APPLICATION OF CLUSTER ANALYSIS AND CENTROID FACTOR ANALYSIS TO THE NUMERICAL TAXONOMY OF SOME SOILS OF THE WORLD

763

by

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B. S., Kansas State University, 1961

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1967

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Classification facilitates the advancement of any science. Basically the problem of classifying involves ordering of numerous individuals into meaningful groups to accomplish some predetermined objective. Mill (1891) believed, "The ends of scientific classification are best answered, when the objects are formed into groups respecting which a greater number of general propositions can be made, and those propositions more important, than could be made respecting any other groups into which the same things could be distributed." Cline (1949) has stated, "The purpose of any classification is so to organize our knowledge that the properties of objects may be remembered and their relationships may be understood most easily for a specific objective." In an effort to comprehend relationships among a myriad of objects (or even ideas), man turned to classifying or arranging these objects (or ideas) into logical groups.

That grouping is needed is undisputable. However, differences of opinion have arisen as to what constitutes a logical group and how membership within a group should be determined. Classical taxonomists through the years have relied on a few carefully selected "diagnostic" characteristics as criteria for belonging to established groups.

According to Sarkar (1966), Aristotle, apparently the first to attempt any kind of classification, formed certain groups of living organisms on the basis of logic and not on misleading resemblances. For example, he included whales with mammals instead of with fishes.

Adanson (1757) challenged this approach with the thesis that the use of as many characteristics as possible would yield an ideal classification that would contain maximum information. Exploitation of this revolutionary concept was virtually impossible until the last decade with the development of and accessibility to electronic computers.

One may gain greater appreciation for the problem confronting those who deal with soil classification by considering hypothetical situations. First, consider that established classes consisting of similar soils within each class are known, and the characteristics of the modal or typical individuals within each class have been established. Placing a recently described or newly discovered soil in the proper class presents little difficulty. It will be included in the class with the modal individual it most resembles. Now consider a second case in which all the same individuals are given, but the classes are not yet known. Cline (1949) stated that classes are determined by the relationships of all soils to the modal individual. However, the modal individual is established by considering the properties of the individuals in the class. It would seem then, that an iterative or trial and error method must be used to delimit classes.

The question arises as to whether the single individual considered in the first situation should be included in the search for groups or whether it should be placed only after the groups are established. If it is considered with the rest, it will likely have an effect on the determination of the modal individual, and therefore on the makeup of the group which it joins. Two alternatives present themselves whenever one attempts to devise a classification scheme. Constructing abstract classes or defining criteria for belonging to a class and then assigning individuals to these classes seems to be a logical approach. However, construction of classes based on properties of the individuals concerned may give class structure with greater stability. Discovery of new individuals and new characters tends to decrease the stability of classes formed by either method.

Re-evaluation of Soil Classification in the United States

Soil classification in the United States adopted a new perspective in 1951. The zonal, azonal, and intrazonal classification system of Thorp and Smith (1949), a revision of the system by Baldwin et al. (1938), was officially in use in the United States at that time. This system placed extreme emphasis on virgin soils and was biased by genetic factors outside the soil itself. These two facets limited the adaptability of the system to changes in technology and advances in knowledge of soils and soil genesis.

Work was begun in 1951 to develop a comprehensive system of soil classification; one based on soil properties that could be seen, felt, or measured. Properties that either influenced soil genesis or resulted from soil genesis were selected for the definition of taxa. However, according to Smith (1963), all known properties of the soils were considered in deciding which soils belonged together. In addition, all that was known about how the soils acquired these properties was considered.

The system was developed to facilitate the soil survey of the United States, through which results of research and experience are selectively applied to individual tracts of land. The goal of the system was to group together soils of similar genesis which also would possess the maximum number of common properties. It was considered highly desirable to develop a system which could be applied objectively and with reasonable uniformity by large numbers of soil scientists with varying backgrounds of education and experience.

Many data had been collected between 1938 and 1951. Kellogg (1963) stated that this new system was needed in order to include as many of the new data as possible and to facilitate the incorporation of data that would become available. This new system also was expected to furnish a basis for predicting how the various soils of the world would respond to modern management, and to eliminate the overemphasis on virgin soils and genetic factors outside the soil itself.

Numerical Taxonomy

<u>Definition and Aims</u>. Sokal and Sneath (1963), prominent in numerical taxonomic work since 1957 and originators of many of the present popular numerical techniques in classification, defined numerical taxonomy as "the evaluation by numerical methods of the affinity or similarity between taxonomic units and the

ordering of these units into taxa on the basis of their affinities." Outstanding aims of numerical taxonomy are repeatability and objectivity in classification. Those who advocate use of numerical principles believe these aims are consistent with that of scientific methodology--to obtain agreement among scientists on the basic facts through repeatability of observations. In addition, the procedures of numerical taxonomy are open to scrutiny of other scientists at every step.

Principles. Adanson (1757) first stated the ideas which have become the basic principles of modern numerical taxonomy. Sokal and Sneath (1963) summarized these ideas in the form of six axioms stated below.

(1) The ideal taxonomy is that in which the taxa have the greatest content of information and which is based on as many characters as possible.

(2) A priori, every character is of equal weight in creating natural taxa.

(3) Overall similarity (or affinity) between any two entities is a function of the similarity of the many characters in which they are being compared.

(4) Distinct taxa can be constructed because of diverse character correlations in the groups under study.

(5) Taxonomy as conceived by us is therefore a strictly empirical science.

(6) Affinity is estimated independently of phylogenetic considerations.

Since these principles of numerical taxonomy are stated in terms of biological entities, their applicability to soils must be clarified. Concerning Axioms 1 and 2, the most general and most versatile non-technical soil classification system would result from using as many equally-weighted characters as possible. At the same time, this classification likely would not be the ideal soil classification for all purposes. The concept of natural taxa (Axiom 2) becomes even more difficult to grasp in terms of soils, since phylogenetic relationships (by descent) are not applicable to soils (Axiom 6). It is possible that "natural" soil taxa do not exist. However, the methods of numerical taxonomy can be made to yield estimates of relationships among soils which are independent of speculations on soil genesis. Axioms 3, 4, and 5 seem applicable to soils as stated.

Similarity as used in numerical taxonomic studies implies the calculation of some objective, quantitative measurement of the likeness between individuals. Correlation is often used; however, it should be recognized that this application of correlation is different from common usage in scientific investigations. It is probably more common to correlate two or more attributes over a number of observations than to correlate two or more individuals over a number of attributes. It may have occurred to the reader at this point that use of various attributes in this manner presents some problems not generally encountered when using correlation. One problem is that the scale used to record numerical values of characteristics is not the same for all characteristics (see Table 2, page 24).

Procedures. Sneath (1964) discussed the logical steps involved in numerical taxonomy. In summary these may be listed as follows:

(1) The first step is to choose the specimens or other units to be classified, such as species. These are the Operational Taxonomic Units, or OTU's, and should represent a cross-section of the organisms under study.

(2) Characteristics possessed by the specimens or OTU's are listed. An attempt should be made to obtain as complete a listing as possible, consisting of at least 50 to 100 characteristics.

(3) Each OTU is compared in turn with every other, yielding a table of <u>overall</u>, <u>phenetic</u> <u>resemblances</u> among the OTU's.

(4) The OTU's are sorted on the basis of their overall resemblances, to give groups called <u>phenons</u>.

(5) Characters may be re-examined to find those of special interest, perhaps for use in constructing keys.

Phenetic (step 3) refers to relationships based on phenotype rather than genotype or relationship by ancestry. Not strictly applicable to soils in this sense, phenetic applied to soils merely implies the use of measurable characteristics.

Sneath emphasized that these steps must be carried out in the order listed. For example, it is impossible to pick out characters diagnostic of the groups before the groups have been constructed.

Choice of Specimens. Choice of specimens or other units to be classified (step 1) involves several important considerations. Individuals chosen for a study could be from one of several known homogeneous groups (for example, a species), from all known groups in a particular population, or from some combination of these. While valid statistical inferences can be made concerning only those particular individuals studied, certainly much information may be gained which is applicable to the population represented. Therefore, choice of individuals may place strict limitations on the extensions and uses of the study.

Another advantage of careful choice of individuals is that of increased efficiency, which may be important from the standpoint of funds available, time involved in calculation, or even computer space.

It is obvious that the nature of the groups formed will be determined by the individuals in the study. For this reason it would be desirable from a number of standpoints to include an equal number of individuals from each group to be formed. However, these groups are not completely known prior to the investigation. This dilemma is the crux of the classification problem as previously mentioned in the discussion of search for groups based on modal individuals. One way in which a numerical taxonomy circumvents this problem is discussed below under step 4.

If characters are to be transformed, a practice usually followed in numerical studies, the extent of variability of individuals chosen for the study will have an effect on the precision of the outcome. If one individual is extremely unlike the rest of the individuals in the study, transformation will de-emphasize the differences between the similar individuals.

Choice of Characters. Step 2, listing of characteristics, is perhaps the most difficult and most critical phase of the study. Most individuals possess many characters which are easily measured, counted or somehow quantified. These characters may be continuous or discreet. Rohlf (1962) referred to both types as dimensional; that is, the various states of the character can be meaningfully ordered in a sequence. According to Rohlf (1962), two-state or multistate discreet dimensional characters may be included in a study with continuous characters.

Non-dimensional characters are those in which the various character states cannot be logically or meaningfully ordered. An example is color pattern, in which the possible states might be spotted, striped, and solid. Any ordering of these states would incorporate subjectivity into the study. Two-state non-dimensional characters may be included with dimensional characters, according to Rohlf (1962); however, "at present it is not possible to include multistate non-dimensional characters in the same study with dimensional characters" (Rohlf, 1962). Rayner (1966) provided for dimensional and multistate non-dimensional characters in his numerical classification of soils. He considered three types of characters--alternatives, dichotomies, and scales; however, 42 of his 50 characters were dimensional, i.e., scales.

In addition to the consideration of dimensionality, Rohlf

(1962) and Sokal and Sneath (1963) emphasized that characters must be logically independent or free of inter-influences. Sarkar, Bidwell, and Marcus (1966) used statistical independence to determine logically independent characters, although some numerical taxonomists believe that this application has serious disadvantages. Characters must also be comparable for all individuals and inherent in the objects being studied.

Transformation of each character over all individuals is commonly used in numerical taxonomy. This involves transforming the characters so that all characters have equal range or equal means and variances. The mathematical manipulations involved are discussed under Material and Methods.

Estimation of Resemblances. Step 3, estimation of resemblances between OTU's, may be accomplished by use of various coefficients. Sokal (1961) listed the following categories:

(1) Coefficients of association
(2) Coefficients of correlation
(3) Coefficients of distance

A fourth coefficient, not mentioned by Sokal, is the index of similarity (Hole and Hironaka, 1960).

Summarizing Relationships. Development of techniques for sorting individuals into groups or displaying relationships among individuals (step 4) could be considered one of the main contributions of multivariate statistics to taxonomy. These techniques are not actually new, nor do they involve extremely complex calculations in most cases. However, calculations are tedious, and without the aid of electronic computers, studies of any size would be virtually impossible.

Four general procedures or devices are commonly used for summarizing relationships among individuals as expressed in the table or matrix of resemblances (step 3). These are as follows:

(1) The first procedure involves shading the similarity matrix so that the magnitude of resemblances among all individuals can be visualized. High degrees of similarity are usually represented by the darkest shades. Rows and columns of the matrix may be rearranged in an effort to obtain clusters of similar individuals.

(2) The dendrogram (see Fig. 1, Part D, page 15), a second device for summarizing relationships, displays clusters of like individuals and the relative degrees of similarity among individuals and clusters by means of a branched tree-like structure.[1] Those individuals and groups which are joined at high levels are more similar than those joined at lower levels.

(3) A third procedure useful for summarizing relationships is factor analysis, which may be applied to classification problems in various ways. Basically, this treatment extracts a large part of the information

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[1] The more specific term phenogram was adopted by numerical taxonomists about two years ago to replace the term dendrogram. "Phenogram" implies that the relationships exhibited are phenetic or phenotypic relationships, as distinct from those represented by cladograms (phylogenetic or ancestral relationships). The term dendrogram was retained in this study since neither phenotype nor genotype are strictly applicable to soils, and the combining form dendro-, meaning tree, (from the Greek word dendron) is suggestive of the diagram's tree-like structure.

from the correlation matrix by mathematical manipulation and expresses relationships among individuals in terms of a few factors. The first two or three factors extracted then may be used as axes of a coordinate system to indicate clusters of like individuals and relationships among clusters in two or three dimensions.

(4) Ordination, the fourth method, plots relationships among individuals on coordinate axes in two or three dimensions.

Dendrograms attempt to express multi-dimensional relationships in one dimension, so that some distortion of the similarity matrix is inevitable. Factor analysis (when used as described above) and ordination attempt to express multi-dimensional relationships in either two or three dimensions and therefore result in some loss of information also.

Rohlf and Sokal (1962) and Rohlf (1962) discussed application of multiple-factor analysis to taxonomy. Pitcher (1966) and Rayner (1966) used factor analysis to yield clusters of similar individuals. This analysis involved the computation of factor scores, which were discussed by Harman (1960).

