pairs of similar soils. Seven of these pairs have components both of which belong to the same soil series but differ only by one class of slope.

One pair of similar soils, CeC-GeC, differs only by one class of pHA. GeC is more acidic in the surface than CeC because of the presence of an O horizon in its profile, as described in the typical pedon description. Another pair, i.e. ApC-DoB, has one level difference in TexA. This is the only pair that includes one soil from the Piedmont Plateau and one from the Sandhills. Although the parent materials are quite different, both soils have weathered into Ultisols, so the only significant difference is in the surface textures, and even those are not widely different. Dothan is loamy sand and Appling is sandy loam.

Five pairs differ in both TexB and pHA, and three of these differ by one class of slope as well. All five, however, are pairs of Appling and Cecil soils. These are similar soils, as Appling has a more acid surface and a clay loam B, whereas Cecil is a little less acid and has a finer-textured (clay) B horizon.

Somewhat Contrasting Soils

Slope is also the dominant property controlling the level of contrast of the somewhat contrasting soils. Where slope alone is the reason, in every case the pair matches a B slope with a D slope, either within the same series or between the otherwise similar Appling and Cecil soils.

pHA is shown as an important property contributing to the contrast in Fig.4.11, but it is not among the properties listed in Table 4.21. The data in Table 4.21, however, do not consider either boundary length or properties that vary at contrast levels lower than those listed. In the case of pHA, the combination of longer boundary lengths and the presence of many pairs that differ at lower contrast levels does make pHA important.

Two pairs (ApB-FaB and ApB-FaC) have identical slopes but differ in DPD and TexB. ApB is derived from granite, but FaC developed from marine deposited sediment. Both Ap and Fa are well drained, but Fa has a plinthite layer that has slow permeability at 37 inches. Fa also has a sandy loam TexB whereas Ap has a clay loam TexB.

One somewhat contrasting pair (EnB-MeC) has 4 factors that differ by one class. These soils are similar with respect to these 4 properties, but the cumulative effect of these small differences warrants placing this pair in the next higher contrast level. Both are Piedmont soils, but EnB is weathered from mixed acidic and basic rocks, whereas MeC is weathered from slate. Both soils are well drained but have slow permeability. EnB has a depth to least permeable layer of 8 inches; that of MeC is only 5 inches. EnB has a DRt of 25 inches. MeC has a DRt of 39 inches.

Contrasting Soils

Unlike similar and somewhat contrasting soils, the contrasting soils are controlled almost entirely by differences in DPD in combination with texture and pH. Texture is important because of the presence of Sandhill soils, and pH is important because of the presence of the very strongly acid Helena soil. Slope and depth of rooting have minimal effects. Thus, contrasting soils are not separated by abrupt changes in slopes.

The contribution of DPD to soil contrast appears to be more than that of TexB using Table 4.21. This is because there are many pairs of soils under DpD. Using weighted average contribution to contrast, however, TexB contributes more to the contrast. This is due to the long boundary between ApC and TrB (Appendix 2.3), which causes the contribution of TexB to soil contrast to be more than that of DPD.

Of the 20 kinds of pairs of contrasting soils, 15 are controlled by DPD alone, although several other properties covary at the next lower level of contrast. Eleven of these pairs involve comparisons with He. He is moderately well drained with slow permeability and a depth to least permeable layer of 15 inches. Ap and Ce, both well drained with moderate permeability, and Do, which is well drained and has moderately slow permeability at 33 inches, all produce contrasting soils when paired with He. The fact that He is different from these soils is evident from the way He is utilized. Most of the acreage of He is wooded, and only 10 percent was cleared and used for pasture and hay when the Soil Survey was published (Lawrence, 1976).

ApC-FaB is a pair of contrasting soils for which both DPD and TexB are somewhat contrasting, but because four other properties also varied at the similar level, the overall difference between these two soils was elevated to contrasting.

The remaining four pairs of contrasting soils that involved a controlling difference in DPD are ApC-PeC, ApB-EnB, GeB-MeC and CeC-EnB. ApC, ApB, GeB and CeC soils have exceedingly high suitability for agriculture as far as DPD is concerned. These soils are well drained, have moderate permeability, and lack a slowly permeable layer. PeC is a moderately well drained soil with slow permeability and depth to least permeable layer of 22 inches. It developed from loamy marine sediment in the Sandhills. EnB and MeC are both well drained, slowly permeable soils whose depths to least permeable layers are 8 and 5 inches, respectively.

Other pairs have differences in other properties. EnB-GeB is a pair of contrasting soils which has 2 levels of difference each in DRt and pHA. Enon has a shallower DRt because of the presence of a slaty R horizon at 26 inches, and it has a neutral subsoil pH. Ge has a DRt greater than 40 inches and a strongly acid subsoil.

Three pairs, i.e. ApC-BnC, ApC-TrB and CeB-FaB, involve contrasting pairs which differ in the texture of the B. All three of these pairs involve Piedmont Plateau and Sandhill soils. BnC and TrB both have a sandy TexB, whereas FaB has a sandy loam TexB. ApC and CeB soils have clay loam and clay textures in the B horizon, respectively. These are different from a pair of ApB-FaB that produce similar soils because FaB is derived from finer parent material.

Very Contrasting Soils

As in the Inceptisols, flooding, with or without accessory properties varying at the next lower level of contrast, is the major reason for very contrasting soils. There is one exception, and that is where extreme variation in B horizon texture controls the contrast. Flooding is associated more with TexB and slope. The neighboring upland soils above the alluvial soils have clay to clay loam texture, whereas alluvial soils have sand to sandy loam texture.

Of the 10 pairs of very contrasting soils, seven involve To, which floods frequently and has a sandy loam texture of the B. Another alluvial soil, Ch, also floods frequently and produces very contrasting soils when paired with ApB and ApC. CeB-TrB is a pair of very contrasting soils in which one (CeB) has a clay texture while the other (TrB) has a sandy texture.

Alluvial soils are always paired with soils in the Piedmont Plateau and not with Sandhills soils. This is because only the Piedmont Plateau is traversed by narrow streams. Alluvial soils are found on narrow stream floodplains, and when paired with upland soils, produce very contrasting soils.

Summary of Levels of and Reasons for Contrast

Similar soils are dominant in the area of Ultisol soils studied, followed by somewhat contrasting, contrasting and very contrasting. Areas of uniform parent materials, i.e. rocks in Piedmont Plateau, produce more similar soils than soils composed of both Piedmont Plateau and Sandhills.

The samples of Ultisols are more or less characterized by uniform slope. There is not even an E or F slope in the area. Slo is a single dominant factor only in similar and somewhat contrasting soils. Thus, the differences in landscape positions are not adequate to interpret the contrast levels of pairs of Ultisol soils.

The differences in parent material accounts for some of the difference in the contrast levels of pairs of soils. Pairs of residual soils are either similar, somewhat contrasting or contrasting. Pairs of soils derived from marine sediments with residual soils from acid or basic rocks form contrasting and somewhat contrasting soils. Pairs of alluvial soils with upland soils are very contrasting due to flooding, TexB and Slo.

The soil properties contributing to the contrast follows this trend: Only 4 properties contribute to the contrast of similar soils (Fig. 4.10) whereas seven properties contribute to the contrast of somewhat contrasting to very contrasting soils (Figs. 4.11-13). The maximum percentage contribution to soil contrast also decreases as the contrast level increases. The maximum percentage for similar soils is 58 whereas that of very contrasting is 21. Not all the properties that are in the graphs (Figs. 4.10-4.13) are important.

The soil properties that contribute highly to each contrast level in the Ultisols are summarized in Table 4.22.

Table 4.22. Summary of soil properties important in each contrast level of the Ultisols

Soil Contrast Level	Soil Property
Similar	Slo, pHA, TexB
Somewhat Contrasting	Slo, TexB, pHA, pHB
Contrasting	TexB, DPD, pHA, pHB, TexA
Very Contrasting	Fld, Slo, TexB

C. Alfisol

The legend for all the map units in all of the Alfisol samples is shown in Table 4.23. The area, number of delineations, and soil order of each map unit are shown in Table 4.24.

Lapeer and Wyocena soils are dominant in Alfisol samples 1 and 2. Lapeer and Wyocena are also dominant in sample 3, but the areas of Winneshiek and Boyer soils almost equal that of Wyocena. Sample 3 has the least area of Wyocena. Alfisol is the most common soil order in the study areas, although Mollisols, Entisols and Inceptisols are also present. Based on the areas of dominant soils, the 3 sample areas do represent the Lapeer-Wyocena association.

Table 4.23. Legend for all map units in the Alfisol samples

Symbol	Name
Ag	Alluvial land
BnC	Boone loamy fine sand, 6 to 12 percent slopes
BnE	Boone loamy fine sand, 12 to 45 percent slopes
BpB	Boyer loamy sand, 2 to 6 percent slopes
BpC2	Boyer loamy sand, 6 to 12 percent slopes, eroded
BrB	Boyer fine sandy loam, 2 to 6 percent slopes
CaB	Channahon silt loam, 2 to 6 percent slopes
CaC2	Channahon silt loam, 6 to 10 percent slopes, eroded
CaE2	Channahon silt loam, 12 to 30 percent slopes, eroded
ChC	Chelsea loamy fine sand, 6 to 12 percent slopes
DrB	Dresden loam, 1 to 6 percent slopes
FrB	Friesland fine sandy loam, 1 to 6 percent slopes
GaA	Gilford fine sandy loam, stratified substratum, 0 to 3 percent slopes
Gb	Granby loamy sand
GeB	Grellton fine sandy loam, 1 to 6 percent slopes
GrB2	Griswold silt loam, 2 to 6 percent slopes, eroded
KbA	Kibbie fine sandy loam, 0 to 4 percent slopes
LaB	Lapeer fine sandy loam, 2 to 6 percent slopes
LaC2	Lapeer fine sandy loam, 6 to 12 percent slopes
LaD2	Lapeer fine sandy loam, 12 to 20 percent slopes
LaE2	Lapeer fine sandy loam, 20 to 30 percent slopes
Mb	Marsh
MnB	Military fine sandy loam, 2 to 6 percent slopes
MnC2	Military fine sandy loam, 6 to 12 percent slopes, eroded
MnD2	Military fine sandy loam, 12 to 20 percent slopes, eroded
MoA	Morocco loamy sand, 0 to 3 percent slopes
NoB	Northfield sandy loam, 2 to 6 percent slopes
OkB	Okee loamy fine sand, 2 to 6 percent slopes
OkC	Okee loamy fine sand, 6 to 12 percent slopes
OmB	Oshtemo loamy sand, 2 to 6 percent slopes
Ot	Otter silt loam
PfB	Plainfield loamy fine sand, 2 to 6 percent slopes
PkB	Plainfield loamy fine sand, loamy substratum, 2 to 6 percent slopes
PuB	Puchyan loamy fine sand, 2 to 6 percent slopes
PuC	Puchyan loamy fine sand, 6 to 12 percent slopes
Rk	Rockland
RoD	Rodman gravelly loam, 12 to 20 percent slopes
SbA	Salter fine sandy loam, 0 to 2 percent slopes
SbB	Salter fine sandy loam, 2 to 6 percent slopes
ScB	Salter fine sandy loam, dark surface variant, 1 to 6 percent slopes
SnA	Sisson fine sandy loam, 0 to 2 percent slopes
SnB	Sisson fine sandy loam, 2 to 6 percent slopes
WnB	Winneshiek fine sandy loam, 2 to 6 percent slopes
WnC2	Winneshiek fine sandy loam, 6 to 12 percent slopes, eroded

Table 4.23. Cont'd.

WoB	Wyocena loamy sand, 2 to 6 percent slopes
WxB	Wyocena sandy loam, 2 to 6 percent slopes
WxC2	Wyocena sandy loam, 6 to 12 percent slopes, eroded
WxD2	Wyocena sandy loam, 12 to 20 percent slopes, eroded
WyB	Wyocena fine sandy loam, sandstone substratum, 2 to 6 percent slopes
WyC2	Wyocena fine sandy loam, sandstone substratum, 6 to 12 percent slopes, eroded
WyD2	Wyocena fine sandy loam, sandstone substratum, 12 to 20 percent slopes, eroded
WyE	Wyocena fine sandy loam, sandstone substratum, 20 to 45 percent slopes
YaA	Yahara fine sandy loam, 0 to 4 percent slopes

Table 4.24. Area in acres, number of delineations, and soil order of each map unit in the Alfisol samples

	Area (Number of Delineations)			Soil Order
	I	II	III	
Ag	8.096 (1)	4.802 (1)	5.913 (1)	
BnC	7.025 (2)	4.008 (1)	4.643 (1)	Entisol
BnE	0	0	32.702 (3)	Entisol
BpB	0	0	65.245 (1)	Alfisol
BpC2	0	0	22.503 (1)	Alfisol
BrB	0	4.286 (1)	0	Alfisol
CaB	0	0	6.429 (1)	Mollisol
CaC2	0	0	25.836 (3)	Mollisol
CaE2	0	0	65.722 (6)	Mollisol
ChC	0	3.215 (1)	0	Entisol
DrB	14.843 (1)	0	0	Alfisol
FrB	0	0	59.848 (1)	Mollisol
GaA	0	12.184 (1)	61.475 (1)	Mollisol
Gb	0	0	27.344 (2)	Mollisol
GeB	0	0	27.027 (2)	Alfisol
GrB	0	0	14.010 (1)	Mollisol
KbA	0	0	4.961 (1)	Alfisol
LaB	859.938 (9)	1397.932 (6)	366.311 (8)	Alfisol
LaC2	41.076 (10)	104.099 (9)	394.648 (18)	Alfisol
LaD2	7.977 (2)	240.344 (8)	21.233 (3)	Alfisol
LaE2	0	15.518 (2)	0	Alfisol
Mb	0	12.898 (1)	22.304 (6)	Alfisol
MnB	120.688 (5)	0	0	Alfisol
MnC2	33.972 (3)	22.503 (2)	6.509 (1)	Alfisol
MnD2	15.319 (2)	11.152 (1)	16.470 (2)	Alfisol
MoA	0	0	6.628 (1)	Entisol
NoB	18.772 (1)	0	0	Alfisol
OkB	0	34.805 (2)	42.902 (2)	Alfisol
OkC	1.865 (1)	38.020 (3)	0	Alfisol
OmB	30.241 (2)	0	8.572 (1)	Alfisol
Ot	0	0	2.222 (1)	Mollisol
PfB	6.350 (2)	0	0	Entisol
PkB	12.898 (2)	51.434 (3)	0	Entisol
PuB	7.382 (1)	0	0	Alfisol
PuC	18.216 (1)	0	0	Alfisol
Rk	7.779 (2)	12.105 (2)	33.677 (1)	
RoD	1.111 (1)	0	0	Mollisol
SbA	1.468 (1)	0	0	Inceptisol
SbB	27.146 (1)	9.406 (1)	0	Inceptisol
ScB	3.413 (1)	0	0	Mollisol
SnA	11.509 (1)	0	0	Alfisol
SnB	23.018 (1)	0	0	Alfisol
WnB	0	0	44.410 (2)	Alfisol
WnC2	0	0	31.273 (2)	Alfisol

Table 4.24. Cont'd.

WoB	16.907 (1)	33.694 (1)	0	Alfisol
WxB	2.659 (1)	19.764 (2)	0	Alfisol
WxC2	2.619 (1)	11.112 (2)	37.623 (2)	Alfisol
WxD2	0	23.971 (2)	0	Alfisol
WyB	224.867 (7)	39.449 (4)	0	Alfisol
WyC2	322.709 (12)	37.941 (4)	15.200 (3)	Alfisol
WyD2	31.313 (4)	9.168 (2)	0	Alfisol
WyE	0	0	35.520 (2)	Alfisol
YaA	0	0	6.906 (1)	Mollisol
TOTAL	1756.983 (79)	1181.720 (63)	2357.527 (79)	
No. of map units	29	25	29	

The soils in the Alfisol group were derived from different parent materials. Most of the soils developed wholly or partly in material laid down by glaciers. Two types of glacial till were deposited as the glacial ice melted. The first type of till is finer in texture (heavy sandy loam) and more calcareous. The content of gravel in this till is mostly dolomitic material mixed with some crystalline material. This till was deposited in the eastern part of the county. Griswold, Marcellon and Military soils have formed from this type of till.

The second type of till is coarser textured (sand or loamy sand) and less calcareous. It has a higher amount of sandstone than limestone in the gravel fraction. This till was deposited in the western part of the county. Some of the soils derived from this till are Lapeer, Wyocena, Northfield and Winneshiek.

Some soils were derived from glacial outwash consisting of varying amounts of well rounded pebbles, cobblestones and sand that were deposited by running water as the glacier melted. Boyer, Dresden, Granby, Rodman, Morocco, Plainfield and Oshtemo were derived from glacial outwash. Some of these soils, however, are also derived from other parent materials. Granby and Morocco also have a more recent alluvial origin as they can be found on river floodplains. Oshtemo is also found in valley trains and moraines, and Plainfield occurs on stream terraces and moraines.

There was considerable deposition of both silt and sand after deglaciation (Hole, 1976). Some soils formed in loess that ranges from a few inches to more than 5 feet in thickness. Channahon soils are formed in shallow deposits of silt that overlie loamy glacial till and bedrock.

In some areas mixed windblown deposits of silt and fine sand occur along the fringe areas of silt deposits. Okee, Chelsea and Puchyan soils formed in windblown deposits of sandy material over earlier deposits of silt and fine sand. Salter and Sisson soils developed from well-sorted, alternating layers of silt and fine sand. Friesland and Grellton soils formed in areas where silt deposits were later covered by mixed windblown deposits of silt and fine sand.

A few soils (Gilford and Kibbie) developed from lacustrine material deposited by very slowly moving or ponded waters of temporary glacial lakes. This material consists of thin layers of clay, silt, very fine sand and fine sand. Some soils such as Boone developed from sandstone.

More complete descriptions of the properties of these soils are included in Appendix 3.1.

The most common pairs of adjacent soil phases in all samples of Alfisols were selected from the matrices in Appendix 3.2 and are shown in Table 4.25. Only one pair of adjacent soil phases, LaB-LaC2, was present in all samples, but it was the most frequently occurring pair only in sample 3. WyC2-WyB and LaC2-LaD2 were the most most common adjacent pairs of soil phases for samples 1 and 2, respectively. This and the distribution of data in Table 4.25 indicate that even though Lapeer and Wyocena soils are dominant, there is a substantial amount of variability in the kinds of soils and the patterns of their occurrences on the landscapes from area to area.

Table 4.25. Contrast level and frequency of occurrence of the most common pairs in the Alfisol samples

Pairs	Contrast Level	Number of Pairs		
		I	II	III
WyC2-WyB	S	18	5	
WyC2-LaB	SC	12		
WyB-LaB	S	9		
LaC2-LaB	S	9	5	24
WyC2-WyD2	SC	6		
WyB-MnB	SC	6		
WyC2-MnB	SC	6		
WyC2-LaC2	S	6		
LaD2-LaC2	S		12	3
LaD2-LaB	SC		11	
WyC2-WyB	S		5	
WyE-LaC2	SC		3	
WyE-LaD2	SC		3	
WyB-LaD2	SC		3	
SbB-LaD2	SC		3	
OkC-LaD2	SC		3	
MnC2-LaD2	SC		3	
MnD2-LaD2	SC		3	
LaE2-LaD2	S		3	
GaA-Gb	VC			5
LaB-GaA	C			4
LaC2-CaE2	C			4
WyC2-BnE	SC			4
OkB-LaB	SC			4
LaB-CaE2	VC			3
WnB-CaE2	VC			3
WnC2-CaE2	C			3
MnD2-LaB	SC			3
MnD2-LaC2	SC			3
MnC2-WnB	SC			3
WyE-WyC2	SC			3

Levels of Contrast

The distributions of the different levels of soil contrast are shown in Table 4.26 and Fig. 4.14 (Method 1) and Table 4.27 and Fig. 4.15 (Method 2).

All three sample areas are dominated by similar and somewhat contrasting levels. The percentage of similar and somewhat contrasting soils is about 80%. The percentages of contrasting and exceedingly contrasting soils are quite low, and there is a variation in the percentages of their contrast levels from one sample to another (Table 4.26 and Fig. 4.14).

The distributions of soil contrast levels are similar for sample areas 1 and 2. These areas have small percentages of contrasting and very contrasting soils because they both lack Ch, GaA, Gb, Ot and Wn, which are components of very contrasting pairs. Sample area 3 has a very different distribution from samples 1 and 2. Sample 3 has lesser percentages of similar and somewhat contrasting pairs and has a higher percentage of very contrasting and exceedingly contrasting soils than the other 2 samples. This difference is due in part to a large mapping unit of LaB that contains many small delineations of CaE2 that form very contrasting pairs with LaB. Area 3 also is the only sample with BnA, BpB, CaB, CaE2, Gb, Ot, YaA, and Wn, all of which are components of very contrasting soils. In addition, Area 3 has large areas of marsh and rocklands that are responsible for exceedingly contrasting soils. These increases in the percentages of very contrasting and exceedingly contrasting soils resulted in lower percentages of similar and somewhat contrasting soils.

The percentage of somewhat contrasting soils is greater than the percentage of similar soils using percent of pairs (Table 4.26 and Fig. 4.14), but the trend reverses using percent of boundary length. The percentage of similar soils is more than that of somewhat contrasting soils using percent of boundary length because the boundaries between similar soils are longer. In sample area 1, for example, pairings of WyB-WyC2, a similar pair, have 13 out of 18 boundary segments that are more than 1.0 inch long. The usual length of a boundary segment is less than 1.0 inch. The longer boundary length has more influence on soil contrast than the number of pairs.

Conversely, each long segment is still counted as a single pair. Greater number of short segments can increase the percentage of a particular contrast to which the pair belongs. The percent of pairs, then, is not recommended to be used for determining even the relative abundance of contrast levels for the study areas. It is useful in giving an idea as to the variety of soils in the area.

Table 4.26. Percent of adjacent pairs in the Alfisol samples belonging to the different soil contrast levels

Contrast Level	Percent of Pairs			Mean
	I	II	III	
VS	1.0	0	0	0.7
S	41.5	34.9	25.6	34.0
SC	48.0	48.8	32.9	43.2
C	5.5	11.4	15.2	10.7
VC	1.0	0	12.2	4.4
EC	3.0	4.8	14.0	7.26

Table 4.27. Distribution of contrast levels of Alfisol samples based on percent of boundary length

Contrast Level	Percent of Boundary Length			Mean
	I	II	III	
VS	0.199	0	0	0.07
S	53.59	43.64	44.67	47.36
SC	38.99	45.77	27.61	37.45
C	6.38	6.83	9.11	7.44
VC	0.74	0	8.90	3.21
EC	0.08	3.75	9.49	4.44

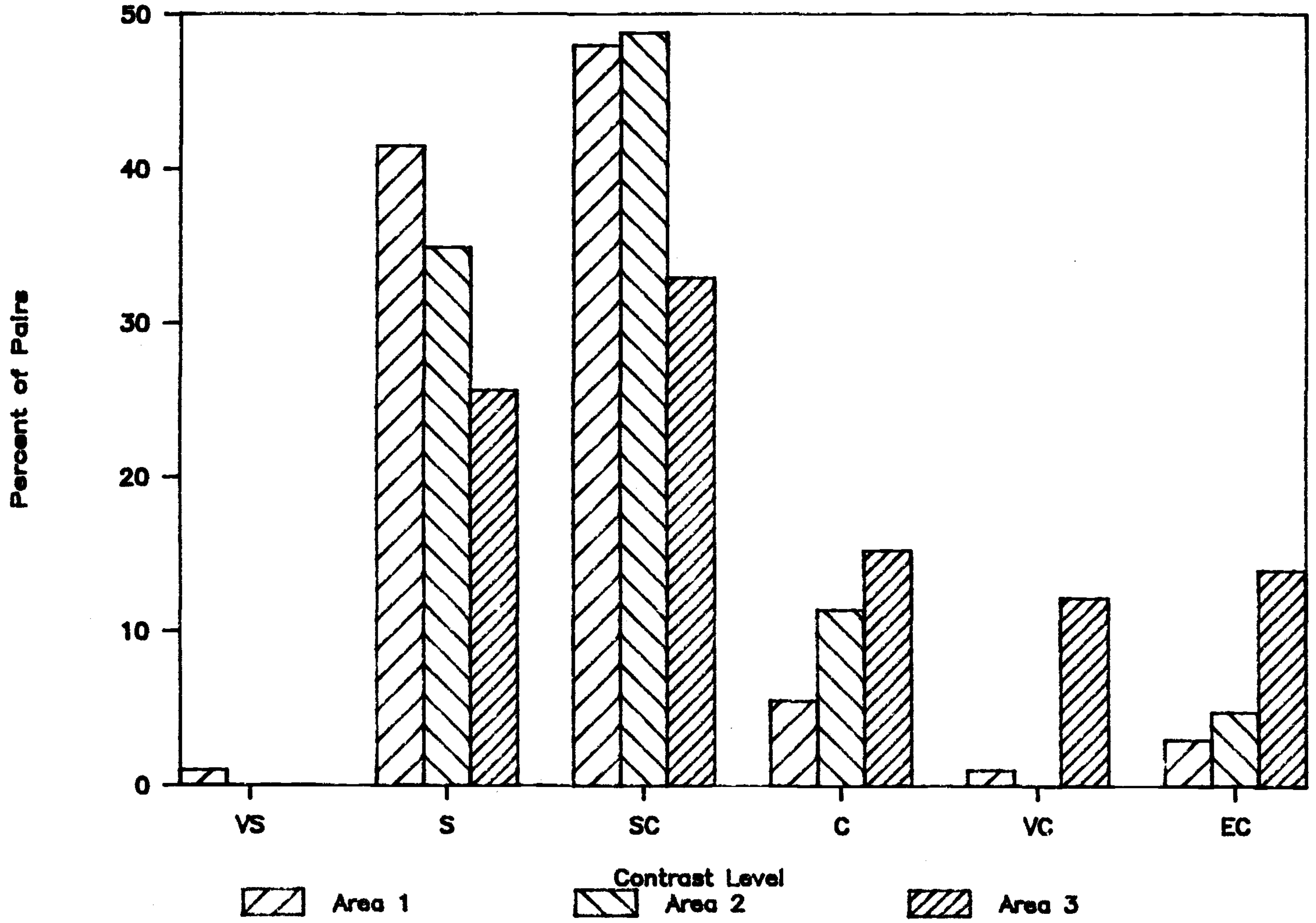

Fig. 4.14. Distribution of the percent of pairs among the different soil contrast levels in the Alfisols

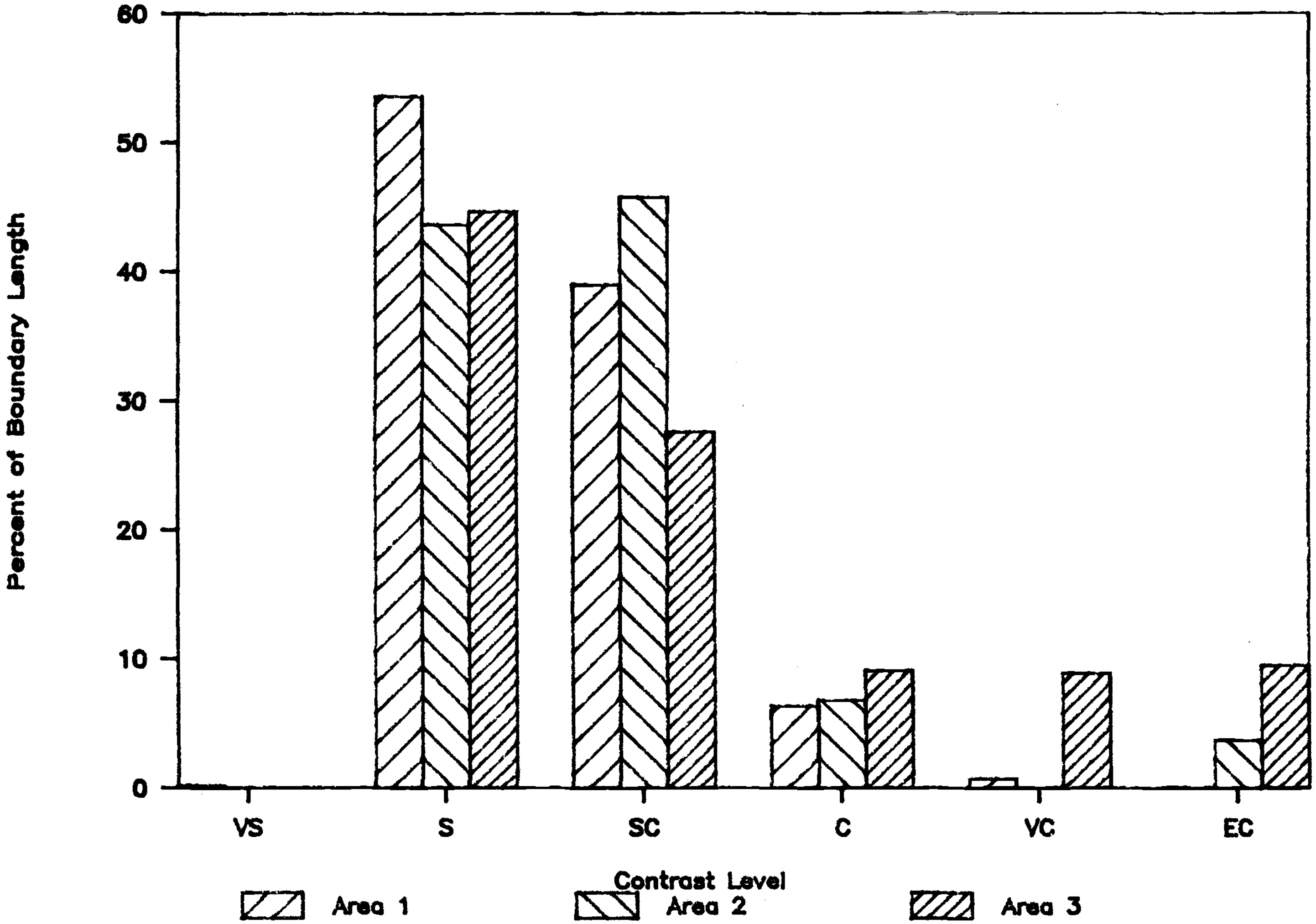

Fig. 4.15. Distribution of the percent of boundary length among the different soil contrast levels in the Alfisols

Reasons for Contrast

The reasons for contrast are shown in Table 4.28 and Figs. 4.16-4.19 (Method 1) and Table 4.29 (Method 2). The boundary length and the contrast code of each property for each pair are shown in Appendix 3.3.

Table 4.28. Weighted average contribution of each soil property to each level of contrast in the Alfisol sampling areas

	Sample	CfA	CfB	Fld	Drt	Slo	DPD	EP	TexA	TexB	pHA	pHB
S	1	0.00	4.10	0.00	0.00	34.61	0.00	31.10	1.27	1.85	4.37	22.70
	2	0.00	0.48	0.00	0.00	49.05	0.00	22.16	6.94	4.18	0.95	16.24
	3	0.05	0.00	0.00	0.00	44.44	0.00	39.38	0.00	7.47	0.66	8.00
	Mean	0.02	1.53	0.00	0.00	42.70	0.00	30.88	2.74	4.50	1.99	15.65
SC	1	0.00	4.78	0.00	25.37	18.02	0.00	11.96	4.64	8.08	6.78	20.37
	2	0.00	0.29	0.00	7.84	28.65	0.20	16.90	9.13	14.21	8.31	14.46
	3	0.00	5.23	0.00	10.83	15.88	2.58	12.09	8.55	15.79	15.81	13.23
	Mean	0.00	3.43	0.00	14.68	20.85	0.92	13.65	7.44	12.69	10.30	16.02
C	1	0.00	4.39	0.00	19.58	19.10	0.00	6.80	8.79	22.99	7.11	11.23
	2	1.68	2.47	0.00	4.23	27.34	1.24	4.34	7.61	21.53	16.72	12.84
	3	0.00	10.06	0.00	9.86	16.17	6.42	3.19	7.91	8.88	19.01	18.50
	Mean	0.56	5.64	0.00	11.22	20.87	2.55	4.78	8.10	17.80	14.28	14.19
VC	1	14.28	14.28	0.00	28.57	9.66	0.00	4.62	7.14	7.14	7.14	7.14
	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	5.01	26.05	6.99	11.47	5.83	2.60	6.98	9.74	12.90	12.43
	Mean	4.76	6.43	8.68	11.85	7.04	1.94	2.41	4.71	5.63	6.68	6.52

Table 4.29. Number of discrete pairs of Alfisol soils for each controlling soil property within each contrast level

Contrast Level	Number of Pairs I	II	III
Similar			
One 2			
Slope	4	5	2
	LaC2-LaD2	SnA-SnB	
	LaD2-LaE2	WxC2-WxD2	
	MnC2-MnD2	WxC2-WyD2	
	OkB-OkC	WyC2-WyD2	
pHB	2	4	3
	FrB-LaB	LaC2-WyC2	
	LaB-WxB	LaD2-WxD2	
	LaB-WyB	LaD2-WyD2	
	LaC2-WxC2		
Two 2's			
Slo, EP	3	1	4
	BpB-BpC2	WxB-WxC2	
	LaB-LaC2	WyB-WyC2	
	MnB-MnC2	WnB-WnC2	
Slo, TexB	0	0	1
	BnC-LaB		
Slo, pHB	1	2	1
	BnC-WoB	LaD2-WyC2	
	LaD2-WxC2		
TexB, pHA	0	0	1
	GaA-KbA		
TexA, TexB	1	2	0
	WoB-WyB		
TexB, pHB	0	1	1
	GeB-LaB	LaD2-SnD2	
pHA, pHB	0	1	0
	LaB-SbB		
EP, TexB	0	0	1
	BnC-LaC2		
EP, pHB	0	1	0
	LaE2-WyE		
Three 2's			
Slo, EP, pHB	2	3	0
	LaB-WyC2	LaC2-WyB	
	LaB-WxC2	LaD2-WyE	
	LaC2-WxB		
CfB, pHA, pHB	2	1	0
	PkB-WoB	ScB-WyB	
	SbB-WyB		

Table 4.29. Cont'd.

CfB, TexB, pHB	2 LaB-SnB LaD2-SnD2	1 SnB-WxB	0
TexA, TexB, pHA	0	1 LaB-PkB	0
TexB, pHA, pHB	1 SbA-SnA	0	0
TexA, TexB, pHB	0	1 LaB-WoB	0
Slo, pHA, pHB	0	1 ChC-PkB	0
TexA, pHA, pHB	1 OmB-WyB	0	0
Somewhat Contrasting			
Four 2's			
Slo, TexB, pHA, pHB	1 PfB-PuC	0	0
EP, TexA, TexB, pHB	1 BnC-WyC2	1 BnE-WyE	1
Slo, TexA, TexB, pHB	1 BnC-WyB	1	0
Slo, EP, TexA, pHB	1	2 WoB-WxC2 WoB-WyC2	0
TexA, TexB, pHA, pHB	0	0	1 Gb-YaA
CfB, Slo, TexB, pHB	1 LaB-SnA	1 LaD2-SnC2	0
CfB, TexA, TexB, pHA	1 LaB-PfB	0	0
Five 2's			
CfB, Slo, EP, pHA, pHB	2 PfB-WyC2 SbB-WyC2	0	0
Slo, TexA, TexB, pHa, pHB	1 PfB-SbA	0	0
CfB, Slo, EP, TexB, pHB	1 SnB-WxC2	0	0
Slo, EP, TexA, pHA, pHB	1 LaC2-OmB	0	0
DRt, Slo, EP, TexA, TexB	0	0	2 BnE-LaD2 BnE-MnD2
Six 2's			
CfB, Slo, EP, TexA, TexB, pHA	1 LaC2-PkB	1	0
Seven 2's			
CfB, DRt, Slo, EP, TexB, pHA, pHB	0	0	1 BpC2-OmB

Table 4.29. Cont'd.

One 3 any 2's			
Slo	10	13	9
	BnC-BnE	LaD2-WoB	
	BnC-WyE	LaD2-WxB	
	BnE-WyC2	LaD2-WyB	
	CaC2-CaE2	LaE2-WyC2	
	LaB-LaD2	OkC-SnA	
	LaB-WxD2	PfB-WyD2	
	LaB-WyD2	WoB-WxD2	
	LaC2-LaE2	WoB-WyD2	
	LaC2-SnA	WxB-WxD2	
	LaC2-WyE	WxD2-WyB	
	LaD2-OmB	WyB-WyD2	
	LaD2-PkB	WyC2-WyE	
	LaD2-SbB		
DRt	16	9	4
	BnC-MnC2	MnB-WyB	
	LaB-MnB	MnB-WyC2	
	LaB-MnC2	MnC2-PuB	
	LaB-MnD2	MnC2-WoB	
	LaC2-MnB	MnC2-WyB	
	LaC2-MnC2	MnC2-WyC2	
	LaC2-MnD2	MnC2-WyD2	
	LaD2-MnC2	MnD2-WxC2	
	LaD2-MnD2	MnD2-WyC2	
	MnB-PfB	MnD2-WyD2	
	MnB-SbB		
TexB	4	10	4
	FrB-GrB2	OkB-WxB	
	FrB-OkB	OkB-WxD2	
	GrB2-LaB	OkB-Wyb	
	LaB-OkB	OkB-WyC2	
	LaB-OkC	OkC-WxC2	
	LaC2-OkB	OkC-WxD2	
	LaC2-OkC	PfB-SnA	
	LaD2-OkC	PfB-SnB	
	MnB-NoB	SbA-SnA	
pHA	5	3	3
	BpB-LaC2	LaB-PuC	
	BpB-WxC2	LaC2-PuB	
	BpC2-LaD2	LaC2-PuC	
	BrB-LaC2	LaD2-PuC	
	BrB-SbB	WyC2-WyE	
	LaB-PuB		
pHB	2	0	0
	SnB-WyB	SnB-WyC2	

Table 4.29. Cont'd.

Two 3's, ≤ three 2's			
DPD, pHA	0	1	0
	GaA-WxB		
Slo, pHA	0	0	1
	BnE-BpC2		
DRt, TexB	3	0	1
	DrB-WxB DrB-WyB		LaC2-WnC2 MnC2-OkC
CfB, pHA	0	0	1
	BbA-GaA		
Slo, pHB	1	0	0
	SnA-WyC2		
DRt, Slo	2	2	1
	LaB-MnD2 MnB-WyD2		MnD2-WyB
Contrasting			
Two 3's, ≥ four 2's			
DRt, Slo	1	0	0
	MnC2-SnA		
DRt, TexB	2	0	0
	DrB-LaC2		DrB-WyC2
Slo, DPD	0	0	1
	LaC2-MoA		
Slo, pHA	0	2	1
	BpB-LaD2		BrB-LaD2
DPD, pHA	0	1	0
	GaA-WoB		
DRt, pHB	1	0	0
	DrB-SnA		DrB-SnB
DPD, pHB	0	0	1
	KbA-LaB		
≥ Three 3's			
DRt, pHA, pHB	0	0	2
	CaC2-WnB		CaE2-LaD2
Slo, pHA, pHB	0	0	1
	CaE2-WnC2		
DPD, pHA, pHB	0	0	1
	GaA-LaB		
DRt, TexA, TexB	1	0	0
	DrB-OmB		
DRt, Slo, pHA, pHB	0	0	1
	CaE2-LaC2		
DRt, TexA, TexB, pHA, pHB	0	0	1
	BnE-CaE2		

Table 4.29. Cont'd.

One 4, < three 3's			
DRt	2	0	1
	CaC2-LaC2	NoB-WyD2	
	LaB-NoC		
Slo	1	5	3
	BnE-BpB	LaB-WyE	
	BnE-WyB	LaE2-SbB	
	BpB-WyE	PkB-WyE	
	BrB-WyE	WyB-WyE	
	LaB-WoE		
TexB	1	4	1
	BpB-OkB	OkC-PfB	
	ChC-OkC	OkC-PkB	
	OkB-WoB	OkC-WoB	
pHA	0	0	1
	GaA-OkB		
Very Contrasting			
One 4, ≥ three 3's			
Slo, DRt, pHA, pHB	0	0	3
	CaE2-LaB	CaE2-WnB	
	BnE-CaB		
One 5, ≤ one 4			
DRt	2	0	0
	RoD-WyB	RoD-WyC2	
Fld	0	0	6
	BpB-Gb	Gb-LaB	
	GaA-YaA	Gb-MoA	
	GaA-Gb	OmB-Ot	
Fld, TexB	0	0	2
	BpB-Ot	Gb-OkB	

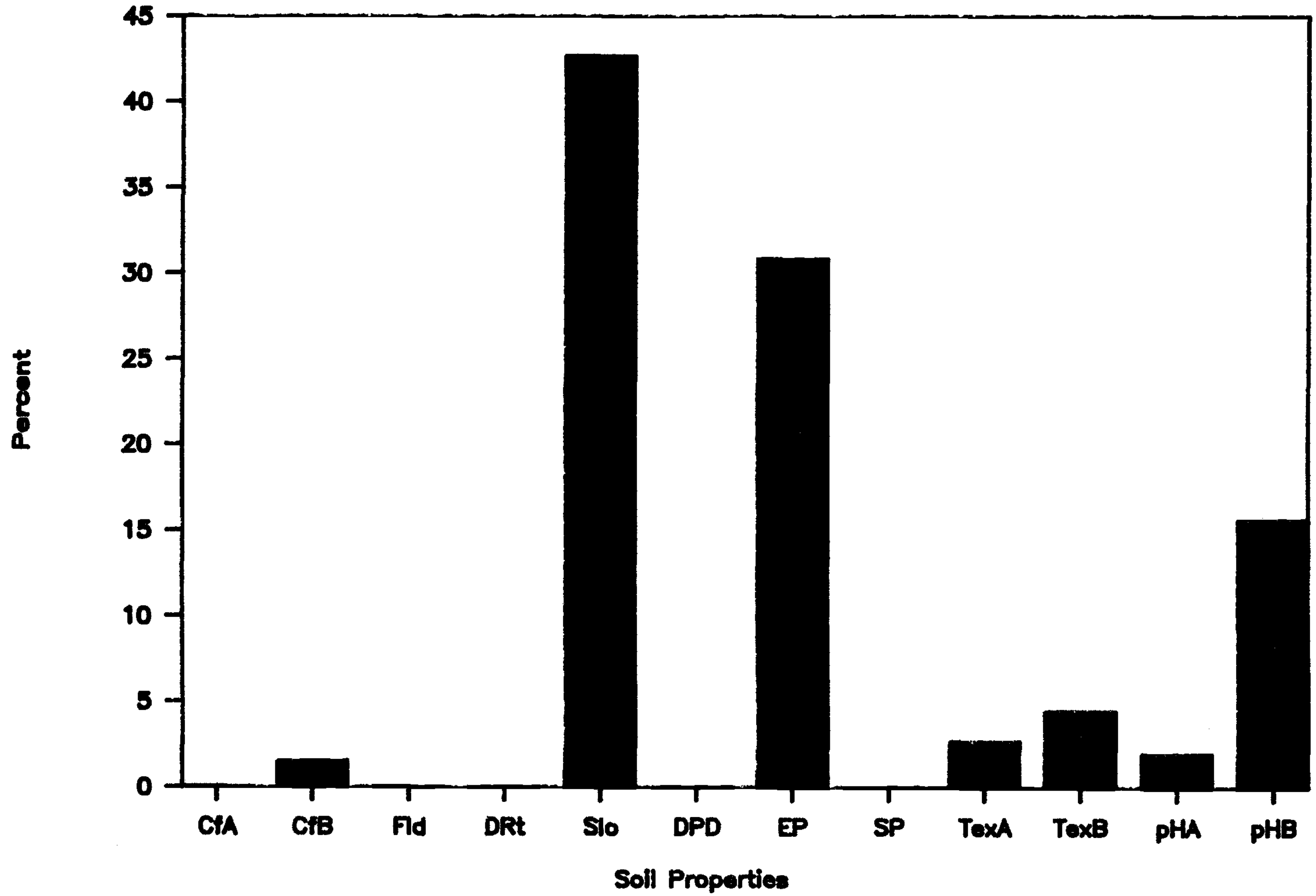

Fig. 4.16. Contribution of soil properties to the contrast of similar soils in the Alfisols

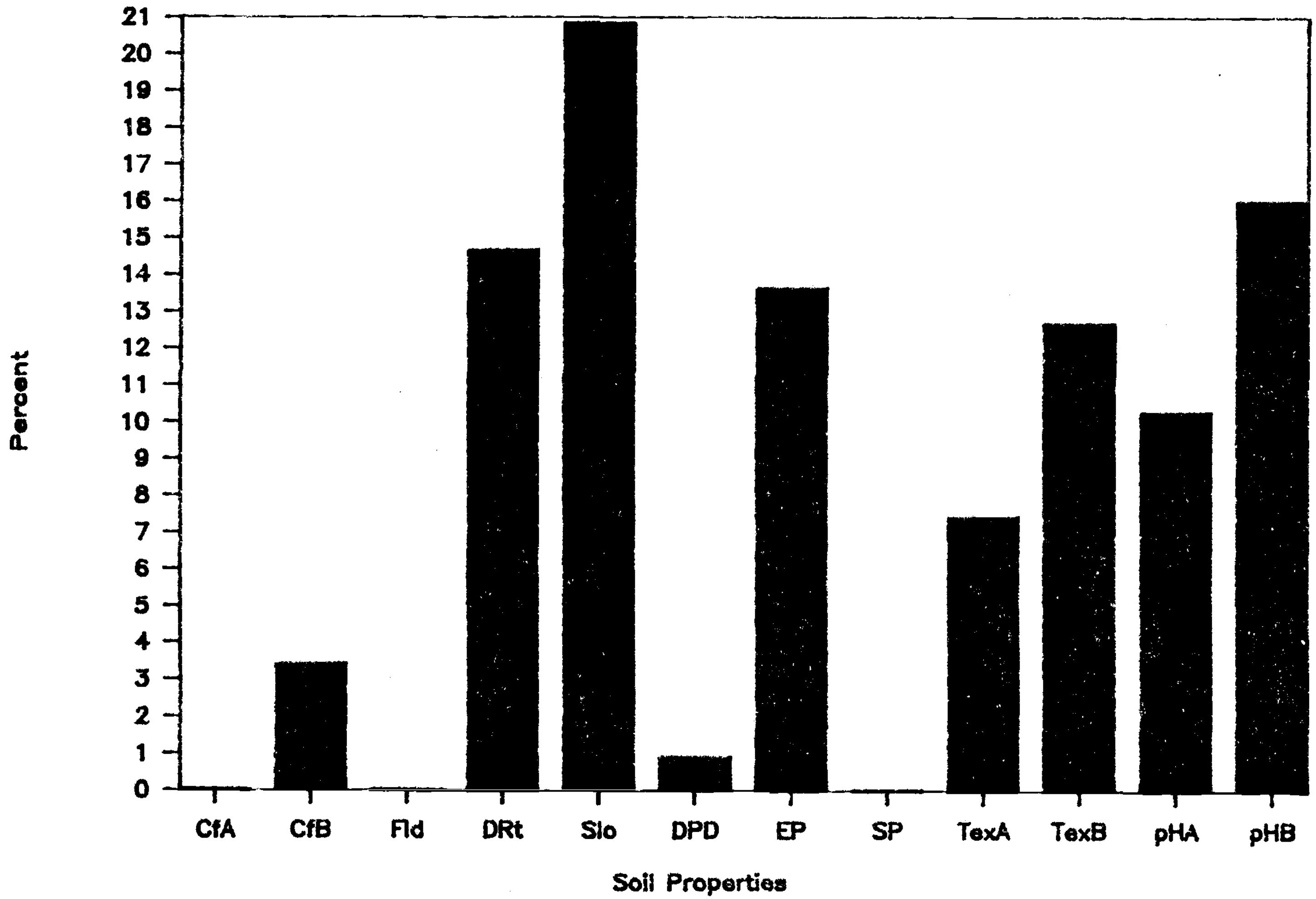

Fig. 4.17. Contribution of soil properties to the contrast of somewhat contrasting soils in the Alfisols

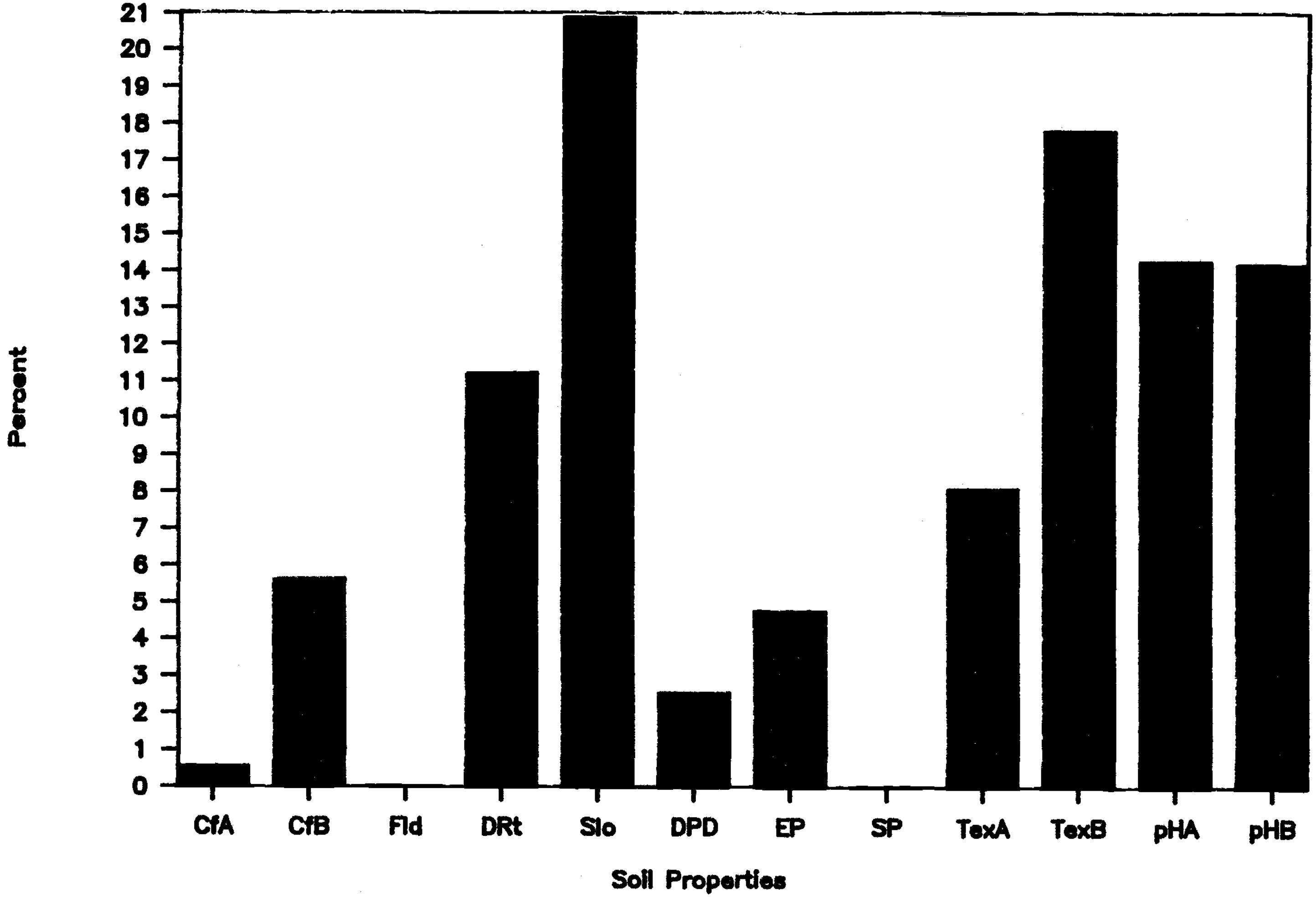

Fig. 4.18. Contribution of soil properties to the contrast of contrasting soils in the Alfisols

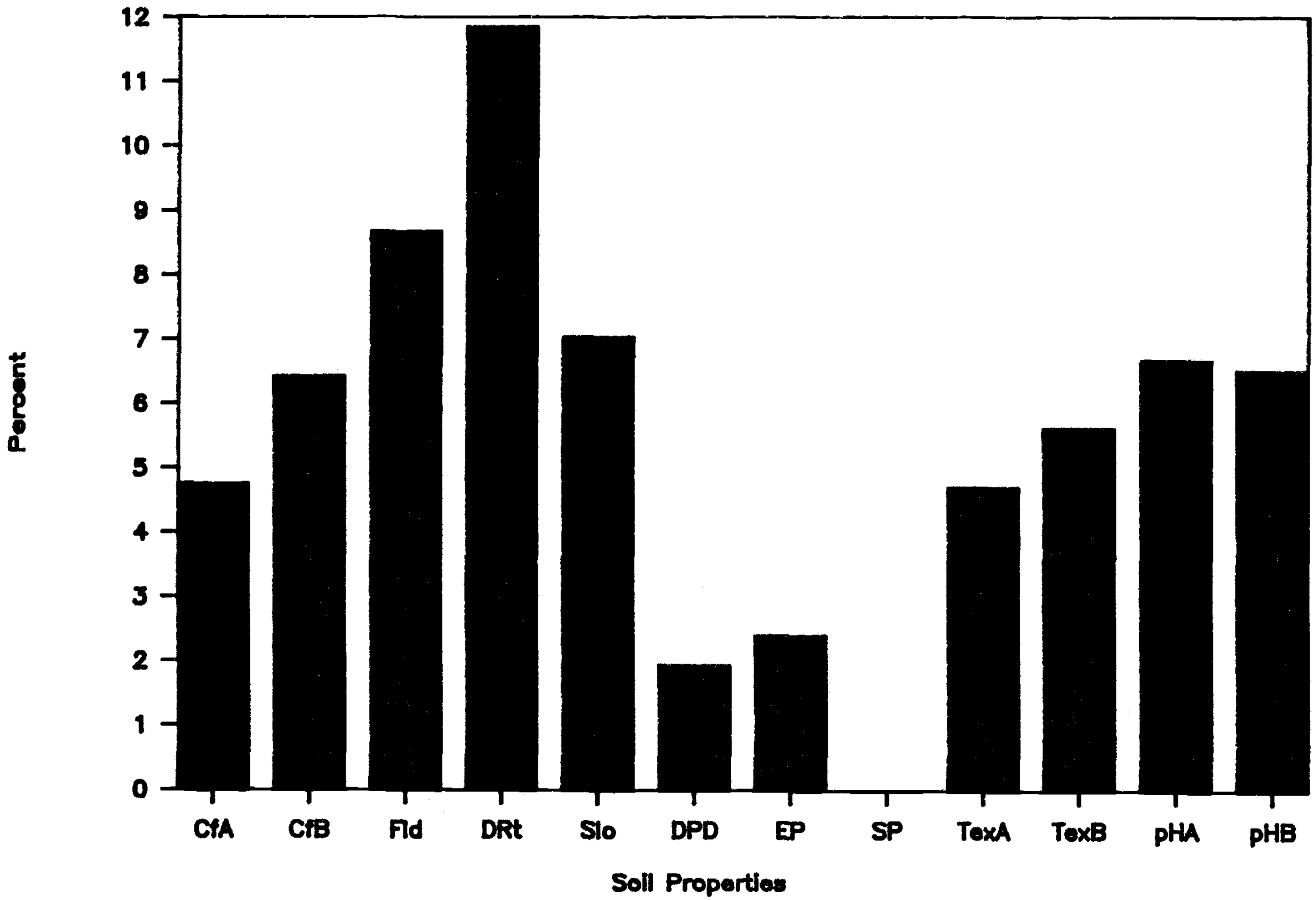

Fig. 4.19. Contribution of soil properties to the contrast of very contrasting soils in the Alfisols

Very Similar Soils

Pairs of Wyocena sandy loam and Wyocena fine sandy loam are very similar because sandy loam and fine sandy loam were assigned the same contrast code in the model. Wyocena fine sandy loam also has a sandstone substratum at a depth of 40 inches below the surface, but because properties below 25 inches were not included in the model, this difference did not affect the contrast either.

Similar Soils

The single most important property influencing the contrast of similar soils is slope. Slope is the only difference between several pairs of slope phases in the same series. Slope differences are accompanied by differences in erosion phases for several other single-series pairs, and for this reason erosion phase emerges as an important factor in determining the contrast of similar soils.

The dominant soils of the association, Lapeer and Wyocena, are also similar soils. Both soils were derived from coarse textured and less calcareous glacial till, but they have different pH values in the B horizon. Sometimes pH is the only difference. Sometimes pH is accompanied by a slope difference, and sometimes both slope and erosion phase covary with pHB. These common pH differences, combined with a variety of less frequently occurring pairs in which pHB differs, accounts for the relatively strong influence of pHB in the similar soils.

Not all pairs of similar soils, however, have the same parent material. Friesland and Lapeer are similar soils even though Lapeer developed from glacial till and Friesland developed from silt deposits that were later covered by mixed windblown deposits of silt and fine sand. BnC is similar to WoB and LaC2. BnC is a residual soil formed in sandstone, whereas LaC2 formed from coarse textured and less calcareous glacial till. Many other infrequently occurring pairs of soils differ in soil texture and pH, and these differences account for most of the remainder of the similar soils.

Unlike the Ultisols and Inceptisols, DPD does not differ at all among any of the similar soils. Nearly all of the soils in these landscapes are well drained, and when drainage differences do occur, they are more highly contrasting.

Somewhat Contrasting Soils

More soil properties contribute to the contrast in somewhat contrasting soils than in similar soils. Slope is the highest contributor of all soil properties, followed by pHB. Erosion phase is still important. The contribution of TexB increases. DRt suddenly emerges as an important property contributing to the soil contrast.

Most pairs for which slope is the single controlling factor are pairs of slope phases in the same series. For these pairs the slope differs by two classes. Some pairs include soils of different series, but in those cases, series differences are less important than slope differences.

Depth of rooting is the single controlling factor for 21 different kinds of pairs. These are all pairs of different series, and in every case the Military soil (Mn) is one member of the pair. Military is moderately deep (25 inches) to sandstone bedrock, whereas the Lapeer and Wyocena soils with which Mn is paired most frequently are deep soils. All of these soils formed in loamy glacial till, and all are Alfisols, so any other differences between series are subordinate to depth of rooting.

Texture of the B is the single controlling factor for 18 different kinds of pairs. This represents an important parent material difference. Most of these pairs represent associations between the sandy Okee soils and the loamy Lapeer and Wyocena soils. Okee, Lapeer and Wyocena all have an argillic horizon at 25 inches depth. The argillic horizon of Okee, however, is a sandy clay loam because it developed in finer-textured silts and fine sands above the till, whereas the sandy loam argillic horizon of Lapeer and Wyocena developed directly in the coarser-textured till. Thus, the TexB of Okee is finer than that of Lapeer and Wyocena.

Other pairs of somewhat contrasting soils with TexB as the main controlling factor are FrB-GrB2, GrB2-LaB, PfB-SnA and PfB-SnB. FrB formed from 20 to 40 inches of loamy sediment over glacial till. It has a sandy loam TexB. GrB2 formed from calcareous sandy loam glacial till mantled with as much as 18 inches of silt. GrB2 has a sandy clay loam texture derived from underlying glacial till and forms a somewhat contrasting pair with FrB. PfB has a sandy TexB, whereas SnA has a loam TexB.

Eleven pairs differed significantly only in the pH of the A horizon. Most of these pairs involved associations with either Boyer or Puchyan soils. Both of these soils have less acidic surface horizons than the Lapeer and Wyocena soils with which they are associated because Boyer is derived from calcareous sandy and gravelly glacial outwash, and Puchyan, though derived from sandy sediments, occurs in slight depressions in upland basins where bases coming from the upland can accumulate and cause a higher pH.

Two pairs of somewhat contrasting soils are controlled by pH of the B horizon. This property, however, varies to a lesser extent in a much larger number of soil pairs because of the variety of parent materials in the landscape. As a result, pHB is the second most important factor in the overall contrast (Fig 4.17) even though it dictates the contrast level in only 2 cases.

Most of these same factors that individually control the contrast level also co-vary to control the contrast when 2 factors have a contrast code of 3. The frequency with which this occurs is low, and many of the soils of such pairs are minor constituents of the landscape.

The data in Fig. 4.17 indicate that erosion phase is a major component of the reason behind somewhat contrasting pairs. Erosion phase by itself, however, does not control the contrast of a single pair of soils. Instead, associations of slightly eroded and moderately eroded soils throughout the landscape are so common that the cumulative effect of many differences at a contrast code of 2 creates a significant contribution when figured into the weighted average.

<u>Contrasting Soils</u>

Slope is still the major factor controlling the contrast of contrasting soils. This trend is unlike that of the Inceptisols and Ultisols where the contribution of slope to soil contrast is high only for similar and somewhat contrasting soils and decreases for contrasting soils. The contribution of EP decreases, whereas TexB increases. DRt is still important.

Channahon (Ca) and Nodaway (No) form contrasting soils with Lapeer. Both are shallow soils, but Channahon overlies limestone bedrock whereas Nodaway overlies sandstone.

Nine pairs of soils are contrasting because slope is the single major property controlling the contrast. These pairs involve in every case a B slope juxtaposed with an E slope. Some of the map units with a B slope, such as BpB, BrB, SbB and PkB, occur on outwash plains and valley trains.

Okee is involved with pairs that are contrasting due to TexB. Okee has a sandy clay loam TexB whereas the other members of the pair have textures of loamy sand or sand. GaA and OkB have moderately alkaline and mildly acid B horizons, respectively. Gilford soils are poorly drained, loamy soils that formed in stratified silt and sand and are on glacial lake plains and stream floodplains.

Very Contrasting Soils

DRt is the soil property with the highest contribution to the contrast of very contrasting soils, followed by flooding (Fig. 4.7). This trend differs from the Inceptisols, for which flooding is the highest and DRt is second to it. It also differs from the Ultisols, for which flooding is the highest contributor but DRt does not contribute at all. The third highest contributor to contrast is DPD.

Flooding may appear to be more important than DRt in Table 4.29, as there are 6 pairs of soils for which flooding is the single dominating property (Table 4.29). However, DRt contributes more than flooding based on the weighted average contribution to soil contrast. There are three reasons for this. The first is that pairs of soils for which flooding is the single dominating property have short boundary lengths, so the weighting factor for the contribution of flooding is low. The second reason is that the pairs of soils for which DRt is the dominating property, i.e. RoD-WyB and RoD-WyC2, have longer boundary lengths. The third reason is that DRt also occurs frequently as a covariate of other dominating properties.

TexB covaries with flooding in two pairs of very contrasting soils, i.e. BpB-Ot and Gb-OkB. BpB formed on outwash plains, valley trains and moraines and has a loamy sand TexB. Although it has an alluvial origin, it does occur in upland positions because of deep stream incision creating on upland landscape. Ot is an alluvial soil on valley floors along streams and in low areas that receive runoff from adjoining uplands. Ot has a silty clay loam TexB.

Gb is an alluvial soil found on floodplains, outwash plains and lake plains. It is subject to occasional flooding and has a sandy TexB. OkB does not flood and has a sandy clay loam TexB.

Other very contrasting pairs involve pairs with 3 classes difference in slope coupled with other properties with 2 classes difference. All such pairs involve an E and a B slope and represent associations between steep soils on the flanks of bedrock ridges and gently rolling soils on till plains. CaE2 occurs on the sides of limestone ridges and is adjacent to LaB and WnB in loamy till. BnE occurs on the sides of sandstone ridges.

Summary of Levels of and Reasons for Contrast

About 84% of the Alfisols in the areas studied are composed of similar and somewhat contrasting pairs. Contrasting, very contrasting and exceedingly contrasting pairs occupy a small percentage. There is variation in the percentage of the contrast levels among the sample areas, however. Because area 3 contains Ca, BpB, Gb, Ot, YaA, MoA and WnB soils, all of which form contrasting pairs with other adjacent soils, area 3 has the largest percentage of contrasting soils.

The reasons for contrast (Table 4.30) are mostly associated with the parent material. This Alfisol landscape is characterized by several different kinds of glacial till ranging from coarse textured acid till to heavy sandy loam calcareous till. The thickness of the glacial till deposits varies, too. Shallow glacial till was deposited on ridges that were already existing before glaciation. In such areas, the soils that developed are shallow. After deglaciation, sandy and silty sediments were deposited over some of the glacial till areas. The kind of sediments, whether sandy, silty or well sorted sand and silt, affect the kind of soil that developed. Some areas are covered with glacial outwash and some are former glacial lake basins, and these developed different soils.

Because of these parent material differences, soils that have different depths, texture of the B horizons, and coarse fragments are found adjacent to each other. These soils have different contrast levels depending on the magnitude of these differences.

Table 4.30. Summary of soil properties important in each contrast level of the Alfisols.

Soil Contrast Level	Soil Property
Similar	Slo, EP, pHB
Somewhat Contrasting	Slo, pHB, DRt, EP, TexB,
Contrasting	Slo, TexB, DRt, pHA, pHB,
Very Contrasting	DRt, Fld, Slo, pHB, pHA, CfB, TexB,

Slope is the most important property contributing to the contrast of all soil contrast levels except very contrasting. This is an indication of the irregularity in the topography of the area. pHB also contributes to the contrast of the Alfisols and is an indication of parent material differences. DRt also contributes to the contrast of the Alfisols and reflects the varying depth of sandy and silty sediments over glacial till. TexB is important for pairs of soils for which one member developed from glacial till that was buried by sandy and silty sediments and the other member developed from deep sandy and silty sediments.

Flooding is an important property for very contrasting soils. Pairs of alluvial soils that flood and alluvial or non-alluvial soils that do not flood are very contrasting.

D. Mollisol

The legend for all the map units in all three samples of the Mollisols is shown in Table 4.31. The area in acres, number of delineations and the soil order of each map unit are shown in Table 4.32. All the map units belong to the Mollisols except those of Ladoga, which is an Alfisol, and those of Nodaway and Ackmore, which are Entisols.

The sample areas were taken from the Sharpsburg-Nira association as mapped in the soil survey. This association formed in loess-mantled till on ridges and hillslopes, as shown in Fig. 4.20. The upland soils are dominated by map units of the Sharpsburg (370). Nira (570) is not as common, and soils developed in the underlying Kansan till (Shelby, Adair) are relatively more abundant. All three sample areas are traversed by relatively large stream systems, so the alluvial soils such as Colo, Ely, and Zook are quite common.

Other minor soils in the association and their parent materials are as follows: Vesser, Nodaway, Humeston and Ackmore developed from silty alluvium; Clearfield, Ladoga, Macksburg and Winterset developed from loess; Arbor developed from loamy alluvium and underlying glacial till; and Dickinson developed from sandy alluvial sediments redeposited by wind.

The relationships between landscape and parent materials of soils in this unit are shown in Fig. 4.20. The area was first covered with Kansan glacial till, and there was a long period of weathering and soil formation in this till before the area was covered by loess. The soils that formed were strongly weathered and had a gray plastic subsoil called gumbotil. This gumbotil is several

Table 4.31. Legend for all map units in the Mollisol samples

Symbol	Legend
11B[1]	Colo-Ely silty clay loams, 2 to 5 percent slopes
24C2	Shelby clay loam, 5 to 9 percent slopes, moderately eroded
24D2	Shelby clay loam, 9 to 14 percent slopes, moderately eroded
24E2	Shelby clay loam, 14 to 18 percent slopes, moderately eroded
24F2	Shelby clay loam, 18 to 25 percent slopes, moderately eroded
51	Vesser silt loam, 0 to 2 percent slopes
54+	Zook silt loam, overwash, 0 to 2 percent slopes
69C	Clearfield silty clay loam, 5 to 9 percent slopes
76B	Ladoga silt loam, 2 to 5 percent slopes
76C2	Ladoga silt loam, 5 to 9 percent, moderately eroded
93D2[2]	Shelby-Adair clay loams, 9 to 14 percent slopes, moderately eroded
93E2[2]	Shelby-Adair clay loams, 14 to 18 percent slopes, moderately eroded
133	Colo silty clay loam, 0 to 2 percent slopes
192D2	Adair clay loam, 9 to 14 percent slopes, moderately eroded
220	Nodaway silt loam, 0 to 2 percent slopes
222C	Clarinda silty clay loam, 5 to 9 percent slopes
222C2	Clarinda silty clay loam, 5 to 9 percent slopes, moderately eroded
222D2	Clarinda silty clay loam, 9 to 14 percent slopes, moderately eroded
269	Humeston silt loam, 0 to 2 percent slopes
273C	Olmitz loam, 5 to 9 percent slopes
287B[3]	Zook-Colo-Ely silty clay loams, 2 to 5 percent slopes
368	Macksburg silty clay loam, 0 to 2 percent slopes
368B	Macksburg silty clay loam, 2 to 5 percent slopes
369	Winterset silty clay loam, 0 to 2 percent slopes
370	Sharpsburg silty clay loam, 0 to 2 percent slopes
370B	Sharpsburg silty clay loam, 2 to 5 percent slopes
370C	Sharpsburg silty clay loam, 5 to 9 percent slopes
370C2	Sharpsburg silty clay loam, 5 to 9 percent slopes, moderately eroded
428B	Ely silty clay loam, 2 to 5 percent slopes
430	Ackmore silty clay loam, 0 to 2 percent slopes
434D	Arbor loam, 9 to 14 percent slopes
570B	Nira silty clay loam, 2 to 5 percent slopes
570C	Nira silty clay loam, 5 to 9 percent slopes
570C2	Nira silty clay loam, 5 to 14 percent slopes, moderately eroded
570D2	Nira silty clay loam, 9 to 14 percent slopes, moderately eroded

Table 4.31. Cont'd.

675D2[4]	Dickinson-Sharpsburg complex, 9 to 14 percent slopes, moderately eroded
822C2	Lamoni silty clay loam, 5 to 9 percent slopes, moderately eroded
822D2	Lamoni silty clay loam, 9 to 14 percent slopes, moderately eroded
822D3	Lamoni silty clay loam, 9 to 14 percent slopes, severely eroded
870B	Sharpsburg silty clay loam, benches, 2 to 5 percent slopes
876C	Ladoga silt loam, benches, 5 to 9 percent slopes.

[1] Represented by Colo

[2] Represented by Adair

[3] Represented by Zook

[4] Represented by Dickinson

Table 4.32. Area in acres, number of delineations, and soil order of each map unit in the Mollisol samples

	Area (No. of Delineations)			Soil Order
	I	II	III	
11B	677.497 (4)	652.454 (4)	585.423 (4)	Mollisol
24C2	0	0	38.774 (5)	Mollisol
24D2	0	23.534 (3)	262.569 (15)	Mollisol
24E2	0	85.605 (4)	60.205 (7)	Mollisol
24F2	0	0	3.453 (1)	Mollisol
69C	0	33.972 8	0	Mollisol
51	26.193 (4)	0	0	Mollisol
54+	20.756 (2)	0	0	Mollisol
76B	14.049 (1)	0	0	Alfisol
76C2	37.901 (1)	0	0	Alfisol
93D2	206.809 (7)	0	0	Mollisol
93E2	4.524 (1)	0	0	Mollisol
133	7.064 (1)	0	0	Mollisol
192D2	0	0	14.565 (2)	Mollisol
220	264.673 (1)	0	0	Entisol
222C	0	24.011 (3)	0	Mollisol
222C2	15.637 (1)	41.433 (4)	0	Mollisol
222D2	0	15.121 (2)	37.266 (3)	Mollisol
269	15.994 (2)	0	0	Mollisol
273C	0	0	5.001 (1)	Mollisol
287B	0	0	323.092 (1)	Mollisol
368	49.013 (5)	90.764 (6)	0	Mollisol
368B	8.572 (1)	2.897 (1)	0	Mollisol
369	0	10.358 (2)	0	Mollisol
370	313.24 (11)	15.557 (3)	0	Mollisol
370B	1743.88 (5)	588.201 (4)	25.400 (2)	Mollisol
370C	39.211 (2)	41.751 (8)	48.299 (6)	Mollisol
370C2	358.731 (5)	27.702 (3)	231.494 (10)	Mollisol
370D	7.580 (2)	4.008 (1)	8.930 (2)	Mollisol
370D2	37.465 (1)	0	83.501 (4)	Mollisol
428B	0	0	25.519 (2)	Mollisol
430	4.008 (1)	0	0	Entisol
434D	0	0	2.183 (1)	Mollisol
570B	0	5.040 (1)	0	Mollisol
570C	9.088 (1)	67.230 (5)	0	Mollisol
570C2	44.846 (2)	88.661 (2)	0	Mollisol
570D2	21.510 (2)	0	0	Mollisol
675D2	38.735 (2)	0	0	Mollisol
822C2	0	51.950 (2)	0	Mollisol
822D2	5.397 (1)	54.292 (3)	60.404 (6)	Mollisol
822D3	0	0	_____ (2)	Mollisol
870B	3.096 (1)	0	0	Mollisol
876C	5.159 (1)	0	0	Alfisol
TOTAL	3980.628 (68)	1924.541 (75)	1834.255 (76)	
No. of map units	27	20	19	

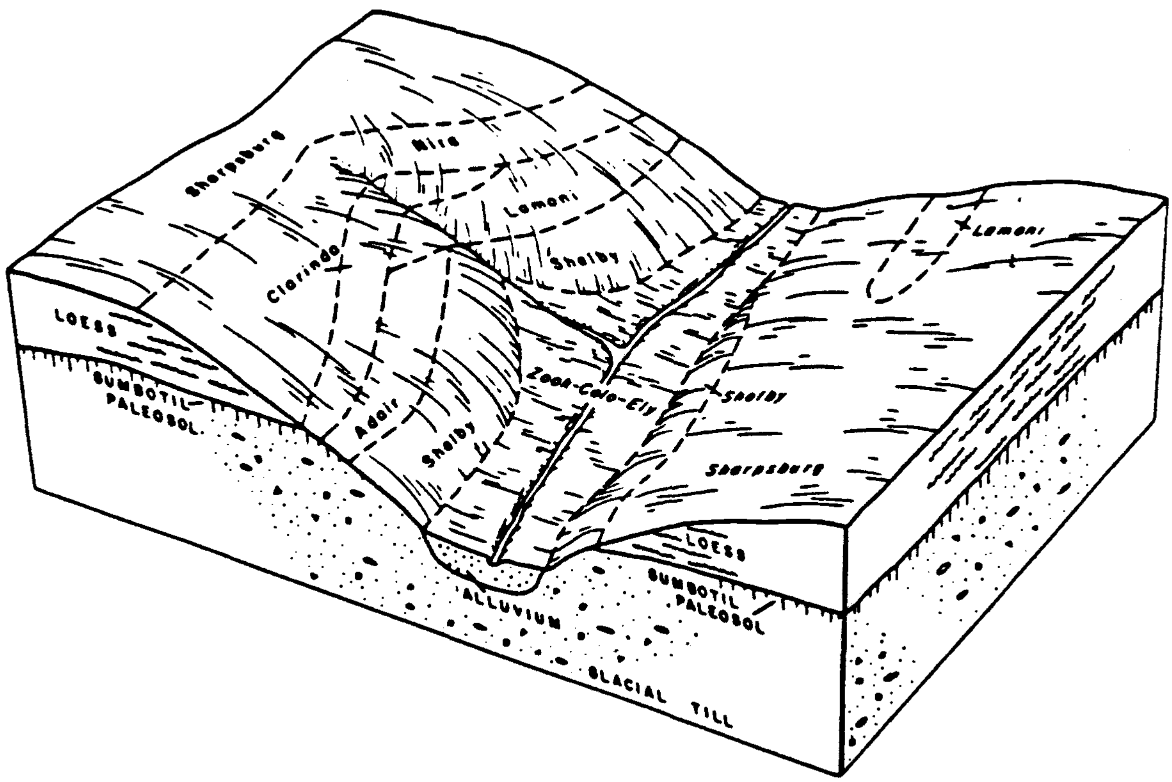

Fig. 4.20. Relationships between landscapes and parent materials of soils in the Sharpsburg-Nira association (Sherwood, 1980)

feet thick and has a very slow permeability. These soils are called the Yarmouth-Sangamon paleosol.