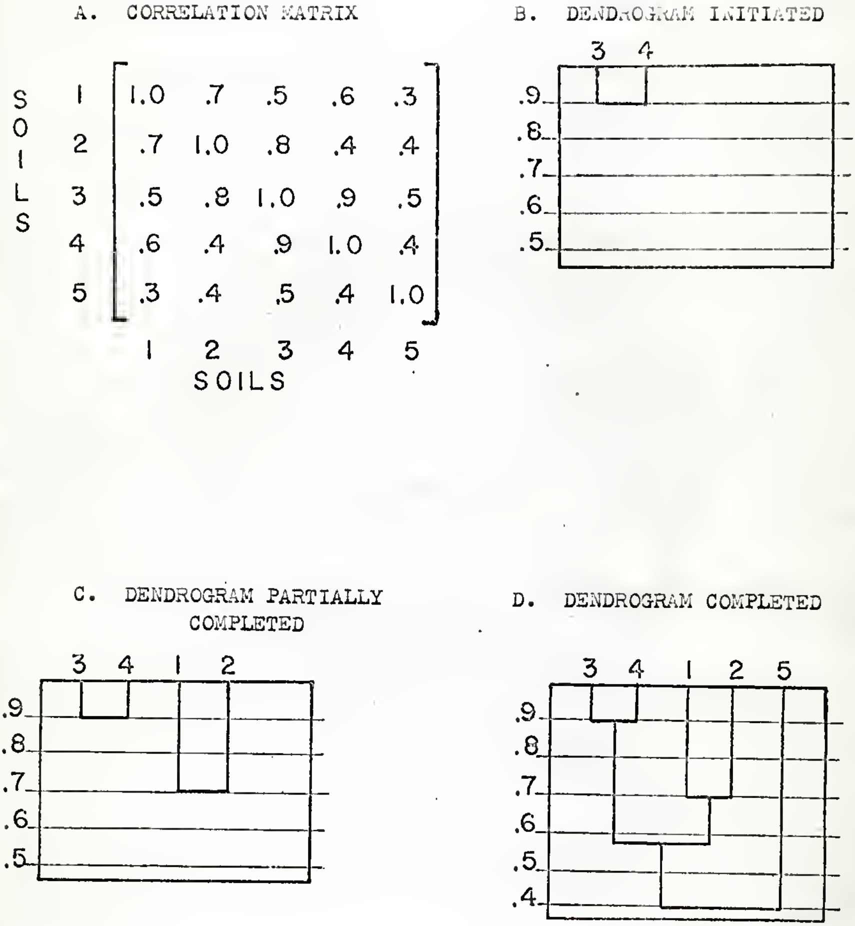
Rohlf (1962) considered the procedures for summarizing relationships among individuals as the search for group structure in the similarity matrices. He discussed two main types of procedures, cluster analysis and factor analysis. Various forms of cluster analysis are available, but those which facilitate the construction of a dendrogram would seem to be the most useful and most interpretable by taxonomists in general. Sokal and Michener (1958) discussed the development and application of several of these methods. Some of these methods which have found rather wide acceptance are known as the weighted-pair-group method, unweighted-pair-group method, weighted-variable-group method, and unweighted-variable-group method.

The following illustration of procedures used in applying the unweighted-pair-group method using arithmetic averages, referred to as UPGM(A), may clarify the general nature of these techniques. Part A of Fig. 1 is a hypothetical 5 X 5 matrix of correlations among soils (OTU's), the result of correlating each soil with every other. Construction of a dendrogram to summarize the relationships between individuals expressed in this matrix begins by joining all mutually highest correlated individuals. Soils 3 and 4 have a correlation of .9. This is the highest correlation soil 3 has with any of the soils in the study; likewise, it is the highest correlation soil 4 has with any of the soils. Therefore, it is the mutually highest correlation for soils 3 and 4, and they are joined at that level in Part B. In order to determine whether any more pairs will cluster during this cycle it is necessary to calculate the average correlation of all remaining individuals with the pair (3,4) already formed. The average correlation of soil 1 with this pair is $\frac{.5 + .6}{2} = .55$. The average correlation of soil 2 with the pair is .6, and the average correlation of soil 5 with the pair is .45. Calculation of these values would be different if a weighted method or a method other than arithmetic averages were used. Correlations between remaining soils (possible pairs) are $r_{1,5} = .3$; $r_{1,2} = .7$; and $r_{2,5} = .4$. The highest correlation found among these six values (including the average correlations just calculated) is .7, and since this is the highest correlation for both soils 1 and 2, this pair is formed in Part C. Note that soil 2 originally had a correlation of .8 with soil 3, but it was not joined to soil 3 since soil 3 had a higher correlation with soil 4. Then soil 2 did not join soil 3 in the cluster with soil 4 since its average correlation with 3 and 4 (.6) was lower than its correlation with soil 1 (.7).

The procedure of calculating all possible correlations between pairs and individuals is then repeated. Since only one soil (5) remains, no more pairs will be formed in this cycle. If there were more soils in the study, the above criteria for determining pairs would apply.

For the second cycle, only the average correlation of soil 5 with each of the pairs in Part C, (3,4) and (1,2), and the average correlation between the two clusters must be calculated. These values are .45, .35, and .575, respectively. The largest of these values is .575, so that the two pairs, (3,4) and (1,2), join as shown in Part D, at a level of .575. Calculation of the average correlation of soil 5 with this cluster of 4 soils gives a value of .4; therefore, soil 5 joins the cluster at this level.

From casual observation the dendrogram would seem to show



A. CORRELATION MATRIX

$$\begin{array}{c|ccccc} & 1 & 2 & 3 & 4 & 5 \\ \hline 1 & 1.0 & .7 & .5 & .6 & .3 \\ 2 & .7 & 1.0 & .8 & .4 & .4 \\ 3 & .5 & .8 & 1.0 & .9 & .5 \\ 4 & .6 & .4 & .9 & 1.0 & .4 \\ 5 & .3 & .4 & .5 & .4 & 1.0 \end{array}$$

B. DENDROGRAM INITIATED

C. DENDROGRAM PARTIALLY COMPLETED

D. DENDROGRAM COMPLETED

Fig. 1. Correlations among five hypothetical soils with illustration of dendrogram construction by unweighted-pair-group method using arithmetic averages (UPGM-A). Cophenetic correlation = .83.

that soils 1, 2, 3, and 4 are all rather closely related and soil 5 is not closely related to any of them. An inspection of the original matrix substantiates this general conclusion, the one exception being that soil 5 is more closely related to soil 3 than soil 4 is to soil 2. Since soils 3 and 4 are so similar to each other ($r_{3,4} = .9$) their individual relationships to other soils are expected to be nearly alike. Comparing columns 3 and 4, this is found to be the case with the exception of soil 2, where $r_{3,2} = .8$ and $r_{4,2} = .4$. This extreme difference is possible but not too likely in an actual study. This type of relationship is one reason why representing a similarity matrix by a dendrogram results in some loss of information.

An objective measurement of the amount of distortion or loss of information in the dendrogram may be obtained by calculation of the cophenetic correlation (Sokal and Rohlf, 1962). This is the correlation between the actual similarity values in the original matrix and the similarity values implied by the dendrogram. Table 1 illustrates this procedure for the hypothetical example just discussed. The first column of Table 1 lists the correlations among soils which are implied by the dendrogram; the second column lists actual correlations from the matrix. The correlation between these two sets of values, known as the cophenetic correlation, is .83.

Table 1. Comparison of cophenetic and original correlation values of the five hypothetical soils from Fig. 1.

Cophenetic value	Original value
$r_{1,2} = .7$	$r_{1,2} = .7$
$r_{1,3} = .575$	$r_{1,3} = .5$
$r_{1,4} = .575$	$r_{1,4} = .6$
$r_{1,5} = .4$	$r_{1,5} = .3$
$r_{2,3} = .575$	$r_{2,3} = .8$
$r_{2,4} = .575$	$r_{2,4} = .4$
$r_{2,5} = .4$	$r_{2,5} = .4$
$r_{3,4} = .9$	$r_{3,4} = .9$
$r_{3,5} = .4$	$r_{3,5} = .5$
$r_{4,5} = .4$	$r_{4,5} = .4$

Application of Numerical Taxonomy to Soils

Smith (1963) stressed that the goal of soil classification is to have groupings of soils with the maximum number of common properties that reflect a common genesis. Based on present knowledge of soil forming factors, it seems that such groupings should be attainable. However, since soil properties are more easily quantified than soil genesis, groupings of soils with similar properties can be easily obtained in any case. Once these groups of soils with similar properties have been obtained (to the precision desired), their very existence can be used as a tool to study soil genesis.

The essence of the matter is this. By employing as many diverse characters as possible, presupposing no genetic criteria for these characters, and considering all characters of equal importance, groups of soils possessing similar properties will be formed. These groups will be as free of subjective bias as the raw data and the methods used to discover groups. The outcome of such a classification is determined by the soils and their properties. In this respect, the possibilities of new experience are not limited by previously established concepts of soil genesis. Cline (1963) emphasized the danger of a classification system that limited the possibilities of new experience and molded research into patterns of the past.

However, the scope of the problem makes it virtually impossible to consider all known characters and to construct a classification which is free of genetic or other bias by any means other than those employed in numerical taxonomy.

While soil scientists did little in numerical classification in the late 1950's, a considerable amount of information regarding numerical classification of soils is now available. Hughes and Lindley (1955) were the first to apply statistical techniques to soil classification. They employed Mahalanobis' D^2 statistic with very few characteristics to demonstrate that numerical methods were applicable to soils.

Hole and Hironaka (1960) used the ordination techniques of Goodall (1954) to examine soils of the Miami family and 25 soils representative of 25 great soil groups of the world. They used the similarity index previously used by Curtis (1959). They displayed their results in a three-dimensional projection and in a graphic linear arrangement. (Later Bidwell and Hole presented these results in a taxonomic dendrogram.)

Hole and Hironaka's results substantiated certain concepts held by scientists experienced in soil classification. The authors believed ordination to be a useful tool for evaluating the significance of great soil groupings and properties on which the groupings were based. They observed, "In an irregular subject like soil classification, explanation of a multifactor dependent relationship may be even more profitable than the prediction of it."

Bidwell and Hole (1964a) presented a dendrogram formed from the same 25 soils of Hole and Hironaka (1960) and suggested the use of dendrograms as a routine aid in soil classification. Bidwell and Hole (1964b) used the ordination technique of Goodall on 29 Kansas soils. They found that the great soil groups were not separated by a three-dimensional ordination, but rather overlapped and interlaced. They also presented their results in a taxonomic dendrogram and a shaded similarity matrix. Chestnut, Chernozem, and Brunizem great soil groups were well separated in the dendrogram; however, the Prairie Planosol and Reddish Prairie soils showed close similarity to the Brunizem great soil group. Some evidence of clustering with respect to geographical location also was apparent in their dendrogram.

Their work demonstrated the possibility of classifying soils numerically, and they further recommended use of numerical techniques for testing the present system of soil classification and for determining whether two soils are sufficiently similar to be classified in the same soil series.

Bidwell, Marcus, and Sarkar (1964) were the first to use the electronic computer in soil classification. They selected 26 soils representing extremes of variability within each of the nine Orders from the 7th Approximation (1960). They used 61, 38, 25, and 17 subjectively-selected characteristics in successive analyses to array the soils in a dendrogram using the unweighted-pair-group method of Sokal and Sneath (1963). The similarity index of Goodall (1954) was employed for estimating resemblances.

Using 61 characteristics, Bidwell et al. (1964) found that soils placed in the same Order in the 7th Approximation (1960) were not necessarily more similar to each other than those placed in different Orders. Specifically, Entisols from Florida and Alaska were quite dissimilar, whereas a South Carolina Entisol and a Mississippi Ultisol were quite similar. A South Carolina Vertisol was slightly more similar to a Louisiana Alfisol than it was to a Mississippi Vertisol. Dendrograms constructed from 38 and 25 characters gave relationships similar to those from 61 characters; however, 17 characters appeared to be too few to maintain the classification's consistency. Bidwell et al. indicated that results might have been more in agreement with 7th Approximation Orders if soils within the same Suborder or Great Group had been used.

They suggested that major problems to be investigated before widespread adoption of numerical classification of soils appeared to be the selection, numerical coding and scaling, and weighting of the characteristics to be considered.

Sarkar et al. (1966) used the 26 soil profiles and 61 characters of Bidwell et al. (1964) in an effort to develop an objective and reliable method of determining the appropriate number and kind of characteristics to use in numerical classification of soils. They calculated all 1830 product-moment correlation coefficients among the 61 characters over the 26 soils. They constructed dendrograms from five successively selected sets of 61, 51, 40, 33, and 22 soil characteristics. At each step they examined highly correlated character pairs and eliminated the character most highly correlated with other characters. All pairs of characters remaining in the final set of 22 characters had absolute correlations of less than .50.