Widespread erosion subsequently cut through this paleosol into the Kansan till beneath. Another paleosol, less strongly weathered, more reddish, and thinner than the gumbotil, formed on the exposed Kansan till. It is called the Late Sangamon paleosol.

The area was then covered by loess, which was later eroded exposing both the gumbotil and the younger paleosol and even some relatively unweathered glacial till beneath the Late Sangamon paleosol. In some areas the strongly weathered Yarmouth-Sangamon paleosol was beveled or truncated so that only its lower part remained.

Sharpsburg soils developed in oxidized loess. They are deep, moderately well drained soils on the convex ridges and side slopes of uplands and on high terraces of valleys. Nira soils developed in grayish, unoxidized loess. They are deep, moderately well drained soils found on plane or convex upland slopes.

The Clarinda soil developed in the gumbotil of the Yarmouth-Sangamon surface. It is poorly drained and is found on the convex side slopes and in coves (hollows) at the head of drainageways on uplands. The Lamoni soil developed in the truncated paleosol and so has a thinner clay layer than Clarinda. It is a somewhat poorly drained soil and is found on the upper part of side slopes and at the head of branching drainageways. The Adair soil formed in areas where the reddish, less strongly weathered Late Sangamon paleosol is exposed. It is somewhat poorly drained to moderately well drained and is found on convex side slopes and ridges. The Shelby soil formed in slightly weathered glacial till in areas where the paleosol was completely removed. It is moderately well drained and is found on upland side slopes along the larger drainageways. Zook, Colo and Ely are formed in alluvium on floodplains. The other characteristics of the soils are shown in Appendix 4.1.

The most common pairs of map units for each sample area were selected from Appendix 4.2 and are shown in Table 4.33. Not even one pair of soil phases occurs in all three sample areas. Only two pairs, 11B-24E2 and 11B-24D2, occur in both samples 2 and 3. Thus, the sample areas are variable as far as most common pairs of soil phases are concerned. In all samples, however, Colo-Ely (11B), Sharpsburg (370) and Shelby (24) are common as one member of the frequently occurring pairs of soil phases.

The variation in the soils between the sample areas may be due to the failure of each sample area to encompass the whole range of the soil-landscape illustrated in Fig. 4.20. Sample 1 is located near the river such that Shelby-Adair and Colo-Ely are the most dominant pairs. Sample 2 was located on a landscape more like that illustrated on the right side of Fig. 4.20, such that Shelby and Sharpsburg are the most dominant pairs. Sample 3 was located on a landscape more like that shown on the left side of Fig. 4.20. Thus, it is important to soil pattern studies to be able to delineate a uniform soil-landscape as much as possible.

Table 4.33. Contrast level and frequency of occurrence of the most common pairs in the Mollisol samples

Pairs	Contrast Level	Number of Pairs I	II	III
11B-93D2	VC	11		
11B-220	SC	5		
51-220	S	4		
370C2-93D2	SC	4		
570C2-370B	S		9	
69C-370B	SC		7	
368-370B	S		7	
11B-24E2	VC		7	7
570C-370B	S		7	
11B-24D2	VC		6	18
370C2-24D2	S			13
822D2-24D2	S			10
11B-370D2	VC			8
822D2-370C2	SC			8

Levels of Contrast

Data on the levels of contrast are shown in Table 4.34 and Fig. 4.21 (method 1) and Table 4.35 and Fig. 4.22 (method 2). The boundary length and the contrast code of each property are shown in Appendix 4.3.

Based on both methods, the order of decreasing abundance of each contrast level is Similar > Very Contrasting > Somewhat Contrasting > Contrasting > Very Similar. Sample 2 has the greatest amount of contrasting pairs of soils but the least amount of very contrasting pairs of all the samples; the percentages of other soil contrast levels do not vary much from those of samples 1 and 3.

Using percent of pairs, sample area 1 has the most pairs of soils belonging to the very contrasting level (Fig. 4.31). The percentage of very contrasting soils is proportional to the number of map units that flood in the sample area. The soils that flood are

Table 4.34. Percent of adjacent pairs in the Mollisol samples belonging to different contrast levels

Contrast Level	Percent of Pairs			Mean
	I	II	III	
VS	0	1	1	0.7
S	33.7	36.1	38.1	35.9
SC	20.6	25.9	22.1	22.8
C	6.2	13.5	7.5	9.0
VC	39.3	24.2	32.1	31.8
EC	0	0	0	0

Table 4.35. Distribution of contrast levels of Mollisol samples based on percent of boundary length

Contrast Level	Percent of Boundary Length			Mean
	I	II	III	
VS	0	1.32	0.11	0.47
S	51.86	37.12	27.44	38.80
SC	14.61	24.68	22.43	20.57
C	8.64	10.12	7.18	8.64
VC	24.87	26.76	42.84	31.49
EC	0	0	0	0

11B, 51, 220, 287B and 430. All the sample areas have 11B in almost equal proportions. Aside from 11B, area 1 has all the other map units that flood whereas area 3 has only one more. Area 2 has only 11B as the map unit that floods. The area of 220 in sample 1 and 287B in sample 3 are almost equal, so that the presence of more map units that flood in sample 1 causes its percentage of very contrasting soils to be higher than samples 3 and 2.

Sample 2 has the least percentage of very contrasting soils because it has only one map unit (11B) of flood-prone soils. However, it has the highest percentage of contrasting soils because

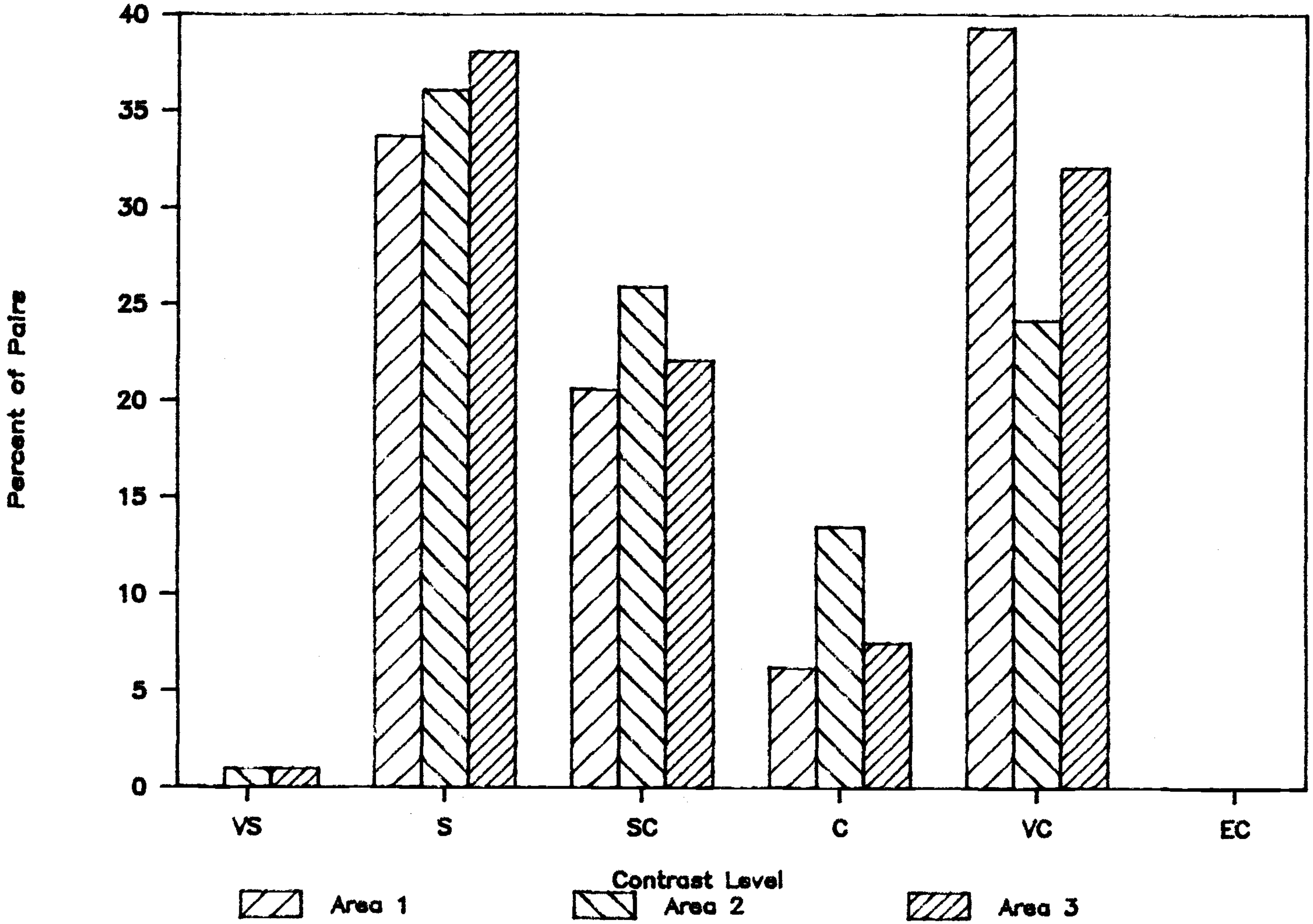

Fig. 4.21. Distribution of the percent of pairs among the different soil contrast levels in the Mollisols

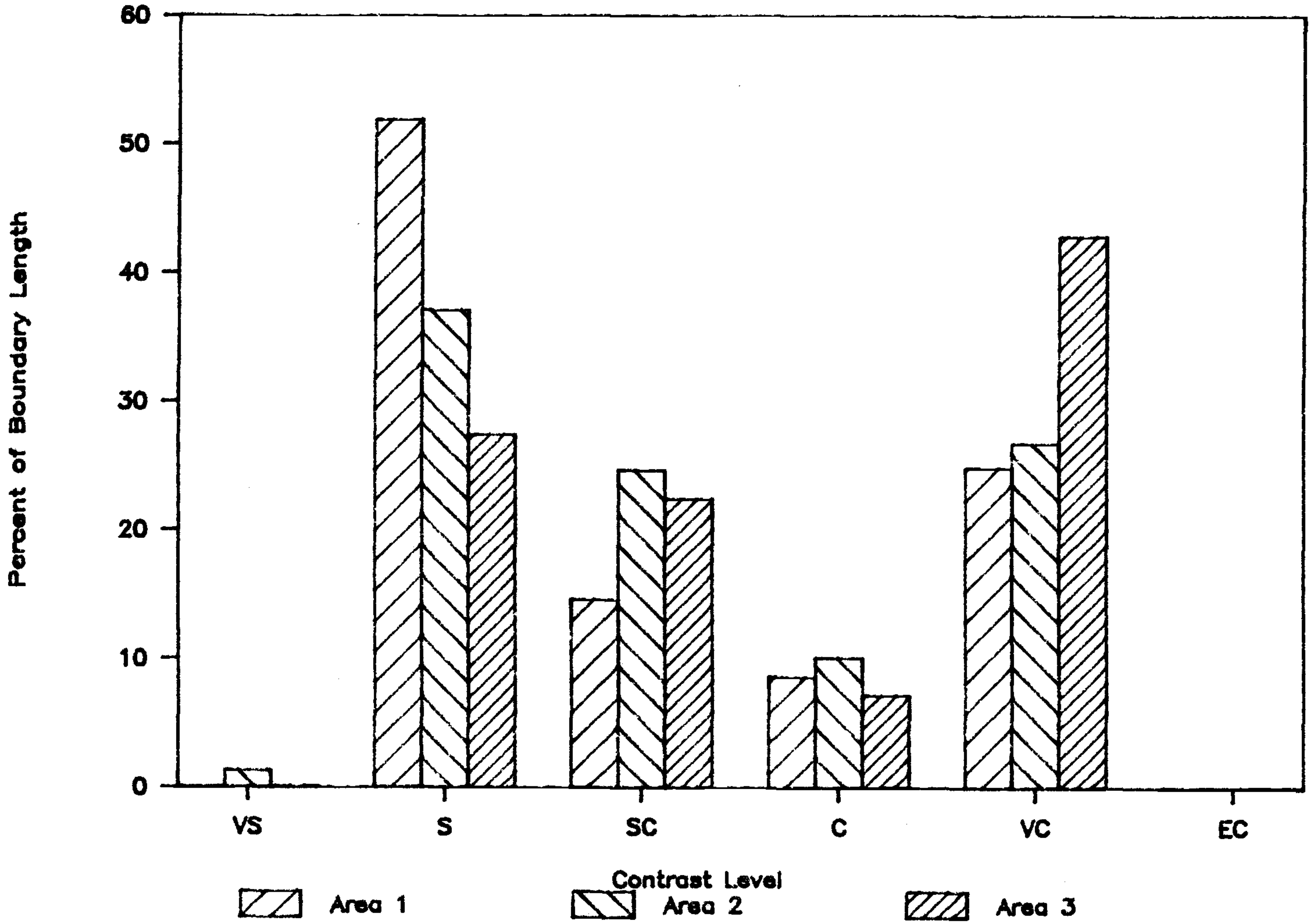

Fig. 4.22. Distribution of the percent of boundary length among the different soil contrast levels in the Mollisols

it has the biggest area of Clarinda soils (222C2 and 222D2). Clarinda soils are poorly drained with very slow permeability and a depth to least permeable layer of 13 inches, which produces contrasting soils with most soils adjacent to them.

Area 3 has a higher percentage of very contrasting soils than area 1 based on percent of boundary length. Area 3 has two very contrasting pairs of soils, i.e. 11B-24D2 and 11B-370D2, that have boundary lengths of 35 and 11 inches, respectively. These pairs will give a count of only two pairs and will have weights equal to those of a pair with a boundary length of 0.1 inch if the percent of adjacent pairs method is used. Thus, using the percent of boundary length, the long boundary between those two pairs will contribute highly to the percent of very contrasting soils and thereby the percent of similar soils will decrease, as the sum of all the contrast levels is 100%.

Reasons for contrast

Data on reasons for contrast are shown in Table 4.36 and Figs. 4.23-4.26 (method 1) and Table 4.37.

Table 4.36. Weighted average contribution of each soil property to each level of contrast in the Mollisol sampling areas

Sample		Fld	Slo	DPD	EP	TexA	TexB	pHA	pHB
S	1	2.18	51.84	7.44	23.27	0.75	1.23	5.88	7.33
	2	0	37.69	12.12	13.35	0	2.87	23.99	9.98
	3	0	40.05	7.22	12.35	0	8.08	32.30	0
	Mean	0.72	43.19	8.92	16.32	0.25	4.07	20.72	5.77
SC	1	3.02	9.91	23.83	2.64	4.35	25.10	25.26	4.86
	2	0	23.02	29.00	2.36	2.12	17.15	18.33	8.02
	3	0	22.20	24.27	10.08	0.58	19.24	20.14	3.49
	Mean	1.06	18.37	25.70	5.02	2.35	20.49	21.24	5.45
C	1	0	9.74	31.23	4.23	16.43	18.77	17.74	1.82
	2	0	5.41	46.97	5.22	0	15.66	11.08	15.66
	3	0	11.84	47.66	4.67	0	15.88	4.58	16.06
	Mean	0	8.99	41.95	4.70	5.47	17.10	11.13	11.18
VC	1	38.42	21.01	9.05	8.09	2.70	8.36	3.23	9.18
	2	39.35	18.75	16.68	7.36	0	2.28	6.10	9.48
	3	37.43	18.34	18.08	8.53	0.16	1.58	6.53	9.34
	Mean	38.40	19.36	14.60	7.99	0.95	4.07	5.28	9.30

Table 4.37. Number of discrete pairs of Mollisol soils for each controlling soil property within each contrast level

	II	II	III
Similar			
One factor			
Slo	5	5	6
	24C2-24D2	370-370B	
	24D2-24E2	370B-370C	
	24D2-24F2	370C-370D	
	93D2-93E2	370C2-370D2	
	222C2-222D2	570C2-570D2	
	368-368B		
EP	1	3	1
	222C-222C2	570C-570C2	
	370C-370C2		
pHA	1	3	2
	24C2-370C2	370C-570C	
	24D2-370D2	370C2-570C2	
	370B-570B		
DPD	0	0	1
	192D2-822D2		
TexB	0	0	1
	11B-287B		
Two factors			
Slo, EP	4	2	2
	76B-76C2	370C2-870B	
	370B-370C2	570B-570C2	
	370C2-370D		
Slo,pHA	2	2	2
	24D2-370C2	370C-570B	
	24E2-370D2	370C2-570D2	
	370B-570C		
DPD, TexA	1	0	0
	76B-370B		
EP, pHA	1	2	2
	24C2-370C	370C-570C2	
	24D2-370D	370C2-570C	
DPD, pHB	1	1	0
	368-370		
TexA, TexB	1	0	0
	54+-133		

Table 4.37. Cont'd.

Three Factors			
Slo, TexA, TexB	1	0	0
	11B-54+		
Slo, EP, pHA	1	1	2
	24D2-370C	370B-570C2	
Fld, DPD, pHB	1	0	0
	51-220		
DPD, TexA, pHA	1	0	0
	76C2-570C2		
DPD, TexB, pHA	1	1	1
	24D2-822D2 570C2-822C2	570D2-822D2	
DPD, TexB, pHB	0	1	0
	69C-222C		
DPD, pHA, pHB	0	1	0
	222C2-822C2		
Slo, DPD, pHB	1	1	0
	368-370B		
Somewhat Contrasting			
Four 2's			
Slo, DPD, EP, TexA	1	0	1
	24E2-434D	76C2-370B	
Slo, DPD, TexB, pHA	1	3	4
	24C2-822D2 24D2-822C2 24E2-822D2	370C2-822C2 570C2-822D2	
DPD, EP, TexB, pHB	0	1	0
	69C-222C2		
Slo, DPD, EP, pHB	0	2	0
	368-570C2	368B-570C	
Slo, DPD, pHA, pHB	0	1	1
	192C2-222D2	368-570B	
Slo, EP, pHA, pHB	0	0	1
	24C2-428B		
DPD, EP, TexB, pHA	0	0	2
	24D2-822D3	370D-822D2	

Table 4.37. Cont'd.

Five 2'S			
DPD, TexA, TexB, pHA, pHB	2	1	0
	51-430	368-369	
	220-430		
DPD, EP, TeXB, pHA, pHB	0	1	0
	69C-822C2		
Slo, DPD, EP, TexB, pHA	0	2	3
	24E2-822D3	370C-822D2	
	370B-822C2	370C2-822D3	
Six 2'S			
Slo, DPD, EP, TexB, pHA, pHB	1	0	0
	76b-570C2		
Seven 2'S			
Fld, Slo, SPS, TexA, TexB, pHA, pHB	1	0	0
	11b-220		
One 3			
DPD	7	7	8
	11B-51	69C-570C	
	24C2-192C2	69C-570C2	
	24D2-192C2	93D2-370C	
	24D2-192D2	93D2-370C2	
	24E2-222D2	93D2-370D	
	69C-370B	93D2-370D2	
	69C-370C	93E2-370D2	
	69C-370C2	192C2-370C2	
	192D2-370C	51-133	
	222D2-822D2	222D2-822D3	
	370D-822D3		
TexB	2	0	0
	54+-220	675D2-876C	
Slo	0	3	7
	24C2-24F2	24E2-822C2	
	24D2-428B	24F2-370C2	
	24E2-370C	370D-428B	
	24E2-370C2	428B-822D2	
Two 3'S			
Slo, DPD	2	0	0
	93D2-370B	93E2-370C2	
DPD, TexB	1	0	0
	220-269		

Table 4.37. Cont'd.

Contrasting			
Three 3'S			
DPD, TexA, TexB	2	0	0
	370C2-675D2	370C2-675D2	
Four 3'S			
Slo, DPD, TexA, TexB	1	0	0
	370B-675D2		
One 4 < three 3'S			
Slo	0	0	1
	24E2-428B		
DPD	3	13	5
	24D2-222C2	222C2-370C	
	24D2-222D2	222C2-570C	
	222C-370B	222C2-570C2	
	222C-370C	222D2-370C	
	222C-370C2	222D2-370C2	
	222C-570C	222D2-370D2	
	222C-570C2	222D2-570C	
	222C2-370B	222D2-570C2	
	51-269	76C2-93D2	
	76C2-222C2		
Two 4'S < three 3'S			
DPD, TexB, TexA	1	0	0
	93D2-675D2		
Very Contrasting			
One 5, ≤ one 4			
Fld	16	13	12
	11B-24C2	11B-570C2	
	11B-24D2	11B-570D2	
	11B-24E2	11B-675D2	
	11B-69C	11B-822C2	
	11B-93D2	11B-822D2	
	11B-192C2	11B-822D3	
	11B-222C	11B-870B	
	11B-222C2	24D2-287B	
	11B-222D2	51-370C	
	11B-370B	51-570C2	
	11B-370C	220-370C	
	11B-370C2	220-370C2	
	11B-370D	220-870B	
	11B-370D2	269-570C2	
	11B-428B	287-370C	
	11B- 570C	370C-430	

Table 4.37. Cont'd.

Fld, DPD	3	0	2
	11B-76C2	11B-675D2	
	11B-273C	11B-370C2	
	11B-434D		
Fld, Slo	11	2	3
	11B-24E2	54+-93D2	
	11B-24F2	54+-570D2	
	11B-93E2	93D2-220	
	24E2-287B	133-570D2	
	24F2-287B	220-570D2	
	51-370D	370D-430	
	51-570D2	133-570D2	
	51-93D2	269-822D2	
One 5, > one 4's			
Fld, Slo, DPD	1	0	0
	269-570D2		

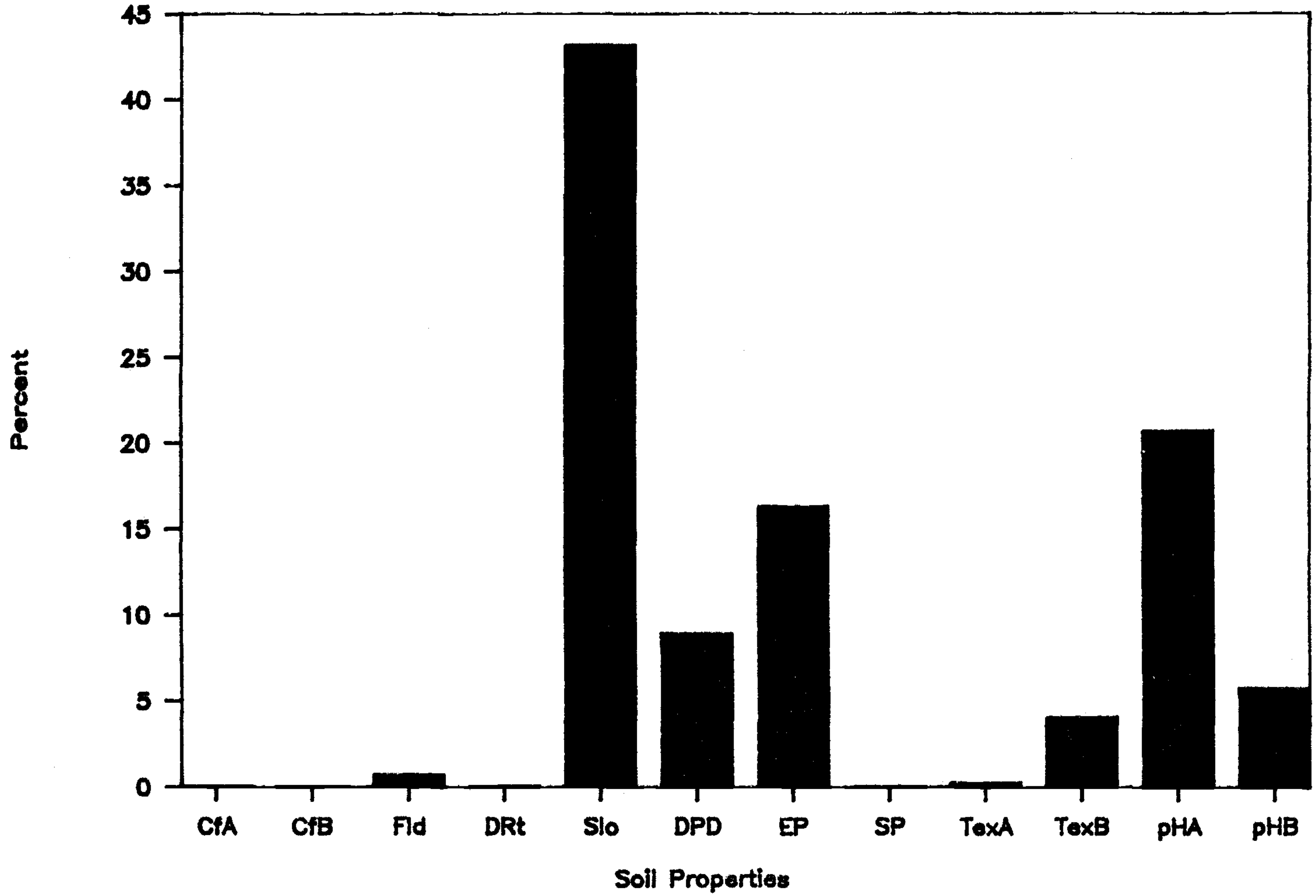

Fig. 4.23. Contribution of soil properties to the contrast of similar soils in the Mollisols

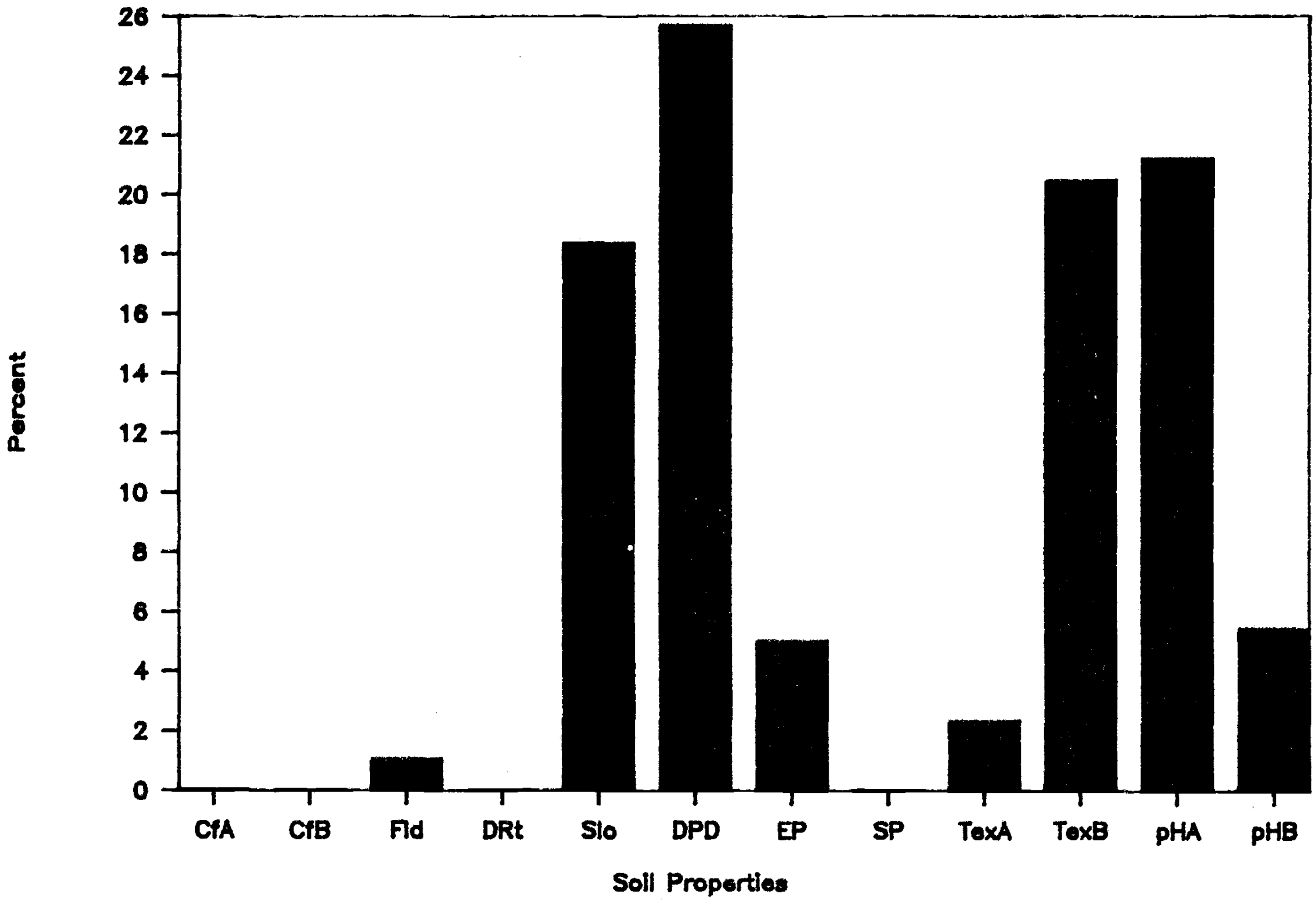

Fig. 4.24. Contribution of soil properties to the contrast of somewhat contrasting soils in the Mollisols

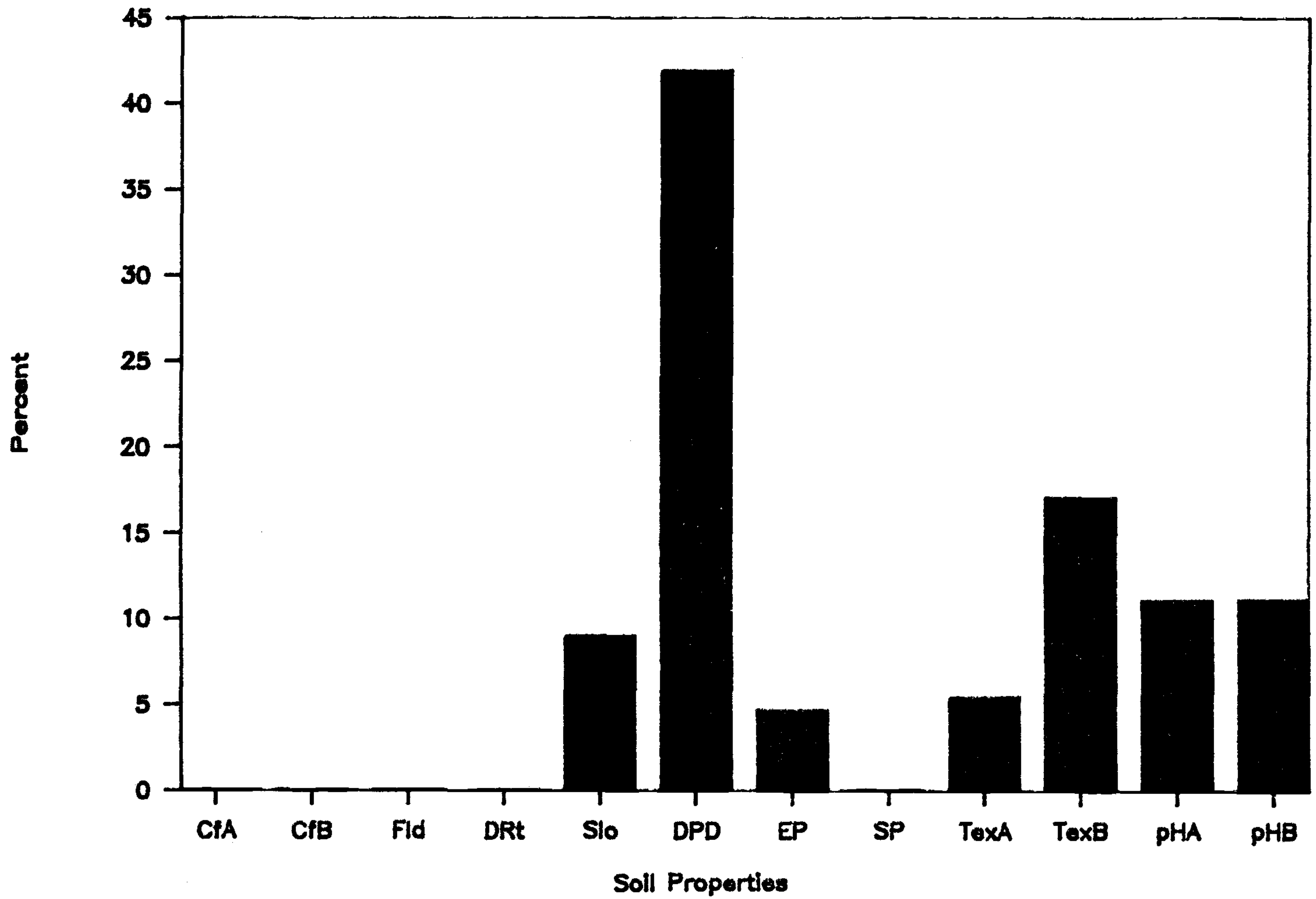

Fig. 4.25. Contribution of soil properties to the contrast of contrasting soils in the Mollisols

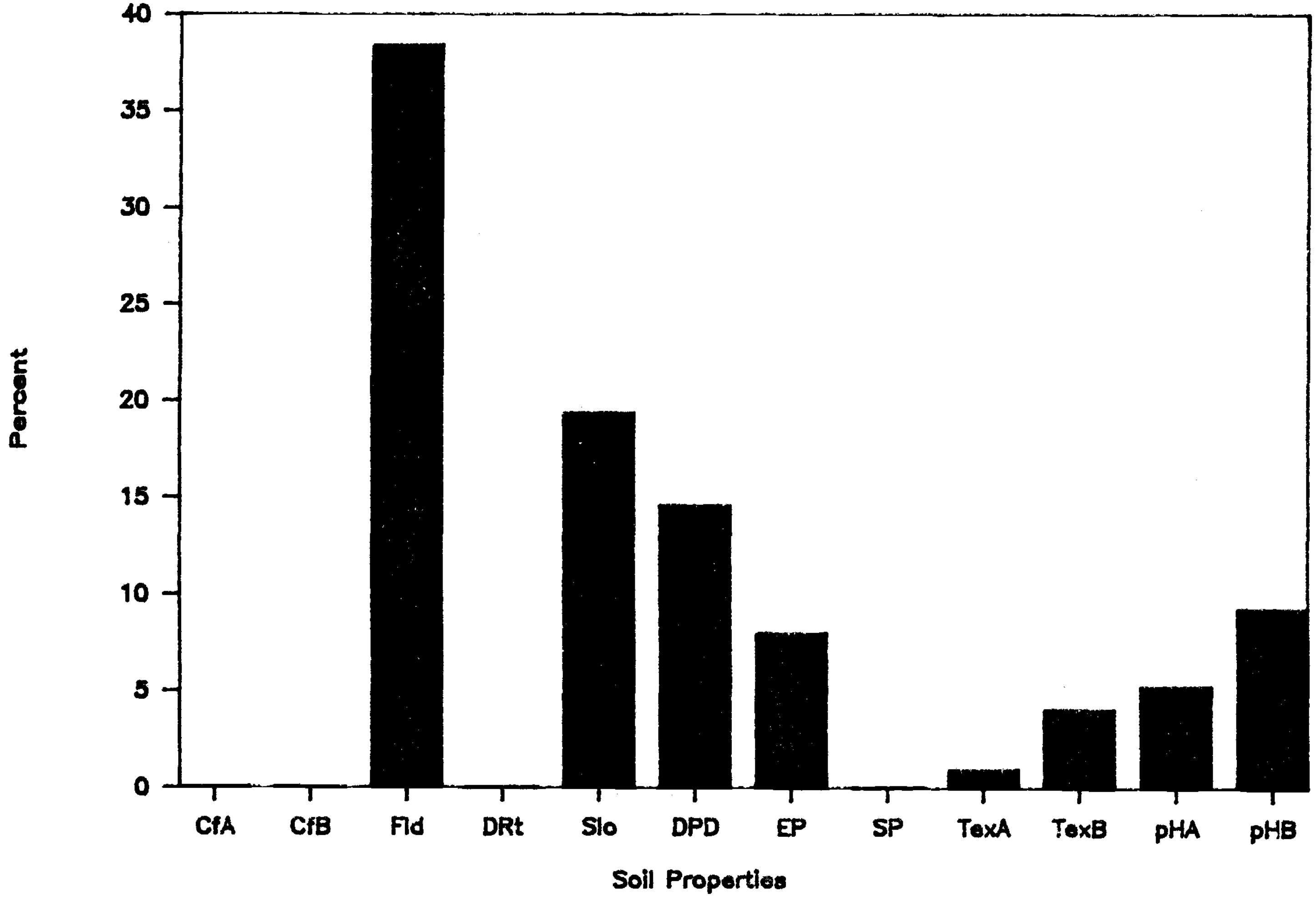

Fig. 4.26. Contribution of soil properties to the contrast of very contrasting soils in the Mollisols

Very Similar

The only pair of very similar soils is 24E2-24F2, and the only reason for this is that E and F slopes were considered equivalent in the model.

Similar Soils

Many different soil properties controlled the soil contrast for some pairs, even at the similar level of soil contrast of the Mollisols. As with all the other orders, slope was the dominant reason, but pHA, EP, DPD and TexB all controlled the contrast of at least one pair.

Slope, pHA and EP were the most common single properties contributing to the contrast of soils in the Mollisol group. The most common combination of two soil properties contributing to the similar contrast level were Slo-pHA, Slo-EP, EP-pHA and DPD-pHB.

Most pairs for which pHA was the single controlling factor involved either Shelby-Sharpsburg or Sharpsburg-Nira. Shelby is derived from glacial till whereas Sharpsburg is derived from loess. Shelby is less acidic than Sharpsburg. Nira is derived from loess also, but it is less acidic than Sharpsburg.