Comparison of the dendrograms based on these 61 and 22 characters revealed remarkable similarities. Three clusters had maintained integrity with the exception that one soil changed clusters and two others left their respective clusters. The authors concluded that a large number of unselected characters may not be superior to a smaller number of characters selected through the correlation criterion.

Rayner (1966) used 23 profile descriptions of soils in Glamorganshire and the laboratory measurements on soil samples of the 91 horizons into which they were divided by the surveyor and arranged them into clusters of similar soils. This contrasted with all previous studies, since only modal soil profile descriptions had been used previously. Realizing the difficulty of estimating the similarity between soil profiles which do not possess the same type of horizon at the same depth, Rayner calculated similarities between horizons and used these similarity values to obtain estimates of the similarity between profiles. He found that the great soil groups to which the soil profiles had been allocated by the surveyor were almost completely separated by numerical methods. He used a dendrogram and factor analysis technique to form clusters of similar soils, and obtained comparable results with these two methods. In addition, he used the computer to rearrange the similarity matrix to obtain clusters of similar soils with no loss of information.

Rayner suggested that even though computers have limited capacity, extension of these numerical methods to practical soil classification on a broad scale could be accomplished. He indicated that this could be done by calculating a representation for a hundred soils and then selecting groups of profiles in this representation to act as standards with which to compare other profiles.

MATERIAL AND METHODS

Selection of Characters

This study was planned as a continuation of the work by Sarkar et al. (1966); therefore, selection of characters was in large part predetermined by their results. Twenty-one characters were chosen from the twenty-two characters selected by Sarkar et al. through the use of character correlations. These 21 characters, with some minor modifications, were used in the present study. Character 5, clayskins in B_2, was used in this study though it had been eliminated by Sarkar et al. Character 45, extractable Na in B, was returned to the study to replace character 48, extractable Na in B/extractable Na in C, since information on extractable Na in C was missing for some soils and use of ratios was considered questionable from a statistical viewpoint. Characters 52 and 53, ratios dealing with silt content of the B horizon, were replaced by a new character, number 62, total silt of B. Character 42, cation exchange capacity of A/cation exchange capacity of B, was deleted entirely since the data for this character were determined by three different methods. Cation exchange capacity is logically correlated with amount of soil colloids present; therefore, the information lost by deletion may not have been so undesirable as the error that would have been incorporated into the study if it had been included. The final 21 characters are listed in Table 2. Character numbers correspond to those of the study by Sarkar et al. with the exception of character 62.

Table 2. Twenty-one characters used in the study.

Character number	Character	Units used
1	Structure of B_2 Horizon	Coded - 1 to 8
2	Thickness of A_1 or Ap Horizon	Inches
3	Thickness of B_2 Horizon	Inches
5	Clay Skins in B_2 Horizon	Coded - 0 to 10
10	Degree of mottling	Coded - 0 to 7
11	Fe-Mn concretions	Coded - 0 to 9
12	Depth to rock or permafrost	Inches
13	Thickness of organic layer above A Horizon	Inches
15	Average percent slope	Percent
16	Consistence of B_2 Horizon	Coded - .5 to 5
20	Chroma of A Horizon	Munsell designations - 0 to 5
21	Hue of B Horizon	Munsell designations - 4 to 11
22	Value of B Horizon	Munsell designations - 2 to 7
23	Chroma of B Horizon	Munsell designations - 1 to 7
30	Percent clay in B_2 Horizon	Percent
31	Percent clay in A_1 Horizon/ Percent clay in B_2 Horizon	Ratio
33	Percent organic carbon in A_1 or Ap Horizon	Percent
34	Percent organic carbon in B_2 Horizon	Percent
38	pH of B Horizon	As given - 4.3 to 8.9
45	Extractable Na in B Horizon	Percent
62	Total silt of B Horizon	Percent

Coding of Qualitative Characters

All characters used in this study were considered dimensional in nature. Fifteen of the characters were quantitative and therefore could be used as raw data in their original form, without coding. Six of the characters (1, 5, 10, 11, 16, and 21) were qualitative characters in the sense that they could not be measured directly. Each of these six characters had to be evaluated quantitatively and coded in a logical sequence to adapt them to numerical techniques. The guidelines followed in coding are listed in Table 2a.

Table 2a. Quantitative evaluation of qualitative characters.

Coded value	Description
	Character 1: Structure of B_2 Horizon
1	Sand, fine sand or massive
2	Granular, very weak subangular blocky, weak subangular blocky, wormcasts or strong thick platy
3	Weak prismatic or weak blocky
4	Moderate blocky or moderate subangular blocky
6	Strong blocky
8	Strong prismatic or columnar
	Character 5: Clay Skins in B_2 Horizon
0	Absent
2	Shiny ped faces may be clay films
4	Very thin, patchy clay skins in pores and vertical fractures
5	Prominant in pores but faint and patchy around peds; or discontinuous clay skins on some peds; or clay skins evident
6	Thin, patchy clay films; or numerous thin clay films; or patches on vertical faces
7	Patchy clay films
7.5	Thin, patchy clay films
8	Thin, continuous clay films

Table 2a (Cont.).

Coded value	Description
	Character 5 (Cont.)
8.5	Medium, continuous clay skins
10	Common, thick, gelatinous films on ped faces or thick, continuous clay films
	Character 10: Degree of Mottling
0	No mottling
	Contrast
1	Faint
2	Distinct
3	Prominent
	Abundance
1	Few
2	Common
3	Many
	Size
1	Fine
2	Medium
3	Coarse
	Total score = sum of the scores for all three features.
	Character 11: Fe-Mn Concretions
0	Absence
2	Coatings of manganese oxide evident, and, in general, material is harder where manganese oxide occurs; or few manganese coatings on ped faces; or coatings of manganese oxide present

Table 2a (Cont.).

Coded value	Description
	Character 11 (Cont.)
3.5	Few black splotches of manganese oxide in 29 to 44 inch zone
4	Common, very dark gray or black manganese stains and concretions in 42 to 60 inch zone
5	Few, fine, black concretions in 17 to 29 inch zone and few black concretions less than 1 millimeter in diameter in 29 to 34 inch zone
7	Distinct mottles and iron-manganese concretions in 44 to 48 inch zone
9	Few concretions of manganese oxide in 0 to 19½ inch zone and streaks of manganese oxide evident in 19½ to 64 inch zone; or few iron concretions 5 to 10 millimeters in diameter in 0 to 6 inch zone, common iron concretions in 6 to 12 inch zone, and 50 percent of soil mass consists of iron concretions in 12 to 18 inch zone; or common very fine black pellets of manganese in 0 to 12 inch zone, few fine black coats of manganese in 12 to 17 inch zone, and few fine black pellets of manganese in 17 to 32 inch zone
	Character 16: Consistence of B_2 Horizon
0	Loose
1	Very friable
2	Hard or friable
3	Very hard or firm
4	Extremely hard or very firm
5	Extremely firm

Table 2a (Concl.).

Coded value	Description
	<u>Character 21</u>: <u>Hue of B Horizon</u>
0	Munsell notation N
2	Munsell notation 10Y
3	Munsell notation 7.5Y
4	Munsell notation 5Y
5	Munsell notation 2.5Y
6	Munsell notation 10YR
7	Munsell notation 7.5YR
8	Munsell notation 5YR
9	Munsell notation 2.5YR
10	Munsell notation 10R
11	Munsell notation 7.5R

Coded values for characters 5 and 11 were difficult to establish since descriptions of these attributes for different soils were not always comparable. This is because uniform nomenclature was not used by the various individuals who wrote the soil descriptions. In coding character 5, clay skins in B_2 horizon, an effort was made to give the highest code values to those soils with the most prominent evidence of clay skins. In coding character 11, Fe-Mn concretions, an effort was made to give the highest code values to those soils with the most concretions throughout the greatest part of the profile or nearest the surface. Manganese coatings and stains were given low code values. For the most part, descriptions for characters 5 and 11, as given in Table 2a, represent the actual wording used by the soil scientist who described the soil; and, for character 11, the depth at which the Fe-Mn phenomena were observed. For example, three separate descriptions, applying to three different soils, were given a coded value of nine for character 11.

Selection of Soils

The 59 soils used in the study were chosen on the basis of availability of data (in the 7th Approximation) for the 21 characters. These soils, with their geographical locations and 7th Approximation Orders, are given in Table 3. Soil numbers refer to profile numbers given in Soil Classification--A Comprehensive System: Seventh Approximation (1960). These numbers were used to identify soils throughout the study.

Table 3. The fifty-nine soil profiles included in the study.

Soil number	Soil series name	Location	Order
2	Sharpsburg	Nebraska	Mollisol
3	Eakin	South Dakota	Mollisol
4	Exline	North Dakota	Mollisol
5	Quillayute	Washington	Inceptisol
8	Odin	Oregon	Aridisol
9	Windthorst	Texas	Alfisol
10	Unnamed	Yugoslavia	Alfisol
11	Alford	Indiana	Alfisol
15	Williams	North Dakota	Mollisol
17	Rhoades	South Dakota	Mollisol
18	Exline	North Dakota	Mollisol
19	Tetonka	North Dakota	Mollisol
21	Leon	Georgia	Spodosol
23	Fillmore	Nebraska	Alfisol

Table 3 (Concl.).

Soil number	Soil series name	Location	Order
27	Nipe	Puerto Rico	Oxisol
29	Scituate	New Hampshire	Inceptisol
31	Redding	California	Alfisol
34	Teas	West Virginia	Inceptisol
35	Tanana	Alaska	Entisol
39	Lakewood	Florida	Entisol
40	Lakeland	South Carolina	Entisol
42	Victoria	Texas	Vertisol
44	Eutaw	Mississippi	Vertisol
46	Unnamed	Arizona	Vertisol
48	Erie	New York	Inceptisol
50	Unnamed	Alaska	Inceptisol
52	Waimea	Hawaii	Inceptisol
55	Burton	Tennessee	Inceptisol
57	Mimbres	New Mexico	Aridisol
58	Blackhawk	Nevada	Aridisol
61	Saltair	Utah	Aridisol
62	Mohave	Arizona	Aridisol
63	Uvada	Utah	Aridisol
64	Fresno	California	Aridisol
66	Tetonka	North Dakota	Mollisol
67	Webster	Minnesota	Mollisol
68	Barnes	North Dakota	Mollisol
69	Unnamed	South Dakota	Mollisol
71	Unnamed	Yugoslavia	Mollisol
72	Shelby	Iowa	Mollisol
73	Morton	North Dakota	Mollisol
74	Keith	Nebraska	Mollisol
76	New Mexico	North Dakota	Mollisol
77	Unnamed	Norway	Spodosol
78	Unnamed	Norway	Spodosol
79	Wrightsville	Louisiana	Alfisol
80	Lacamas	Washington	Alfisol
84A	Lansing	New York	Alfisol
86	Redding	California	Alfisol
87	Carlsbad	California	Alfisol
88	Redbluff	California	Alfisol
89	Corning	California	Alfisol
91	Sabana Seca	Puerto Rico	Ultisol
95	Aiken	Oregon	Ultisol
96	Cahaba	Alabama	Ultisol
99	Catalina	Puerto Rico	Oxisol
100	Cialitos	Puerto Rico	Oxisol
101	Unnamed	Congo	Oxisol
102	Molokai	Hawaii	Oxisol

Collection of Raw Data

The term raw data in this study refers to the data in Table 4 (Appendix). Basically these data were recorded in the units given in the 7th Approximation. However, raw data includes coded values for the six qualitative characters mentioned above. In addition, raw data includes transformed values for soils 34, 52, 72, 95, 99, and 100 for character 15. These six values were transformed because after all raw data for the 59 soils had been extracted from the 7th Approximation, character 15 (average percent slope) was observed to have an extremely uneven distribution of character state values. All but 11 of the soils had values of three percent or less, and there were three soils with values of 25 percent (soils 34, 99, and 100). In an effort to obtain greater spread between the values from zero to three percent, the higher values for character 15 were transformed. Values of 25 percent were transformed to 15 percent, values of 15 percent were transformed to 13 percent, and values of 12 percent were transformed to 11 percent. These transformed values of 15, 13, and 11 percent are listed in Table 4 (Appendix) as raw data.

Except for percent slope, raw character values were recorded as given in the 7th Approximation (1960) whenever possible. Some soil descriptions, however, did not conform to the format of the characters being used in this study. For example, the B_2 horizon of soil 62 was subdivided into B_{21} and B_{22}. Clay percentages for these two horizons were 21.6 and 27.9, so the average, 24.8 percent, was used for character 30. When soils did not possess a B horizon, values for characteristics of the B were taken from those given for the A_{13}, AC, or C_1, depending on which was present. Raw character values for the 24 soils of the previous study by Sarkar et al. (1966) were taken directly from Sarkar (1966).

Values for character 31, a ratio, were recorded to two decimal places to obtain the best available estimate, not because they were accurate to two decimal places.