In some cases, one class difference in pH of the pairs Shelby-Sharpsburg and Sharpsburg-Nira was accompanied by one class difference in slope. This does not change the contrast classification, however. It may also appear that there is a difference in TexA, as Sharpsburg is a silty clay loam and Shelby is a clay loam. These textural classes are both in the same contrast class, however, so Sharpsburg and Shelby are very similar in TexA.

Adair (192D2) and Lamoni (822D2) produce similar soils due to DPD. Both Adair and Lamoni are derived from glacial till. Adair is somewhat poorly drained with slow permeability and a depth to least permeable layer of 15 inches. Lamoni is also somewhat poorly drained but has very slow permeability and a depth to least permeable layer of 10 inches.

Another pair, i.e. 11B (Colo) and 287B (Zook) produce similar soils due to TexB. 11B has a silty clay loam TexB while Zook has a silty clay TexB. Both soils are derived from alluvium.

pHB does not serve as the single controlling factor for any pair. However, it is frequently involved in combination with one or two other properties, so its overall contribution to the contrast of similar soils is also high (Fig. 4.23).

Thus for the similar contrast level in this Mollisol landscape, soils derived from the same parent material are similar because of variation in a single property. Pairs of soils derived from different parent materials, e.g. glacial till and loess, are similar because two or more properties covary to control the contrast.

Somewhat Contrasting Soils

DPD is the most important soil property contributing to the contrast of somewhat contrasting soils. DPD has the most pairs of somewhat contrasting soils, and all but 2 of these pairs are pairs in which at least one member is a paleosol. The Yarmouth-Sangamon paleosols have the most severe drainage limitation as they are the most highly weathered and have developed a plastic subsoil called gumbotil that has very slow permeability. The Clarinda soil (222) represents this situation. The younger Late Sangamon paleosol does not have a well developed gumbotil, and the corresponding Lamoni and Adair soils are somewhat poorly drained with moderately slow to slow permeabilty. Sharpsburg and Shelby, which developed from loess and fresh till, are not paleosols, and they are both moderately well drained with moderately slow permeability. Thus drainage classes and permeability are related to the presence or absence of a paleosol and to the age of the paleosol.

The difference in DPD between the soils in the Mollisol landscape can be related also to the location of soils in terms of the linear area of seepage created by the paleosols. Water cannot percolate through the paleosol, so it moves horizontally along the contact between the gumbotil and loess, creating a linear area of seepage. The linear area of seepage creates pairs of somewhat contrasting soils in which one member is above the seepage line and one is below.

Some of the pairs of somewhat contrasting soils due to DPD are Shelby (24) and Adair (192), Sharpsburg (370) and Adair (192), Clearfield (69) and Sharpsburg (370), and Clearfield (69) and Nira (570). These soils differ in drainage, permeability and location relative to a source of seepage. Adair is somewhat poorly drained and slowly permeable and is located downslope from the linear area of seepage. Shelby and Sharpsburg are moderately well drained with moderately slow permeability and are located upslope from the linear area of seepage. Thus Adair has a more severe drainage limitation than Shelby and Sharpsburg.

Clearfield also has a more severe drainage limitation than Sharpsburg and Nira. Clearfield is poorly drained with very slow permeability due to its being developed on thin loess over a partially truncated gumbotil paleosol. It also contains excess water coming from seepy areas in coves or bays around the head of drainageways on uplands. Sharpsburg and Nira are located upslope from a linear area of seepage. Nira, however, is also located around the head of waterways and on side slopes between waterways, but it is moderately well drained and has moderately slow permeability, so it has a higher drainage suitability than Clearfield.

Slope is another important property controlling the contrast of somewhat contrasting soils. It is not as important a factor in the contrast of somewhat contrasting soils as in other soil orders, but it does covary with other properties, so it turned out to have a high contribution to soil contrast even though there were few pairs controlled by it.

TexB is important for some of the somewhat contrasting soils in the Mollisols. The two pairs of somewhat contrasting soil with TexB as the main difference are 54+(Zook)-220 (Nodaway) and 657(Dickinson)-876(Ladoga). 54+ has a sic TexB whereas 220 has a sil TexB. Both soils are derived from alluvium, but Zook is derived from fine-textured alluvium, as it is situated in low flat areas in the floodplain. Nodaway is derived from coarser alluvium, as it is situated along stream channels. The other pair of somewhat contrasting soils with TexB as the main difference is Dickinson (675) and Ladoga (876). Dickinson is formed from sandy alluvial sediments whereas Ladoga is formed from loess. Dickinson has a sandy loam TexB whereas Ladoga has a silty clay loam TexB.

Contrasting Soils

DPD really stands out among the soil properties influencing the contrast of contrasting soils. Except for two pairs, all of the contrasting soils involve combinations with Clarinda (222), the mostly highly weathered, clayey paleosol in gumbotil. Clarinda is a poorly drained soil with very slow permeability and with a depth to least permeable layer of 13 inches. The soils that form contrasting pairs with Clarinda are Shelby, Sharpsburg, Nira and Ladoga, all of which are moderately well drained with moderately slow permeability.

Very Contrasting Soils

Flooding really stands out, whether as a single controlling variable or in combination with others. Most of the pairs of soils for which flooding is the single dominating factor involve 11B (Colo-Ely silty clay loam). Other alluvial soils such as 51 (Vesser silt loam) and 220 (Nodaway silt loam) are involved in the pairs.

Slope also contributes to the contrast of very contrasting soils in the Mollisols. Soils with E and F slopes adjacent to B slopes as well as A slopes juxtaposed with D slopes can be found.

Summary of Levels of and Reasons for Contrast

In summary, the order of increasing abundance observed in each contrast level using percent of pair and percent of boundary length in Mollisols is as follows: Similar > Contrasting >Somewhat Contrasting >Contrasting > Very Similar.

The soil properties that are important for each contrast level of Mollisols are shown in Table 4.38.

Table 4.38. Summary of soil properties important in each contrast level of the Mollisols

Soil Contrast Level	Soil Properties
Similar	Slo, pHA, EP
Somewhat Contrasting	DPD, pHA, TexB, Slo
Contrasting	DPD, TexB, pHA, pHB
Very Contrasting	Fld, Slo, DPD, pHB, TexB

DRt did not contribute to the contrast of Mollisols. DPD was the least important soil property for similar soils but it became the most important property for somewhat contrasting and contrasting soils. Flooding was the most important soil property for very contrasting soils.

The differences between Mollisols can be attributed mainly to the type of parent material. Soils of recent parent materials of the same kind are usually similar. Colo and Zook are both alluvial soils derived from fine textured alluvium. Soils of the same parent material that have undergone different degrees of weathering can be contrasting. Clarinda and Adair, for example, are both derived from glacial till, but the glacial till of Clarinda is more weathered than that of the glacial till that formed Adair.

The presence of a paleosol subsoil called gumbotil influenced the contrast of the soils very much, and DPD became important for both somewhat contrasting and contrasting soils. The water cannot move downward through the paleosol so it moves laterally, creating a linear area of seepage on the slopes where such lateral movement of water ends. Soils below the linear area of seepage are wet and soggy, whereas soils above it are better drained. The soils above and below the lateral area of seepage are contrasting.

Thus the Mollisol area sampled is an example of an area where a paleosol has major effects on soil contrast.

Very contrasting soils are determined mainly by flooding. Soils that are on slopes adjacent to floodplains are very contrasting compared to soils on floodplains due to flooding.

E. Aridisol

The legend for all the map units in the Aridisol sample areas is shown in Table 4.39. Table 4.40 shows the area in acres, the number of delineations, and the soil order of each map unit.

All the soil phases involving Grassy Butte either as a soil phase or representing a complex are referred to as GB. All those involving Matheson, Zwiefel, and Rock outcrop are referred to as Math, ZWI, and RO, respectively.

Sample area 2 is very much different from sample areas 1 and 3. Sample area 2 has only 3 map units. About 88% of the area is composed of a single, very large delineation of Diston loamy sand (24). Six out of 8 delineations of Diston-Rock outcrop complex (27) occur as enclosed soils within the large delineation of 24, and most of these are in the upper, northern part of the area.

Table 4.39. Legend for all map units in the Aridisol samples

1	Aecet-Rock outcrop complex, 0 to 12 percent slopes*
24	Diston loamy sand, 0 to 4 percent slopes
27	Diston-Rock outcrop complex, 2 to 8 percent slopes*
30	Grassy Butte sand, 2 to 4 percent slopes
31	Grassy Butte sand, 2 to 20 percent slopes
32	Grassy Butte loamy sand, 2 to 4 percent slopes
34	Grassy Butte loamy sand, 2 to 20 percent slopes
35	Grassy Butte-Matheson complex, 1 to 8 percent slopes**
36	Grassy Butte-Medano complex, 0 to 4 percent slopes***
37	Grassy Butte-Rock outcrop complex, 0 to 20 percent slopes*
61	Lidy sandy loam, 0 to 2 percent slopes
66	Malm-Matheson-Rock outcrop complex, 2 to 8 percent slopes*
67	Malm-Rock outcrop complex, 2 to 20 percent slopes*
69	Matheson loamy sand, 2 to 4 percent slopes
70	Matheson loamy sand, 2 to 8 percent slopes
93	Montlid-Heiseton complex, mainly 0 to 1, but up to 4% slopes****
127	Zwiefel sand, 2 to 4 percent slopes
128	Zwiefel loamy sand, 0 to 2 percent slopes

*Rock outcrop is used to represent this complex
**Grassy Butte is used to represent this complex
***Medano is used to represent this complex
****Heiseton is used to represent this complex

Table 4.40. Area in acres, number of delineations, and soil order of each map unit in the Aridisol samples

Map Unit	Area (number of delineations) I	II	III	Soil Order
1	0	0	1059.35 (2)	
24	0	3853.66 (1)	0	Aridisol
27	0	433.97 (8)	0	Aridisol
30	2008.51 (2)	0	0	Aridisol
31	0	0	450.80 (4)	Aridisol
32	989.90 (1)	0	0	Aridisol
34	0	0	78.64 (2)	Aridisol
35	0	0	454.02 (2)	Aridisol
36	461.38 (1)	0	0	Aridisol
37	0	89.77 (2)	0	Aridisol
61	72.84 (1)	0	0	Aridisol
66	0	0	434.15 (4)	Aridisol
67	0	0	254.60 (2)	Aridisol
69	118.47 (1)	0	0	Aridisol
70	547.93 (1)	0	4638.54 (1)	Aridisol
93	0	0	357.34 (1)	Entisol
127	898.20 (3)	0	0	Entisol
128	345.39 (3)	0	0	Entisol
TOTAL	5442.60	4377.40	7727.44	
No. of Map Units	(14)	(11)	(18)	

The association sampled was the Grassy Butte-Matheson-Diston soil association. The soils in this map unit formed in sandy eolian deposits. The topography is irregular because of underlying basalt flows. Overall the association is composed of about 30 percent Grassy Butte soils, 20 percent Matheson soils, and 15 percent Diston soils. The remaining 35 percent are mostly Bondfarm soils, Dune land and Rock outcrop.

Grassy Butte soils formed in wind-laid deposits of sand derived from mixed sources. These soils have a grayish brown loamy sand surface layer about 7 inches thick. The underlying material is grayish brown and gray loamy sand to a depth of 60 inches or more. These soils are somewhat excessively drained.

Matheson soils formed from alluvium and wind-laid sandy deposits derived from mixed sources. They typically have a surface layer of light brownish gray sandy loam about 10 inches thick. The underlying material is light brownish gray and light gray sandy loam to a depth of 60 inches or more. These soils are well drained.

Diston soils developed from sandy eolian deposits derived from mixed sources. They typically have a surface layer of grayish brown loamy sand about 5 inches thick. The upper part of the underlying material is light brownish gray and light gray loamy sand about 26 inches thick. The middle part is light gray loamy sand, 8 inches thick over an indurated hardpan about 16 inches thick. The lower part is sand to a depth of 60 inches or more. These soils are somewhat excessively drained.

Other soils in the soil association include Zwiefel sand, 2 to 4 percent slopes, Lidy sandy loam, 0 to 2 percent slopes, and Montlid-Heiseton complex.

The Zwiefel soil is a deep, well drained soil on old lakebeds. It formed in lacustrine and wind-laid deposits derived from mixed sources. Typically, the surface layer is grayish brown sand about 3 inches thick. The upper part of the underlying material is grayish brown fine sand about 18 inches thick. The lower part to a depth of 60 inches or more is light brownish gray sandy clay and silty clay. The permeability of Zwiefel is slow.

Lidy sandy loam, 0 to 2 percent slopes, is a well drained soil on alluvial fans. It formed in alluvium derived from mixed sources.

Typically, the surface layer is pale brown sandy loam about 5 inches thick. The underlying material to a depth of 60 inches or more is light gray sandy loam 24 inches thick over sand and gravel. The soil is calcareous throughout and has a layer of lime accumulation at a depth of 5 inches. Depth to gravel ranges from 23 to 34 inches.

The Montlid-Heiseton complex is in playas on the fringes of old lakebeds. The slope is mainly 0 to 1 percent but can be as much as 4 percent. Montlid very stony silty clay loam makes up about 65 percent of this complex; Heiseton very stony loam makes up 15 percent. The Montlid soil is in level areas and the Heiseton soil is in steeper areas.

This complex is represented by Heiseton which has a steeper slope than Montlid. Heiseton soil is deep and moderately well drained. It formed in alluvium derived from mixed sources. Typically, the surface layer is light brownish gray, moderately saline-alkali-affected very stony loam about 7 inches thick. The underlying material is light brownish gray loam to silt loam about 43 inches thick over sand and gravel that extend to a depth of 60 inches or more.

The properties of the soils and their codes are shown in Appendix 5.1. The most common pairs of adjacent map units were selected from the matrices in Appendix 5.2 and are shown in Table 4.41.

Table 4.41. Contrast level and frequency of occurrence of the most common pairs in the Aridisol samples

Pair	Contrast Level	Number of Pairs I	II	III
127-30	VC	4		
128-127	VS	4		
36-32	C	3		
70-30	S	2		
24-27	EC		8	
24-37	EC		2	
66-31	EC			6
67-70	EC			4
66-35	EC			4
1-31	EC			4
70-35	S			4
31-35	S			4

The most common pairs of map units in the Aridisol group belong to the exceedingly contrasting level, due to the presence of rock outcrops. The most common pairs of soil phases not involving rock outcrop are Zwiefel sand (127)-Grassy Butte (30), Zwiefel sand (127)-Zwiefel loamy sand (128), Matheson loamy sand (70)-Grassy Butte-Matheson complex (35) and Grassy-Butte (32)-Grassy Butte complex (35).

Levels of Contrast

The levels of contrast are shown in Table 4.42 and Fig. 4.27 (method 1) and Table 4.43 and Fig. 4.28 (method 2). There is no somewhat contrasting pair of soils in any of these sample areas. The boundary length and the contrast level for each property of a pair of soils are shown in Appendix 5.3.

Table 4.42. Percent of adjacent pairs in the Aridisol samples belonging to different contrast levels

Contrast Level	Percent of Pairs			Mean
	I	II	III	
VS	18.18	0	5.00	7.72
S	27.27	0	25.00	27.42
SC	0	0	0	0
C	18.18	0	7.5	8.56
VC	36.36	0	5.00	13.78
EC	0	100	57.5	52.50

Table 4.43. Distribution of contrast levels of Aridisol samples based on percent of boundary length

Contrast Level	Percent of Boundary Length			Mean
	I	II	III	
VS	14.90	0	2.26	5.72
S	22.35	0	13.90	12.08
SC	0	0	0	0
C	24.88	0	3.16	9.34
VC	37.84	0	0.33	12.72
EC	0	100	80.32	60.10

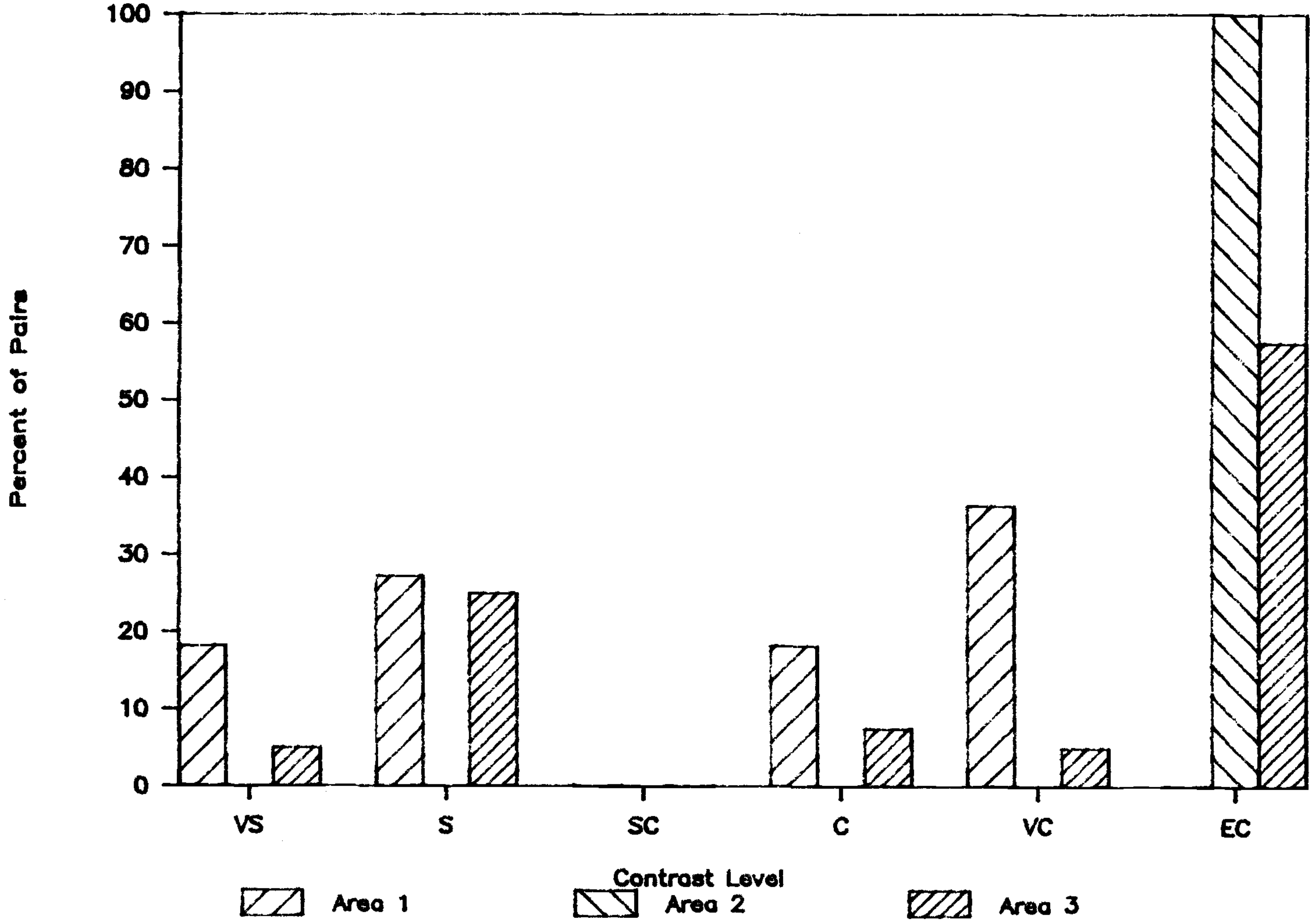

Fig. 4.27. Distribution of the percent of pairs among the different soil contrast levels in the Aridisols

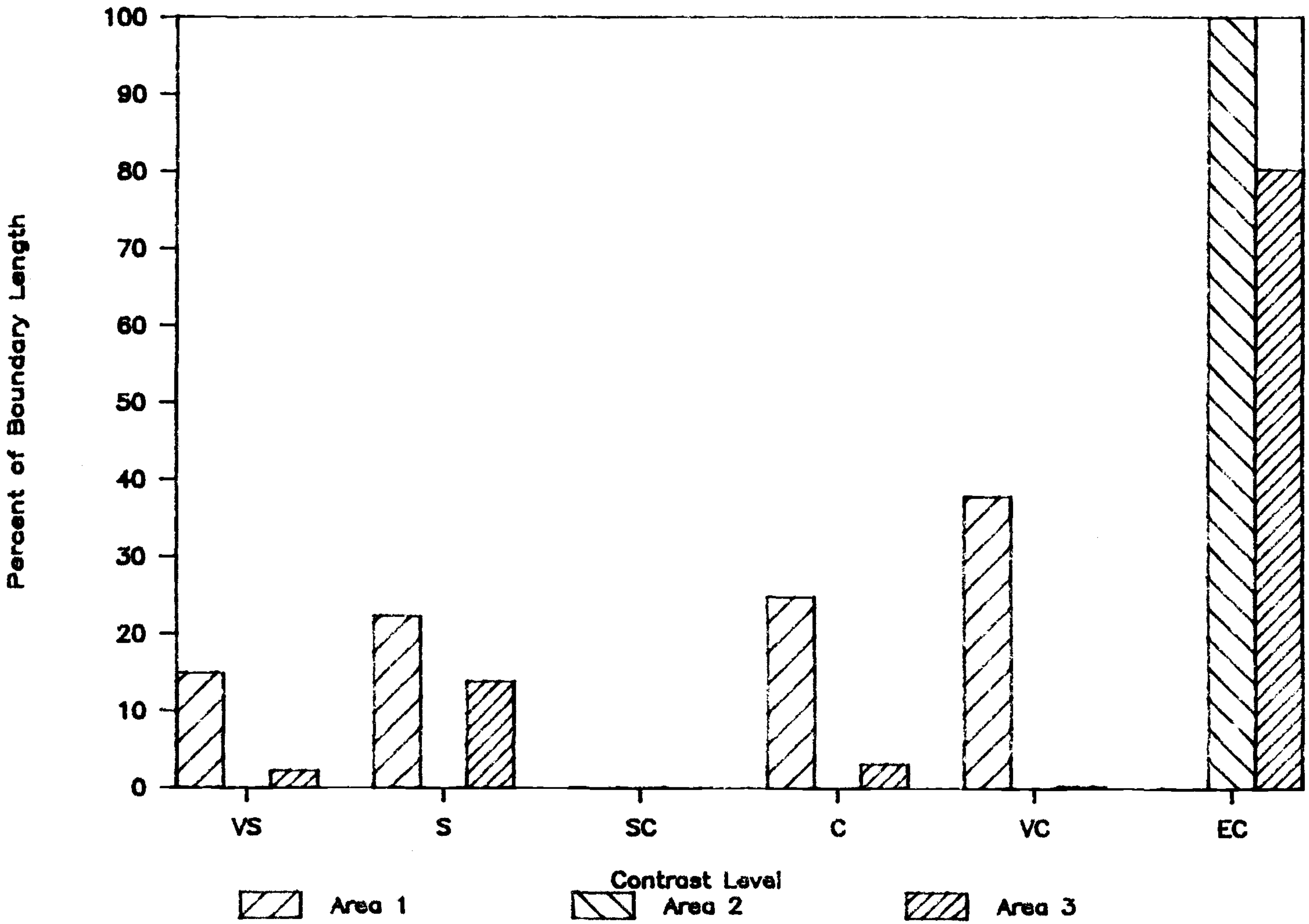

Fig. 4.28. Distribution of the percent of boundary length among the different soil contrast levels in the Aridisols

The order of increasing abundance of contrast levels is Exceedingly Contrasting > Similar > Very Contrasting > Contrasting > Very Similar. Unlike any of the other orders, this one has a relatively high percentage of very similar soils. The distribution of contrast levels among the sample areas, however, is variable. Both areas 2 and 3 have very high proportions of EC due to rock outcrop, whereas area 1 has no exceedingly contrasting soils. Area 2 is noticeably different from areas 1 and 3 in that it contains only exceedingly contrasting soils. The exceedingly contrasting soils, however, occupy only the northern half of the area, whereas the southern half is composed of only one delineation. Area 2 is not really composed of 100 percent exceedingly contrasting soils because the lower half is composed of very similar soils. Thus the spatial pattern of areas of different contrast levels needs to be studied.

The spatial analysis of the distribution of different contrast levels can be conducted by determing whether one contrast level tends to be concentrated in one area or distributed all over the area. It can also be conducted by determining whether there are some contrast levels that tend to be associated with each other.

The percent of boundary length and percent of pairs give values that are quite close to each other except that the frequency of EC soils comes out much higher using the percent boundary method. This is due to relatively long boundaries between soils and rock outcrops. Sample area 1 is characterized by long linear delineations with boundaries that are of fairly equal length, hence the two methods very nearly agree.

<u>Reasons for Contrast</u>

The soil properties controlling the soil contrast of the Aridisols are shown in Table 4.44 and Figs.4.29-4.31 (method 1) and Table 4.45 (method 2).

Table 4.44. Weighted average contribution of each soil property to each level of contrast in the Aridisol sampling areas

	Sample	CfA	CfB	Slo	DPD	SP	TexA	TexB	pHA
S	1	0	0	20.00	0	0	39.7	39.7	0
	2	0	0	0	0	0	0	0	0
	3	0	0	34.00	0	0	32.1	33.9	0
	Mean	0	0	18.16	0	0	23.93	24.53	0
C	1	0	25.00	0	37.50	0	12.50	0	12.50
	2	0	0	0	0	0	0	0	0
	3	35.00	0	11.70	6.70	23.30	16.70	6.70	0
	Mean	11.66	8.33	3.90	14.73	7.76	9.73	2.23	4.16
VC	1	0	0	0	33.60	0	0	67.30	0
	2	0	0	0	0	0	0	0	0
	3	30.00	0	20.00	10.00	20.00	20.00	0	0
	Mean	10.00	0	6.67	14.50	6.67	6.67	26.70	0

Table 4.45. Number of discrete pairs of Aridisol soils for each controlling soil property within each contrast level

	I		II		III
Similar					
One 2					
Slo	1		0		2
		35-34 70-69		31-35	
Two 2's					
TexA, TexB	2		0		1
		30-69 32-61		35-70	
Slo, TexB	0		0		1
		31-70			
Three 2's					
Slo, TexA, TexB	2		0		0
		30-70		36-70	
Contrasting					
One 4					
DPD	2		0		0
		30-36		32-36	
CfA	0		0		2
		35-93		70-193	
Very Contrasting					
One 5					
TexB	3		0		0
		30-127 30-128		32-128	
CfA	0		0		1
		31-93			

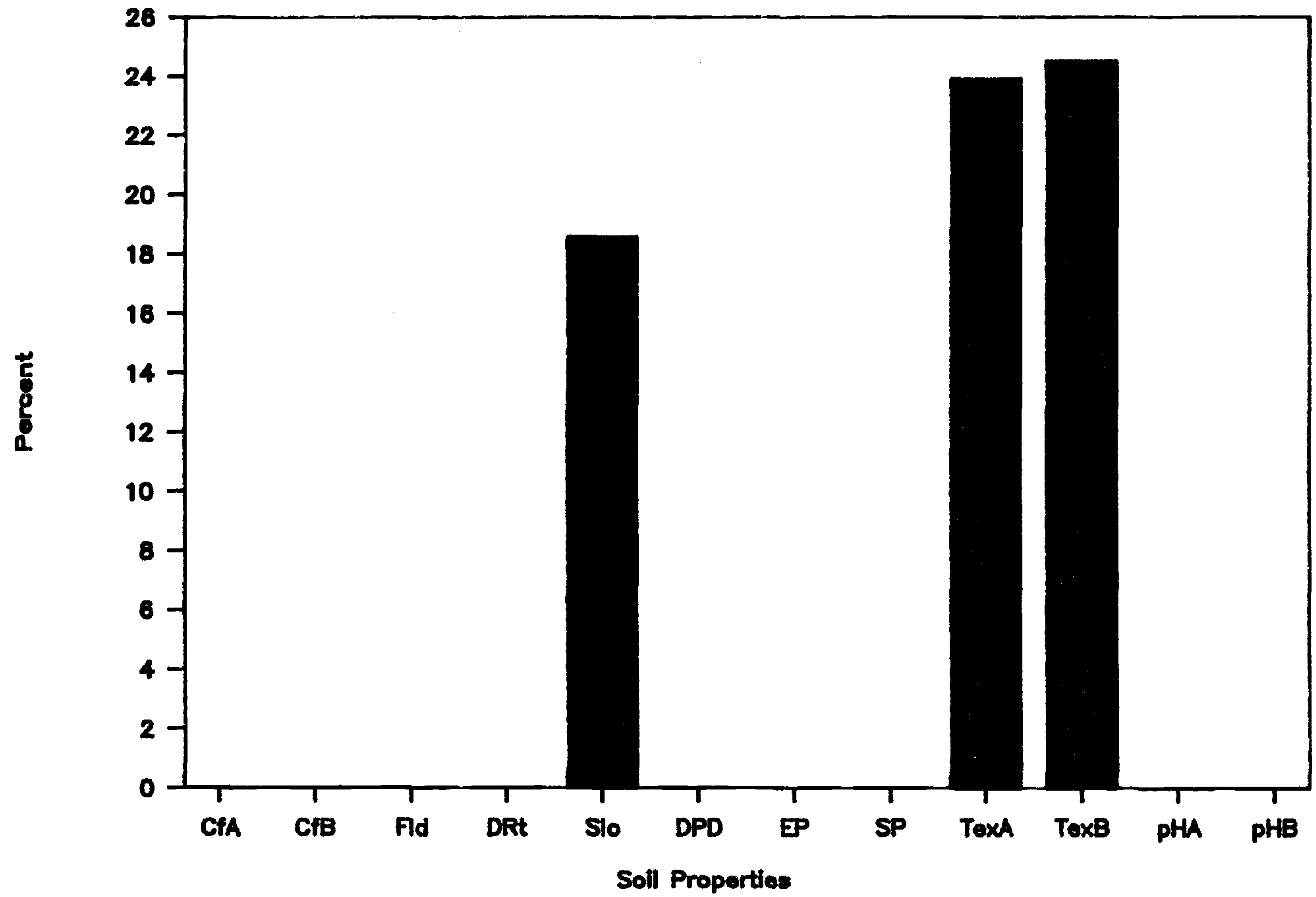

Fig. 4.29. Contribution of soil properties to the contrast of similar soils in the Aridisols

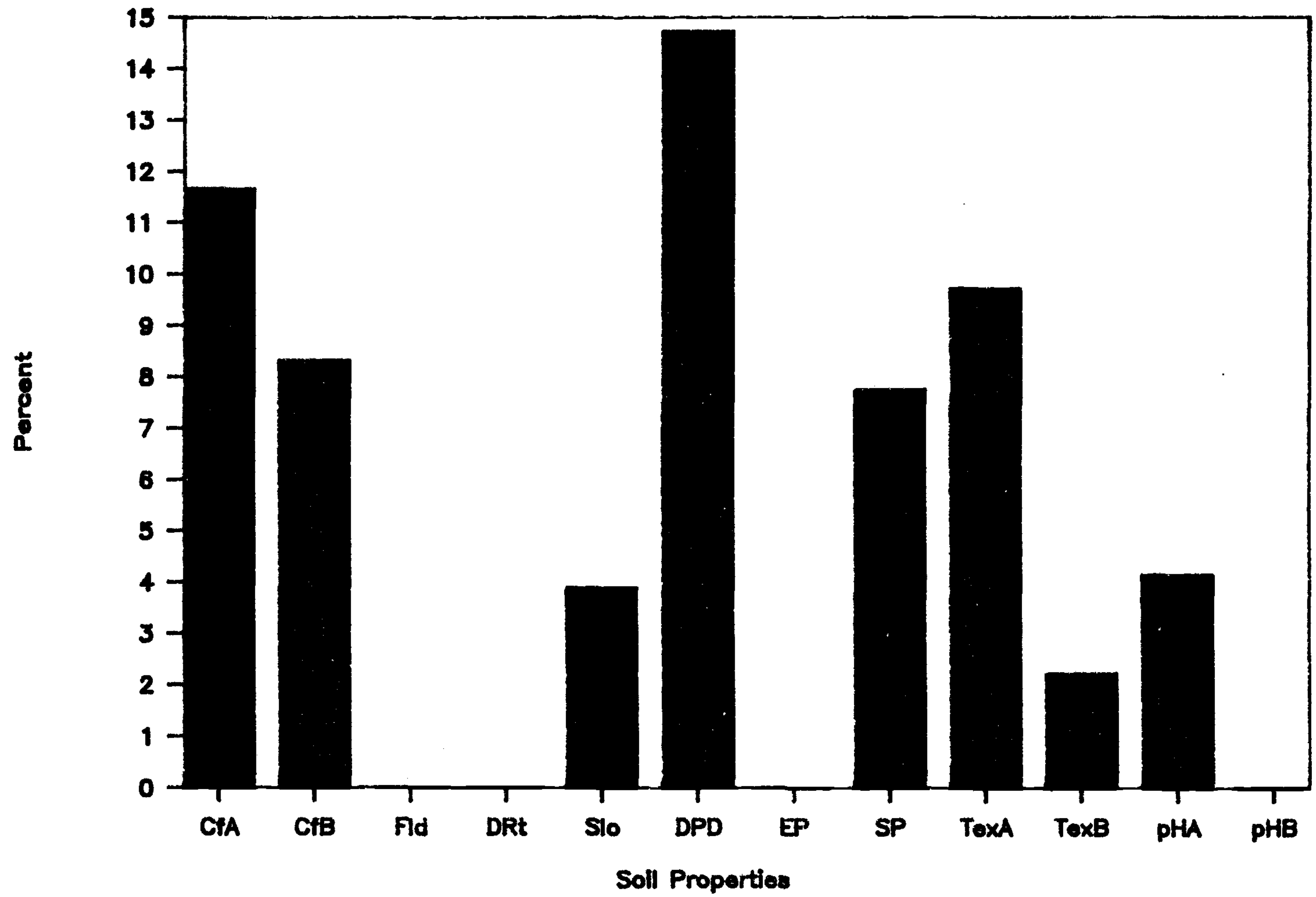

Fig. 4.30. Contribution of soil properties to the contrast of contrasting soils in the Aridisols

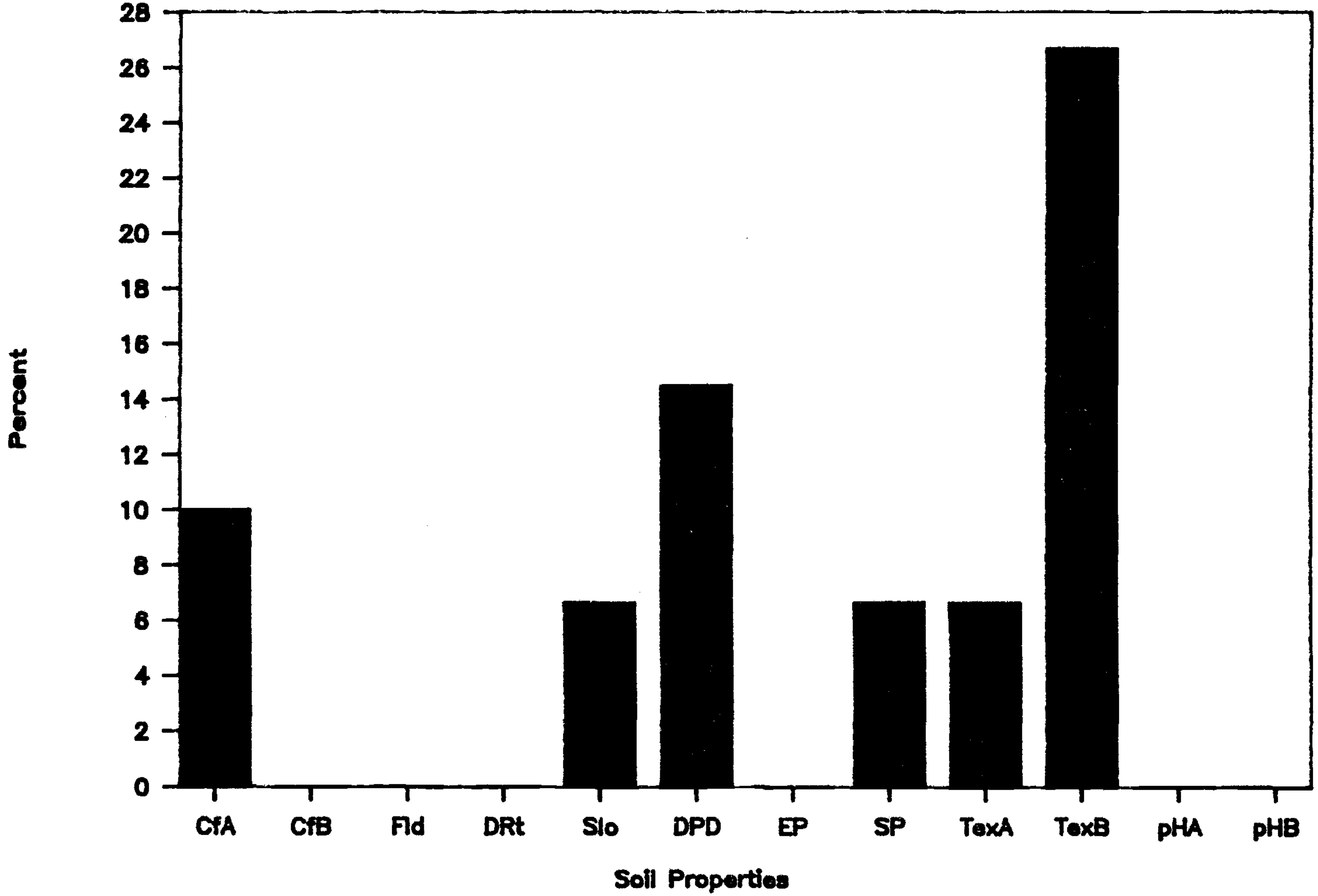

Fig. 4.31. Contribution of soil properties to the contrast of very contrasting soils in the Aridisols

Very Similar Soils

The Aridisol areas that were sampled were characterized by soils in complex with rock outcrops. Pairs of map units both of which are defined as complexes containing rock outcrop are declared very similar because rock outcrops are used to represent both complexes. Another reason for the high percentage of very similar soils is that the two phases of Zweifel, though having slightly different slopes and A horizon textures, were not differentiated into separate contrast classes by the criteria of the contrast model.