Transformation and Standardization of Data

Units of measurement and number of character states varied from character to character. In order to pool the information given by different characters for the purpose of calculating correlations and distances among soils, it was necessary to transform the character values so that all characters had comparable units. The raw data of Table 4 (Appendix) were transformed according to the method used by Sarkar (1966), to give each character a range from 0 to 1000 (hereafter referred to as transformed data or 0 to 1000 data). These transformed data are given in Table 5 (Appendix). Initially, these 0 to 1000 data were to be used without further alteration in the computation of similarity matrices; therefore, they were keypunched on IBM cards. Each character was punched in a five-column field in columns 6 through 80, using two cards per soil. However, before any computations were performed it was found advisable to use data which were transformed to give each character a mean of zero and a variance of unity (hereafter referred to as standardized data or 0,1 data). Sokal and Sneath (1963) and Rohlf (1962) referred to this type of data as standardized data. The 0 to 1000 data of Table 5 (Appendix) were used to calculate the standardized (0,1) data of Table 6 (Appendix).

The value of a given character for a given soil was standardized by subtracting the mean value of that character and dividing by the standard deviation of that character according to the formula:

$$X'_{ij} = \frac{X_{ij} - \overline{x}_j}{s_j} \circ$$

where X_{ij} was the transformed 0 to 1000 character state value for OTU i on character j, $\overline{x}_j$ was the mean value of character j over 59 soils, s_j was the standard deviation of character j over 59 soils, and X'_{ij} was the standardized character state code for OTU i on character j.

It would have been more advisable to have computed standardized (0,1) values directly from the original raw data (rather than from the 0 to 1000 transformed data) to reduce rounding and copying errors. However, except for rounding differences, the outcome, or standardized values (Table 6, Appendix), would be the same whether raw data (Table 4, Appendix) or transformed 0 to 1000 data (Table 5, Appendix) were used. Rohlf (1962) and Sokal and Sneath (1963) discussed the purposes and implications of standardization.

Calculation of Similarity Matrices

Correlation and distance coefficients were computed for the 59 soils, but since coefficients of association are adapted for use with non-dimensional characters, they were not considered. Correlation was calculated by the product-moment method used by Sarkar (1966) and others (Michener and Sokal, 1957; Rohlf, 1962). Distance was calculated by the following formula:

$$d_{jk} = \sqrt{\frac{\sum_{i=1}^{n}(X'_{ij} - X'_{ik})^2}{n}}$$

where

d_{jk} = distance between soils j and k

X'_{ij} and X'_{ik} = standardized values of character i for soils j and k

n = number of characters

Sokal (1961) discussed the use of this coefficient for estimating similarity between individuals.

The index of similarity of Goodall (1954) was not used in the present study; however, it was used by Sarkar et al. (1966) as a basis for the dendrogram shown in Fig. 10 (Appendix). The index of similarity is calculated by the following formula (Sarkar, 1966):

$$S.I._{1,2} = \frac{2W}{A + B} \times 100$$

where

$X.I._{1,2}$ = index of similarity between soils 1 and 2

A = sum of all transformed character values for soil 1

B = sum of all transformed character values for soil 2

W = sum of the minimum transformed character values for each character for the two soils concerned

Distance, correlation, and similarity index each measure affinity between soils in a different manner. It is believed, however, that when used in numerical taxonomy, these three estimates of similarity will disclose grossly comparable relationships among individuals.

Summarizing Relationships Among Soils

Two dendrograms, one based on the distance matrix and one based on the Z-transformed correlation matrix, were constructed. The cluster analyses were accomplished by the unweighted-pair-group method using arithmetic averages (UPGM-A) in both cases. This method of cluster analysis (UPGM-A) was used since Rohlf (1962) reported that it gave the highest cophenetic correlations.

A centroid-factor analysis was conducted on the 21 x 21 matrix of correlations among characters to obtain a third representation of the relationships among soils. Factor scores were calculated and all 59 soils were projected onto centroid-character axes. This projection facilitated the presentation of relationships among soils in three dimensions.

Computation and Programming

Virtually all computations were performed at the University of Kansas Computation Center using NTSYS programs which were available at that installation. NTSYS is a collection of multivariate statistical programs of use in numerical taxonomy. The various programs, written in FORTRAN IV for the IBM 7040 computer, had been combined onto a chain tape with a supervisory control program, to allow various combinations of the programs to be used in any desired order within a single run. Dr. Robert R. Sokal and Dr. F. James Rohlf, of the University of Kansas Department of Entomology, had been instrumental in the writing of these programs.

The five programs used most in this study, and the functions of each program, were as follows:

(1) STAND--Standardization of data matrices

(2) CORDST--Computation of correlation and distance matrices

(3) TAXON--Cluster analysis with phenogram and cophenetic value output

(4) PROJET--Centroid-factor analysis with projections of individual OTU's (soils) onto the centroid-character axes

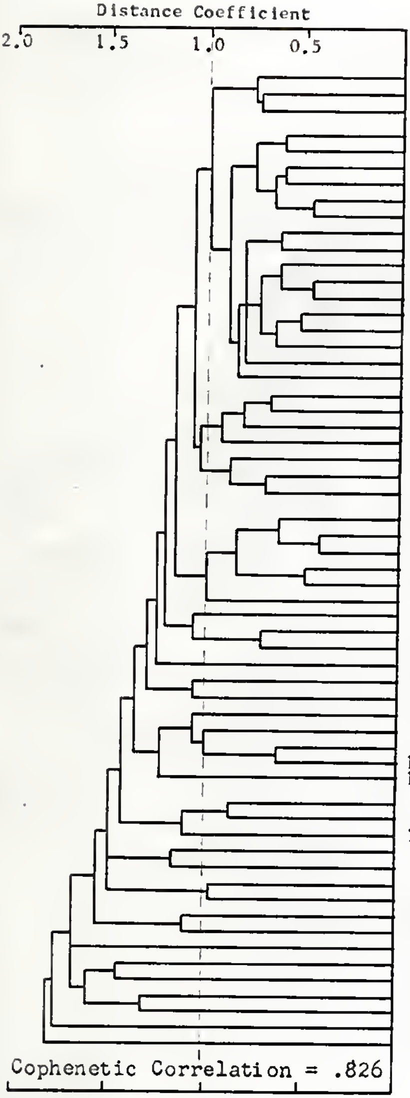
(5) CENTRD--Centroid-factor analysis

RESULTS AND DISCUSSION

Comparison of Distance and Correlation Dendrograms

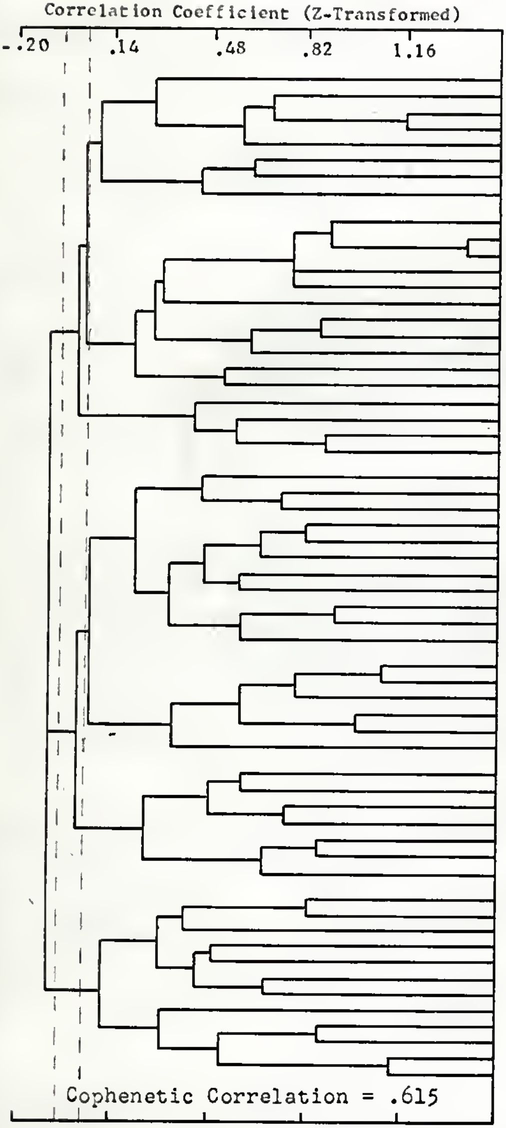
Figures 2 and 3 show relationships among all 59 soils. Z values are plotted on the X-axis in Fig. 3 and in Figs. 7, 8, and 9 (Appendix), rather than correlation values, since there is no statistical justification for averaging correlation coefficients. A Z value of .867 corresponds to a correlation value of about .700. The dashed line, or phenon line, drawn across the dendrogram (Fig. 3) at Z = -.03, yields three clusters of soils, known as phenons, with each cluster supported by a single stem. The first cluster or phenon is shown in Fig. 7 (Appendix), expanded along the Y-axis. The scale was not changed along the X-axis. Part of the second cluster is reproduced in Fig. 8 (Appendix), and the remaining soils are shown in Fig. 9 (Appendix). A similar division of the distance dendrogram (Fig. 2) is made in Figs. 4, 5, and 6 (Appendix). Clusters were not well defined in the lower portion of the distance dendrogram; therefore, the second division was made arbitrarily between soils 101 and 87. These divisions (Figs. 4, 5, 6, 7, 8, and 9, Appendix) do not alter any of the relationships among soils shown by the two dendrograms (Figs. 2 and 3); the breakdowns are made merely to facilitate location of the various soils for the purposes of discussion.

Numbers at the right ends of the stems of all dendrograms correspond to profile numbers in the 7th Approximation (1960). The soil series name is given next, for example, Sharpsburg,



Profile No.	Soil Series Name	Text. Class	Loc.
2	Sharpsburg	SiCL	Neb
3	Eakin	SiL	SD
72	Shelby	CL	Iowa
4	Exline	FSL	ND
18	Exline	CL	ND
15	Williams	L	ND
69	Unnamed	SiL	SD
19	Tetonka	SiL	ND
66	Tetonka	SiCL	ND
8	Odin	SiL	Oregon
17	Rhoades	VFSL	SD
11	Alford	SiL	Indiana
76	New Mexico	L	ND
84A	Lansing	SiL	NY
68	Barnes	CL	ND
73	Morton	L	ND
74	Keith	L	Neb
23	Fillmore	SiL	Neb
62	Mohave	CSL	Ariz
29	Scituate	SL	NH
48	Erie	CL	NY
67	Webster	CL	Minn
55	Burton	L	Tenn
57	Mimbres	CL	NM
58	Blackhawk	SiL	Nev
61	Saltair	SiL	Utah
9	Windthorst	LVFS	Tex
89	Corning	L	Cal
96	Cahaba	FSL	Ala
31	Redding	L	Cal
86	Redding	L	Cal
79	Wrightsville	SiL	La
21	Leon	S	Ga
39	Lakewood	S	Fla
40	Lakeland	S	SC
44	Eutaw	SiC	Miss
10	Unnamed	SiC	Yugo
46	Unnamed	SiCL	Ariz
27	Nipe	C	P Rico
95	Aiken	SiC	Ore
99	Catalina	C	P Rico
100	Cialitos	C	P Rico
101	Unnamed	SCL	Congo
87	Carlsbad	SL	Cal
88	Red Bluff	L	Cal
102	Molokai	CL	Hawaii
42	Victoria	C	Tex
71	Unnamed	SCL	Yugo
80	Lacamas	SiL	Wash
91	Sabana Seca	C	P Rico
63	Uvada	FSL	Utah
64	Fresno	SiL	Cal
5	Quillayute	SiL	Wash
35	Tanana	SiL	Alaska
77	Unnamed	SiL	Norway
50	Unnamed	FSL	Alaska
52	Waimea	SL	Hawaii
34	Teas	SiL	W Va
78	Unnamed	FS	Norway

Fig. 2. Dendrogram for fifty-nine soils based on distance coefficients. The dendrogram was prepared by the unweighted-pair-group method using arithmetic averages, UPGM(A). Distance matrix was computed from the standardized data of Table 6 (Appendix).



Profile No.	Soil Series Name	Text. Class	Loc.
2	Sharpsburg	SiCL	Neb
72	Shelby	CL	Iowa
99	Catalina	C	P Rico
100	Cialitos	C	P Rico
95	Aiken	SiC	Oregon
10	Unnamed	SiC	Yugo
34	Teas	SiL	W Va
46	Unnamed	SiCL	Ariz
9	Windthorst	LVFS	Tex
89	Corning	L	Calif
96	Cahaba	FSL	Ala
31	Redding	L	Calif
86	Redding	L	Calif
62	Mohave	CSL	Ariz
87	Carlsbad	SL	Calif
88	RedBluff	L	Calif
102	Molokai	CL	Hawaii
27	Nipe	C	P Rico
101	Unnamed	SCL	Congo
44	Eutaw	SiC	Miss
79	Wrightsville	SiL	La
80	Lacamas	SiL	Wash
91	Sabana Seca	C	P Rico
3	Eakin	SiL	SD
73	Morton	L	ND
74	Keith	L	Neb
8	Odin	SiL	Ore
76	New Mexico	L	ND
23	Fillmore	SiL	Neb
11	Alford	SiL	Indiana
84A	Lansing	SiL	NY
17	Rhoades	VFSL	SD
63	Uvada	FSL	Utah
64	Fresno	SiL	Calif
4	Exline	FSL	ND
18	Exline	CL	ND
69	Unnamed	SiL	SD
19	Tetonka	SiL	ND
66	Tetonka	SiCL	ND
15	Williams	L	ND
42	Victoria	C	Tex
71	Unnamed	SiCL	Yugo
67	Webster	CL	Minn
68	Barnes	CL	ND
57	Mimbres	CL	NM
58	Blackhawk	SiL	Nev
61	Saltair	SiL	Utah
5	Quillayute	SiL	Wash
55	Burton	L	Tenn
52	Waimea	SL	Hawaii
35	Tanana	SiL	Alaska
77	Unnamed	SiL	Norway
50	Unnamed	FSL	Alaska
78	Unnamed	FS	Norway
21	Leon	S	Ga
29	Scituate	SL	NH
48	Erie	CL	NY
39	Lakewood	S	Fla
40	Lakeland	S	SC

Fig. 3. Dendrogram for fifty-nine soils based on product-moment correlation coefficients (Z-transformed). The dendrogram was prepared by the unweighted-pair-group method using arithmetic averages. Correlation matrix was computed from the standardized data of Table 6.(Appendix).

Eakin, and Shelby in Fig. 2 (and in Fig. 4, Appendix). Profiles which did not have series names are listed as Unnamed on the dendrograms. Surface textural classes, given in the third column, correspond to the following accepted texture abbreviations:

C	clay
CL	clay loam
CSL	coarse sandy loam
FS	fine sand
FSL	fine sandy loam
L	loam
LVFS	loamy very fine sand
S	sand
SCL	sandy clay loam
SL	sandy loam
SiC	silty clay
SiCL	silty clay loam
SiL	silt loam
VFSL	very fine sandy loam

Ideally, one might expect to obtain identical relationships among the soils, using either distance or correlation coefficients, when the similarity matrices are summarized in the form of dendrograms. However, these two coefficients did not measure similarity between individuals in the same manner. In order to obtain perfect likeness between two soils by distance (a distance coefficient of 0.0), the two soils must have identical values for all characters. However, perfect correlation (a correlation coefficient of 1), could have been obtained if all character values of one soil had been exactly twice those of the other. If this perfect correlation had been interpreted to indicate that the soils were identical, it would have been a gross misrepresentation of their true natures. In this respect, distance is considered a stricter measure of similarity than is correlation, since the magnitude of the distance coefficient is determined by deviations from a fixed line rather than from a trend line which is influenced by the data. This is one criticism of the use of correlation as a measure of similarity.

The difference in the way correlation and distance measured similarity or affinity is indicated by a relatively low magnitude of correlation between the distance and correlation values. This correlation coefficient, between corresponding elements of the distance matrix and the correlation matrix, (based on 1711 observations) is -.565. This relatively low value is not necessarily undesirable, since it is undoubtedly statistically significant with 1711 observations. Rohlf (1962) reported average correlations between distance and correlation matrices of approximately -0.5, and considered these values to indicate general agreement between the two matrices. The correlation coefficient between correlation and distance matrices is negative since distance is a measure of degree of dissimilarity and correlation is a measure of degree of similarity.

Close scrutiny of Figs. 2 and 3 revealed areas of agreement between distance and correlation dendrograms. These areas of agreement were not always apparent upon initial casual observation. First, the distance dendrogram (Fig. 2) contained 11 pairs of soils that also occurred in the correlation dendrogram (Fig. 3). These were the pairs 4 and 18, 19 and 66, 29 and 48, 89 and 96, 31 and 86, 39 and 40, 99 and 100, 87 and 88, 42 and 71, 80 and 91, and 35 and 77. The correlation of .921 for soils 31 and 86 converted to a Z value greater than 1.5, which the computer did not print out in the dendrogram since values greater than 1.5 were not anticipated by the program. Second, four small clusters of soils found in the distance dendrogram also occurred in the correlation dendrogram. These were 57, 58, and 61 (three Aridisols); 4, 18, 15, 69, 19, and 66 (six Mollisols); 9, 89, 96, 31, and 86 (five Alfisols and one Ultisol); and 87, 88, and 102 (two Alfisols and an Oxisol). Third, some other clustering relationships among soils occurred which were more complex to describe. These were typified by the example of soils 10 and 46 (a pair by distance) which were not a pair by correlation but were included in the cluster consisting of soils 10, 34, and 46. At least three other clusters of soils indicated relationships of this nature. These clusters were as follows (based on distance dendrogram, Fig. 2):

(1) Soils 35, 77, 50, and 52

(2) Soils 27, 95, 99, 100, and 101

(3) Soils 21, 39, and 40

Figures 4 and 8 (Appendix) express some comparable relationships among soils. The phenon line drawn at a distance of 1.0 (Fig. 4, Appendix) gives a cluster of 19 soils supported by a single stem. This cluster is known as a 1.0 phenon in the nomenclature of numerical taxonomy. These 19 soils are primarily Mollisols and are referred to as the Mollisol cluster throughout the study. All soils in Fig. 8 (Appendix) form a cluster when a phenon line is drawn at Z = .06. All soils of this cluster, which is known as a .06 phenon, are included in the 1.0 phenon mentioned above with the exception of the Aridisols 63 and 64. Soils found in this 1.0 phenon but not found in the .06 phenon in Fig. 8 (Appendix) are 2, 72, 68, and 62. The sub-cluster of soils 4, 18, 15, 69, 19, and 66 is found in both dendrograms as previously mentioned.

Obvious differences exist between the general structures of the distance dendrogram (Fig. 2) and the correlation dendrogram (Fig. 3). Clusters of soils occur rather uniformly throughout the correlation dendrogram; whereas few well defined clusters occur in the lower part of the distance dendrogram, where most soils join at low levels of similarity. This lack of clusters in Fig. 2 seems to point out the fact that, in general, the soils in the lower portion of the distance dendrogram are not close (by the statistical distance measurement) to any soils in the study.

Examination of correlation coefficients (Table 7, Appendix) for these soils in the lower portion of the distance dendrogram (specifically, soils 5, 35, 77, 50, 52, 34, and 78) indicates that they are not highly correlated with any soils. Thus, correlation and distance matrices express agreement on the general nature of these soils (5, 35, 77, 50, 52, 34, and 78), but the fact that they have some affinity for one another is not obvious from the distance dendrogram. Conversely, the fact that these soils (5, 35, 77, 50, 52, 34, and 78) are unlike the rest of the soils in the study is not obvious from the correlation dendrogram.

As the clusters of Fig. 2 are scanned from the top downward, soil 44 (a Mississippi Vertisol) is the first soil to join a cluster at a distance greater than 1.1. This indicates that soil 44 has some affinity for many of the soils above it but little affinity for those soils below it, which is verified by examination of the distance matrix (Table 8, Appendix). The distance matrix discloses the fact that soils most similar to 44 are 48, 15, 79, 61, and 67, in that order. Soils found to be least like 44 by the distance criterion are 78, 52, 34, 50, and 5, in that order. Soils most similar to 44 by correlation (Table 7, Appendix) are 91, 48, 79, 61, 15, 86, and 67, in that order, which is fairly good agreement with distance relationships. These correlations are all less than or equal to .510, however; and of these, only soils 91 and 79 appear closely related to soil 44 in the correlation dendrogram (Fig. 3). The extreme dissimilarity between soil 44 and soils 78, 52, 34, 50, and 5 which is suggested by distance is not verified by correlation (Table 7, Appendix), except in the case of soil 52. In fact, several soils (4, 23, 73, 74, 84A, and 102) are more unlike soil 44 by correlation than are soils 5, 50, 34, and 78.

Evaluation of Dendrograms by Cophenetic Correlation

The cophenetic correlation (discussed on pages 16 and 17) between the distance matrix and the distance dendrogram is 0.826. The cophenetic correlation between the correlation matrix and the correlation dendrogram is 0.615. Since the cophenetic correlation for distance (0.826) is greater than the cophenetic correlation for correlation (0.615), it is concluded that the distance dendrogram gives a more reliable representation of its matrix than the correlation dendrogram gives of its matrix.

Comparison With Results of a Previous Study

One means of judging the success of using the 21 characters similar to those selected by Sarkar et al. (1966) by objective methods was to observe those soils which were included in both studies. Figure 10 (Appendix) shows the 26 soils of their study. All but two of these soils (84 and 97) were included in the present study. Profiles 84 and 97 were deleted because they were polygenetic soils; that is, they had presumably formed under climates and vegetation different from those of the present. Their polygenetic nature would have made it difficult to obtain valid comparisons with the rest of the soils. The 24 soils common to the two studies exhibited relationships in this study which were comparable to the relationships observed by Sarkar et al. (1966). Since 35 other soils were studied also, complete agreement between the two studies was not only difficult to obtain but difficult to recognize when it occurred. However, results disclosed by the correlation dendrogram (Fig. 3) were interpretable in terms of the previous study.

Sarkar et al. (1966) found 16 soils that stayed within a given cluster through successive reductions of soil characters from 61 to 22. These soils are marked by * in Fig. 10 (Appendix). The three groups of soils which maintained integrity throughout character reduction are labeled I, II, and III. Soils which formed no consistent pattern in their study were 61, 35, 40, 48, 52, 50, 77, 78, 39, and 101. Of these ten soils, six formed pairs with relative consistency throughout character reduction.

These pairs were Entisols 39 and 40 (not paired in Fig. 10, Appendix), Inceptisols 50 and 52, and Spodosols 77 and 78. Soil 61 stayed in Group I throughout reduction except when 40 characters were used; soil 35 was rather erratic while soils 48 and 101 were considered the most unstable soils by the authors.

Comparison of Fig. 3 and Fig. 10 (Appendix) reveals that the six stable soils in Group I of Sarkar et al. (1966) are found, except for soil 46, in the large central cluster of the correlation dendrogram. (The delineation of this large central cluster by the -.03 phenon line is discussed on page 37.) Since this central cluster (Fig. 3) also contains soil 61 but lacks soils of Groups II and III (Sarkar et al.), it indicates relatively good agreement with group I of Sarkar et al. As mentioned above, soil 46 is not included in the large central cluster of the correlation dendrogram; however, it joins soils 10 and 34 (top cluster, Fig. 3) which were not present in the previous study. The affinity of soils 10 and 46 is verified by distance in this study.

The four stable soils from Group II of Sarkar et al. (72, 95, 99, 102) were found in the top cluster of Fig. 3, and were joined by the soils of Group III (44, 79, 80, 91) just as in their study (Fig. 10, Appendix). As previously mentioned, soils 84 and 97 were excluded from the present study. Group II (Fig. 10, Appendix) showed that soils 48 and 72 (New York and Iowa soils, respectively) formed a pair. Data from the 7th Approximation indicated that both soils were formed from calcareous glacial till, that temperature and precipitation were similar

(Figs. 13 and 11, Appendix), and that particle size distribution, pH, cation exchange capacity, and amounts of extractable cations were comparable. Although soil 48 stayed in Group II with reduction to 51 and 40 characters, its affinity for soil 72 was only apparent when using 61 characters.

The affinity of soils 48 and 72 is not substantiated by the present study if it exists. The distance between soils 48 and 72 is 1.012, which is not an extreme dissimilarity; however, soil 72 is closer than this by distance to many Mollisols and some Alfisols. Distance relationships of soils 48 and 72 to all other soils in the study indicate similarity between the two soils; that is, they both show similar relationships to many of the other soils. However, correlation between these two soils is only .057 (Table 9, Appendix), and both soils show many correlations with other soils which are higher than this. Soil 72 was highly correlated with Oxisols 99 and 100 and Ultisol 95, and soil 48 had correlations greater than .40 with soils 29, 2, 5, 15, 44, 55, 61, 67, and 77.

Sarkar (1966) found that soil 48 clustered with Spodosols 77 and 78 and Entisols 39 and 40 when he used correlation coefficients. Figure 3 and Fig. 9 (Appendix) demonstrate general agreement with his result in this case. Overall, however, soil 48 was considered to be unstable in the present study. Even though it showed definite affinity for soil 29 by correlation and distance, its relationships to other soils (Mollisols, Spodosols, and Vertisols) were rather erratic. Its behavior gave credence to its classification as an Inceptisol.

The three soil pairs mentioned above (Entisols 39 and 40, Inceptisols 50 and 52, and Spodosols 77 and 78) were verified relatively well in the present study (Figs. 2 and 3). The close relationship of Ultisol 95 and Oxisol 99 was verified also, as were the common affinities of three Oxisols (99, 101, and 102).

Three Aridisols (57, 61, and 64) are shown in Group I (Fig. 10, Appendix). Close relationship between two of these (57 and 61) was indicated by the present study; however, soil 64 was found to have greater affinity for soil 63 (not included in the study by Sarkar et al., 1966) which, as a pair, lacked strong affinity for other Aridisols. This relationship is logical, since soils 63 and 64 have much more well developed profiles than the rest of the Aridisols (except soil 62). In Fig. 8 (Appendix), soils 63 and 64 cluster with soil 17, a South Dakota soil. All were sodium affected (Table 4, Appendix).