Similar Soils

Similar soils are controlled by only three properties. Because there are only a few soils in the Aridisols, there are only a few reasons for contrast.

Unlike the other four soil orders studied, where slope was the highest contributor to the contrast of similar soils, the contributions of TexA and TexB in Aridisols are more than slope. The sample areas are flat and are basalt plains that were covered by wind deposited sands. Grassy Butte soils have both loamy sand TexA and TexB, but when paired with Matheson and Lidy soils, which have sandy loam textures, the result is similar soils with one class difference each in TexA and TexB. Matheson and Lidy have finer textures because they developed from alluvial materials. Pairs of these soils with Grassy Butte could have been very contrasting if flooding had occurred on Matheson and Lidy, but because flooding does not occur even in these alluvial soils, these pairs are only similar.

Similar soils in which slope is the single contributing factor are pairs in which both members are slope phases of the same soil series.

Contrasting Soils

Contrasting soils are determined either by DPD or by CfA. Other properties including TexA, CfB, SP and Slo also vary, but at lower levels of contrast.

Contrasting pairs of soils involve Grassy Butte and Medano (36). Medano is in complex with Grassy Butte, but since Medano is more limiting it was chosen to represent the complex. The GB-Medano complex is in an old lakebed. GB is in the higher lying areas on dunes, whereas the Medano soil is in concave depressions. Medano is derived from alluvium and lake-laid sediment.

Medano is contrasting in terms of DPD when paired with GB30 and GB32. GB30 and GB32 are excessively and somewhat excessively drained with no drainage limitation. Medano is a very poorly drained soil even if moderately permeable, because run-off is ponded on this soil and there is a fluctuating water table at the surface to a depth of 2 feet at some time. Pairs of Medano with GB30 or GB32 could have been very contrasting, but the moderate permeability of Medano increases its drainage suitability to moderate, thus reducing the level of contrast.

Two pairs of contrasting soils involve CfA. HEI93 is the soil phase that represents the Montlid-Heiseton complex. Montlid very stony clay loam makes up 65% of this complex and Heiseton very stony loam makes up 15%. This complex is in playas on the fringes of old lakebeds. In this position colluvium derived from adjacent uplands is the most likely source of the coarse fragments in the surface soil. HEI93, when paired with Grassy Butte and Matheson, produces contrasting pairs. These pairs of soils vary in salinity also, but the presence of coarse fragments contributes to the contrast more than salinity.

Very Contrasting Soils

Flooding does not control the very contrasting contrast level as in the other soil orders. In this Aridisol landscape, where soils derived from lacustrine materials are surrounded by adjacent sandy soils, TexB, and to a lesser extent CfA, controls the very contrasting contrast level. DPD and slope have minor effects.

One pair, GB31-HEI93, is similar to the contrasting pair of GB-HEI93, only this pair also has a one class difference in slope, which raises it to the very contrasting level.

ZWI127 forms a very contrasting pair with GB even though they differ only in TexB and DPD. ZWI is a deep, well drained soil on old lakebeds. It formed in lacustrine and wind-laid deposits derived from mixed sources. It has a sandy clay texture of the B with slow permeability. Grassy Butte has a loamy sand TexB. The slow permeability of ZWI causes it to have DPD that is somewhat contrasting with the DPD of Grassy Butte even if both have the same drainage class. The overall contrast, however, is determined by TexB.

<u>Summary of Levels of and Reasons for Contrast</u>

The Aridisol samples are very different from each other. Area 2, for example, is composed of 100% exceedingly contrasting soils. Area 3, however, also has a high percentage of exceedingly contrasting soils.

Based on the mean percentage of soil contrast levels, the order of abundance of soil contrast level is Exceedingly Contrasting > Similar > Very Contrasting > Very Similar > Contrasting.

Of all the soil orders, the Aridisols have the highest percentage of exceedingly contrasting soils. This is due to the presence of basalt outcrops in the area. There is also a relatively high percentage of very similar soils and an absence of somewhat contrasting soils.

The percent of contrast levels using both percent of pairs and percent of boundary length is quite close to each other. This is due to the presence of long linear delineations that are separated by boundaries of fairly equal length.

The reasons for contrast for each soil contrast level in Aridisols are shown in Table 4.46.

Table 4.46. Summary of soil properties important in each contrast level of the Aridisols

Contrast Levels	Soil Properties
Similar	TexB, TexA, Slo
Contrasting	DPD, CfA, TexA, CfB, SP
Very Contrasting	TexB, DPD, CfA

TexB differences occur when there is a pair of alluvial soils in which one is finer in texture than the other.

DPD is important when pairs of soils that formed on wind-deposited sands occur. Soils that formed in concave depressions between dunes and those that are on the dune differ in DPD.

CfA and CfB are important in some of the Aridisols. The coarse fragments probably came from adjacent basalt outcrops. Aridisol is the only soil order for which salinity phase is important. Soils are not well leached of salts because of the limited rainfall.

Comparison of Soil Contrast Levels Between Soil Orders

The mean percentages of the different soil contrast levels are shown in Table 4.47 and Figure 4.32 (method 1) and Table 4.48 and Fig. 4.33 (method 2).

Similar soils dominate the contrast levels of Inceptisols, Ultisols and Mollisols. The trend in the distribution of contrast levels can be related to the landscape. Inceptisols are composed dominantly of soils derived from dense, channery glacial till. Most pairs of soils derived from this material are similar soils.

Most of the adjacent pairs of soils in the Ultisols belong to a single physiographic province having the same parent material, and similar soils are the most frequent of all contrast levels. Similar soils also dominate the Mollisols because of the dominance of soils that developed in loess and freshly weathered till.

Table 4.47. Distribution of contrast levels in each soil order based on percent of adjacent pairs*

Contrast Level	Mean Percent of Soil Contrast Levels				
	In	Ult	Alf	Mol	Arid
VS	0	0	0.7	0.7	7.7
S	44.8	36.0	34.0	35.9	20.6
SC	21.6	29.1	43.2	22.8	5.5
C	11.1	24.4	10.7	9.0	7.5
VC	10.0	10.4	4.4	31.8	15.9
EC	12.5	0	7.2	0	51.9

*In - Inceptisol, Ult - Ultisol, Alf - Alfisol, Mol - Mollisol, Arid - Aridisol.

Table 4.48. Distribution soil contrast levels in each soil order based on percent of boundary length

Contrast Level	Percent of Soil Contrast Levels				
	In	Ult	Alf	Mol	Arid
S	57.3	51.0	47.3	38.8	16.4
SC	20.4	20.0	37.4	20.5	1.1
C	8.2	18.9	7.4	8.6	9.3
VC	5.9	9.9	3.2	31.4	13.6
EC	8.0	0	4.4	0	58.3

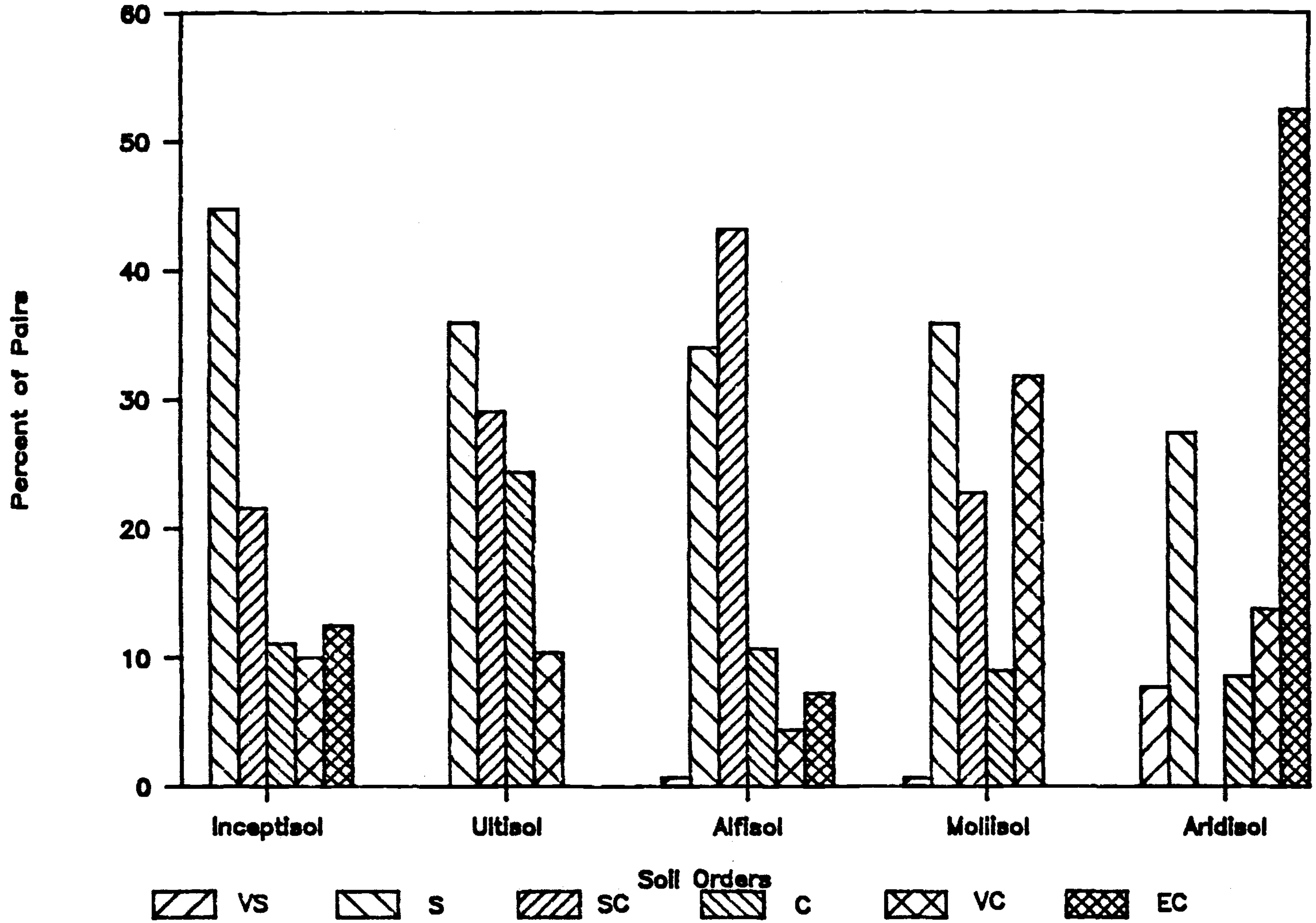

Fig. 4.32. Comparison of the distributions of percent of pairs among contrast levels in each of the 5 soil orders sampled

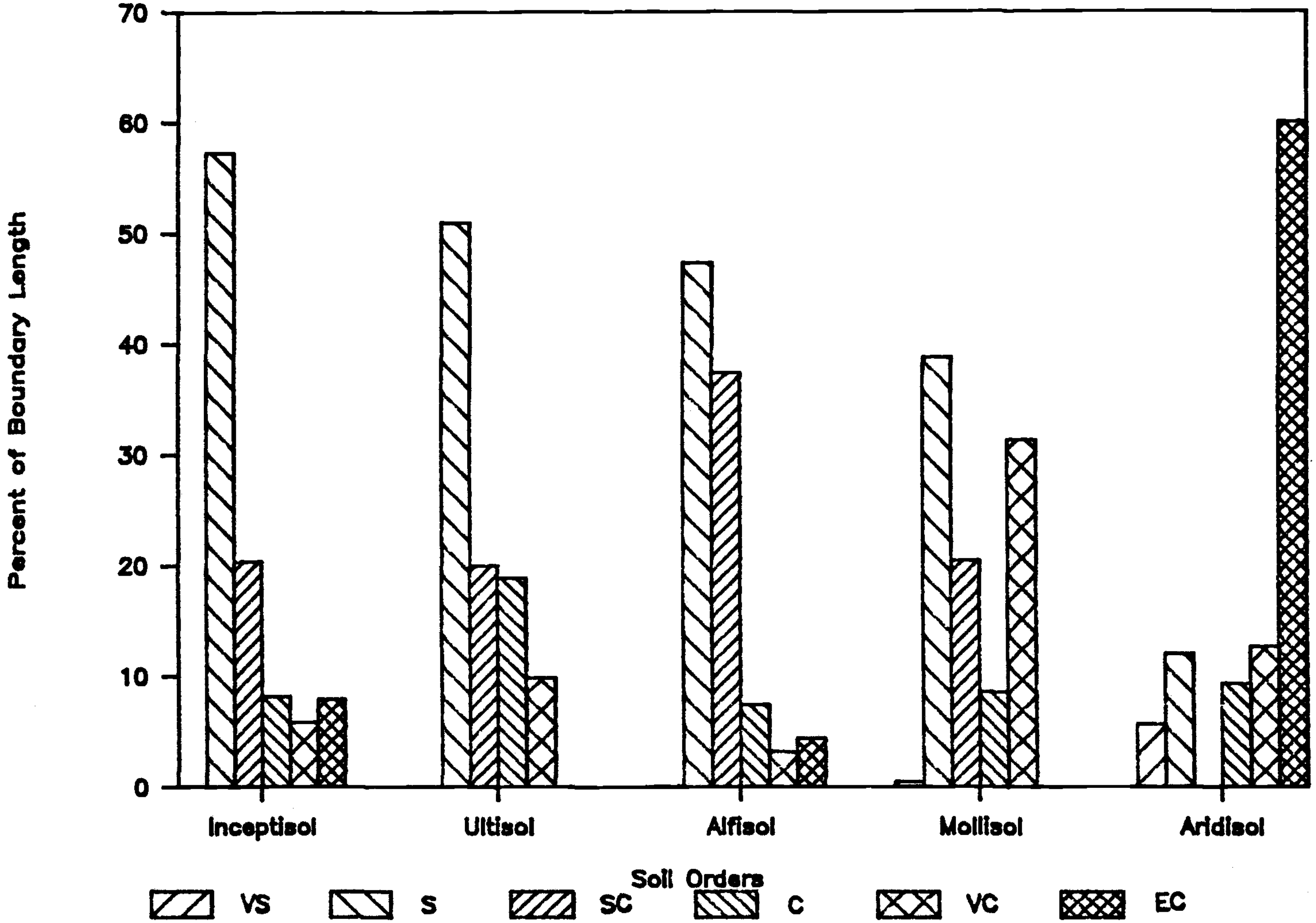

Fig. 4.33. Comparison of the distributions of percent of boundary length among contrast levels in each of the 5 soil orders sampled

Similar and somewhat contrasting soils dominate the soil contrast levels of Alfisols. The Alfisol landscapes are composed mostly of soils developed from sandy glacial till. Lapeer and Wyocena, which dominate the Alfisols, developed from this till and are similar soils. Other combinations of differences in parent material, depth of rooting, and slope resulted in the highest percentage of somewhat contrasting soils of all the orders.

The length of soil boundaries affect the apparent distributions of the contrast levels in each order. In the Alfisols, Ultisols, and Inceptisols, the boundary segments of similar soils are few but long, so that the percentage of similar soils using percent of boundary length is greater than that using percent of pairs. In the Mollisols and Aridisols, the boundary lengths are all approximately equal, and there is little difference between the two methods.

Mollisols differ from Inceptisols and Ultisols in that the second most abundant contrast level is very contrasting rather than somewhat contrasting. The percentage of very contrasting soils is almost the same as that of similar soils. This high percentage of very contrasting soils is due to the presence of many long, narrow areas of soils that flood frequently, creating many long boundaries between flooded and nonflooded soils.

Aridisols that developed in basalt plains that were later covered by wind deposited sands have the highest percentage of exceedingly contrasting soils. This is due to the presence of rock outcrops that form exceedingly contrasting pairs with a soil.

The distributions of the different contrast levels of the Ultisols vary according to the method of calculation. Using percent of pairs, the percentages of similar, somewhat contrasting, and contrasting soils are not widely different. Using the percent of boundary length, similar soils occupy about 50% of the soil contrast levels, and the remaining levels have substantially lower percentages. These observations indicate that the number of boundary segments belonging to similar, somewhat contrasting, and contrasting soils are nearly equal, but the presence of many large areas of similar soils creates relatively large cumulative totals of boundary lengths between these soils.

Comparison of Reasons for Soil Contrast of the Different Soil Orders

The determination of soil properties that affect the soil contrast is important. It is helpful in making one aware of the differences in soils that are most likely to occur in an area.

Table 4.49 shows the 3 most important soil properties that determine the soil contrast of each contrast level in each soil order.

Table 4.49. Summary of soil properties that contribute highly to each contrast level of each soil order

	SOIL PROPERTIES			
Soil Order	S	SC	C	VC
IN	Slo, DPD	Slo, DPD	DPD, Slo, DRt	Fld, DRt,
ULT	Slo, pHA, TexB	Slo, TexB, pHA	TexB, DPD, pHA	Fld, TexB,
ALF	Slo, EP, pHB	Slo, pHB, DRt	Slo, TexB, DRt	DRt, Fld,
MOLL	Slo, pHA, EP	DPD, pHA, pHB	DPD, TexB, pHA/pHB	Fld, Slo,
ARID	TexA, TexB, Slo	-	DPD, CfA, TexA	TexB, DPD,

Similar Soils

Slope is the highest contributor to soil contrast in all soil orders but the Aridisols. Of all the five soil orders sampled, the Aridisol landscape had the least relief, and slope did not contribute as much to soil contrast. TexA is the highest contributor to similar soils in the Aridisols, as phases of different series with the same slope and with one class difference in texture of the A occur side by side.

DPD is associated with slope only in the Inceptisols and is due to the occurrence of two drainage class, well drained and moderately well drained, in a single series (Mardin). On A, B, and C slopes the soil is moderately well drained, but on steeper slopes it is well drained. Adjacent delineations having these differences are similar, even though both slope and DPD vary by one class. Because these soils occupy a large area of the Inceptisols, the contribution of DPD to soil contrast in the Inceptisols is large.

Soil pH, either in the A or the B, is associated with slope in the Ultisols, Alfisols and Mollisols. These 3 soil orders are more developed than Inceptisols and Aridisols, such that more leaching has occurred in some soils in the landscape, thereby creating pH differences between adjacent soils.

Erosion phase is associated with slope in cases where it was determined in the survey, as in the Alfisols and Mollisols.

Somewhat Contrasting

Slope is still the major contributor to the contrast of somewhat contrasting soils in all soil orders but the Mollisols. DPD replaces slope as the soil property that contributes highly to the contrast of the Mollisols.

Inceptisols and Ultisols are still influenced by the same soil properties as in similar contrast levels. Most of the soil series that paired in similar soils are the same series that paired in somewhat contrasting soils only their slope phases are different.

DRt becomes important in Alfisols. Alfisol landscapes contain soils that are shallow to bedrock due to the varying depth of deposition of glacial till and loess in some areas such as ridges of sandstone. The pH of the B is also important in Alfisols because of the varying types of parent material that are originally of different pH and so would create soils of different pH. Boyer soils, for example, are acidic due to their parent material, i.e. glacial outwash of calcareous sand and gravel.

DPD and pH are important in the Mollisols because of the presence of large areas of soils with DPD differences adjacent to each other. Such occurrence is due to the linear areas of seepage associated with a paleosol that differs from soils below and above it in terms of DPD.

Contrasting

DRt becomes one of the properties contributing to the contrast level of contrasting soils in Inceptisols and Alfisols. Depth of rooting is restricted in the Inceptisols by a fragipan and in the Alfisols by shallow depth to bedrock.

TexB also becomes important for Alfisols and Mollisols. In Alfisols, soils with coarse textured A horizons and finer textured B horizons occur where sandy materials are deposited over till. In the Mollisols, loessial soils with fine textured B horizons are adjacent to alluvial soils with coarse textured B horizons. DPD is still important in Mollisols, and in all soils with DPD as the single dominant factor, a soil that developed on a paleosol with a gumbotil is involved. DPD is also important in the Aridisols because excessively drained soils on dunes are adjacent to very poorly drained but permeable soils in interdunal depressions.

Very Contrasting

Flooding contributes highly to the contrast of very contrasting soils in the Inceptisols, Ultisols and Mollisols, whereas DRt and TexB are most important for the Alfisols and Aridisols, respectively.

Very contrasting soils in the Inceptisols, Ultisols and Mollisols are pairs of alluvial soils that flood frequently with upland soils that do not flood. Properties covarying with flooding are DRt, TexB and Slo in the Inceptisols, Ultisols and Mollisols, respectively. Alluvial soils are adjacent to soils with fragipans in the Inceptisols, so DRt is also important for very contrasting soils. In the Ultisols, most of the alluvial soils are coarse textured, as their alluvium came from upland areas dominated by granite.

DRt is important in pairs of Alfisols in which one soil developed from glacial outwash that is very shallow to gravel and sand, which limits DRt, and the other developed from deep glacial till that has no restriction on DRt.

TexB and CfA are the most important factors in the Aridisols because clayey soils that formed in lakebeds and soils with high percentages of coarse fragments are juxtaposed with sandy wind-blown soils.

Soil Properties Contributing Little or None to Soil Contrast

Other soil properties contribute to the contrast of the different contrast levels in each order but in lesser degrees than those in Table 4.49. Salinity, for example, is important in the very contrasting soils of the Aridisols, but it is not one of the first 3 soil properties contributing to soil contrast.

Some soil properties, however, make little or no contribution to any level of soil contrast. Texture and pH are not important soil properties in the Inceptisol soils. Inceptisols are fairly young soils, and illuviation of clays and pH changes have not yet taken place.

DRt and coarse fragments contribute little to the contrast of Ultisols and Mollisols. In both sampling areas the soils are characterized by deep soils. They are also developed soils and could have had enough time to weather any coarse fragments that may have been in the parent material. Ultisols are also characterized by upland soils and by marine deposited sands, both of which contain few or no coarse fragments at all. The lack of coarse fragments in upland soils can be due to their being well developed and more highly weathered soils. Most of the soils in the Mollisols developed from loess and so are free of coarse fragments.

TexA and DPD do not contribute highly to the contrast of Alfisols. The soils in the Alfisol group are mostly sandy with drainage that is excessively drained to well drained.

Flooding, pHA and pHB do not contribute to the contrast of Aridisol soils. Flooding does not contribute to the contrast because of the climate, particularly the lack of precipitation in the area. Most soils have high pH, so pH does not contribute to the contrast. CfB and TexA also do not contribute to soil contrast as Aridisols developed from sandy eolian deposits.

The observations on the distribution of the contrast levels, as well as the soil properties contributing to soil contrast of a particular area, cannot be used to infer that all areas of each soil order would have the same characteristics. The sampling was not done thoroughly enough to be able to make such inferrences, and it was not the objective of this study to make a complete evaluation of patterns and reasons for contrast within the entire geographic extent of any of the soil orders.

CHAPTER 5

SUMMARY AND CONCLUSIONS

A study was conducted to develop a model for determining soil contrast for general agriculture in response to the lack of well defined and quantitative methods to determine it. The model was tested using 3 samples of mapped soil areas from each of five soil associations representing five different soil orders.

Various models were developed and tested until a final model was derived, using the insights gained from the previous models that were rejected.

The final model for determining soil contrast is based on 12 properties: coarse fragments of the A and B (CfA, CfB); flooding (Fld); Depth of Rooting (DRt); slope (Slo); combined effects of drainage, permeability and depth to least permeable layer (DPD); erosion phase (EP); salinity phase (SP); texture of the A and B (TexA, TexB); and pH of the A and B (pHA, pHB). Five levels of soil contrasts were set up, to describe both differences within each soil property and overall differences between two soils. They are very similar (VS), similar (S), somewhat contrasting (SC), contrasting (C) and very contrasting (VC). A VS property occurs when two soils have the same value, or the same class of values, for that property. A VS contrast between two soils occurs when all twelve properties are VS for both soils. A VC property usually occurs when pairs of soils have values that occupy opposite ends of the classes that were established for that property. The presence of at least one property that is very contrasting makes the overall contrast of the soils very contrasting. Other criteria, however, were set up for very contrasting soils. Another level, exceedingly contrasting, was set up for situations in which a miscellaneous land type was paired with a soil.

The range of values of each soil property was divided into several classes, usually 5, and each class was assigned a class code. The classes were arranged in terms of increasing limitation in all properties except texture and pH. Texture was arranged from fine texture to coarse texture, and pH was arranged in terms of increasing alkalinity. Each class was assigned a class code that ranged from 0 to 10. The first class, usually the least limiting one for general agriculture, was assigned a code of 0, and the last class, usually the most limiting, was assigned a code of 10.

A list of all the possible pairs of classes was then prepared for each property. The first class was compared with the 2nd class and then to the third class and so on. The absolute difference of the class codes of each pair was recorded. The absolute difference increases as the classes far apart are being compared.

These absolute differences in class codes were used to determine the contrast levels for each property. Each pair of classes was assigned a contrast score from 1 to 5, 1 for very similar and 5 for very contrasting. The same absolute difference, however, may give different contrast levels for different properties. EP and SP, for example, were given less weight in the model, and their maximum differences were only somewhat contrasting and contrasting, respectively. Some soil properties have classes more than 5 classes, and in these cases a given contrast level was defined by a range of absolute values. A table was set up for quick and easy determination of contrast level based on each soil property.

The overall contrast of a pair of soils was determined using criteria based on the highest and next-to-highest codes in the set of twelve. When a single property had a contrast code higher than any of the others, the overall contrast of the pair was set equal to that of the most contrasting property. When several properties covaried, empirical criteria were established to elevate the overall contrast one class if several properties all had the same contrast code.

The model was tested on 3 sample areas from a soil association representing each of five different soil orders. The properties of each map unit in the area were determined, assigned to a particular class, and their class codes recorded. The actual pairs of soils in the areas, their number of occurrences, and their boundary lengths were also recorded. The absolute differences between the class codes of all properties were determined for each pair. The percent of the pairs of soils and the boundary lengths that fell in a certain contrast level were computed for each sample area.

The reasons for contrast were determined by recording the properties having the highest code(s) for each contrast level and determining the number of distinct pairs whose contrast was controlled by each property. The higher the number of distinct pairs under a property, the more important the soil property was. The weighted average contribution to contrast of each property was calculated by multiplying the contrast code for that property by the proportional length of boundary between each pair of soils. In this way a soil property that has a high contrast code, and for which the pair possessing it occurs frequently and is separated by long boundaries, makes a greater contribution to the overall contrast in the sampling area.

Results of the testing indicate that the model is useful for determining soil contrast. In the Ultisol sample, for example, Helena and Cecil soils were declared contrasting even though they have the same slope values. This is because Helena is moderately well drained but with slow permeability and depth to least permeable layer of 15 inches, whereas Cecil is well drained with moderate permeability. To this day Helena is used mainly for woodland, whereas Cecil is one of the best cropland soils in the county. In the Alfisols, Rodman soils were declared very contrasting with Wyocena because Rodman has a very shallow rooting depth and very gravelly texture, whereas Wyocena is a deep soil and has much lower amounts of coarse fragments in the A and B horizons. Rodman was used for woodland at the time of the survey whereas Wyocena was used for cropland. Soils devoted to woodland may have properties not suitable for agriculture.

Data obtained by using the model to determine the contrast between all adjacent pairs of soils in the landscapes sampled were used to determine the distribution of the different contrast levels in each soil order. All soil orders but the Aridisols were characterized by a high percentage of similar soils. The percentage of similar soils in each order, however, varied. About 2/3 of the sample area of the Inceptisols was similar, and the remaining 1/3 was distributed equally among the other soil contrast levels. One third of the sample areas in the Ultisols and Mollisols belonged to the similar contrast level. The percentages of somewhat contrasting and contrasting soils in the Ultisols occupied about 25% each of the total area. About 20% and 30% of the Mollisols belonged to somewhat contrasting and very contrasting contrast levels, respectively. Mollisols had the highest percentage of somewhat contrasting soils (37%) of all the soil orders. Aridisols had the highest percentage of exceedingly contrasting soils.

The difference in the distribution of the contrast levels can be related to the presence of streams and the type of parent material in the area. An area that is traversed by relatively large streams, for example, will result in a high percentage of alluvial soils that, when adjacent to upland soils, form very contrasting pairs. Soil landscapes in which a paleosol with a very slowly permeable subsoil is present result in very contrasting soils when paired with other soils developed in relatively unweathered glacial till. Other parent material differences are not as important. In the Ultisols, for example, juxtaposition of predominantly granitic soils with soils developed from marine sediments creates nothing more than a high percentage of similar soils. The results of using the model correspond well to what can be predicted about the contrast level based on topography and parent material. Thus, the model can be used to determine the overall contrast of an area.

The main reasons for contrast for each soil order were also determined. Some soil properties contribute to the contrast of some soil orders but not others. Slope is the property that contributes most highly to the similar and somewhat contrasting levels of

Inceptisols, Ultisols and Alfisols. Soil pH and soil texture were found to be important for comparing relatively developed soils with relatively undeveloped soils. DPD was important for determining the contrasting level in all soil orders but the Alfisols. Alfisols in the study areas were almost all well drained, and DPD was not important. Flooding is the soil property that causes most of the contrast of very contrasting soils in all soil orders but the Alfisols and Aridisols. The contribution of DRt, however, is higher than flooding in the Alfisols, as there are more occurrences of very shallow soil due to the varying depth of glacial till deposits. TexB replaces flooding as the most important property controlling very contrasting soils in the Aridisols. Flooding is not important because the prevaling climate in the area is characterized by a low amount of precipitation. The importance of TexB is due to the presence of adjacent soils in which one developed from lacustrine sediments with clayey subsoils and the other from sandy deposits with sandy subsoils.

The results of applying the model in determining the contrast between mapping units, the overall contrast of soils in terms of the distribution of different contrast levels, and the reasons for contrast between different sample areas, all indicate that the final model can be useful. There are some aspects of the model, however, that need to be improved. For example, texture of the B is difficult to determine for soils that are developed in stratified lacustrine deposits. The 25-inch depth may be in a fine-textured but thin horizon, thereby creating a high contrast level with surrounding areas that have coarse textured subsoils.

DPD should encompass areas which are fed with water through seeps from upland soils. Drainage may be feasible in those areas but may be limited by the contant supply of water from above.

Sizes of map unit delineations may need to be considered for determining soil contrast in addition to boundary lengths and numbers of adjacent pairs. One Aridisol sample area, for example, turned out to have 100 percent exceedingly contrasting soils even though the lower half of the area contrained no adjacent delineations of very contrasting soils.

The pattern of soils having different contrast levels also needs to be studied. Very contrasting soils, for example, occur on floodplains. Their long boundary lengths with adjacent upland soils can give a higher percentage of very contrasting soils than the other contrast levels. However, they are concentrated in one area, so the effect of these very contrasting soils on soil management may not be as much as when they are distributed throughout the area.

The model can be utilized for making decisions as to the differences in soil management requirements of an area. It can also be utilized for making decisions on the kind and allowable amount of inclusions within a map unit. It is recommended that soils that form very similar, similar, and somewhat contrasting soils with the matrix soils be considered as similar inclusions, whereas contrasting, very contrasting and exceedingly contrasting soils compared with the matrix soils be considered dissimilar soils. The six overall soil contrast levels, however, can be used for a more thorough classification of overall soil contrast.

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APPENDICES

APPENDICES

The appendices are arranged into 5 sections, each of which corresponds to one of the 5 soil orders sampled. The different sections are: Inceptisol (1), Ultisol (2), Alfisol (3), Mollisol (4) and Aridisol (5). Each section is in turn divided into 3 subsections. The three subsections are: values of the 12 soil properties used in the model for all of the soils in the 3 sample areas (1), matrices of map units in each sample area that occur adjacent to each other along with their contrast codes (2), and for each pair of adjacent soils, both the boundary length separating that pair and the contrast level of each soil property (3). Thus, Appendix 1.1 means the section that corresponds to the Inceptisols and the subsection that corresponds to the soil properties of all soils in the 3 sample areas.

Subsection 1 includes the values of all soil properties and their class codes. The values of the soil properties are enumerated if there are many soil phases with different values for that property in the series. The soil phase will have a value corresponding to the order in which the soil phase is enumerated at the top of each column of values. An example of this arrangement is shown below with slope as the soil property.

	Code			
	MhB	MhC	MhD	MhE
Slo- B, C, D, E	2.5	5.0	7.5	10.0

MhD is listed 3rd in the list of soil phases. The 3rd value listed after slope is D, so the slope value of MhD is D.

The depth to least permeable layer (dlp) is not given if the permeability is moderate or higher. Other symbols are used for drainage (drn) and permeability (perm). The depth of the B horizon is also indicated if its depth is other than 25 inches. The value of erosion phase is reported either as none (N), moderate (M), or severe (S). The soils in all the samples for each soil order are included in just one list.

Subsection 2 includes the matrices of adjacent map units for each sample. Each matrix includes the number of times a particular pair of map units occurs and the contrast level for that pair. An example of a matrix of map units is shown below:

	LdC	LdD
ArD	1SC	1S

The LdC-ArD pair of soils occurs once, and its overall soil contrast level is somewhat contrasting. LdD-ArD also occurs once, but it is a similar pair of soils.

Subsection 3 lists the actual pairs of soils for all overall soil contrast levels. For each pair, the boundary length separating the two soils is given both as an absolute value and as a proportion of the cumulative total length separating all soils in that same contrast level. This subsection also gives the contrast level for each soil property of each pair of soils in the similar, somewhat contrasting, contrasting, and very contrasting classes. For the very similar and exceedingly contrasting pairs of soils, only the boundary length and the proportion of total boundary length are included.
An example using the very contrasting soils of Alfisol sample 1 is shown below:

Pair	Boundary Length	Propn. of TOTAL	CfA	CfB	DRt	Slo	EP	TexA	TexB	pHA	pHB
RoD-WyB	0.3533860	0.353	3	3	5	3	1	2	2	2	2
RoD-WyC2	0.6469390	0.647	3	3	5	2	4	2	2	2	2
TOTAL	1.0003250										

The data in this section provide the basis for computing the weighted average contribution of a soil property to soil contrast. To do this the contrast codes under each soil property must first be reduced by one. This gives a value of zero for soil properties that do not contribute to soil contrast. Then for each pair of soils, each of the reduced contrast codes is multiplied by the proportion of total boundary length for those two soils. For each soil property, these products are summed over all soil pairs in that contrast level. Finally, these column sums are expressed as a percentage of the total of all column sums to determine the weighted average contribution to contrast.

APPENDIX 1

INCEPTISOLS

APPENDIX 1.1

SOIL PROPERTIES AND CODES OF MAP UNITS OF THE INCEPTISOL SAMPLES

Soil Properties	Codes
Alden	AcA
CfA - none	0
CfB - 5-10% coarse fragments	1
Fld - none	0
DRt - 20" (few roots) 20-45" is massive and sticky and no roots	5
Slo - A	0
DPD	6
drn - very poorly drained	
perm - <.20 in/hr, slow	
dlp - 20"	
EP - none	0
SP - none	0
TexA - silt loam	5
TexB - silty clay loam	5
pHA - medium acid	3
pHB - neutral	5.5
B is at 10" from the surface	
Arnot	ArD
CfA - channery	5
CfB - channery	5
Fld - none	0
DRt - 16"	7.5
Slo - D	7.5
DPD	1.5
drn - moderately well drained	
perm - moderate	
dlp - 16"	
EP - none	0
SP - none	0
TexA - silt loam	5
TexB - silt loam	5
pHA - strongly acid	2
pHB - strongly acid	2
B is at 8" from the surface	

Chenango	ChC
CfA - gravelly	4
CfB - very gravelly	7
Fld - none	0
DRt - >40"	0
Slo - C	5
DPD	0
drn - well drained	
perm - moderate	
EP - none	0
SP - none	0
TexA - loam	4
TexB - sandy loam	7
pHA - medium acid	3
pHB - medium acid	3

Lordstown	LdB	LdC	LdD	LoE*
CfA - channery	5	5	5	5
CfB - very channery	7	7	7	7
Fld - none	0	0	0	0
DRt - 28"	5	5	5	5
Slo - B, C, D, E	2.5	5.0	7.5	10
DPD	0	0	0	0
drn - well drained				
perm - moderate				
EP - none	0	0	0	0
SP - none	0	0	0	0
TexA - silt loam	5	5	5	5
TexB - silt loam	5	5	5	5
pHA - strongly acid	2	2	2	2
pHB - strongly acid	2	2	2	2

*A complex represented by Ld with an E slope.

Mardin	MhB	MhC
CfA - channery	5	5
CfB - channery	5	5
Fld - none	0	0
DRt - 18-22" (ave. 20")	7.5	7.5
Slo - B, C	2.5	5
DPD	4.5	4.5
drn - moderately well drained		
perm - <.20 in/hr		
dlp - 18"		
EP - none	0	0
SP - none	0	0
TexA - silt loam	5	5
TexB - silt loam	5	5
pHA - strongly acid	2	2
pHB - strongly acid	2	2

B is 10" from the surface

Mardin	MhD	MhE	MrF*
CfA - channery	5	5	5
CfB - channery	5	5	5
Fld - none	0	0	0
DRt - 18-22" (ave. 20")	7.5	7.5	7.5
Slo - D, E, F	7.5	10	10
DPD	3	3	3
drn - well drained			
perm - slow			
dlp - 15"			
EP - none	0	0	0
SP - none	0	0	0
TexA - silt loam	5	5	5
TexB - silt loam	5	5	5
pHA - strongly acid	2	2	2
pHB - strongly acid	2	2	2

B is 10" from the surface

*A complex represented by Mh with an F slope

Middlebury	Ms
CfA - none	0
CfB - none	0
Fld - occasional during growing season	8
DRt - 45"	0
Slo - A	0
DPD	1.5
drn - moderately well drained	
perm - moderate to moderately rapid	
EP - none	0
SP - none	0
TexA - silt loam	5
TexB - sandy loam	7.5
pHA - slightly acid	4
pHB - slightly acid	4

Tioga	Ta	Tg
CfA - none	0	0
CfB - none	0	0
Fld - occasional during growing season	8	8
DRt - >40"	0	0
Slo - A	0	0
DPD	0	0
drn - well drained		
perm - moderate to moderately rapid		
EP - none	0	0
SP - none	0	0
TexA - silt loam	5	5
TexB - silt loam	5	5
pHA - medium acid	3	3
pHB - medium acid	3	3

Tuller	TuD
CfA - channery	5
CfB - channery	5
Fld - none	0
DRt - 17"	7.5
Slo - D	7.5
DPD	3
drn - somewhat poorly drained	
perm - moderate	
EP - none	0
SP - none	0
TexA - silt loam	5
TexB - silt loam	5
pHA - medium acid	3
pHB - strongly acid	2
B is 8" from the surface	

Volusia	VoA	VoB	VoC	VoD
CfA - channery	5	5	5	5
CfB - channery	5	5	5	5
Fld - none	0	0	0	0
DRt - 15-18"	7.5	7.5	7.5	7.5
Slo - A, B, C, D	0	2.5	5.0	7.5
DPD	6	6	6	6
drn - somewhat poorly drained				
perm - slow				
dlp - 17"				
EP - none	0	0	0	0
SP - none	0	0	0	0
TexA - silt loam	5	5	5	5
TexB - silt loam	5	5	5	5
pHA - strongly acid	2	2	2	2
pHB - strongly acid	2	2	2	2
B is 8" from the surface				

Wayland	Wd
CfA - none	0
CfB - none	0
Fld - occasional during growing season	8
DRt - >40"	0
Slo - A	0
DPD	4.5
drn - poorly drained	
perm - moderately slow	
dlp - 40"	
EP - none	0
SP - none	0
TexA - silt loam	5
TexB - silt loam	5
pHA - slightly acid	4
pHB - neutral	5.5

APPENDIX 1.2

MATRIX OF MAP UNITS OF THE INCEPTISOL SAMPLES

INCEPTISOL SAMPLE 1

	LdC	LdD	LoE	MhB	MhC	MhD	MhE	Ms	TuD	VoB	VoC	VoD	Wd
Ad					2EC	2EC		2EC		2EC	2EC	1EC	
ArD	1SC	1S											
ChC					1C			1VC			1C		
LdC		4S	1SC	2C	3C				1SC	2SC			
LdD			1S	1C	4C	1SC				4C			
LoE					1C								
MhB					2S		1C			3S	2S		
MhC						5S	1SC	2VC		12S	6S		1VC
MhD							2S	1VC		3SC	6SC	2SC	
MhE											2SC	1SC	
MrF											1SC		
Ms										1VC	1VC		
TuD										1SC	1C		
VoB											7S	1SC	1VC
VoC												3S	1VC
VoD													
Wd													

INCEPTISOL SAMPLE 2

	LdC	LdD	LoE	MhB	MhC	MhD	MhE	MrF	Ms	Ta	Tg	VoA	VoB	VoC	VoD	Wd
Ad			1EC		5EC	1EC	1EC	1EC	2EC	2EC	3EC		3EC	9EC	2EC	1EC
LdB	2S	2SC														
LdC		5S	1SC													
LdD			2S	1C	1C		1SC							5C		
LoE						2SC	1SC							2C		
MhB					4S									1S		
MhC						6S	2SC		2VC	5VC	3VC	1SC	3S	22S		2VC
MhD							2S	1S					1SC	8SC	2SC	
MhE														6SC		
MrF													1C	1SC		
Ms											2C		1VC	2VC		
Ta													2VC	4VC		1C
Tg														1VC		
VoA														1SC		
VoB														8S	2SC	
VoC															5S	1VC

INCEPTISOL SAMPLE 3

	MhB	MhC	MhD	MhE	Ms	Ta	VoB	VoC	VoD
Ad		1EC	1C	1EC	2EC	1EC		3EC	1EC
AcA	2C						1C	3C	1C
LdD								1C	
MhB		3S	2SC	1C			4S	8S	
MhC			9S	2SC	1VC		3S	12S	7S
MhD				1S	1VC		7SC	7SC	3SC
MhE							1C	3SC	2SC
Ms						2SC	2VC	2VC	1VC
Ta							1VC	1VC	
VoB								9S	3SC
VoC									9S
VoD									

APPENDIX 1.3

RAW DATA FOR THE INCEPTISOL SAMPLES

Similar, Inceptisol 1

Pairs	Boundary Length	Propn. of TOTAL	CfB	DRt	Slo	DPD
LdC-LdD	7.5996905	0.1614	1	1	2	1
LdD-ArD	1.1252880	0.0239	2	2	1	2
LdD-LoE	0.7446342	0.0158	1	1	2	1
MhB-MhC	2.0467171	0.0434	1	1	2	1
MhB-VoB	5.4490749	0.1157	1	1	1	2
MhB-VoC	2.1078552	0.0447	1	1	2	2
MhC-MhD	5.9539352	0.1265	1	1	2	2
MhC-VoB	10.8622180	0.2308	1	1	2	2
MHC-VoC	5.4219340	0.1152	1	1	1	2
MhD-MhE	0.3822365	0.0081	1	1	2	1
VoB-VoC	4.4045443	0.0935	1	1	2	1
VoC-VoD	0.9623739	0.0204	1	1	2	1
TOTAL	47.0604051					

Somewhat Contrasting, Inceptisol 1

Pairs	Boundary Length	Propn. of TOTAL	CfB	DRt	Slo	DPD	pHA
LdC-ArD	1.3264870	0.0618	2	2	2	2	1
LdC-LoE	0.8086133	0.0376	1	1	3	1	1
LdD-MhD	3.0390870	0.1416	2	2	1	3	1
MhC-MhE	2.0587510	0.0959	1	1	3	2	1
MhD-VoB	2.5659443	0.1195	1	1	3	3	1
MhD-VoC	5.3478871	0.2491	1	1	2	3	1
MhD-VoD	0.3463955	0.0161	1	1	1	3	1
MhE-VoC	0.9628520	0.0448	1	1	3	3	1
MhE-VoD	1.2299910	0.0573	1	1	2	3	1
TuD-LdC	1.0379690	0.0483	2	2	2	3	1
VoB-TuD	1.9097080	0.0889	1	1	3	3	2
VoB-VoD	0.7837511	0.0365	1	1	3	1	1
VoC-MrF	0.0436807	0.0020	1	1	3	3	1
TOTAL	21.4611202						

Contrasting, Inceptisol 1

Pairs	Boundary Length	Propn. of TOTAL	CfB	DRt	Slo	DPD	TexB	pHA	pHB
ChC-MhC	0.3637402	0.028	2	4	1	4	2	2	2
ChC-VoC	0.2765440	0.021	2	4	1	4	2	2	2
LdC-MhB	0.3336890	0.025	2	2	2	4	1	1	1
LdC-MhC	3.2469300	0.251	2	2	1	4	1	1	1
LdC-VoB	2.1440329	0.165	2	2	2	4	1	1	1
LdD-MhB	1.1287100	0.087	2	2	3	4	1	1	1
LdD-MhC	1.0365532	0.080	2	2	2	4	1	1	1
LdD-VoB	2.8454715	0.219	2	2	3	4	1	1	1
LoE-MhC	0.2080495	0.160	2	2	3	4	1	1	1
MhB-MhE	0.9810584	0.075	1	1	4	2	1	1	1
TuD-VoC	0.3718340	0.028	1	1	2	4	1	2	1
TOTAL	12.93649								

Very Contrasting, Inceptisol 1

Pairs	Boundary Length	Propn. of TOTAL	CfA	CfB	Fld	DRt	Slo	DPD	TexB	pHA	pHB
ChC-Ms	0.7190057	0.1253	3	4	5	1	3	2	1	2	2
MhC-Ms	0.3249562	0.0566	3	3	5	4	3	3	2	2	2
MhC-Wd	0.2728814	0.0475	3	3	5	4	3	1	1	2	3
MhD-Ms	0.3461524	0.0603	3	3	5	4	4	2	2	2	2
Ms-VoB	1.8077200	0.3151	3	3	5	4	2	4	2	2	2
Ms-VoC	0.8585401	0.1496	3	3	5	4	3	4	2	2	2
VoB-Wd	1.2719870	0.2217	3	3	5	4	2	2	1	2	3
VoC-Wd	0.1342894	0.0234	3	3	5	4	3	2	1	2	3
TOTAL	5.7355322										

Similar, Inceptisol 2

Pairs	Boundary Length	Propn. of TOTAL	Slo	DPD
LdB-LdC	1.5939682	0.018	2	1
LdC-LdD	8.9878289	0.101	2	1
LdD-LoE	1.4531028	0.016	2	1
MhB-MhC	3.1883499	0.036	2	1
MhB-VoC	0.1161075	0.001	2	2
MhC-MhD	5.0051427	0.056	2	2
MhC-VoB	1.5110006	0.017	2	2
MhC-VoC	43.6655780	0.495	1	2
MHD-MHE	2.6488587	0.030	2	1
MhD-MRF	0.1810003	0.002	2	1
VoB-VoC	15.4613250	0.175	2	1
VoC-VoD	4.3317565	0.049	2	1
TOTAL	88.144019			

Somewhat Contrasting, Inceptisol 2

Pairs	Boundary Length	Propn. of TOTAL	CfA	CfB	DRt	Slo	DPD
LdB-LdD	0.8431514	0.026	1	1	1	3	1
LdC-LoE	0.7389990	0.023	1	1	1	3	1
LdD-MhE	0.1732308	0.005	1	2	2	2	3
LoE-MhD	0.5382511	0.016	2	2	2	2	3
LoE-MhE	0.4480718	0.014	1	2	2	1	3
MhC-MhE	0.8056382	0.025	1	1	1	3	2
MhC-VoA	0.0251794	0.0007	1	1	1	3	2
MhD-VoB	0.2005489	0.006	1	1	1	3	2
MhD-VoC	12.3377600	0.388	1	1	1	2	3
MhD-VoD	2.0327656	0.064	1	1	1	1	3
MhE-VoC	10.6073960	0.334	1	1	1	3	3
VoA-VoC	0.9470782	0.029	1	1	1	3	1
VoB-VoD	1.3043800	0.041	1	1	1	3	1
VoC-MrF	0.7252446	0.022	1	1	1	3	3
TOTAL	31.727685						

Contrasting, Inceptisol 2

Pairs	Boundary Length	Propn. of TOTAL	CfA	CfB	DRt	Slo	DPD	TexB	pHA	pHB
LdD-MhB	0.1130617	0.012	1	2	2	3	4	1	1	1
LdD-MhC	0.3456298	0.037	1	2	2	2	4	1	1	1
LdD-VoC	5.3417585	0.585	1	2	2	2	4	1	1	1
LoE-VoC	1.1902308	0.130	1	2	2	3	4	1	1	1
MrF-VoB	0.7326826	0.080	1	1	1	4	3	1	1	1
Ta-Wd	0.3182837	0.034	1	1	1	1	4	1	2	2
TOTAL	9.1162304									

Very Contrasting, Inceptisol 2

Pairs	Boundary Length	Propn. of TOTAL	CfA	CfB	Fld	DRt	Slo	DPD	TexA	pHA	pHB
MhC-Ms	0.7479571	0.054	3	3	5	4	3	3	2	2	2
MhC-Ta	2.8345186	0.206	3	3	5	4	3	4	1	2	2
MhC-Tg	0.9766800	0.070	1	3	5	4	3	4	1	2	2
MhC-Wd	0.1698005	0.012	3	3	5	4	3	1	1	2	3
Ms-VoB	0.4868247	0.035	3	3	5	4	3	4	2	2	2
Ms-VoC	3.7323826	0,271	3	3	5	4	2	4	2	2	2
Ta-VoB	2.1503108	0.156	3	3	5	4	2	4	1	2	2
Ta-VoC	1.4870839	0.108	3	3	5	4	3	4	1	2	2
Tg-Voc	0.7770463	0.056	1	3	5	4	3	4	1	2	2
VoC-Wd	0.4063932	0.030	3	3	5	4	3	2	1	2	3
TOTAL	13.768998										

Similar, Inceptisol 3

Pairs	Boundary Length	Propn. of TOTAL	Slo	DPD
MhB-MhC	2.6537190	0.032	2	1
MhB-VoB	3.9534202	0.048	1	2
MhB-VoC	12.6118470	0.154	2	1
MhC-MhD	8.2900608	0.101	2	2
MhC-VoB	3.2923464	0.040	2	2
MhC-VoC	24.2777770	0.297	1	2
MhC-VoD	6.5848436	0.080	2	2
MhD-MhE	0.0574940	0.0007	2	2
VoB-VoC	8.5173811	0.104	2	1
VoC-VoD	11.2613610	0.138	2	1
TOTAL	81.500025			

Somewhat Contrasting, Inceptisol 3

Pairs	Boundary Length	Propn. of TOTAL	CfB	DRt	Slo	DPD	TexB	pHA	pHB
MhB-MhD	2.9698041	0.130	1	1	3	2	1	1	1
MhC-MhE	1.3232816	0.058	1	1	3	2	1	1	1
MhD-VoB	0.0267902	0.133	1	1	3	1	1	1	1
MhD-VoC	8.7661705	0.386	1	1	2	3	1	1	1
MhD-VoD	1.4200050	0.062	1	1	1	3	1	1	1
MhE-VoC	0.9100283	0.040	1	1	3	3	1	1	1
MhE-VoD	1.8252370	0.080	1	1	2	3	1	1	1
Ms-Ta	0.4901732	0.021	1	1	1	2	2	2	2
VoB-VoD	1.9514830	0.086	1	1	1	3	1	1	1
TOTAL	22.68267								

Contrasting, Inceptisol 3

Pairs	Boundary Length	Propn. of TOTAL	CfA	CfB	DRt	Slo	DPD	pHA	pHB
Ald-MhB	1.8581638	0.028	3	2	2	2	2	1	3
Ald-VoB	0.0929317	0.014	3	2	2	2	1	2	3
Ald-VoC	2.5427365	0.407	3	2	2	3	1	2	3
Ald-VoD	0.0290170	0.004	3	2	2	4	1	2	3
LdD-VoC	0.3066270	0.049	1	2	2	2	4	1	1
MhB-MhE	0.5182217	0.083	1	1	1	4	2	1	1
MhE-VoB	0.8875567	0.142	1	1	1	4	3	1	1
TOTAL	6.2352544								

Very Contrasting, Inceptisol 3

Pairs	Boundary Length	Propn. of TOTAL	CfA	CfB	Fld	DRt	Slo	DPD	TexB	pHA	pHB
MhC-Ms	0.2653282	0.070	3	3	5	4	3	3	2	2	2
MhD-Ms	0.9650749	0.257	3	3	5	4	4	2	2	2	2
Ms-VoB	0.5295076	0.141	3	3	5	4	3	4	2	2	2
Ms-VoC	1.9322078	0.514	3	3	5	4	3	4	2	2	2
Ms-VoD	0.0422016	0.011	3	3	5	4	4	4	2	2	2
Ta-VoB	0.4122501	0.109	3	3	5	4	2	4	1	2	2
Ta-VoC	0.2833282	0.075	3	3	5	4	3	4	1	2	2
TOTAL	3.7523200										

APPENDIX 2

ULTISOLS

APPENDIX 2.1

SOIL PROPERTIES AND CODES OF MAP UNITS OF THE ULTISOL SAMPLES

Map Unit	Soil Properties	Codes		
Appling		ApB	ApC	ApD
	CfA - none	0	0	0
	CfB - none	0	0	0
	Fld - none	0	0	0
	DRt - >40"	0	0	0
	Slo - B, C, D	2.5	5	7.5
	DPD	0	0	0
	drn - well drained			
	perm - moderate			
	EP - none	0	0	0
	SP - none	0	0	0
	TexA - sandy loam	7.5	7.5	7.5
	TexB - clay loam	2.5	2.5	2.5
	pHA - slightly acid, 6.2	4	4	4
	pHB - strongly acid, 5.4	2	2	2
Blaney		BnC		
	CfA - none	0		
	CfB - none	0		
	Fld - none	0		
	DRt - 25"	5		
	Slo - C	5		
	DPD	3		
	drn - well drained			
	perm - slow			
	dlp - 25"			
	EP - none	0		
	SP - none	0		
	TexA - sand	10		
	TexB - sand	10		
	pHA - strongly acid	2		
	pHB - strongly acid	2		
	B is at 12" from the surface			

Cecil	CeB	CeC	CeD
CfA - none	0	0	0
CfB - none	0	0	0
Fld - none	0	0	0
DRt - >40"	0	0	0
Slo - B, C, D	2.5	5	7.5
DPD	0	0	0
drn - well drained			
perm - moderate			
EP - none	0	0	0
SP - none	0	0	0
TexA - sandy loam	7.5	7.5	7.5
TexB - clay	0	0	0
pHA - medium acid, 6.0	3	3	3
pHB - very strongly acid, 5.0	2	2	2

Chenneby	Ch
CfA - none	0
CfB - none	0
Fld - frequent, brief at least once a year	10
DRt - >40"	0
Slo - A	0
DPD	3
drn - somewhat poorly drained	
perm - moderate	
EP - none	0
SP - none	0
TexA - silty clay loam	2.5
TexB - silt loam	5
pHA - strongly acid, 5.5	2
pHB - medium acid, 6.0	3

Dotham	DoB
CfA - none	0
CfB - none	0
Fld - none	0
DRt - >40"	0
Slo - B	2.5
DPD	0
drn - well drained	
perm - moderately slow	
dlp - 33"	
EP - none	0
SP - none	0
TexA - loamy sand	10
TexB - sandy clay loam	2.5
pHA - slightly acid, 6.5	4
pHB - strongly acid, 5.3	2

Enon	EnB	
CfA - none	0	
CfB - none	0	
Fld - none	0	
DRt - 26"	5	
Slo - B	2.5	
DPD	4.5	
drn - well drained		
perm - slow		
dlp - 8"		
EP - none	0	
SP - none	0	
TexA - silt loam	5	
TexB - clay loam	2.5	
pHA - medium acid, 6.0	3	
pHB - neutral, 7.0	5.5	
Fuquay	FaB	FaC
CfA - none	0	0
CfB - none	0	0
Fld - none	0	0
DRt - >40"	0	0
Slo - B, C	2.5	5
DPD	3	3
drn - well drained		
perm - slow		
dlp - 37"		
EP - none	0	
SP - none	0	
TexA - loamy sand	10	
TexB - sandy loam	7.5	
pHA - strongly acid	2	
pHB - very strongly acid	1	
Georgeville	GeB	GeC
CfA - none	0	0
CfB - none	0	0
Fld - none	0	0
DRt - >40"	0	0
Slo - B, C	2.5	5
DPD	0	0
drn - well drained		
perm - moderate		
EP - none	0	0
SP - none	0	0
TexA - sandy loam	7.5	7.5
TexB - clay	0	0
pHA - strongly acid, 5.4	2	2
pHB - strongly acid, 5.5	2	2

Helena	HeB	HeC
CfA - none	0	0
CfB - none	0	0
Fld - none	0	0
DRt - >40"	0	0
Slo - B, C	2.5	5
DPD	4.5	4.5
drn - moderately well drained		
perm - slow		
dlp - 15"		
EP - none	0	0
SP - none	0	0
TexA - sandy loam	7.5	7.5
TexB - clay	0	0
pHA - very strongly acid, 4.5	1	1
pHB - very strongly acid, 4.6	1	1

Mecklenburg	MeC
CfA - none	0
CfB - none	0
Fld - none	0
DRt - 39"	2.5
Slo - C	5
DPD	4.5
drn - well drained	
perm - slow	
dlp - 5"	
EP - none	0
SP - none	0
TexA - silt loam	5
TexB - clay	0
pHA - medium acid, 5.8	3
pHB - slightly acid, 6.5	4

Pelion	PeC
CfA - none	0
CfB - none	0
Fld - none	0
DRt - 39"	2.5
Slo - C	5
DPD	4.5
drn - moderately well drained	
perm - slow	
dlp - 22"	
EP - none	0
SP - none	0
TexA - loamy sand	10
TexB - sandy clay loam	2.5
pHA - medium acid, 5.6	3
pHB - strongly acid, 5.4	2
B is at 11" from the surface	

Toccoa	To
CfA - none	0
CfB - none	0
Fld - frequent	10
DRt - >40"	0
Slo - A	0
DPD	0
drn - well drained	
perm - moderately rapid	
EP - none	0
SP - none	0
TexA - sandy loam	7.5
TexB - sandy loam	7.5
pHA - slightly acid, 6.5	4
pHB - medium acid	3

Troup	TrB
CfA - none	0
CfB - none	0
Fld - none	0
DRt - >40"	0
Slo - B	2.5
DPD	0
drn - somewhat excessively drained	
perm - moderately	
EP - none	0
SP - none	0
TexA - sand	10
TexB - sand	10
pHA - medium acid, 5.8	3
pHB - medium acid, 5.6	3

APPENDIX 2.2

MATRIX OF MAP UNITS OF THE ULTISOL SAMPLES

ULTISOL SAMPLE 1

	ApC	CeB	CeC	CeD	DoB	EnB	GeB	GeC	HeB	HeC	MeC	To
ApB	3S	2S	3SC	1SC	1SC				5C	5C		
ApC		1S		1SC					2C			
ApD		1SC										
CeB			2S	2SC			1SC		3C	3C		1VC
CeC				1S		1C	2S	1S	1C	4C		2VC
CeD									1C	2C		1VC
DoB									1C	1VC		
EnB							1C				1SC	
GeB								1S			1SC	
GeC											1C	
HeB										4S		
HeC												3VC
MeC												1VC

ULTISOL SAMPLE 2

	ApC	ApD	BnC	CeB	CeC	ChC	EnB	FaB	FaC	HeC	PeC	To	TrB
ApB	7S	3SC		2S		2VC	1C	1C		1C			
ApC		3S	2C	4S	1S	3VC		3C	1C		1C	1VC	1C
ApD				2SC	1SC							1VC	
BnC													1VC
CeB					1S			1C		1C		1VC	
CeC													
ChC													
EnB													
FaB									1S				
FaC													
HeC													
PeC													
To													

ULTISOL SAMPLE 3

	ApB	ApC	CeB	CeC
ApB				
ApC	4S			
CeB	3S	3S		
CeC	2SC		5S	
CeD	4SC	4SC	5SC	5S
DoB			1C	

APPENDIX 2.3

RAW DATA FOR THE ULTISOL SAMPLES

Similar, Ultisol 1

Pairs	Boundary Length	Propn. of TOTAL	Slo	TexA	TexB	pHA
ApB-ApC	4.8339050	0.1871	2	1	1	1
ApC-CeB	1.2349130	0.0478	1	1	2	2
ApB-CeC	1.5210966	0.0589	2	1	2	2
ApB-DoB	2.0922110	0.0809	1	2	1	1
ApC-CeB	0.9380442	0.0363	2	1	2	2
ApC-CeD	0.2724791	0.0105	2	1	2	2
CeB-CeC	5.4279990	0.2101	2	1	1	1
CeB-GeB	0.2823914	0.0109	1	1	1	2
CeC-CeD	2.3712160	0.0918	2	1	1	1
CeC-GeB	0.9732299	0.0376	2	1	1	2
CeC-GeC	0.2649234	0.0102	1	1	1	2
GeB-GeC	2.8366300	0.1098	2	1	1	1
HeB-HeC	2.7820727	0.1077	2	1	1	1
TOTAL	25.83111					

Somewhat Contrasting, Ultisol 1

Pairs	Boundary Length	Propn. of TOTAL	DRt	Slo	TexB	pHA	pHB
ApB-CeD	0.2279092	0.0292	1	3	2	2	1
ApD-CeB	0.1458430	0.0186	1	3	2	2	1
CeB-CeD	2.6328130	0.3375	1	3	1	1	1
EnB-MeC	4.7934580	0.6145	2	2	2	1	2
TOTAL	7.800023						

Contrasting, Ultisol 1

Pairs	Boundary Length	Propn. of TOTAL	DRt	Slo	DPD	TexA	TexB	pHA	pHB
ApB-HeB	10.0911380	0.2892	1	1	4	1	2	3	2
ApB-HeC	11.7775440	0.3375	1	2	4	1	2	3	2
ApC-HeB	0.7953405	0.0227	1	2	4	1	2	3	2
CeB-HeB	1.2394487	0.0355	1	1	4	1	1	2	2
CeB-HeC	1.2607530	0.0361	1	2	4	1	1	2	2
CeC-EnB	1.8364090	0.0526	3	2	4	2	2	1	3
CeC-HeB	0.3148955	0.0090	1	2	4	1	1	2	2
CeC-HeC	2.2180992	0.0635	1	1	4	1	1	2	2
CeD-HeB	0.1180588	0.0033	1	3	4	1	1	2	2
CeD-HeC	1.6198028	0.0460	1	2	4	1	1	2	2
DoB-HeB	0.3392446	0.0097	1	1	4	2	2	3	2
DoB-HeC	0.5707455	0.0163	1	2	4	2	2	3	2
EnB-GeB	1.7662780	0.0506	3	1	2	2	2	2	3
GeB-MeC	0.7088014	0.0203	2	2	4	2	1	2	2
GeC-MeC	0.2362200	0.0067	2	1	4	2	2	2	2
TOTAL	34.892778								

Very Contrasting, Ultisol 1

Pairs	Boundary Length	Propn. of TOTAL	Fld	DRt	Slo	DPD	TexA	TexB	pHA	pHB
CeB-To	0.8025108	0.0699	5	1	2	1	1	4	2	2
CeC-To	3.7445050	0.2936	5	1	3	1	1	4	2	2
CeD-To	4.0271480	0.3158	5	1	4	1	1	4	2	2
HeC-To	3.7772944	0.2962	5	1	2	4	2	4	3	2
MeC-To	0.3089399	0.0242	5	2	3	4	2	4	2	2
TOTAL	12.7503985									

Similar, Ultisol 2

Pairs	Boundary Length	Propn. of TOTAL	Slo	TexB	pHA
ApB-ApC	21.5618900	0.6782	2	1	1
ApB-CeB	1.4101651	0.0443	1	2	2
ApC-ApD	0.9777254	0.0307	2	1	1
ApC-CeB	5.1943520	0.1634	2	2	2
ApC-CeC	0.4299668	0.0135	1	2	2
ApD-CeC	0.4837744	0.0152	2	2	2
CeB-CeC	0.6932743	0.0218	2	1	1
FaB-FaC	1.0422270	0.0328	2	1	1
TOTAL	31.793375				

Somewhat Contrasting, Ultisol 2

Pairs	Boundary Length	Propn. of TOTAL	Slo	DPD	TexA	TexB	pHA	pHB
ApB-ApD	10.3856570	0.8436	3	1	1	1	1	1
ApB-FaB	0.3537963	0.0287	1	3	2	3	2	2
ApC-FaC	0.5995739	0.0487	1	3	2	3	2	2
ApD-CeB	0.9714658	0.0789	2	1	1	2	2	1
TOTAL	12.310493							

Contrasting, Ultisol 2

Pairs	Boundary Length	Propn. of TOTAL	DRt	Slo	DPD	TexA	TexB	pHA	pHB
ApB-EnB	1.2184230	0.1736	3	2	4	2	1	2	3
ApB-HeC	0.6436443	0.0917	1	2	4	1	2	3	2
ApC-BnC	0.5914631	0.0843	3	1	3	2	4	2	1
ApC-FaB	0.4712952	0.0672	1	2	3	2	3	2	2
ApC-PeC	0.4440914	0.0633	3	1	4	2	1	2	1
ApC-TrB	2.1833390	0.3112	1	2	1	2	4	2	2
CeB-FaB	0.6121395	0.0872	1	1	3	2	4	2	2
CeB-HeC	0.8520021	0.1214	1	2	4	1	1	2	2
TOTAL	7.0163976								

Very Contrasting, Ultisol 2

Pairs	Boundary Length	Propn. of TOTAL	Fld	Slo	DPD	TexA	TexB	pHA	pHB
ApB-Ch	2.4344917	0.2855	5	2	3	3	2	2	2
ApC-Ch	4.0159617	0.4711	5	3	3	3	2	2	2
ApC-To	0.0427409	0.0051	5	3	1	1	3	1	2
ApD-To	1.5245970	0.1788	5	4	1	1	3	1	2
CeB-TrB	0.2807651	0.0329	1	1	1	2	5	1	2
CeC-To	0.2259227	0.0265	5	3	1	1	4	2	2
TOTAL	8.5244791								

Similar, Ultisol 3

Pairs	Boundary Length	Propn. of TOTAL	Slo	TexB	pHA
ApB-ApC	7.5867530	0.2118	2	1	1
ApB-CeB	2.2628071	0.0631	1	2	2
ApB-CeC	1.0835165	0.0302	2	2	2
ApC-CeB	4.7125208	0.1315	2	2	2
ApC-CeD	3.6130285	0.1008	2	2	2
CeB-CeC	12.3264530	0.3441	2	1	1
CeC-CeD	4.2291533	0.1180	2	1	1
TOTAL	35.814232				

Somewhat Contrasting, Ultisol 3

Pairs	Boundary Length	Propn. of TOTAL	Slo	TexB	pHA
ApB-CeD	5.8512806	0.4320	3	1	1
CeB-CeD	7.6926886	0.5680	3	1	1
TOTAL	13.543969				

Contrasting, Ultisol 3

Pairs	Boundary Length	Propn. of TOTAL	TexA	TexB	pHA	pHB
CeB-DoB	1.0729840	1.0000	2	4	1	1

APPENDIX 3

ALFISOLS

APPENDIX 3.1

SOIL PROPERTIES AND CODES OF MAP UNITS OF THE ALFISOL SAMPLES

Map Unit	Soil Properties	Codes		
Boone		BnC	BnE	
	CfA - none	0	0	
	CfB - 12%	2.5	2.5	
	Fld - none	0	0	
	DRt - >40", 35"	0	2.5	
	Slo - C, E	5	10	
	DPD	0	0	
	drn - excessively drained			
	perm - rapid			
	EP - none	0	0	
	SP - none	0	0	
	TexA - loamy fine sand	10	10	
	TexB - fine sand	10	10	
	pHA - slightly acid	4	4	
	pHB - slightly acid	4	4	
Boyer		BpB	BPC2	BrB
	CfA - none	0	0	0
	CfB - none	0	0	0
	Fld - none	0	0	0
	DRt - 32"	2.5	2.5	2.5
	Slo - B, C, B	2.5	5	2.5
	DPD	0	0	0
	drn - well drained			
	perm - moderately rapid			
	EP - none, moderate, none	0	3	0
	SP - none	0	0	0
	TexA - loamy sand	10	10	10
	TexB - loamy sand	10	10	10
	pHA - mildly alkaline	7.5	7.5	7.5
	pHB - neutral	5.5	5.5	5.5

Channahon	CaB	CaC2	CaE2
CfA - none	0	0	0
CfB - none	0	0	0
Fld - none	0	0	0
DRt - 16"	7.5	7.5	7.5
Slo - B, C, E	2.5	5	10
DPD	0	0	0
drn - well drained			
perm - moderate			
EP - none, moderate, moderate	0	3	3
SP - none	0	0	0
TexA - loamy sand	10	10	10
TexB - sand	10	10	10
pHA - moderately alkaline	7.5	7.5	7.5
pHB - moderately alkaline	7.5	7.5	7.5
B is at 8" from the surface			

Chelsea	ChC
CfA - none	0
CfB - none	0
Fld - none	0
DRt - >40	0
Slo - C	5
DpD	0
drn - excessively drained	
perm - rapid	
EP - none	0
SP - none	0
TexA - loamy sand	10
TexB - sand	10
pHA - slightly acid	4
pHB - neutral	5.5

Dresden	DrB
CfA - none	0
CfB - gravelly	5
Fld - none	0
DRt - 26"	5
Slo - B	2.5
DPD	0
drn-well drained	
perm - moderate	
EP - none	0
SP - none	0
TexA - loam	5
TexB - sandy clay loam	2.5
pHA - neutral	5.5
pHB - neutral	5.5

Friesland		FrB	
	CfA - none	0	
	CfB - none	0	
	Fld - none	0	
	DRt - >45"	0	
	Slo - B	2.5	
	DPD	0	
	drn - moderately well drained		
	perm - moderate		
	EP - none	0	
	SP - none	0	
	TexA - sandy loam	7.5	
	TexB - sandy loam	7.5	
	pHA - slightly acid	4	
	pHB - medium acid	3	
Gilford		GaA	
	CfA - none	0	
	CfB - none	0	
	Fld - none	0	
	DRt - >40 "	0	
	Slo - A	0	
	DPD	3	
	drn - poorly drained		
	perm - moderate		
	EP - none	0	
	SP - none	0	
	TexA - sandy loam	7.5	
	TexB - sandy loam	7.5	
	pHA - mildly alkaline		7.5
	pHB - mildly alkaline		7.5
Granby		Gb	
	CfA - none	0	
	CfB - none	0	
	Fld - occasional at growing season	8	
	DRt - >40"	0	
	Slo - A	0	
	DPD	3	
	drn - poorly drained		
	perm - rapid		
	EP - none	0	
	SP - none	0	
	TexA - loamy sand	10	
	TexB - sand	10	
	pHA - slightly acid	4	
	pHB - neutral	5.5	

Grellton	GeB
CfA - none	0
CfB - none	0
Fld - none	0
DRt - >40"	0
Slo - B	2.5
DPD	0
drn - well drained	
perm - moderate	
EP - none	0
SP - none	0
TexA - sandy loam	7.5
TexB - silty loam	5
pHA - slightly acid	4
pHB - medium acid	3

Griswold	GrB2
CfA - none	0
CfB - 5%	2.5
Fld - none	0
DRt - >40"	0
Slo - B	2.5
DPD	0
drn - well drained	
perm - moderate	
EP - moderate	3
SP - none	0
TexA - silt loam	5
TexB - sandy clay loam	2.5
pHA - neutral	5.5
pHB - slightly acid	4

Kibbie	KbA
CfA - none	0
CfB - none	0
Fld - none	0
DRt - >40"	0
Slo - A	0
DPD	3
drn - somewhat poorly drained	
perm - moderate	
EP - none	0
SP - none	0
TexA - sandy loam	7.5
TexB - loam	5
pHA - neutral	5.5
pHB - mildly alkaline	7.5

Lapeer	LaB	LaC2	LaD2	LaE2
CfA - none	0	0	0	0
CfB - 10% gravel	2.5	2.5	2.5	2.5
Fld - none	0	0	0	0
DRt - >40"	0	0	0	0
Slo - B, C, D, E	2.5	5.0	7.5	10
DPD	0	0	0	0
drn - well drained				
perm - moderate				
EP - none, moderate, moderate, moderate	0	3	3	3
SP - none	0	0	0	0
TexA - sandy loam	7.5	7.5	7.5	7.5
TexB - sandy loam	7.5	7.5	7.5	7.5
pHA - slightly acid	4	4	4	4
pHB - slightly acid	4	4	4	4

Military	MnB	MnC2	MnD2
CfA - none	0	0	0
CfB - 8% gravel	2.5	2.5	2.5
Fld - none	0	0	0
DRt - 25"	5	5	5
Slo - B, C, D	2.5	5.0	7.5
DPD	0	0	0
drn - well draine			
perm - moderate			
EP - none, moderate, moderate	0	3	3
SP - none	0	0	0
TexA - sandy loam	7.5	7.5	7.5
TexB - sandy loam	7.5	7.5	7.5
pHA - slightly acid	4	4	4
pHB - moderately acid	3	3	3

Morocco	MoA
CfA - none	0
CfB - none	0
Fld - none	0
DRt - >40"	0
Slo - A	0
DPD	3
drn - somewhat poorly drained	
perm - rapid	
EP - none	0
SP - none	0
TexA - loamy sand	10
TexB - sand	10
pHA - slightly acid	4
pHB -medium acid	3

Northfield	NoB	NoC
CfA - none	0	0
CfB - none	0	0
Fld - none	0	0
DRt - 18"	7.5	7.5
Slo - B, C	2.5	5
DPD	0	0
drn - well drained		
perm - moderate		
EP - none	0	0
SP - none	0	0
TexA - sandy loam	7.5	7.5
TexB - sandy clay loam	2.5	2.5
pHA - strongly acid	2	2
pHB - medium acid	3	3

Okee	OkB	OkC
CfA - none	0	0
CfB - 10 %	2.5	2.5
Fld - none	0	0
DRt - >40"	0	0
Slo - B, C	2.5	5
DPD	0	0
drn - well drained		
perm - moderate		
EP - none	0	0
SP - none	0	0
TexA - loamy sand	10	10
TexB - sandy clay loam	2.5	2.5
pHA - neutral	5.5	5.5
pHB - medium acid	3	3

Oshtemo	OmB
CfA - none	0
CfB - 5 %	2.5
Fld - none	0
DRt - >40"	0
Slo - B	2.5
DPD	0
drn - well drained	
perm - rapid	
EP - none	0
SP - none	0
TexA - loamy sand	10
TexB - sandy loam	7.5
pHA - neutral	5.5
pHB -medium acid	3

Otter	Ot	
CfA - none	0	
CfB - none	0	
Fld - frequent at growing season	10	
DRt - >40"	0	
Slo - A	0	
DPD	3	
drn - poorly drained		
perm - moderate		
EP - none	0	
SP - none	0	
TexA - sandy loam	5	
TexB - sandy clay loam	2.5	
pHA - mildly alkaline	7.5	
pHB - mildly alkaline	7.5	
Plainfield	PfB	PkB
CfA - none	0	0
CfB - none	0	0
Fld - none	0	0
DRt - >40"	0	0
Slo - B, B	2.5	2.5
DPD	0	0
drn - excessively drained		
perm - rapid		
EP - none	0	0
SP - none	0	0
TexA - loamy sand	10	10
TexB - sand	10	10
pHA - neutral	5.5	5.5
pHB - slightly acid	4	4
Puchyan	PuB	PuC
CfA - none	0	0
CfB - none	0	0
Fld - none	0	0
DRt - >40"	0	0
Slo - B, C	2.5	5
DPD	0	0
drn - well drained		
perm - moderate		
EP - none	0	0
SP - none	0	0
TexA - loamy sand	10	10
TexB - sand	10	10
pHA - mild alkaline	7.5	7.5
pHB - neutral	5.5	5.5