Within limits, results of this study agreed well with those of Sarkar et al. (1966). This agreement reinforces the validity of the relationships discovered by numerical taxonomic methods, since numerous changes in procedures and data were made. First, two soils were eliminated and thirty-five others were added. Second, some changes were made in the characters used (see Material and Methods). One character was eliminated entirely (character 42), one new one was added (character 62) to replace two others (characters 52 and 53), and one substitution was made (character 45 for character 48). Third, 21 characters were then standardized over 59 soils to give each character a mean of zero and a variance of unity, whereas Sarkar et al. (1966) had transformed 61 characters over 26 soils to give each character a range of 0 to 1000. Fourth, Sarkar et al. (1966) computed the index of similarity of Goodall (1954) as a measure of affinity, whereas the present study used correlation and distance coefficients (and factor analysis, which is discussed separately later). The fifth and final difference in the procedures used in the two studies is that Sarkar et al. (1966) used the weighted-pair-group method (WPGM) of cluster analysis to construct dendrograms, whereas this study employed the unweighted-pair-group method with arithmetic averages. Comparison was made primarily between relationships indicated by correlation in this study and those indicated by similarity index using 61 characters and weighted-pair-group method of cluster analysis in the study by Sarkar et al. (1966). Relationships indicated by Sarkar (1966) using distance, correlation, and similarity index, for various numbers of objectively and subjectively selected characters, were quite instructive however.

Evaluation of Dendrograms With Respect to Logical Relationships Between Soils

Perhaps the most critical evaluation of the methods of numerical taxonomy comes when results are analyzed for logical relationships. In this respect the investigator can protect himself from drawing false conclusions when using statistical procedures he does not fully understand. Sokal and Sneath (1963) pointed out that a taxonomist need not have a complete understanding of these procedures to employ them to good advantage, just as any scientist may not completely understand a complex piece of mechanical equipment he uses in his research.

Most of the relationships indicated by the dendrograms (Figs. 2 and 3) are logical. Some of these already have been pointed out; others may have been observed by the reader. Some relationships which seem illogical to soil scientists can be explained by an examination of the raw data (Table 4, Appendix). In addition to relationships discussed in this section, others will be pointed out in the section, Comparison to 7th Approximation Classifications. The first 19 soils shown in Fig. 4 (Appendix) form a logical group and are mainly soils of one geographical area. They are all Mollisols except the Odin soil of Oregon (8), the Alford soil of Indiana (11), the Lansing soil of New York (84A), the Fillmore soil of Nebraska (23), and the Mohave soil of Arizona (62). The presence of the two Alfisols (8 and 11) in the Mollisol cluster is not too objectionable, although the dendrogram, perhaps, should not be interpreted to indicate that these two soils (8 and 11) are as typical of the Mollisol Order as are the Mollisols Barnes, Morton, and Keith (68, 73, 74). Rather, it is felt this situation represents a limitation of the methods of numerical taxonomy in that it is, like conventional taxonomy, iterative to a certain extent. If more precise relationships were desired, this group of 19 soils could be studied separately, perhaps employing more characters. This approach is discussed later under the section, Some General Considerations in the Study.

Soils of the same series (4 and 18, 19 and 66) reacted as would be expected, which lends support to the validity of numerical taxonomy in soils (Fig. 4, Appendix). Soils 31 and 86 (Fig. 5, Appendix), the Redding gravelly loam, are identical profiles. However, two of the 21 characters had different values recorded in the 7th Approximation. Soil 31 had an 8 recorded for its structure (strong prismatic), and soil 86 had a 6 recorded (strong blocky). Hue of B was recorded as 8 for soil 31 and 5 for soil 86 (Table 4, Appendix). These very slight, artificially introduced differences resulted in a correlation coefficient of 0.921 between the two soils. As previously discussed, this correlation value transformed to a Z value of 1.59, so that the true relationship between these two soils is not shown in Fig. 3 and Fig. 7 (Appendix). By distance (Table 8, Appendix), however, soils 31 and 86 were less closely related than were soils 89 and 96. The Tetonka soils (19 and 66), different soil types of the same series, had 15 characters of slightly differing values (Table 4, Appendix), giving a correlation of 0.753, a high value for this particular study. The Exline soils (4 and 18) had slightly differing values for 17 characters (Table 4, Appendix), and a correlation of 0.802 (Table 7, Appendix). It is interesting to observe the effect of this slight change in data for two descriptions of an identical soil (31 and 86) as compared to different soil types of the same series (4 and 18, 19 and 66).

The second cluster in Fig. 5 (Appendix) consists of three soils, Leon, Lakewood, and Lakeland sands. These all occur in southeastern United States. They differ in mean annual precipitation by only 7.3 inches (46.2 to 53.5 inches), and in mean annual temperature by only 7 degrees (64 to 71° F.).

The bottom cluster of five soils (27, 95, 99, 100, 101) in Fig. 5 (Appendix) consists of four Oxisols and one Ultisol, the Aiken silty clay. The Aiken has been classified in the past as a Reddish-Brown Lateritic soil, a great soil group characteristic of Puerto Rico and the Phillipines.

As was discussed in the last section, soil 48 (Erie clay loam) was difficult to place in this classification and in previous numerical classifications. It appeared to have affinity for soils in all of the nine Orders studied except Oxisols. In Fig. 10 (Appendix) it is clustered with a Mollisol (72), an Entisol (40), an Alfisol (84), and an Ultisol (97). In the present study (Figs. 9 and 4, Appendix) it consistently formed a pair with soil 29 (Scituate sandy loam). This close relationship between Erie (48) and Scituate (29) is rather logical, as they possess many common attributes. Among these attributes are glacial till parent materials, fragipans at a depth of 16 inches, climate, free iron oxides, more clay in A Horizon than in B Horizon, pH, color, mottling, and amounts of various extractable cations. However, the pair (29 and 48) then clustered with a Spodosol (21) and two Entisols (39 and 40) by correlation (Fig. 9, Appendix); and with a Mollisol (67), an Inceptisol (55), and three Aridisols (57, 58, 61) by distance (Fig. 4, Appendix).

Erie (48) also had an affinity for some other soils, primarily Mollisols, which was not apparent from the dendrograms

(Figs. 2 and 3) but was noted in the similarity matrices (Tables 8 and 9, Appendix). Those soils with which Erie (48) was most highly correlated were 29, 67, 15, 2, 5, 55, 44, 77, and 61, in that order. The high relationship of Erie (48) to Webster clay loam (67) is of some interest since the latter did not seem to have so much affinity for Mollisols (except for Barnes) as it perhaps should have. Webster (67) was rather unstable in this classification study. The relationship of Erie (48) to Williams (15) is also of interest and will be discussed later in the section, Some General Considerations in the Study. These two soils were both developed in calcareous glacial till and have comparable surface textures and colors; however, they are not normally thought of as similar soils.

Trends in mean annual temperature and mean annual precipitation (Figs. 11, 12, and 13, Appendix) revealed interesting relationships. The three dendrograms of Figs. 11, 12, and 13 (Appendix) are duplications of Figs. 7, 8, and 9 (Appendix), respectively. The cluster in Fig. 11 (Appendix) has soils with uniformly high temperatures. The average temperature for all soils in this large cluster was 63.8° F. The first subcluster of eight soils (2, 72, 99, 100, 95, 10, 34, and 46) had lower temperatures than this in general, and the next two clusters had higher temperatures, in general. Precipitation was not very uniform within clusters. Fig. 12 (Appendix) consisted primarily of North and South Dakota soils which were expected to have uniformly low mean annual temperatures. Most temperatures were between 40° and 50° F. The bottom cluster of six soils had a notable tendency for annual temperatures of 42° F. It included the two duplicated soils, Tetonka and Exline. Data for both Tetonka soils was from the same weather station and therefore identical. The Exline is a salt-affected intrazonal soil, in which climate is not so important as it is in the formation of zonal soils. Precipitation was rather uniformly low with an average of 18.4 inches for the cluster. Temperature considerations made the New York and Oregon soils seem more logical members of this group.

Fig. 13 (Appendix) shows no particular trends in temperature or precipitation. The middle subcluster (5, 55, 52, 35, 77, 50, and 78) has four soils (35, 77, 50, and 78) with low temperatures; an Entisol, an Inceptisol, and two Spodosols, soils from three of the ten Orders of the 7th Approximation. Two of these soils are found in Alaska and two in Norway. In defense of the 7th Approximation, four out of seven of the soils in this cluster are Inceptisols, an order which has been criticized strongly because it brings together soils of great geographical separation (Washington, Tennessee, Hawaii, and Alaska in this case).

Results of Factor Analysis Applied to Character Correlation Matrix

This analysis could be considered to indicate relationships which are independent of the results of the distance and correlation dendrograms since it was based on correlations among characters rather than on comparisons among soils. The same standardized data were used, however, so that one would expect similar relationships among soils to be indicated. In fact, Figs. 14 and 15 (Appendix) seem to clarify some relationships among soils which were difficult to visualize in the dendrograms.

Figures 14 and 15 (Appendix) present partial results of this factor analysis of the 21 X 21 matrix of correlations among characters. Ten factors were extracted but only the relationships indicated by the first three are shown. A statistical interpretation of factor analysis is beyond the scope of this study; however, numerous logical relationships among soils are suggested (Figs. 14 and 15, Appendix). Since Fig. 14 (Appendix) shows all 59 soils projected onto centroid character axes for the first two factors extracted (I and II), it contains more information than would a projection of any other two factors. In this case 25.26 percent of the information in the 21 X 21 correlation matrix is explained by Factors I and II. Fig. 15 (Appendix) shows 59 soils projected onto centroid character axes for Factors I and III, and can be thought of as a view of Fig. 14 (Appendix) from the top. These two figures together give three-dimensional relationships among soils. For example, in this perspective, soil 101 actually lies behind soil 11, and soil 95 lies behind soil 63, giving much greater separation between soils 63 and 95 than is indicated in Fig. 14 (Appendix). Figs. 13 and 14 (Appendix) together (that is, Factors I, II, and III) explain 37.36 percent of variability in the 21 X 21 matrix.

In Fig. 14 (Appendix) boundaries were drawn to enclose those soils which are thought to be similar. These boundaries would be difficult to determine without prior knowledge of the soils, since there are no tight clusters of soils such as sometimes have been found in biological investigations with different species (Pitcher, 1966). Boundaries of group A were determined primarily by relationships indicated in the distance dendrogram (Fig. 4, Appendix). An attempt was made to include as many Mollisols in group A as could be enclosed without also including non-Mollisols. The formation of the group was fairly successful in this respect but soil 67 (Webster) was left out to prevent inclusion of Aridisol 58. Likewise, soil 71 was omitted to prevent inclusion of 42, a Texas Vertisol (Victoria clay). It is noted that group A includes some non-Mollisols. These were soil 11 (an Indiana Alfisol), soil 57 (a New Mexico Aridisol), soil 23 (a Nebraska Alfisol), and soil 101 (a Congo Oxisol). A consideration of Fig. 15 (Appendix) does not alleviate this situation unless group A is formed according to the dashed line, in which case soils 2 and 72 (Nebraska and Iowa Mollisols, respectively) were eliminated also.

Six soils (9, 89, 96, 31, 86, and 79) which clustered in Fig. 5 (Appendix) were taken as the nucleus of group B. This group is considered the Alfisol group; however, it includes soil 96, an Alabama Ultisol (previously classified as Red-Yellow Podzolic soil). It is incomplete with respect to Alfisols since soils 10, 11, 23, 80, and 84A are not included. This problem is partially remedied by forming group B as indicated by the dashed line in Fig. 15 (Appendix); however, this causes the inclusion of Aridisol 62 and ultisol 91 (soil 10 still is not included since it is located above group B as was observed in Fig. 14, Appendix).

Group C is comprised of Spodosols, but Fig. 15 (Appendix) indicates that they did not actually form as tight a cluster as they appeared to form in Fig. 14 (Appendix). Figure 14 (Appendix) clarifies the similarity of soils 29 (Scituate) and 48 (Erie) to the Spodosols (21, 77, 78) and to Entisols 39 and 40, which was indicated in the correlation dendrogram (Fig. 9, Appendix). Whether this explains these similarities is not known; however, it at least allows them to be visualized. These seven soils (29, 48, 21, 77, 78, 39, and 40) are included in a group free of other soils, as is indicated by comparison of Figs. 14 and 15 (Appendix).

Group D includes seven Inceptisols. It is an exclusive group since it is located behind soil 67 in Fig. 14 (Appendix) and above soil 77 in Fig. 15 (Appendix). Soil 35 (an Alaska Entisol) and soil 50 (an Alaska Inceptisol) show an affinity for each other in these two figures. In this respect soil 35 seems more closely related to Inceptisols than to Entisols. The seven Inceptisols were not uniquely clustered in the dendrograms; however, soils 5, 55, and 52 were clustered in Fig. 9 (Appendix) and soils 50 and 52 were clustered in Fig. 6 (Appendix), which indicated that they had some affinity for one another.

Group E includes the five Oxisols of the study (27, 99, 100, 101, and 102) and Ultisol 95 which exhibited an affinity for Oxisols by both correlation and distance. These six soils were never clustered uniquely by the dendrograms, although they were all members of a large cluster by correlation (Fig. 7, Appendix); and all except 102, the Hawaii Oxisol, clustered in Fig. 5 (Appendix).

The cluster of soils in the lower portion of Fig. 4 (Appendix) (29, 48, 67, 55, 57, 58, and 61) was not verified by these projections. Rather, it appeared that soils 29, 48, and 55 formed a cluster, 58 and 61 formed a pair, soil 57 stayed in the middle of group A (Mollisols), and soil 67 stayed near soils 58 and 68. These relationships were not inconsistent with the dendrograms, nor did they allow specific placement of soil 67 (Webster) in a cluster. Webster had affinity for some Inceptisols, some Mollisols, and even some Aridisols (Tables 8 and 9, Appendix). It had greatest affinity for Barnes (68) by both correlation and distance and was next most like Erie (48). Its affinity for Erie was somewhat understandable, as both were gleyed.

Vertisols (42, 44, and 46) did not show a definite cluster in this projection, and Aridisols (except soil 57) appeared to form a loose cluster around the Mollisol cluster (group A). There was some indication that Aridisols 57, 58, and 61 had more affinity for one another than they did for the other Aridisols (62, 63, and 64). This was not unlikely, since the latter three soils had more strongly developed profiles.

Comparison to 7th Approximation Classification

Results of this study indicated several areas of agreement with the 7th Approximation at the Order level. Mollisols, Alfisols, Inceptisols, and Oxisols clustered well in Figs. 14

and 15 (Appendix) in general. Aridisols, Vertisols, and Spodosols did not form well-defined clusters; however, the individual soils of the three Orders seemed to maintain their identity apart from those clusters which were more clearly defined. An exception to this fact was that Aridisol 57 joined the Mollisol cluster.

Aridisols had some affinity for Mollisols throughout the study which was evidenced in Figs. 14 and 15 (Appendix) by the distribution of Aridisols around the fringes of the Mollisol cluster. Vertisols behaved in a manner similar to this; they showed affinity for Mollisols but never became a part of the Mollisol cluster. Tables 8 and 9 (Appendix) indicated that Vertisols had greater affinity for various other soils (primarily Mollisols) than they did for other Vertisols. The closest distance between any two Vertisols was 1.384 and the greatest correlation was .274. Texas and Arizona Vertisols were more like each other than either was like the Mississippi Vertisol. Both showed affinity for soil 71, a Yugoslavia Mollisol (Vermudoll).

Spodosols maintained separation from the other soils, but indicated some affinity for Entisols 39 and 40. The Georgia Spodosol (21) especially showed affinity for the Florida and South Carolina Entisols (39 and 40, respectively). Entisol 35 from Alaska showed almost no affinity for Entisols 39 and 40 but was found consistently in a cluster with the Alaska Inceptisol (50).

Ultisols (91, 95, and 96) were not closely related to one another. Rather, Ultisol 95 clustered with Oxisols (Figs. 5, 7, 14, and 15, Appendix) and Ultisol 96 clustered with Alfisols (Fig. 5, Appendix) while Ultisol 91 exhibited a tendency to cluster with Alfisols, but to a lesser extent than did Ultisol 96 (Figs. 6, 7, and 14, Appendix).

Some General Considerations in the Study

Robust Nature of Cluster Analysis. Two errors in the early phases of the study revealed some advantages of cluster analysis techniques. Discussion of the results obtained using these erroneous data is included here because it emphasizes an important feature of cluster analysis techniques. Values for character 11, Fe-Mn concretions, were erroneously key punched as 555.5 for the 13 soils from 50 through 69, whereas these values should have all been zeros. The second error caused character 1, structure of B_2, to be omitted entirely from the computation of correlation and distance matrices.

The first error caused gross inaccuracies in the standardized values of character 11 for most soils. For example, the standardized value of character 11 for soil 2 was .722, but later was found to be 1.344 when correct data were used and character 11 was restandardized. The standardized value for zero for character 11 went from -.716 to -.385, the standardized value for 1000 went from 2.521 to 3.505, and the standardized values of character 11 for the 13 soils directly affected went from 1.082 to -.385 when correct data were used. All other characters were unaffected.

The effects of these two errors on correlation and distance relationships varied from one pair of soils to another. When character 1 was returned to the study and proper values were used for character 11, $r_{48,15}$ decreased from .718 to .618, $r_{48,67}$ increased from .494 to .636, $r_{67,69}$ decreased from .510 to .006, and $r_{88,96}$ decreased only .001 (from .889 to .888). Distances changed in a similar manner, but not so drastically as did correlations in most cases. For example, the distance between soils 67 and 69 increased from .682 to 1.007. Many changes in correlation values of the magnitude of approximately .10 were indicated; and certain soils, such as soil 69, had several changes in correlation values of the magnitude of approximately .30.

While these erratic changes in the similarity matrices were expected to produce quite different dendrograms, they did not do so, especially for the distance criterion.

Comparing the original erroneous distance dendrogram with Fig. 2, it was noted that essentially only five soils had been affected, and that all clusters were comparable in the two dendrograms. Referring to Fig. 2 as the basis for comparison, five differences were noted in the original erroneous distance dendrogram. These differences were:

(1) Soils 67 and 68 were in the cluster of soils 4, 18, 15, 69, 19, and 66 and soil 15 was not.

(2) Soils 68 and 62 were not in the cluster consisting of soils 8, 17, 11, 76, 84A, 68, 73, 74, 23, and 62 in Fig. 2.

(3) Soil 15 replaced soil 67 in the cluster 29, 48, 67, and 55 in Fig. 2.

(4) The cluster of Aridisols 57, 58, and 61 joined the main dendrogram (consisting of all soils above this cluster) instead of joining the cluster 15, 48, 29, and 55.

(5) Soil 62 joined the cluster consisting of soils 87, 88, and 102, and this cluster of four soils then joined the large cluster consisting of soils 9, 89, 96, 31, 86, and 79.

(6) Soil 44 joined the pair of soils 80 and 91.

In some respects, certain relationships indicated by this dendrogram were considered better representations of the natures of these soils than were those indicated by the dendrogram based on the corrected data. However, the most encouraging fact was that cluster analysis yielded highly similar dendrograms from dissimilar distance matrices based on dissimilar data. Good agreement was also indicated between the two correlation dendrograms based on the two sets of data, but not as strikingly as for the distance criterion. This agreement between two sets of dendrograms indicated that the methods of cluster analysis were rather robust.

Importance of Mutual Similarity. Erie (48) and Williams (15) soils possessed strong affinity for each other which could not be detected from the dendrograms (Figs. 2 and 3). The correlation between these two soils was .533, and it was the highest correlation soil 15 had with any of the soils. Because of this high correlation, soils 15 and 48 were expected to form a pair in the correlation dendrogram, or at least to show some close relationship.

Soil 48, however, had higher correlations with two other soils, 29 and 67, its highest correlation being with 29 (Table 7, Appendix). The correlation between 29 and 48, which was .696, was not mutually highest for these two soils as 29 had a correlation of .699 with soil 40. Soils 29 and 40 did not form a pair since soil 40 had a higher correlation with soil 39. Therefore, soils 39 and 40 paired, leaving 48 and 29 free to pair in the next clustering cycle. Soil 15 did not join the pair of soils 29 and 48 in the third clustering cycle because the pair of soils 39 and 40 had a greater average similarity with soils 29 and 48 than did soil 15. The average similarity of soil 15 to these four soils was so low that it was forced to join the cluster of Mollisols 4, 18, 69, 19, and 66.

This sequence of events and its final outcome emphasized the discriminating power of this clustering method. Soil 15 was thought to be more logically similar to the Mollisols which it joined than it was to soil 48, in spite of the fact that the correlation matrix indicated otherwise. For this reason the procedure by which it was placed in this cluster was of interest when evaluating the clustering method.

In this example the use of correlation values would give the same clusters as would the use of Z values. However, in some cases the two outcomes could be different since transformation to Z values before averaging would give the higher correlations slightly more weight in the determination of clusters.

Erroneous Values. After the analyses had been conducted some erroneous values were discovered in the data. These were as follows:

(1) Extractable Na in B for soils 50, 52, 57, and 61 should have been 0, .7, 2.2, and 10.9, respectively, instead of the values given in Table 4 (Appendix).

(2) Values for pH of B for soils 15, 73, 74, and 76 were correct in the raw data (Table 4, Appendix) but were incorrect in the 0 to 1000 transformed data (Table 5, Appendix), which therefore gave incorrect values in the 0,1 standardized data (Table 6, Appendix).

(3) Character 20 (chroma of A) for soil 89 should have been 6.00 instead of 3.00 in Table 4 (Appendix).

(4) Values for depth to rock or permafrost (character 12) were recorded in Table 4 (Appendix) directly in inches for soils 10 and 34, but were recorded as percent of 60 inches for soils 35, 46, and 52.

After examination of the results it appeared that these errors had little effect on the outcome, although the exact effect was uncertain. Use of proper chroma information for soil 89 would have decreased its correlation of .888 with soil 96, but the cluster of soils 9, 89, 96, 31, and 86 would most likely have persisted due to the mutually high correlations within this cluster.

Amount of Precision Attained. Sokal and Sneath (1963) indicated that greatest precision would be attained through the use of the greatest number of characters. It appeared from this study that precision was also related to the number of soils included and the amount of variability among these soils. The two established soil series, Tetonka and Exline, provided an indication of the amount of precision attained. The cluster of "Mollisols" were homogeneous when compared with the rest of the soils in the study. If greater separation of soils within this homogeneous group were desired, a separate study could be conducted using these soils alone. Raw values would be restandardized to give greater separation of the character-state values, similarities would be recalculated, and cluster analysis or factor analysis would be performed on the new similarity matrices.

Cluster Analysis Versus Factor Analysis. The cluster analysis technique used in this study is based upon the assumption of a system of nested clusters. Results of the factor analysis (Figs. 14, 15, and 16, Appendix) indicate that the underlying structure of the data may not be one composed of nested clusters. Since these two methods of summarizing relationships among soils seemed to disagree in this respect, some objective method (analogous to cophenetic correlation for evaluating dendrograms) of evaluating the factor analysis projections was needed.

An objective method for evaluation of the factor analysis projections has recently become available. This evaluation yielded a correlation of .779 between the original distance values (Table 8, Appendix) and a new set of distances based on the first three factor analysis projections (Table 10, Appendix).

This correlation value was not high enough to conclude that the lack of tight and nested clusters indicated by the projections is the better representation of the nature of the soils (assuming the distance matrix represented true relationships).

This dilemma, therefore, was not completely resolved. However, since soils are a continuum in nature, the lack of nested clusters as shown in Figs. 14 and 15 seems logical.

Factor analysis projections and dendrogram relationships were found to be complementary. In general, the dendrogram relationships are the most precise for those soils which are closely related in the distance matrix; whereas, the factor analysis relationships are most precise for those soils which are not closely related in the distance matrix. As previously mentioned (page 54), the factor analysis is not based on the distance matrix but on the character correlation matrix.

SUMMARY AND CONCLUSIONS

In summary, a study was conducted including some of the same soils that were previously used by Sarkar et al. (1966). Characters used in the second case were essentially those which had been selected in the original study by eliminating those characters which were highly correlated (absolute value) with others. Results of the two studies were in sufficient agreement to conclude that use of the smaller number of characters did not appreciably distort the relationships among soils that were originally indicated with the larger number of characters.

Dendrograms based on distance and correlation criteria indicated similar relationships among most of the soils. A centroid-factor analysis, which facilitated the projection of all 59 soils onto centroid-character axes in three dimensions, did not yield tight clusters of soils. However, reference to the distance dendrogram allowed clusters to be delineated.

When results of all three analyses were considered, several areas of agreement with 7th Approximation classifications were noted. Soils of the same soil series (which acted as controls) indicated close relationships to each other. Mollisols, Alfisols, Inceptisols, Spodosols, and Oxisols demonstrated good agreement with the 7th Approximation in general. Aridisols and Vertisols seemed to exhibit some affinity for Mollisols, and one Entisol exhibited strong affinity for Inceptisols. Entisols, Aridisols, and Vertisols reacted more as individual soils than they did as groups (Orders).

Numerous logical and interesting relationships involving pairs or clusters of soils were elucidated by these numerical methods for discovering group structure. A Vermudoll was seen to resemble a Vertisol; some Inceptisols were seen to resemble some Mollisols; and a Georgia Spodosol was seen to resemble Florida and South Carolina Entisols.

Soils of similar climates exhibited strong affinity in most cases. However, affinity of four Ustalfs (9, 89, 31, and 86) for a Typochrult (96) was difficult to understand from the standpoint of present climate. The fact that some Ustalfs were found on old land surfaces offered one possible explanation for the morphologic similarities of Ustalfs and Ultisols. The affinity of some well developed Aridisols for the Mollisols also indicated a possible effect of a more humid climate in the past.