Rodman	RoD	
CfA - gravelly	5	
CfB - very gravelly	7.5	
Fld - none	0	
DRt - 7"	7.5	
Slo - D	7.5	
DPD	0	
drn - excessively drained		
perm- very rapid		
EP - none	0	
SP - none	0	
TexA - loam	5	
TexB - loam	5	
pHA - neutral	5.5	
pHB - mildly alkaline	7.5	
Salter, dark surface variant	ScB	
CfA - none	0	
CfB - none	0	
Fld - none	0	
DRt - >40"	0	
Slo - B	2.5	
DPD	0	
drn - well drained		
perm - moderate		
EP - none	0	
SP - none	0	
TexA - sandy loam	7.5	
TexB - sandy loam	7.5	
pHA - neutral	5.5	
pHB - slightly acid	4	
Salter	SbA	SbB
CfA - none	0	0
CfB - none	0	0
Fld - none	0	0
DRt - >40"	0	0
Slo - A, B	0	2.5
DPD	0	0
drn - well drained		
perm - moderate		
EP - none	0	0
SP - none	0	0
TexA - sandy loam	7.5	7.5
TexB - sandy loam	7.5	7.5
pHA - medium acid	3	3
pHB - medium acid	3	3

Sisson	SnA	SnB	SnC2	SnD2
CfA - none	0	0	0	0
CfB - none	0	0	0	0
Fld - none	0	0	0	0
DRt - >40"	0	0	0	0
Slo - A, B, C, D	0	2.5	5	7.5
DPD	0	0	0	0
drn - well drained				
perm - moderate				
EP - N, N, M, M	0	0	3	3
SP - none	0	0	0	0
TexA - sandy loam	7.5	7.5	7.5	7.5
TexB - loam	5	5	5	5
pHA - slightly acid	4	4	4	4
pHB - strongly acid	2	2	2	2

Winneshiek	WnB	WnC2
CfA - none	0	0
CfB - 10%	2.5	2.5
FlD - none	0	0
DRt - 33"		
Slo - B, C	2.5	5
DPD	0	0
drn - well drained		
perm - moderate		
EP - N, M	0	3
SP - none	0	0
TexA - sandy loam	7.5	7.5
TexB - sandy clay loam	2.5	2.5
pHA - slightly acid	4	4
pHB - slightly acid	4	4

Wyocena	WoB	WoE
CfA - 2%	0	0
CfB - 10%	2.5	2.5
Fld - none	0	0
DRt - >40"	0	0
Slo - B, E	2.5	10
DPD	0	0
drn - well drained		
perm - moderately rapid		
EP - none, none	0	0
SP - none, none	0	0
TexA - loamy sand	10	10
TexB - loamy sand	10	10
pHA - slightly acid	4	4
pHB - neutral	5.5	5.5

Wyocena	WxB	WxC2	WxD2	WyB	WyC2	WyD2	WyE
CfA - 2%	0	0	0	0	0	0	0
CfB - 10%	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Fld - none	0	0	0	0	0	0	0
DRt - >40"	0	0	0	0	0	0	0
Slo - B, C, D, B, C, D, E	2.5	5	7.5	2.5	5	7.5	10
DPD	0	0	0	0	0	0	0
drn - well drained							
perm - moderately rapid							
EP - N, M, M, N, M, M, N	0	3	3	0	3	3	0
SP - none	0	0	0	0	0	0	0
TexA - sandy loam	7.5	7.5	7.5	7.5	7.5	7.5	7.5
TexB - sandy loam	7.5	7.5	7.5	7.5	7.5	7.5	7.5
pHA - slightly acid	4	4	4	4	4	4	4
pHB - neutral	5.5	5.5	5.5	5.5	5.5	5.5	5.5

Yahara	YaA
CfA - none	0
CfB - none	0
Fld - occasional at growing season	8
DRt - >40"	0
Slo - A	0
DPD	3
drn - somewhat poorly drained	
perm - moderate	
EP - none	0
SP - none	0
TexA - sandy loam	7.5
TexB - sandy loam	7.5
pHA - neutral	5.5
pHB - medium acid	3

APPENDIX 3.2

MATRIX OF MAP UNITS OF THE ALFISOL SAMPLES

ALFISOL SAMPLE 1

	Ae	BnC	BnE	DrB	LaB	LaC2	LaD2	MnB	MnC2	MnD2	NoB	OkC	OmB	PfB
Ae	1EC													
BnC														
BnE														
DrB														
LaB														
LaC2				2C	9S									
LaD2					1SC	2S								
MnB					3SC	1SC								
MnC2		1SC			1SC	1SC		2S						
MnD2														
NoB								1SC						
NoC					1C									
OkC									1SC					
OmB				1C		1SC	1SC							
PfB					1SC			1SC				1C		
PuB					1SC	1SC			1SC					
PuC					1SC	1SC	1SC							1SC
PkB						1SC								
Rk										1EC				
SbA														1SC
SbB								1SC						
ScB														
SnA				1C	1SC	1SC			1C			1SC		1SC
SnB				1SC	1S	1SC								1SC
WoB							1SC							
WxB				1SC										
WxC2										1SC				
WxD2														
WyB		1SC	2C	1SC	9S	5S		6SC	3SC	4SC			2S	
WyC2		1SC		1C	12S	6S	1S	6SC	3SC	2SC			1SC	1SC
WyD2					1SC			2SC	1SC	1SC	1C			1SC

ALFISOL SAMPLE 1 (CONT'D)

	PkB	Rk	RoD	SbA	SbB	ScB	SnA	SnB	WoB	WxB	WxC2	WxD2	WyB	WyC2
PuC	2SC													
PkB														
Rk														
SbA														
SbB														
ScB														
SnA				1S										
SnB				1SC			1S							
WoB														
WxB								1S						
WxC2								1SC		1S				
WxD2														
WyB		1EC	1VC		2S	1S		3SC	1S	1VS		1SC		
WyC2		2EC	1VC		3SC		1SC	3SC	1SC		1VS		18S	
WyD2		1EC							1SC		1S		3SC	6S

ALFISOL SAMPLE 2

	BnC	BpB	BrB	ChC	GaA	LaB	LaC2	LaD2	LaE2	Mb	MnC2	MnD2	OkB	OkC
BnC														
BpB														
BrB														
ChC														
GaA														
LaB					2C									
LaC2			1SC			5S								
LaD2		1C	2C	2SC		11SC	12S							
LaE2							2SC	3S						
Mb					1EC									
MnC2						1SC	1SC	3SC						
MnD2						2SC		3SC			2S			
OkB						2SC	2SC							
OkC				2C		2SC	2SC	3SC					1S	
PkB				1S		1S	1SC	2SC						2C
PkC														
Rk						1EC							1EC	
SbB			1SC			1S		3SC	1C					
SnC2								1SC						
SnD2								1S						
WoB	1S				1SC	2S					1SC		1C	2C
WxB					1SC	1S	2S	2SC		1EC			1SC	
WxC2						1S		1S					1SC	
WxD2						1SC		2SC					1SC	
WyB	2SC					1S		3SC			2SC	1C	1SC	
WyC2	2SC						2S		1SC		2SC	1SC	1SC	
WyD2						1SC		2S				1SC		
WyE			1C			1C	3SC	3S	1S					

	PkB	PkC	WoB	WxB	WxC2	WyB	WyC2
Rk	2EC	1EC					
SbB							
SnC2							
SnD2							
WoB	1S						
WxB							
WxC2			1SC				
WxD2			1SC	1SC	1S		
WyB			2S				
WyC2			1SC			5S	
WyD2						1SC	1S
WyE	1C					1C	2SC

ALFISOL SAMPLE 3

	Ag	BbA	BnC	BnE	BpB	BpC2	CaC2	CaE2	FrB	GaA	Gb	GeB	GrB2	KbA
Ag														
BbA														
BnC														
BnE			1SC											
BpB	3EC			1C										
BpC2				1SC	2S									
CaB				1C										
CaE2				2C			1SC							
FrB														
GaA		1SC												
Gb	1EC				1VC					5VC				
GeB														
GrB2									2C					
KbA										1S				
LaB			1S	2SC				3VC	2S	4C	2VC	2S	1SC	1SC
LaC2	1EC		1S		1SC		1C	4C						
LaD2	1EC			1SC	2C	1SC		1C						
Mb										5EC	3EC			
MnC2														
MnD2				1SC										
MaB														
MoA	1EC										1VC			
OkB					1C				2SC	1C	1VC			
OmB					2SC	1SC								
Ot														
Rk				2EC			1EC							
SnA														
Swamp														
WnB														
WnC2								3C						
WoE														
WxC2					2SC									
WyC2			1SC	4SC										
WyE			1SC	2SC	1C									
YaA										2VC	1SC			

ALFISOL SAMPLE 3 (CONT'D)

	LaB	LaD2	MaB	MnC2	OmB	Rk	Swamp	WnB	WyC2
LaC2	24S								
LaD2	1SC								
Mb			1EC				1EC		
MnC2	2SC	1SC							
MnD2	3SC			1S					
MaB									
MoA									
OkB	4SC								
OmB					1VC				
Ot									
Rk									
SnA	1S								
Swamp									
WnB									
WnC2								3S	
WoE	1C								
WxC2		1SC							
WyC2	2SC					2EC			
WyE						1EC			3SC
YaA									

APPENDIX 3.3

RAW DATA FOR THE ALFISOL SAMPLES

Very Similar, Alfisol 1

Pairs	Boundary Length	Propn. of TOTAL
WxB-WyB	0.1235029	0.4642
WxC2-WyC2	0.1425425	0.5358
TOTAL	0.2660454	

Similar, Alfisol 1

Pairs	Boundary Length	Propn. of TOTAL	CfB	Slo	EP	TexA	TexB	pHA	pHB
LaB-Lac2	7.8541034	0.0951	1	2	2	1	1	1	1
LaB-SnB	0.9563578	0.116	2	1	1	1	2	1	2
LaB-WyB	10.3351760	0.1251	1	1	1	1	1	1	2
LaB-WyC2	14.1545050	0.1714	1	2	2	1	1	1	2
LaC2-LaD2	1.3245652	0.0160	1	2	1	1	1	1	1
LaC2-WyB	3.0712781	0.0372	1	2	2	1	1	1	2
LaC2-WyC2	2.6528220	0.0321	1	1	1	1	1	1	2
LaD2-WyC2	0.2424293	0.0029	1	2	1	1	1	1	2
MnB-MnC2	1.3785752	0.0167	1	2	2	1	1	1	1
OmB-WyB	1.2196046	0.0148	1	1	1	2	1	2	2
SbA-SnA	0.4949235	0.0060	1	1	1	1	2	2	2
SbB-WyB	4.5163311	0.0547	2	1	1	1	1	2	2
ScB-WyB	1.3312090	0.0161	2	1	1	1	1	2	2
SnA-SnB	0.4282008	0.0052	1	2	1	1	1	1	1
SnB-WxB	0.2835616	0.0034	2	1	1	1	2	1	2
WoB-WyB	0.9634698	0.0117	1	1	1	2	2	1	1
WxB-WxC2	0.3156300	0.0038	1	2	2	1	1	1	1
WxC2-WyD2	0.2883019	0.0035	1	2	1	1	1	1	1
WyB-WyC2	26.9892980	0.3268	1	2	2	1	1	1	1
WyC2-WyD2	3.7893051	0.0459	1	2	1	1	1	1	1
TOTAL	82.5896474								

Somewhat Contrasting, Alfisol 1

Pairs	Boundary Length	Propn. of TOTAL	CfB	DRt	Slo	DPD	EP	TexA	TexB	pHA	pHB
BnC-MnC2	0.7064440	0.0144	1	3	1	1	2	2	2	1	2
BnC-WyB	1.1194070	0.0229	1	1	2	1	1	2	2	1	2
BnC-WyC2	0.6842028	0.0140	1	1	1	1	2	2	2	1	2
DrB-SnB	0.1195756	0.0024	2	3	1	1	1	2	2	1	3
DrB-WxB	0.3388983	0.0069	1	3	1	1	1	2	3	2	1
DrB-WyB	0.2814989	0.0058	1	3	1	1	1	2	3	2	1
LaB-LaD2	0.614126	0.0012	1	1	3	1	2	1	1	1	1
LaB-MnB	2.4950109	0.0510	1	3	1	1	1	1	1	1	2
LaB-MnC2	0.2667256	0.0054	1	3	2	1	2	1	1	1	2
LaB-PfB	0.1682707	0.0034	2	1	1	1	1	2	2	2	1
LaB-PuB	0.4438678	0.0091	2	1	1	1	1	2	1	3	2
LaB-PuC	0.3220439	0.0066	2	1	2	1	1	2	1	3	2
LaB-SnA	0.0850512	0.0017	2	1	2	1	1	1	2	1	2
LaB-WyD2	0.2846859	0.0058	1	1	3	1	2	1	1	1	2
LaC2-MnB	0.8216311	0.0168	1	3	2	1	2	1	1	1	2
LaC2-MnC2	0.0924335	0.0019	1	3	1	1	1	1	1	1	2
LaC2-OmB	0.4899274	0.0100	1	1	2	1	2	2	1	2	2
LaC2-PkB	0.0592438	0.0012	2	1	2	1	2	2	2	2	1
LaC2-PuB	0.9446792	0.0193	2	1	2	1	2	2	1	3	2
LaC2-PuC	0.3702812	0.0076	2	1	1	1	2	2	1	3	2
LaC2-SnA	0.2980685	0.0061	1	1	3	1	2	1	2	1	2
LaC2-SnB	0.2428597	0.0050	1	1	2	1	2	1	2	1	2
LaD2-OmB	0.5422396	0.0111	1	1	3	1	2	2	1	2	2
LaD2-PuC	0 1024123	0.0021	1	1	2	1	2	2	1	3	2
LaD2-WoB	0.6944394	0.0142	1	1	3	1	2	2	2	1	2
MnB-NoB	1.4879870	0.0304	2	2	1	1	1	1	3	2	1
MnB-PfB	0.1001257	0.0020	2	3	1	1	1	2	2	2	2
MnB-SbB	0.0268330	0.0006	2	3	1	1	1	1	1	2	2
MnB-WyB	6.4080360	0.1309	1	3	1	1	1	1	1	1	2
MnB-WyC2	3.9473068	0.0806	1	3	2	1	2	1	1	1	2
MnB-WyD2	0.6273418	0.0128	1	3	3	1	2	1	1	1	2
MnC2-OkC	0.4063805	0.0083	1	3	1	1	2	2	3	2	1
MnC2-PuB	0.5940545	0.0121	2	3	2	1	2	2	2	2	2
MnC2-WyB	3.9612864	0.0809	1	3	2	1	2	1	1	1	2
MnC2-WyC2	0.7789019	0.0159	1	3	1	1	1	1	1	1	2
MnC2-WyD2	1.1916990	0.0243	1	3	2	1	1	1	1	1	2
MnD2-WxC2	0.1105911	0.0023	1	3	2	1	1	2	2	1	2
MnD2-WyB	3.8415675	0.0785	1	3	3	1	2	1	1	1	2
MnD2-WyC2	0.8962616	0.0183	1	3	2	1	1	1	1	1	2
MnD2-WyD2	0.2080269	0.0042	1	3	1	1	1	1	1	1	2
OkC-SnA	0.1145316	0.0023	2	1	3	1	1	2	2	2	2
OmB-WyC2	0.1186975	0.0024	1	1	2	1	2	2	1	2	2
PfB-PuC	0.5810852	0.0119	1	1	2	1	1	1	2	2	2
PfB-SbA	0.1569560	0.0032	1	1	2	1	1	2	2	2	2
PfB-SnA	0.5494093	0.0112	1	1	2	1	1	2	3	2	2
PfB-SnB	0.3281167	0.0067	1	1	1	1	1	2	3	2	2

Somewhat Contrasting, Alfisol 1, continued

PfB-WyC2	0.3546435	0.0072	2	1	2	1	2	1	1	2	2
PfB-WyD2	0.0418688	0.0009	2	1	3	1	1	1	1	2	2
PkB-PuC	1.7498505	0.0357	1	1	2	1	1	1	2	2	2
SbA-SnB	0.1164149	0.0024	1	1	1	1	1	2	3	2	2
SbB-WyC2	2.4263445	0.0496	2	1	2	1	2	1	1	2	2
SnA-WyC2	0.1160133	0.0024	2	1	3	1	2	1	2	1	3
SnB-WxC2	0.5997081	0.0122	2	1	2	1	2	1	2	1	2
SnB-WyB	1.5011547	0.0307	2	1	1	1	1	1	2	1	3
SnB-WyC2	0.9744041	0.0199	2	1	2	1	2	1	2	1	3
WoB-WyC2	0.1782686	0.0036	1	1	2	1	2	2	2	1	1
WoB-WyD2	0.3938875	0.0080	1	1	3	1	2	2	2	1	1
WxD2-WyB	1.0689980	0.0218	1	1	3	1	2	1	1	1	1
WyB-WyD2	0.9667248	0.0197	1	1	3	1	2	1	1	1	1

TOTAL 48.958788

Contrasting, Alfisol 1

Pairs	Boundary Length	Propn. of TOTAL	CfB	DRt	Slo	EP	TexA	TexB	pHA	pHB
BnE-WyB	3.0965882	0.3637	1	2	4	2	2	2	2	2
DrB-LaC2	0.2905066	0.0341	2	3	2	1	2	3	1	2
DrB-OmB	1.0743980	0.1262	2	3	1	1	3	3	1	2
DrB-SnA	0.8731081	0.1026	2	3	2	1	2	2	1	3
DrB-WyC2	0.6527386	0.0767	1	3	2	2	2	3	2	1
LaB-NoC	0.7300343	0.0857	2	4	2	1	1	3	2	2
MnC2-SnA	0.4841222	0.0569	2	3	3	2	1	2	1	2
NoB-WyD2	1.2335520	0.1449	1	4	3	2	1	2	2	2
OkC-PfB	0.0787372	0.0092	2	1	2	1	1	4	1	2
TOTAL	8.5137852									

Very Contrasting, Alfisol 1

Pairs	Boundary Length	Propn. of TOTAL	CfA	CfB	DRt	Slo	EP	TexA	TexB	pHA	pHB
RoD-WyB	0.3533860	0.353	3	3	5	3	1	2	2	2	2
RoD-WyC2	0.6469390	0.647	3	3	5	2	2	2	2	2	2
TOTAL	1.0003250										

Exceedingly Contrasting, Alfisol 1

Pairs	Boundary Length	Propn. of TOTAL
Ae-LaB	2.3453420	0.340
MnD2-Rk	1.2915160	0.187
Rk-WyB	0.3770278	0.055
Rk-WyC2	2.7779849	0.402
Rk-WyD2	0.1094835	0.016
TOTAL	6.9013542	

Similar, Alfisol 2

Pairs	Boundary Length	Propn. of TOTAL	CfB	Slo	EP	TexA	TexB	pHA	pHB
BnC-WoB	0.3737280	0.0073	1	2	1	1	1	1	2
ChC-PkB	0.1957191	0.0038	1	2	1	1	1	2	2
LaB-LaC2	11.6014870	0.2263	1	2	2	1	1	1	1
LaB-PkB	0.1467409	0.0029	1	1	1	2	2	2	1
LaB-SbB	0.2964566	0.0058	1	1	1	1	1	2	2
LaB-WoB	2.0292145	0.0396	1	1	1	2	2	1	2
LaB-WxB	0.1711899	0.0033	1	1	1	1	1	1	2
LaB-WxC2	1.4460370	0.0282	1	2	2	1	1	1	2
LaB-WyB	0.0691811	0.0013	1	1	1	1	1	1	2
LaC2-LaD2	16.2771580	0.3175	1	2	1	1	1	1	1
LaC2-WxB	0.9295805	0.0181	1	2	2	1	1	1	2
LaC2-WyC2	0.9214070	0.0180	1	1	1	1	1	1	2
LaD2-LaE2	0.6363899	0.0124	1	2	1	1	1	1	1
LaD2-SnD2	0.2187015	0.0043	2	1	1	1	2	1	2
LaD2-WxC2	0.3921782	0.0076	1	2	1	1	1	1	2
LaD2-WxD2	0.2181199	0.0043	1	1	1	1	1	1	2
LaD2-WyD2	1.1937245	0.0233	1	1	1	1	1	1	2
LaD2-WyE	5.4511393	0.1063	1	2	2	1	1	1	2
LaE2-WyE	0.4474522	0.0087	1	1	2	1	1	1	2
MnC2-MnD2	0.4870388	0.0095	1	2	1	1	1	1	1
OkB-OkC	2.5349560	0.0494	1	2	1	1	1	1	1
PkB-WoB	0.2123425	0.0041	2	1	1	1	1	2	2
WoB-WyB	1.3481386	0.0263	1	1	1	2	2	1	1
WxC2-WxD2	0.2859147	0.0056	1	2	1	1	1	1	1
WyB-WyC2	2.6956142	0.0526	1	2	1	2	1	1	1
WyC2-WyD2	0.6860868	0.0134	1	2	1	1	1	1	1

TOTAL 51.265697

Somewhat contrasting, Alfisol 2

Pairs	Boundary Length	PropNn. of TOTAL	CfB	DRt	Slo	DPD	EP	TexA	TexB	pHA	pHB
BnC-WyB	0.7135935	0.0132	1	1	2	1	1	2	2	1	2
BnC-WyC2	0.4131451	0.0076	1	1	1	1	2	2	2	1	2
BrB-LaC2	0.2903405	0.0054	2	2	2	1	2	2	2	3	2
BrB-SbB	0.0670766	0.0012	1	2	1	1	1	2	2	3	2
ChC-LaD2	0.6856598	0.0127	1	1	2	1	2	2	2	1	2
GaA-WxB	0.2610059	0.0048	2	1	2	3	1	1	1	3	2
LaB-LaD2	9.7452062	0.1800	1	1	3	1	2	1	1	1	1
LaB-MnC2	1.2137920	0.0224	1	3	2	1	2	1	1	1	2
LaB-MnD2	0.7385466	0.0136	1	3	3	1	2	1	1	1	2
LaB-OkB	2.0944984	0.0387	1	1	1	1	1	2	3	2	2
LaB-OkC	1.4674090	0.0271	1	1	2	1	1	2	3	2	2
LaB-WxD2	1.2724830	0.0235	1	1	3	1	2	1	1	1	2
LaB-WyD2	1.1567450	0.0214	1	1	3	1	2	1	1	1	2
LaC2-LaE2	1.1411104	0.0211	1	1	3	1	1	1	1	1	1
LaC2-MnC2	0.6118300	0.0113	1	3	1	1	1	1	1	1	2
LaC2-OkB	1.6971935	0.0313	1	1	2	1	2	2	3	2	2
LaC2-OkC	0.7459055	0.0138	1	1	1	1	2	2	3	2	2
LaC2-PkB	0.0661890	0.0012	1	1	2	1	2	2	2	2	1
LaC2-WyE	0.8140427	0.0150	1	1	3	1	2	1	1	1	2
LaD2-MnC2	1.1219585	0.0207	1	3	2	1	1	1	1	1	2
LaD2-MnD2	0.9991922	0.0184	1	3	1	1	1	1	1	1	2
LaD2-OkC	4.0578939	0.0749	1	1	2	1	2	2	3	1	1
LaD2-PkB	0.7752712	0.0143	1	1	3	1	2	2	2	2	1
LaD2-SbB	2.3892700	0.0441	1	1	3	1	2	1	1	2	2
LaD2-SnC2	0.1869358	0.0034	2	1	2	1	1	1	2	1	2
LaD2-WxB	2.5396046	0.0469	1	1	3	1	2	1	1	1	2
LaD2-WyB	1.4488293	0.0268	1	1	3	1	2	1	1	1	2
LaE2-WyC2	0.5058497	0.0093	1	1	3	1	1	1	1	1	2
MnC2-WoB	0.1782229	0.0033	1	3	2	1	2	2	2	1	2
MnC2-WyB	1.7214272	0.0318	1	3	2	1	2	1	1	1	2
MnC2-WyC2	0.6754353	0.0125	1	3	1	1	1	1	1	1	2
MnD2-WyB	0.7082675	0.0131	1	3	3	1	2	1	1	1	2
MnD2-WyC2	0.8005373	0.0148	1	3	2	1	1	1	1	1	2
MnD2-WyD2	0.3230957	0.0060	1	3	1	1	1	1	1	1	2
OkB-WxB	0.4542734	0.0083	1	1	1	1	1	2	3	2	2
OkB-WyB	0.3224477	0.0060	1	1	1	1	1	2	3	2	2
OkB-WxC2	1.1156770	0.0206	1	1	2	1	2	2	3	2	2
OkB-WyC2	0.7334918	0.0135	1	1	2	1	2	2	3	2	2
OkB-WxD2	0.3189468	0.0059	1	1	3	1	2	2	3	2	2
WoB-WxC2	1.217492	0.0225	1	1	2	1	2	2	2	1	1
WoB-WxD2	1.3524680	0.0250	1	1	3	1	2	2	2	1	1
WoB-WyC2	1.1397510	0.0210	1	1	2	1	2	2	2	1	1
WxB-WxD2	1.9185900	0.0354	1	1	3	1	2	1	1	1	1
WyB-WyD2	0.4474598	0.0083	1	1	3	1	2	1	1	1	1
WyC2-WyE	1.5003299	0.0277	1	2	1	1	2	2	2	3	1
TOTAL	54.148491										

Contrasting, Alfisol 2

Pairs	Boundary Length	Propn. of TOTAL	CfA	CfB	DRt	Slo	DPD	EP	TexA	TexB	pHA	pHB
BpB-LaD2	0.2937252	0.0364	1	1	2	3	1	2	2	2	3	2
BrB-LaD2	1.4316711	0.1777	1	1	2	3	1	1	2	2	3	2
BrB-WyE	0.6950790	0.0863	1	2	2	4	1	2	2	2	3	1
ChC-OkC	0.4430890	0.0550	1	2	1	1	1	1	1	4	2	2
GaA-LaB	0.0780557	0.0097	1	1	1	2	3	1	1	1	3	3
GaA-WoB	0.2753149	0.0342	1	2	1	2	3	1	2	2	3	2
LaB-WyE	0.3116269	0.0387	1	1	1	4	1	1	1	1	1	2
LaE2-SbB	0.7972721	0.0990	1	1	1	4	1	2	1	1	2	2
OkB-WoB	0.1265101	0.0157	1	1	1	1	1	1	1	4	2	2
OkB-WxD2	0.6955590	0.0863	1	1	1	3	1	2	2	3	2	2
OkC-PkB	0.8589135	0.1066	1	1	1	2	1	1	1	4	1	2
OkC-WoB	0.9930635	0.1233	1	1	1	2	1	1	1	4	2	2
PkB-WyE	0.9577155	0.1189	2	1	1	4	1	1	2	2	2	2
WyB-WyE	0.0990406	0.0123	1	1	1	4	1	1	1	1	1	1
TOTAL	8.0566361											

Exceedingly Contrasting, Alfisol 2

Pairs	Boundary Length	Propn. of TOTAL
GaA-Mb	1.2815200	0.290
LaB-Rk	0.2881070	0.065
Mb-WxB	0.2745407	0.062
OkB-Rk	0.3610752	0.082
PkB-Rk	1.4682375	0.333
PkC-Rk	0.3356083	0.076
Rk-WxD2	0.4141835	0.094
TOTAL	4.4232723	

Similar, Alfisol 3

Pairs	Boundary Length	Propn. of TOTAL	CfA	Slo	EP	TexB	pHA	pHB
BnC-LaB	0.3106220	0.0040	1	2	1	2	1	1
BnC-LaC2	0.4418559	0.0057	1	1	2	2	1	1
BpB-BpC2	2.9275580	0.0378	1	2	2	1	1	1
FrB-LaB	1.1631571	0.0150	1	1	1	1	1	2
GaA-KbA	0.9885232	0.0128	1	1	1	2	2	1
GeB-LaB	6.7660930	0.0875	1	1	1	2	1	2
LaB-LaC2	51.9288230	0.6713	1	2	2	1	1	1
LaB-SnA	2.7067960	0.035	1	2	1	2	1	2
LaC2-LaD2	4.3038260	0.0556	1	2	1	1	1	1
LaC2-WxC2	1.0654922	0.0138	1	1	1	1	1	2
LaC2-WyC2	0.2362818	0.0030	1	1	1	1	1	2
LaD2-WxC2	0.0674256	0.0009	2	2	1	1	1	2
MnC2-MnD2	0.6357526	0.0082	1	2	1	1	1	1
WnB-WnC2	3.8134342	0.0493	1	2	2	1	1	1
TOTAL	77.355644							

Somewhat Contrasting, Alfisol 3

Pairs	Boundary Length	Propn. of TOTAL	CfA	CfB	DRt	Slo	DPD	EP	TexA	TexB	pHA	pHB
BbA-GaA	0.1465337	0.0035	1	3	1	1	1	1	2	1	3	1
BnC-BnE	0.3453992	0.0083	1	1	2	3	1	1	1	1	1	1
BnC-WyC2	0.3641013	0.0088	1	1	1	1	1	2	2	2	1	2
BnC-WyE	0.1913663	0.0046	1	1	1	3	1	1	2	2	1	2
BnE-BpC2	1.2823300	0.0309	1	2	1	3	1	2	1	1	3	2
BnE-LaB	0.8006777	0.0193	1	1	2	3	1	1	2	2	1	1
BnE-LaD2	0.0230870	0.0006	1	1	2	2	1	2	2	2	1	1
BnE-MnD2	0.5456672	0.0132	1	1	2	2	1	2	2	2	1	1
BnE-WyC2	0.9607480	0.0232	1	1	2	3	1	2	2	2	1	2
BnE-WyE	0.8750447	0.0211	1	1	2	1	1	1	2	2	1	2
BpB-LaC2	0.1976917	0.0048	1	2	2	2	1	2	2	2	3	2
BpB-OmB	1.2627868	0.0305	1	2	2	1	1	1	1	2	2	2
BpB-WxC2	1.7631167	0.0425	1	2	2	2	1	2	2	2	3	1
BpC2-LaD2	1.6750450	0.0404	1	2	2	2	1	1	2	2	3	2
BpC2-OmB	1.5353970	0.0370	1	2	2	2	1	2	1	2	2	2
CaC2-CaE2	0.1628587	0.0039	1	1	1	3	1	1	1	1	1	1
FrB-OkB	0.6789726	0.0164	1	2	1	1	1	1	2	3	2	1
FrB-GrB2	3.3924580	0.0819	1	2	1	1	2	2	2	3	2	2
Gb-YaA	0.3191733	0.0077	1	1	1	1	1	1	2	2	2	2
GrB2-LaB	2.5696410	0.0620	1	1	1	1	2	2	2	3	2	1
LaB-LaD2	0.1703051	0.0041	1	1	1	3	1	2	1	1	1	1
LaB-MnC2	1.8452635	0.0445	1	1	3	2	1	2	1	1	1	2
LaB-MnD2	0.7627105	0.0184	1	1	3	3	1	2	1	1	1	2
LaB-OkB	5.2409685	0.1265	1	1	1	1	1	1	2	3	2	2
LaB-WyC2	1.7662631	0.0426	2	1	1	2	1	2	1	1	1	2
LaC2-MnC2	0.4714066	0.0114	1	1	3	1	1	1	1	1	1	2
LaC2-MnD2	3.0637549	0.0739	1	1	3	2	1	1	1	1	1	2
LaC2-WnC2	1.0893830	0.0263	1	1	3	1	1	1	1	3	1	1
LaC2-WyE	4.8708690	0.1175	2	1	1	3	1	2	1	1	1	2
LaD2-MnD2	0.4821179	0.0116	1	1	3	1	1	1	1	1	1	2
WyC2-WyE	2.5843626	0.0624	1	1	2	1	1	2	2	2	3	1
TOTAL	41.439501											

Contrasting, Alfisol 3

Pairs	Boundary Length	Propn. of TOTAL	CfB	DRt	Slo	DPD	EP	TexA	TexB	pHA	pHB
BnE-BpB	0.1162997	0.0078	2	1	4	1	1	1	1	3	2
BnE-CaE2	0.6735403	0.0451	2	3	1	1	2	3	3	3	3
BpB-LaD2	1.1127484	0.0745	2	1	3	1	2	1	2	3	2
BpB-OkB	0.3627693	0.0243	2	2	1	1	1	1	4	2	2
BpB-WyE	0.3101584	0.0208	2	2	4	1	1	2	2	3	1
CaC2-LaC2	0.2450636	0.0164	2	4	1	1	1	2	2	3	3
CaC2-WnB	1.4769090	0.0989	2	3	2	1	2	2	2	3	3
CaE2-LaC2	2.7432199	0.1837	2	3	3	1	1	2	2	3	3
CaE2-LaD2	0.0810593	0.0054	2	3	2	1	1	2	2	3	3
CaE2-WnC2	2.5397287	0.1700	2	2	3	1	1	2	2	3	3
GaA-LaB	2.8600896	0.1915	2	1	2	3	1	1	1	3	3
GaA-OkB	0.4314436	0.0289	2	1	2	3	1	2	2	4	1
KbA-LaB	0.8350787	0.0559	2	1	2	3	2	2	1	2	3
LaB-WoE	0.7479019	0.0501	1	1	4	1	1	2	2	1	2
LaC2-MoA	0.3996143	0.0267	2	1	3	3	2	2	2	1	2
TOTAL	14.935625										

Very Contrasting, Alfisol 3

Pairs	Boundary Length	Propn. of TOTAL	CfB	Fld	DRt	Slo	DPD	EP	TexA	TexB	pHA	pHB
BnE-CaB	0.3485023	0.0238	2	1	3	4	1	1	1	1	3	3
BpB-Gb	1.4612410	0.1001	1	5	2	2	3	1	1	1	3	1
BpB-Ot	0.9947639	0.0681	1	5	2	2	3	1	3	4	1	2
CaE2-LaB	2.0931956	0.1434	2	1	3	4	1	2	2	2	3	3
CaE2-WnB	1.9666769	0.1347	2	1	3	4	1	2	2	2	3	3
GaA-Gb	2.7139968	0.1859	1	5	1	1	1	1	2	2	3	2
GaA-YaA	1.5861909	0.1086	1	5	1	1	1	1	1	1	2	3
Gb-LaB	0.8432050	0.0577	2	5	1	2	3	1	2	2	1	2
Gb-MoA	1.1717280	0.0802	2	5	1	1	1	1	1	1	1	2
Gb-OkB	1.1084090	0.0759	2	5	1	2	3	1	1	4	2	2
OmB-Ot	0.3046543	0.0208	2	5	1	2	2	1	3	3	2	3
TOTAL	14.592564											

Exceedingly Contrasting, Alfisol 3

Pairs	Boundary Length	Propn. of TOTAL
Ag-BpB	2.1070941	0.1354
Ag-Gb	0.4650230	0.0299
Ag-LaC2	0.0142126	0.0009
Ag-LaD2	0.1491572	0.0096
Ag-MoA	0.2745201	0.0176
BnE-Rk	0.6028131	0.0387
GaA-Mb	4.2023687	0.2701
Gb-Mb	1.9260805	0.1238
Mb-Swamp	1.6151120	0.1038
TOTAL	4.4232723	

APPENDIX 4

MOLLISOLS

APPENDIX 4.1

SOIL PROPERTIES AND CODES OF MAP UNITS OF THE MOLLISOL SAMPLES

Map Unit	Soil Properties	Codes
Ackmore		430
	CfA - none	0
	CfB - none	0
	Fld - occasional at growing season	8
	DRt - >40"	0
	Slo - A	0
	DPD	4.5
	drn - poorly drained	
	perm - moderately slow	
	EP - none	0
	SP - none	0
	TexA - silty clay loam	2.5
	TexB - silty clay loam	2.5
	pHA - slightly acid	4
	pHB - neutral	5.5
Adair		192D2
	CfA - none	0
	CfB - none	0
	Fld - none	0
	DRt - >40"	0
	Slo - D	7.5
	DPD	6
	drn - somewhat poorly drained	
	perm - slow	
	dlp - 15"	
	EP - moderate	3
	SP - none	0
	TexA - clay loam	2.5
	TexB - clay	0
	pHA - medium acid	3
	pHB - medium acid	3

Arbor	434D
CfA - none	0
CfB - none	0
Fld - none	0
DRt - >40"	0
Slo - D	7.5
DPD	1.5
drn - moderately well drained	
perm - moderately slow	
dlp - 18"	
EP - none	0
SP - none	0
TexA - loam	4
TexB - clay loam	2.5
pHA - medium acid	3
pHB - medium acid	3

Clarinda	222C	222C2	222D2
CfA - none	0	0	0
CfB - none	0	0	0
Fld - none	0	0	0
DRt - >40"	0	0	0
Slo - C, C, D	5	5	7.5
DPD	8.5	8.5	8.5
drn - poorly drained			
perm - very slow			
dlp - 13"			
EP - none, moderate, moderate	0	3	3
SP - none	0	0	0
TexA - silty clay loam	2.5	2.5	2.5
TexB - clay	0	0	0
pHA - slightly acid	4	4	4
pHB - neutral	5.5	5.5	5.5

Clearfield	69C
CfA - none	0
CfB - none	0
Fld - none	0
DRt - >40"	0
Slo - 5-9% (C)	5
DPD	6
drn - poorly drained	
perm - very slow	
dlp - >40"	
EP - none	0
SP - none	0
TexA - silty clay loam	2.5
TexB - silty clay loam	2.5
pHA - slightly acid	4
pHB - slightly acid	4

Colo	11B	133
CfA - none	0	0
CfB - none	0	0
Fld - occasional at growing season	8	8
DRt - >40"	0	0
Slo - B, A	2.5	0
DPD	6	6
drn - poorly drained		
perm - moderately slow		
dlp - 0		
EP - none	0	0
SP - none	0	0
TexA - sandy clay loam	2.5	2.5
TexB - sandy clay loam	2.5	2.5
pHA - slightly acid	4	4
pHB - slightly acid	4	4

Dickinson	675D2
CfA - none	0
CfB - none	0
Fld - none	0
DRt - >40"	0
Slo - D	7.5
DPD	0
drn - well drained	
perm - rapid	
EP - moderate	3
SP - none	0
TexA - sandy loam	7.5
TexB - sandy loam	7.5
pHA - neutral	5.5
pHB - medium acid	3

Ely	428B
CfA - none	0
CfB - none	0
Fld - none	0
DRt - >40"	0
Slo - B	2.5
DPD	3
drn - somewhat poorly drained	
perm - moderate	
EP - none	0
SP - none	0
TexA - silty clay loam	2.5
TexB - silty clay loam	2.5
pHA - slightly acid	4
pHB - medium acid	4

Humeston	269
CfA - none	0
CfB - none	0
Fld - none	0
DRt - >40"	0
Slo - A	0
DPD	8.5
drn - very poorly drained	
perm - very slow	
dlp - 29"	
EP - none	0
SP - none	0
TexA - silty loam	5
TexB - silty loam	5
pHA - neutral	5.5
pHB - medium acid	3

Ladoga	76B	76C2	876C
CfA - none	0	0	0
CfB - none	0	0	0
Fld - none	0	0	0
DRt - >40"	0	0	0
Slo - B, C, C	2.5	5	5
DPD	1.5	1.5	1.5
drn - moderately well drained			
perm - moderately slow			
dlp - 10"			
EP - none, moderate, none	0	3	0
SP - none	0	0	0
TexA - silty loam	5	5	5
TexB - silty clay loam	2.5	2.5	2.5
pHA - slightly acid	4	4	4
pHB - strongly acid	2	2	2

Lamoni	822C2	822D2	822D3
CfA - none	0	0	0
CfB - none	0	0	0
Fld - none	0	0	0
DRt - >40"	0	0	0
Slo - C, D, D	5	7.5	7.5
DPD	6	6	6
drn - somewhat poorly drained			
perm - slow to very slow			
dlp - 10"			
EP - moderate	3	3	3
SP - none	0	0	0
TexA - silty clay loam	2.5	2.5	2.5
TexB - clay	0	0	0
pHA - strongly acid	2	2	2
pHB - medium acid	3	3	3

Macksburg	368	368B
CfA - none	0	0
CfB - none	0	0
Fld - none	0	0
DRt - >40"	0	0
Slo - A, B	0	2.5
DPD	4.5	4.5
drn - somewhat poorly drained		
perm - moderately slow		
dlp - 20"		
EP - none	0	0
SP - none	0	0
TexA - silty clay loam	2.5	2.5
TexB - silty clay loam	2.5	2.5
pHA - slightly acid	4	4
pHB - strongly acid	2	2

Nira	570B	570C	570C2	570D2
CfA - none	0	0	0	0
CfB - none	0	0	0	0
Fld - none	0	0	0	0
DRt - >40"	0	0	0	0
Slo - B, C, C, D	2.5	5	5	7.5
DPD	3	3	3	3
drn - moderately well drained				
perm - moderately slow				
dlp - 10"				
EP - none (0), moderate (3)	0	0	3	3
SP - none	0	0	0	0
TexA - silty clay loam	2.5	2.5	2.5	2.5
TexB - silty clay loam	2.5	2.5	2.5	2.5
pHA - medium acid	3	3	3	3
pHB - medium acid	3	3	3	3

Nodaway	220
CfA - none	0
CfB - none	0
Fld - frequent	10
DRt - >40"	0
Slo - A	0
DPD	1.5
drn - moderately well drained	
perm - moderate	
EP - none	0
SP - none	0
TexA - silty loam	5
TexB - silty loam	5
pHA - neutral	5.5
pHB - neutral	5.5

Olmitz	273C
CfA - none	0
CfB - none	0
Fld - none	0
DRt - 40"	0
Slo - C	5
DPD	1.5
drn - moderately well drained	
perm - moderate	
EP - none	0
SP - none	0
TexA - loam	5
TexB - clay loam	2.5
pHA - slightly acid	4
pHB - medium acid	3

Sharpsburg	370	370B	370C	370C2	370D	370D2
CfA - none	0	0	0	0	0	0
CfB - none	0	0	0	0	0	0
Fld - none	0	0	0	0	0	0
DRt - >40"	0	0	0	0	0	0
Slo - A, B, C, C, D, D	0	2.5	5	5	7.5	7.5
DPD	3	3	3	3	3	3
drn - moderately well drained						
perm - moderately slow						
dlp - 21"						
EP - N, N, N, M, N, M	0	0	0	3	0	3
SP - none	0	0	0	0	0	0
TexA - silty clay loam	2.5	2.5	2.5	2.5	2.5	2.5
TexB - silty clay loam	2.5	2.5	2.5	2.5	2.5	2.5
pHA - slightly acid	4	4	4	4	4	4
pHB - medium acid	3	3	3	3	3	3

Sharpsburg	870B
CfA - none	0
CfB - none	0
Fld - none	0
DRt - 40"	0
Slo - B	2.5
DPD	3
drn - moderately well drained	
perm - moderate slow	
dlp - 21"	
EP - none	0
SP - none	0
TexA - silty clay loam	2.5
TexB - silty clay loam	2.5
pHA - slightly acid	4
pHB - medium acid	3

Shelby	24C2	24D2	24E2	24F2
CfA - none	0	0	0	0
CfB - none	0	0	0	0
Fld - none	0	0	0	0
DRt - >40"	0	0	0	0
Slo - C, D, E, F	5	7.5	10	10
DPD	3	3	3	3
drn - moderately well				
perm - moderately slow				
dlp - 11"				
EP - moderate	3	3	3	3
SP - none	0	0	0	0
TexA - clay loam	2.5	2.5	2.5	2.5
TexB - clay loam	2.5	2.5	2.5	2.5
pHA - medium acid	3	3	3	3
pHB - medium acid	3	3	3	3

Vesser	51
CfA - none	0
CfB - none	0
Fld - occasional at growing season	8
DRt - >40"	0
Slo - A	0
DPD	3
drn - poorly drained	
perm - moderate	
EP - none	0
SP - none	0
TexA - silty loam	5
TexB - silty loam	5
pHA - neutral	5.5
pHB - medium acid	3

Winterset	369
CfA - none	0
CfB - none	0
Fld - none	0
DRt - >40"	0
Slo - A	0
DPD	6
drn - poorly drained	
perm - slow	
dlp - 16"	
EP - none	0
SP - none	0
TexA - silty loam	5
TexB - silty loam	5
pHA - neutral	5.5
pHB - medium acid	3

Zook	54+	287B
CfA - none	0	0
CfB - none	0	0
Fld - occasional at growing season	8	8
DRt - >40"	0	0
Slo - A, B	0	2.5
DPD	6	6
drn - poorly drained		
perm - slow		
dlp - 23"		
EP - none	0	0
SP - none	0	0
TexA - silty clay loam	2.5	2.5
TexB - silty clay	0	0
pHA - neutral	5.5	5.5
pHB - medium acid	3	3

APPENDIX 4.2

MATRIX OF MAP UNITS OF THE MOLLISOL SAMPLES

MOLLISOL SAMPLE 1

	11B	51	54+	76B	76C2	93D2	93E2	133	220	222C2	269
11B											
51	2SC										
54+	2S										
76B											
76C2	2VC			1S							
93D2	11VC	3VC	1VC		2C						
93E2	1VC					2S					
133		1VC	1VC								
220	5SC	4S	2SC			1VC		1VC			
222C											
222C2	1VC				1VC						
269		1VC							2VC		
368											
368B											
370											
370B				1S	1SC	2SC					
370C	1VC	1VC				1SC			2VC		
370C2	2VC					4SC	1SC				1VC
370D	1VC	1VC				1SC					
370D2	1VC					1SC	1SC				
430		1SC							1VC		
570C											
570C2	1VC	1VC			1S					1C	1VC
570D2	1VC	1VC	1VC					1VC	1VC		1VC
675D2	1VC					1C					
822D2											1VC
870B	1VC								1VC		
876C											

	368	368B	370	370B	370C	370C2	370D	570C2	570D2	675D2
370	3S									
370B	2S	1S	11S							
370C										
370C2				5S	1S					
370D					1S	1S				
370D2						1S				
430					1VC		1VC			
570C						1S				
570C2				1S		2S				
570D2						2S		2S		
675D2				1C	2C	1C				
822D2						1SC			1S	
870B						1S				
876C										1SC

MOLLISOL SAMPLE 2

	11B	24D2	24E2	69C	222C	222C2	222D2	368	368B
11B									
24D2	6VC								
24E2	7VC	5S							
24F2	1VC		1VS						
69C	2VC								
222C	4VC			2S					
222C2	5VC	1C	1SC						
222D2	1VC		1SC			1S			
368									
368B								1S	
369								2SC	
370									
370B	1VC			7SC	4C	2C		7S	2S
370C	4VC		1SC	3SC	1C	3C	1		
370C2	2VC			1SC	1C				
370D	1VC	1S							
570B								1C	
570C	2VC			3SC	3C	1C	1C		SC
570C2	2VC			2SC	1C	3C	1C	2SC	
822C2	2VC	3SC	2SC	1SC		1S			
822D2	3VC		5SC				2SC		

	370	370B	370C	370C2	570B	570C
370B	3S					
370C						
370C2		3S	1S			
370D						
570B		2S	1S			
570C		7S	1S			
570C2		9S	4S	1S	2S	1S
822C2		1SC				2S
822D2			3SC	2SC		2SC

MOLLISOL SAMPLE 3

	11B	24C2	24D2	24E2	24F2	192C2	192D2	222D2	287
11B									
24C2	3VC								
24D2	18VC	4S							
24E2	7VC		6S						
24F2		1SC	2S	1VS					
192C2	1VC	1SC	1SC						
192D2			1SC						
222D2	1VC		4C			1SC			
273C	1VC								
287									
287B	3S		2VC	2VC	2VC				
370C	5VC	1S	4S	1SC			1SC	2C	1VC
370C2	7VC			1SC	1C				
370D	1VC	1S							
370D2									
428									
570B								1C	
570C	2VC			3SC	3C	1C	1C		SC
570C2	2VC			2SC	1C	3C	1C	2SC	
822C2	2VC	3SC	2SC	1SC		1S			
822D2	3VC		5SC				2SC		

	370B	370C	370C2	370D	370D2	428B
370C	2S					
370C2			1S			
370D						
370D2						
428						
570B		2S	1S			
570C		7S	1S			
570C2		9S	4S	1S	2S	1S
822C2		1SC				2S
822D2			3SC	2SC		2SC

APPENDIX 4.3

RAW DATA FOR THE MOLLISOL SAMPLES

Similar, Mollisol 1

Pairs	Boundary Length	Propn. of TOTAL	Fld	Slo	DPD	EP	TexA	TexB	pHA	pHB
11B-54+	1.3024125	0.0119	1	2	1	1	1	2	1	1
51-220	4.0742408	0.0375	2	1	2	1	1	1	1	2
54+-133	1.0586730	0.0097	1	1	1	1	2	2	1	1
76B-76C2	3.5394290	0.0325	1	2	1	2	1	1	1	1
76B-370B	0.1910024	0.0017	1	1	2	1	2	1	1	2
76C2-570C2	0.1812922	0.0016	1	1	2	1	2	1	2	1
93D2-93E2	0.4941071	0.0045	1	2	1	1	1	1	1	1
368-370	2.1946015	0.0202	1	1	2	1	1	1	1	2
368-370B	5.0522640	0.0465	1	2	2	1	1	1	1	2
368B-370B	2.1780970	0.0200	1	1	2	1	1	1	1	2
370-370B	35.7802750	0.3295	1	2	1	1	1	1	1	1
370B-370C2	34.7247710	0.3198	1	2	1	2	1	1	1	1
370B-570C	1.4088040	0.0129	1	2	1	1	1	1	2	1
370B-570C2	3.7090930	0.0341	1	2	1	2	1	1	2	1
370C-370C2	0.4522880	0.0041	1	1	1	2	1	1	1	1
370C-370D	0.3572919	0.0032	1	2	1	1	1	1	1	1
370C2-370D	0.2972227	0.0027	1	2	1	2	1	1	1	1
370C2-370D2	5.0308250	0.0463	1	2	1	1	1	1	1	1
370C2-570C	0.1927229	0.0017	1	1	1	2	1	1	2	1
370C2-570C2	1.2627195	0.0116	1	1	1	1	1	1	2	1
370C2-570D2	4.2095340	0.0387	1	2	1	1	1	1	2	1
370C2-870B	0.5191856	0.0047	1	2	1	2	1	1	1	1
570C2-570D2	0.3226826	0.0029	1	2	1	1	1	1	1	1
570D2-822D2	0.0448216	0.0004	1	1	2	1	1	2	2	1

Somewhat Contrasting, Mollisol 1

Pairs	Boundary Length	Propn. of TOTAL	Fld	Slo	DPD	EP	TexA	TexB	pHA	pHB
11B-51	1.0051375	0.0328	2	1	3	1	2	2	2	2
11B-220	2.6722022	0.0873	2	2	2	1	2	2	2	2
51-133	0.2427075	0.0079	1	1	3	1	2	2	2	2
51-430	0.0290688	0.0009	1	1	2	1	2	2	2	2
54+-220	1.9271313	0.0629	2	1	2	1	1	3	2	2
76B-570C2	0.3490398	0.0114	1	2	2	2	2	1	2	2
76C2-370B	0.3491611	0.0114	1	2	2	2	2	1	1	1
93D2-370B	0.0645117	0.0021	1	3	3	2	1	2	2	1
93D2-370C	2.2204490	0.0725	1	2	3	2	1	2	2	1
93D2-370C2	12.3731710	0.4043	1	2	3	1	1	2	2	1
93D2-370D	0.1792001	0.0058	1	1	3	2	1	2	2	1
93D2-370D2	13.647424	0.1191	1	1	3	1	1	2	2	1
93E2-370C2	0.5289014	0.0172	1	3	3	1	1	2	2	1
93E2-370D2	0.2179808	0.0071	1	2	3	1	1	2	2	1
133-220	1.4966130	0.0489	2	1	2	1	2	2	2	2
220-269	1.8301551	0.0598	1	1	3	1	2	3	2	1
220-430	0.7104253	0.0232	1	1	2	1	2	2	2	2
370C2-822D2	0.1684522	0.0055	1	2	2	1	1	2	2	1
675D2-876C	0.5908508	0.0193	1	2	2	1	2	3	2	1
TOTAL	30.6025826									

Contrasting, Mollisol 1

Pairs	Boundary Length	Propn. of TOTAL	Slo	DPD	EP	TexA	TexB	pHA	pHB
51-269	0.5718323	0.0315	1	4	1	1	1	1	1
76C2-93D2	5.6020810	0.3094	2	4	1	2	2	2	1
93D2-675D2	0.7608389	0.0420	1	4	1	3	4	2	1
222C2-570C2	2.6797180	0.1480	1	4	1	1	2	2	2
370B-675D2	0.2090653	0.0115	3	3	2	3	3	2	1
370C-675D2	5.7967900	0.3201	2	3	2	3	3	2	1
370C2-675D2	2.4856480	0.1372	2	3	1	3	3	2	1
TOTAL	18.105974								

Very Contrasting, Mollisol 1

Pairs	Boundary Length	Propn. of TOTAL	Fld	Slo	DPD	EP	TexA	TexB	pHA	pHB
11B-76C2	1.1107070	0.0213	5	2	4	2	2	1	1	2
11B-93D2	0.6061356	0.0116	5	3	1	2	1	2	2	2
11B-93E2	0.0890692	0.0017	5	4	1	2	1	2	2	2
11B-222C2	2.7725660	0.0532	5	2	2	2	1	2	1	2
11B-370C	2.3066540	0.0442	5	2	3	1	1	1	1	2
11B-370C2	0.9683356	0.0185	5	2	3	2	1	1	1	2
11B-370D	0.7132213	0.0136	5	3	3	1	1	1	1	2
11B-370D2	11.3766740	0.1397	5	3	3	2	1	1	2	2
11B-570C2	1.8222730	0.0349	5	2	3	2	1	1	2	2
11B-570D2	1.835903	0.0352	5	3	3	2	1	1	2	2
11B-675D2	1.5126280	0.0290	5	3	4	2	3	3	2	2
11B-870B	0.3595873	0.0069	5	1	3	1	1	1	1	2
51-93D2	11781834	0.0226	5	4	3	2	2	3	2	1
51-370C	0.6817276	0.0130	5	3	1	1	2	2	2	1
51-370D	0.4078571	0.0078	5	4	1	1	2	2	2	1
51-570C2	0.2598448	0.0049	5	3	1	2	2	2	2	1
51-570D2	0.2707132	0.0051	5	4	1	2	2	2	2	1
54+-93d2	0.5905511	0.0113	5	4	1	2	2	1	2	2
54+-570D2	0.3064331	0.0058	5	4	3	2	2	2	2	2
76C2-222C2	1.0653120	0.0204	1	1	5	1	2	2	1	2
93D2-220	0.4683494	0.0089	5	4	2	2	2	3	2	2
133-570D2	0.1582803	0.0030	5	4	3	2	1	1	2	2
220-370C	2.7788310	0.0533	5	3	2	1	2	2	2	2
220-370C2	0.3107196	0.0059	5	3	2	2	2	2	2	2
220-570D2	0.0619120	0.0011	5	4	2	2	2	2	2	2
220-870B	0.5454568	0.0104	5	2	2	1	2	3	3	2
269-370C2	0.1443727	0.0027	5	3	4	2	2	2	2	1
269-570C2	0.1582504	0.0030	5	3	3	1	2	2	2	2
269-570D2	0.8528484	0.0163	5	4	4	2	2	2	2	1
269-822D2	1.1107070	0.0213	5	4	3	2	2	3	3	2
370C-430	0.6020071	0.0115	5	3	2	1	1	1	1	2
370D-430	0.1321899	0.0025	5	4	2	1	1	1	1	2
TOTAL	52.075555									

Very Similar, Mollisol 2

Pairs	Boundary Length	Propn. of TOTAL
24E2-24F2	2.635621	1.0000

Similar, Mollisol 2

Pairs	Boundary Length	Propn. of TOTAL	Slo	DPD	EP	TexB	pHA	pHB
24D2-24E2	1.9451185	0.0272	2	1	1	1	1	1
24D2-370D	1.2241410	0.0171	1	1	2	1	2	1
69C-222C	1.2156194	0.0170	1	2	1	2	1	2
222C-222C2	0.3247288	0.0045	1	1	2	1	1	1
222C2-222D2	0.1153197	0.0016	2	1	1	1	1	1
222C2-822C2	0.0975355	0.0014	1	2	1	1	2	2
368-368B	0.5157827	0.0072	2	1	1	1	1	1
368-370B	14.8485340	0.2076	2	2	1	1	1	2
368B-370B	0.3477245	0.0049	1	2	1	1	1	2
370-370B	4.8554350	0.0679	2	1	1	1	1	1
370B-370C	2.2858170	0.0319	2	1	1	1	1	1
370B-370C2	4.8470329	0.0678	2	1	2	1	1	1
370B-570B	0.6850280	0.0096	1	1	1	1	2	1
370B-570C	18.2381150	0.2549	2	1	1	1	2	1
370B-570C2	14.2401940	0.1991	2	1	2	1	2	1
370C-370C2	0.1352197	0.0019	1	1	2	1	1	1
370C-570B	0.2212975	0.0031	2	1	1	1	2	1
370C-570C	0.3075202	0.0043	1	1	1	1	2	1
370C-570C2	0.9274165	0.0130	1	1	2	1	2	1
370C2-570C2	0.2232409	0.0031	1	1	1	1	2	1
570B-570C2	0.2671779	0.0037	2	1	2	1	1	1
570C-570C2	0.1252209	0.0017	1	1	2	1	1	1
570C2-822C2	3.5414290	0.0495	1	2	1	2	2	1
TOTAL	71.534649							

Somewhat Contrasting, Mollisol 2

Pairs	Boundary Length	Propn. of TOTAL	Slo	DPD	EP	TexA	TexB	pHA	pHB
24D2-822C2	8.6765922	0.1661	2	2	1	1	2	2	1
24E2-222D2	1.9262690	0.0369	1	3	1	2	2	2	2
24E2-370C	0.7291345	0.0139	3	1	2	1	1	2	1
24E2-822C2	4.4594722	0.0853	3	2	1	1	2	2	1
24E2-822D2	9.9299716	0.1900	2	2	1	1	2	2	1
69C-222C2	0.0475879	0.0009	1	2	2	1	2	1	2
69C-370B	9.2798521	0.1775	2	3	2	2	2	1	2
69C-370C	0.8839467	0.0169	1	3	1	1	1	1	2
69C-370C2	0.2226209	0.0043	1	3	2	1	1	1	2
69C-570C	0.7169769	0.0137	1	3	1	1	1	2	2
69C-570C2	0.2842160	0.0054	1	3	2	1	1	2	2
69C-822C2	0.2696226	0.0052	1	2	2	1	2	2	2
222D2-822D2	0.3915196	0.0074	1	3	1	1	1	2	2
368-369	2.8307370	0.0542	1	2	1	2	2	2	2
368-570C2	0.2746939	0.0053	3	2	2	1	1	1	2
368-570B	0.5871980	0.0112	2	2	1	1	1	2	2
368B-570C	0.3220686	0.0062	2	2	2	1	1	1	2
370B-822C2	0.3401250	0.0065	2	2	2	1	2	2	1
370C-822D2	2.8193829	0.0539	2	2	2	1	2	2	1
370C2-822D2	5.2501420	0.1004	2	2	1	1	2	2	1
570C2-822D2	2.0234734	0.0387	2	2	1	1	2	2	1
TOTAL	52.2656032								

Contrasting, Mollisol 2

Pairs	Boundary Length	Propn. of TOTAL	Slo	DPD	EP	TexB	pHA	pHB
24D2-222C2	0.5042405	0.0249	2	4	1	2	2	2
222C-370B	1.1726118	0.0583	2	4	1	2	1	2
222C-370C	1.6632940	0.0820	1	4	1	2	1	2
222C-370C2	0.0650319	0.0032	1	4	2	2	1	2
222C-570C	3.4658659	0.1710	1	4	1	2	2	2
222C-570C2	0.2102337	0.0104	1	4	2	2	2	2
222C2-370B	1.1544363	0.0570	2	4	2	2	1	2
222C2-370C	1.3269242	0.0655	1	4	2	2	1	2
222C2-570C	2.3106170	0.1140	1	4	2	2	2	2
222C2-570C2	4.2186345	0.2081	1	4	1	2	2	2
222D2-370C	0.5373340	0.0265	2	4	2	2	1	2
222D2-570C	1.1575570	0.0571	2	4	2	2	2	2
222D2-570C2	2.4730450	0.1220	2	4	1	2	2	2
TOTAL	20.269826							

Very Contrasting, Mollisol 2

Pairs	Boundary Length	Propn. of TOTAL	Fld	Slo	DPD	EP	TexB	pHA	pHB
11B-24D2	11.3850940	0.2124	5	3	3	2	1	2	2
11B-24E2	15.2122210	0.2837	5	4	3	2	1	2	2
11B-24F2	2.0428570	0.0381	5	4	3	2	1	2	2
11B-69C	1.9643199	0.0366	5	2	1	1	1	1	1
11B-222C	2.5426345	0.0474	5	2	2	1	2	1	2
11B-222C2	7.2635881	0.1335	5	2	2	2	2	1	2
11B-222D2	0.8044196	0.0150	5	3	2	2	2	1	2
11B-370B	0.4059635	0.0076	5	1	3	1	1	1	2
11B-370C	5.4750003	0.1021	5	2	3	1	1	1	2
11B-370C2	1.3000673	0.0242	5	2	3	2	1	1	2
11B-370D	0.6217781	0.0116	5	3	3	1	1	1	2
11B-570C	2.5016067	0.0467	5	2	3	1	1	2	2
11B-570C2	0.2852452	0.0053	5	2	3	2	1	2	2
11B-822C2	0.1537789	0.0029	5	2	2	2	2	2	2
11B-570D2	1.6559361	0.0309	5	3	2	2	2	2	2
TOTAL	53.614510								

Very Similar, Mollisol 3

Pairs	Boundary Length	Propn. of TOTAL
24E2-24F2	0.2030873	1.0000

Similar, Mollisol 3

Pairs	Boundary Length	Propn. of TOTAL	Slo	DPD	EP	TexB	pHA
11B-287B	0.9622868	0.0184	1	1	1	2	1
24C2-24D2	3.2464826	0.0622	2	1	1	1	1
24C2-370C	0.4694566	0.0090	1	1	2	1	2
24C2-370C2	1.8941111	0.0363	1	1	1	1	2
24D2-24E2	4.3129459	0.0827	2	1	1	1	1
24D2-24F2	0.5935386	0.0114	2	1	1	1	1
24D2-370C	1.8593634	0.0357	2	1	2	1	2
24D2-370C2	14.3552370	0.2752	2	1	1	1	2
24D2-370D	0.8664672	0.0166	1	1	2	1	2
24D2-370D2	1.5887283	0.0305	1	1	1	1	2
24D2-822D2	6.7468201	0.1294	1	2	1	2	2
24E2-370D2	0.9609936	0.0184	2	1	1	1	2
192D2-822D2	0.1418502	0.0027	1	2	1	1	1
370B-370C	1.2840199	0.0246	2	1	1	1	1
370B-370C2	6.3900411	0.1225	2	1	2	1	1
370B-570C2	1.4360943	0.0275	2	1	2	1	2
370C-370C2	0.6178772	0.0118	1	1	2	1	1
370C-370D	0.3668722	0.0070	2	1	1	1	1
370C2-370D	0.1500191	0.0029	2	1	2	1	1
370C2-370D2	3.2622689	0.0626	2	1	1	1	1
370C2-570C2	0.6495070	0.0124	1	1	1	1	2
TOTAL	52.154981						

Somewhat Contrasting, Mollisol 3

Pairs	Boundary Length	Propn. of TOTAL	Slo	DPD	EP	TexA	TexB	pHA	pHB
24C2-24F2	0.3061274	0.0070	3	1	1	1	1	1	1
24C2-192C2	1.7341390	0.0397	1	3	1	1	2	1	1
24C2-428B	2.6369310	0.0605	2	1	2	1	1	2	2
24C2-822D2	0.0834357	0.0019	2	2	1	1	2	2	1
24D2-192C2	1.1142510	0.0255	2	3	1	1	2	1	1
24D2-192D2	1.0691120	0.0245	1	3	1	1	2	1	1
24D2-428B	1.3788677	0.0316	3	1	2	1	1	2	2
24D2-822D3	0.4456517	0.0102	1	2	2	1	2	2	1
24E2-370C	0.3274143	0.0075	3	1	2	1	1	2	1
24E2-370C2	0.6656827	0.0152	3	1	1	1	1	2	1
24E2-434D	1.0715410	0.0245	2	2	2	2	1	1	1
24E2-822D2	1.3183654	0.0302	2	2	1	1	2	2	1
24E2-822D3	2.5808210	0.0591	2	2	2	1	2	2	1
24F2-370C2	0.0213774	0.0005	3	1	1	1	1	2	1
192C2-222D2	0.2806758	0.0064	2	2	1	1	1	2	2
192C2-370C2	2.6270700	0.0601	1	3	1	1	2	2	1
192D2-370C	0.2977946	0.0068	2	3	2	1	2	2	1
222D2-822D2	0.1023750	0.0023	1	3	1	1	1	2	2
222D2-822D3	0.1589963	0.0036	1	3	2	1	1	2	2
370C-822D2	1.4782659	0.0338	2	2	2	1	2	2	1
370C2-822D2	11.9480210	0.2734	2	2	1	1	2	2	1
370C2-822D3	6.8436130	0.1566	2	2	2	1	2	2	1
370D-428B	1.3146541	0.0301	3	1	1	1	1	1	2
370D-822D2	0.6615958	0.0151	1	2	2	1	2	2	1
370D2-822D3	0.6053952	0.0138	1	3	1	1	2	2	1
428B-822D2	0.5888596	0.0135	3	2	2	1	2	2	2
570C2-822D2	2.0358290	0.0466	2	2	1	1	2	2	1
TOTAL	43.696863								

Contrasting, Mollisol 3

Pairs	Boundary Length	Propn. of TOTAL	Slo	DPD	EP	TexB	pHA	pHB
24D2-222D2	2.7772932	0.2034	1	4	1	2	2	2
24E2-428B	0.1226338	0.0090	4	1	2	1	2	2
222D2-370C	3.8504599	0.2821	2	4	2	2	1	2
222D2-370C2	4.2938163	0.3145	2	4	1	2	1	2
222D2-370D2	1.6020300	0.1174	1	4	1	2	1	2
222D2-570C2	1.0050550	0.0736	2	4	1	2	2	2
TOTAL	13.651288							

Very Contrasting, Mollisol 3

Pairs	Boundary Length	Propn. of TOTAL	Fld	Slo	DPD	EP	TexA	TexB	pHA	pHB
11B-24C2	2.6896534	0.0330	5	2	3	2	1	1	2	2
11B-24D2	35.1042350	0.4312	5	3	3	2	1	1	2	2
11B-24E2	7.3634220	0.0904	5	4	3	2	1	1	2	2
11B-192C2	0.1102706	0.0014	5	2	1	2	1	2	2	2
11B-222D2	2.8093430	0.0345	5	3	2	2	1	2	1	2
11B-273C	1.3760930	0.0169	5	2	4	1	2	1	1	2
11B-370C	4.1547279	0.0510	5	2	3	1	1	1	1	2
11B-370C2	4.3390959	0.0533	5	2	3	2	1	1	1	2
11B-370D2	11.3766740	0.1397	5	3	3	2	1	1	1	2
11B-434D	1.1027090	0.0136	5	3	4	1	1	1	2	2
11B-428B	0.1237862	0.0015	5	1	3	1	1	1	1	1
11B-822D2	5.0811054	0.0624	5	3	2	2	1	2	2	2
11B-822D3	0.3467078	0.0043	5	3	1	2	1	2	2	2
24D2-287B	2.2082715	0.0271	5	3	3	2	1	2	2	2
24E2-287B	1.8797405	0.0231	5	4	3	2	1	2	2	2
24F2-287B	0.9025742	0.0111	5	4	3	2	1	2	2	2
287B-370C	0.4468886	0.0055	5	2	3	1	1	2	1	2
TOTAL	81.415298									

APPENDIX 5

ARIDISOLS

APPENDIX 5.1

SOIL PROPERTIES AND CODES OF MAP UNITS OF THE ARIDISOL SAMPLES

Map Unit	Soil Properties	Codes				
Diston		24				
	CfA - none	0				
	CfB - none	0				
	Fld - none	0				
	DRt - 40"					
	Slo - A	0				
	DPD	0				
	drn - somewhat excessively drained					
	perm - rapid					
	EP - none	0				
	SP - none	0				
	TexA - loamy sand	10				
	TexB - loamy sand	10				
	pHA - moderately alkaline	7.5				
	pHB - moderately alkaline	7.5				
Grassy Butte		30	31	32	34	35
	CfA - none	0	0	0	0	0
	CfB - none	0	0	0	0	0
	Fld - none	0	0	0	0	0
	DRt - 40"					
	Slo - A, C, A, C, B	0	5	0	5	2.5
	DPD	0	0	0	0	0
	drn - somewhat excessively drained					
	perm - rapid					
	EP - none	0	0	0	0	0
	SP - none	0	0	0	0	0
	TexA - s, ls, ls, ls, ls	10	10	10	10	10
	TexB - s, ls, ls, ls, ls	10	10	10	10	10
	pHA - moderately alkaline	7.5	7.5	7.5	7.5	7.5
	pHB - moderately alkaline	7.5	7.5	7.5	7.5	7.5

Heiseton	93	
CfA - none	0	
CfB - none	0	
Fld - none	0	
DRt - 60" or more	0	
Slo - A	0	
DPD	1.5	
drn - moderately well drained		
perm - moderately slow		
EP - none	0	
SP - moderately saline	8	
TexA - loam	5	
TexB - loamy sand	10	
pHA - mildly alkaline	7.5	
pHB - moderately alkaline	7.5	
Lidy	61	
CfA - none	0	
CfB - none	0	
Fld - none	0	
DRt - 60" or more	0	
Slo - A	0	
DPD	0	
drn - well drained		
perm - moderately rapid		
EP - none	0	
SP - none	0	
TexA - sandy loam	7.5	
TexB - sandy loam	7.5	
pHA - moderately alkaline	7.5	
pHB - moderately alkaline	7.5	
Malm	65	66
CfA - extremely stony		
CfB - basalt		
Fld - none	0	0
DRt - 40"		
Slo - B, B,	2.5	2.5
DPD	0	0
drn - well drained		
perm - moderately rapid		
EP - none	0	0
SP - none	0	0
TexA - sandy loam	7.5	7.5
TexB -		
pHA - strongly alkaline	10	10
pHB -		

Matheson	69	70
CfA - none	0	0
CfB - none	0	0
Fld - none	0	0
DRt - 60" or more	0	0
Slo - A, B	0	2.5
DPD	0	0
drn - well drained		
perm - moderately rapid		
EP - none	0	0
SP - none	0	0
TexA - sandy loam	7.5	7.5
TexB - sandy loam	7.5	7.5
pHA - moderately alkaline	7.5	7.5
pHB - moderately alkaline	7.5	7.5

Medano	36
CfA - none	0
CfB - gravelly	5
Fld - none	0
DRt - 60" or more	0
Slo - A	0
DPD	4.5
drn - very poorly drained	
perm - moderately rapid	
EP - none	0
SP - none	0
TexA - sandy loam	7.5
TexB - coarse sand	10
pHA - strongly alkaline	8.5
pHB - moderately alkaline	7.5

Zwiefel	127	128
CfA - none	0	0
CfB - none	0	0
Fld - none	0	0
DRt - 60" or more	0	0
Slo - A, A	0	0
DPD	3	3
drn - well drained		
perm - slow		
dlp - 21"		
EP - none	0	0
SP - none	0	0
TexA - sand	10	10
TexB - sandy clay	0	0
pHA - moderately alkaline	7.5	7.5
pHB - moderately alkaline	7.5	7.5

APPENDIX 5.2

MATRIX OF MAP UNITS OF THE ARIDISOL SAMPLES

ARIDISOL SAMPLE 1

	24	27	32	36	61	69	70	127	128
24									
27	8EC								
37	2EC								
36	1C		3C						
61			1S						
69	1S								
70	2S			1S		1S			
127	4VC		2VC						
128	2VC							4VS	

ARIDISOL SAMPLE 2

	24	27	37
24			
27	8EC		
37	2EC		

ARIDISOL SAMPLE 3

	1	15	31	34	35	66	67	70	93
1									
15	1S								
31	4EC								
34									
35			4S	1S					
66	2VS		6EC		4EC				
67			1EC						
70			1S		4S		4EC		
93	1EC		2C		2C			1C	

APPENDIX 5.3

RAW DATA FOR THE ARIDISOL SAMPLES

Very Similar, Aridisol 1

Pairs	Boundary Length
127-128	12.9014730

Similar, Aridisol 1

Pairs	Boundary Length	Propn. of TOTAL	Slo	TexA	TexB
70-30	6.1586750	0.318	2	2	2
70-69	0.7361730	0.038	2	1	1
30-69	6.8206020	0.352	1	2	2
36-70	2.7223730	0.141	2	2	2
32-61	2.9122690	0.151	1	2	2
TOTAL	19.350092				

Contrasting, Aridisol 1

Pairs	Boundary Length	Propn. of TOTAL	CfB	DPD	TexA	pHA
30-36	6.1406210	0.285	3	4	2	2
32-36	15.3976700	0.715	3	4	2	2
TOTAL	21.538291					

Very Contrasting, Aridisol 1

Pairs	Boundary Length	Propn. of TOTAL	DPD	TexB
32-127	7.5503940	0.230	3	5
30-127	17.5466960	0.536	3	5
30-128	7.6603050	0.234	3	5
TOTAL	32.757395			

Exceedingly Contrasting, Aridisol 2

Pairs	Total Bdry Length	Prop. of Bdry Length
24-27	30.2889160	0.8000
24-37	7.5613990	0.2000
TOTAL	37.850315	

Very Similar, Aridisol 3

Pairs	Boundary Length
1-66	1.8006271

Similar, Aridisol 3

Pairs	Boundary Length	Propn. of TOTAL	Slo	TexA	TexB
31-35	2.9033437	0.263	2	1	1
70-31	0.3104276	0.028	2	1	2
35-34	2.4757960	0.224	2	1	1
70-35	5.3629632	0.485	1	2	2
TOTAL	11.0525305				

Contrasting, Aridisol 3

Pairs	Boundary Length	Propn. of TOTAL	CfA	Slo	DPD	SP	TexA	TexB
35-93	1.078387	0.429	4	2	1	3	3	1
70-93	1.435178	0.571	4	2	2	3	2	2
TOTAL	2.513565							

Very Contrasting, Aridisol 3

Pairs	Boundary Length	Propn. of TOTAL	CfA	Slo	DPD	SP	TexA	TexB	pHA	pHB
70-93	1.4351780	0.5160	4	2	2	3	3	3	1	1
93-35	1.0783870	0.3877	4	2	2	3	4	4	3	3
93-31	0.2673884	0.0961	4	3	2	3	4	4	3	3
TOTAL	2.7809534									

Exceedingly Contrasting, Aridisol 3

Pairs	Boundary Length	Propn. of TOTAL
1-31	17.4934440	0.274
1-93	3.3868760	0.053
70-67	8.0488678	0.126
31-66	18.7483370	0.294
31-67	1.9026300	0.030
34-67	2.4666090	0.039
35-66	5.2395564	0.082
37-67	6.5490092	0.102
TOTAL	63.835329	