Numerical taxonomy is believed to provide an invaluable tool for use in soil classification. It incorporates objectivity and repeatability into the scientific investigation of complex relationships among soils. Use of electronic computers makes numerical taxonomy adaptable to large amounts of new data.

ACKNOWLEDGMENTS

The author wishes to express his sincere gratitude and appreciation to Dr. O. W. Bidwell for his valuable assistance, guidance, enthusiasm, and inspiration throughout the entire course of this research project; to Dr. Leslie F. Marcus for his assistance in the early phases of this study; to Dr. R. L. Vanderlip and Dr. Richard Smith for their encouragement and helpful suggestions; to Dr. F. James Rohlf, whose work in numerical taxonomy and personal interest in this research project furnished valuable guidance; to the Agricultural Experiment Station for providing funds which made this research possible; to Mr. Dennis Swartz and Computation Center staff at the University of Kansas who cooperated in every way to facilitate the processing of data; to Mrs. Beth Unger and Ron Dillon who assisted in writing of programs; and to his wife, Janice, for her understanding and assistance throughout the course of this research.

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APPENDIX

Table 4. Raw data for the fifty-nine soils used in this study.

CHARACTER NUMBER*	SOIL NUMBER					
	2	3	4	5	8	9
1	3.00	2.00	8.00	2.00	6.00	4.00
2	6.00	3.50	6.00	32.00	3.00	3.00
3	22.00	10.50	10.00	48.00	17.00	18.00
5	2.00	7.50	.00	4.00	10.00	.00
10	7.00	4.00	3.00	3.00	.00	4.00
11	4.00	.00	.00	.00	.00	.00
12	100.00	100.00	100.00	100.00	100.00	100.00
13	.00	.00	.00	.00	.00	.00
15	9.00	5.00	.50	1.00	.50	2.00
16	3.00	4.00	4.00	2.50	3.50	4.00
20	2.00	2.00	1.00	1.50	2.00	2.00
21	5.50	6.00	6.00	6.00	5.00	8.00
22	3.50	3.00	2.00	4.00	3.50	4.00
23	2.50	2.00	1.00	3.50	2.00	7.00
30	33.20	32.90	23.60	4.90	62.30	28.00
31	1.09	.80	.62	2.72	.21	.16
33	2.01	4.62	2.71	11.52	1.39	.79
34	.47	1.91	.98	1.05	.38	.45
38	6.60	6.50	8.50	5.80	6.75	5.10
45	.10	.10	7.66	.10	.29	.00
62	62.20	57.90	25.00	86.00	32.00	16.00

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*Character numbers refer to characters listed in Table 2; soil numbers refer to profile numbers listed in Soil Classification--A Comprehensive System: Seventh Approximation (1960).

Table 4 (cont.).

CHARACTER NUMBER	SOIL NUMBER					
	10	11	15	17	18	19
1	4.00	4.00	5.00	6.00	8.00	5.00
2	6.00	6.00	8.00	3.00	6.00	6.00
3	20.00	23.00	3.00	9.00	11.00	16.00
5	10.00	6.00	.00	4.00	.00	4.00
10	.00	.00	3.00	.00	.00	4.00
11	.00	.00	.00	.00	.00	.00
12	44.00	1.00	100.00	100.00	100.00	100.00
13	.00	.00	.00	.00	.00	.00
15	2.00	2.00	3.00	3.00	.50	.00
16	4.00	3.00	2.00	2.50	4.00	4.00
20	3.00	2.50	2.00	2.00	1.00	1.00
21	9.00	7.00	6.00	5.70	4.50	6.00
22	3.00	4.00	4.00	3.00	3.00	3.00
23	3.50	4.00	2.00	2.50	1.50	1.00
30	62.90	26.10	28.30	36.80	30.30	38.90
31	.73	.49	.89	.35	.86	.77
33	1.68	.86	2.85	1.36	2.43	3.25
34	1.02	.21	1.20	.81	.93	.75
38	6.40	6.20	7.30	7.70	7.70	6.00
45	.20	.10	.10	4.90	1.60	.15
62	36.00	72.00	33.00	25.00	29.00	32.00

Table 4 (cont.).

CHARACTER NUMBER	SOIL NUMBER					
	21	23	27	29	31	34
1	1.00	6.00	2.00	2.00	8.00	4.00
2	3.00	5.00	11.00	9.00	8.00	2.00
3	3.00	40.00	30.00	7.00	2.50	6.00
5	.00	10.00	.00	.00	.00	5.00
10	5.00	.00	.00	5.00	.00	.00
11	.00	.00	.00	.00	2.00	.00
12	100.00	100.00	100.00	100.00	100.00	23.00
13	.00	.00	.00	.00	.00	3.00
15	2.00	1.00	2.80	2.00	1.00	15.00
16	2.00	2.50	2.00	2.00	5.00	2.00
20	1.00	1.00	4.00	3.00	4.00	3.00
21	7.50	5.00	11.00	6.50	8.00	8.00
22	3.00	3.00	3.00	5.00	4.00	3.00
23	3.00	2.00	5.50	6.00	6.00	4.00
30	4.40	30.10	58.30	2.70	55.50	23.20
31	.27	.75	.93	2.26	.17	.69
33	1.12	2.10	6.34	2.61	.36	5.48
34	1.82	.28	.97	.66	.35	.33
38	4.90	6.30	5.40	5.70	5.30	4.70
45	.05	.22	.00	.10	.29	.05
62	6.30	46.00	25.00	26.00	20.00	65.00

Table 4 (cont.).

CHARACTER NUMBER	SOIL NUMBER					
	35	39	40	42	44	46
1	2.00	1.00	1.00	4.00	4.00	2.00
2	3.00	1.00	10.00	38.00	9.00	11.00
3	.00	7.00	21.00	.00	.00	.00
5	.00	.00	.00	.00	.00	.00
10	7.00	.00	3.50	5.50	5.50	.00
11	.00	.00	.00	.00	2.00	5.00
12	48.00	100.00	100.00	100.00	100.00	57.00
13	5.00	.00	.00	.00	.00	.00
15	1.00	5.00	5.00	1.00	1.00	2.50
16	2.00	.50	1.00	4.00	2.00	5.00
20	1.50	.00	2.50	1.00	4.50	2.00
21	4.00	6.00	6.00	6.00	4.00	7.00
22	4.00	6.00	6.00	3.00	6.50	3.00
23	1.00	5.00	6.00	1.00	1.50	2.00
30	16.60	2.00	4.50	58.00	59.90	42.90
31	.92	.60	.62	.94	.80	.91
33	11.51	1.04	.77	1.05	1.17	1.03
34	1.62	.15	.07	.76	.15	.53
38	6.90	5.80	5.80	7.85	4.40	7.60
45	.40	.00	.10	7.30	.50	.70
62	78.00	.10	7.60	26.00	40.00	46.00

Table 4 (cont.).

CHARACTER NUMBER	SOIL NUMBER					
	48	50	52	55	57	58
1	2.00	2.00	2.00	2.00	2.00	1.00
2	9.00	15.00	5.00	8.00	13.00	8.00
3	7.00	.00	42.00	8.00	7.00	6.00
5	.00	.00	.00	.00	.00	.00
10	6.00	.00	.00	.00	.00	.00
11	.00	.00	.00	.00	.00	.00
12	100.00	100.00	78.00	100.00	100.00	100.00
13	.00	5.00	.00	.00	.00	.00
15	3.00	1.00	11.00	1.00	1.00	2.00
16	2.00	2.00	1.00	2.50	3.00	2.00
20	2.00	2.00	2.00	1.50	4.00	2.50
21	6.00	8.00	7.00	6.00	6.00	6.00
22	5.00	3.00	3.00	4.00	4.00	5.00
23	2.00	2.00	2.50	3.00	4.00	2.00
30	14.30	4.40	3.70	15.00	35.80	7.40
31	1.97	1.00	.48	1.56	1.08	1.23
33	3.57	7.10	8.20	9.47	.04	.62
34	.51	4.83	3.90	1.68	.43	.29
38	5.60	4.80	7.50	4.60	8.10	8.70
45	.10	.70	.00	.05	10.90	4.70
62	45.00	43.00	53.00	52.00	49.00	53.00

Table 4 (cont.).

CHARACTER NUMBER	SOIL NUMBER					
	61	62	63	64	66	67
1	1.00	5.00	6.00	3.00	4.00	1.00
2	1.00	4.00	5.00	6.00	10.00	17.00
3	.00	17.00	8.00	6.00	18.00	9.00
5	.00	8.00	8.00	7.00	.00	.00
10	4.00	4.00	.00	3.00	4.00	5.00
11	.00	.00	.00	.00	.00	.00
12	100.00	100.00	100.00	100.00	100.00	100.00
13	.00	.00	.00	.00	.00	.00
15	1.00	.50	1.00	1.00	.50	.00
16	3.00	2.00	2.00	4.00	3.50	2.00
20	2.00	4.00	3.00	2.00	1.00	1.00
21	4.00	8.00	8.00	5.00	6.70	4.00
22	6.00	4.00	4.00	4.50	2.50	4.50
23	2.00	4.00	4.00	2.00	1.00	2.00
30	28.30	24.80	39.80	25.40	35.30	29.80
31	.71	.43	.21	.38	.93	1.10
33	.31	.16	.55	9.00	6.58	3.15
34	.21	.15	.56	.21	.60	.61
38	8.90	7.90	8.80	8.90	5.70	7.60
45	2.20	.55	18.39	14.80	.00	.30
62	53.00	27.00	49.00	48.00	30.00	31.00

Table 4 (cont.).

CHARACTER NUMBER	SOIL NUMBER					
	68	69	71	72	73	74
1	4.00	8.00	2.00	3.00	3.00	2.00
2	14.00	7.00	34.00	7.00	5.00	8.00
3	3.00	15.00	.00	23.00	9.00	12.00
5	6.00	5.00	.00	8.50	6.00	8.50
10	3.00	3.00	.00	4.00	3.00	.00
11	.00	.00	7.00	.00	.00	.00
12	100.00	100.00	100.00	100.00	100.00	100.00
13	.00	.00	.00	.00	.00	.00
15	.50	1.00	1.00	13.00	3.00	1.00
16	3.00	2.50	3.00	3.50	2.00	3.00
20	1.50	1.00	2.00	2.00	2.00	2.00
21	5.00	6.00	6.00	6.00	6.00	6.00
22	4.00	3.00	3.25	3.75	3.00	3.00
23	2.00	2.00	1.75	3.50	3.00	2.50
30	28.00	33.30	30.80	34.80	20.00	31.50
31	1.03	.79	.87	.81	1.02	.60
33	2.30	3.73	1.64	2.56	1.73	1.25
34	.94	1.01	1.22	.51	.99	.55
38	7.60	6.70	7.90	5.60	7.30	7.50
45	.10	.10	.10	.10	.05	.20
62	36.00	27.00	62.00	33.00	43.00	44.00

Table 4 (cont.).

CHAR-ACTER NUMBER	SOIL NUMBER					
	76	77	78	79	80	84A
1	6.00	2.00	2.00	4.00	8.00	4.00
2	10.00	.00	.00	1.00	7.00	4.00
3	8.00	8.00	10.00	29.00	56.00	6.00
5	8.50	.00	.00	.00	10.00	6.00
10	.00	5.00	.00	5.50	5.50	.00
11	.00	.00	.00	.00	.00	.00
12	100.00	100.00	100.00	100.00	100.00	100.00
13	.00	6.00	8.50	.00	.00	.00
15	1.00	1.00	1.00	1.00	1.00	3.00
16	3.00	3.00	5.00	3.00	5.00	3.00
20	2.00	.00	1.00	2.00	2.00	2.00
21	5.50	7.00	4.00	6.00	4.00	6.00
22	4.50	5.00	2.00	5.50	5.00	4.00
23	3.50	6.00	1.00	4.00	2.00	4.50
30	32.90	.80	2.30	34.40	54.70	23.40
31	.66	3.12	.30	1.95	.31	.46
33	1.24	1.38	.65	19.40	4.35	3.17
34	.67	1.26	2.63	.11	.14	.48
38	7.40	5.50	4.60	5.10	5.50	6.90
45	2.05	.10	.10	2.80	.60	.10
62	35.00	66.00	9.00	5.00	42.00	39.00

Table 4 (cont.).

CHAR-ACTER NUMBER	SOIL NUMBER					
	86	87	88	89	91	95
1	6.00	2.00	6.00	4.00	3.00	4.00
2	8.00	12.00	10.50	7.00	10.00	4.00
3	2.50	15.00	35.50	16.50	57.00	15.00
5	.00	.00	.00	.00	6.00	8.00
10	.00	3.00	4.00	.00	6.50	.00
11	2.00	9.00	9.00	.00	.00	3.50
12	100.00	100.00	100.00	100.00	100.00	100.00
13	.00	.00	.00	.00	.00	.00
15	1.00	.30	.50	2.00	1.00	13.00
16	5.00	2.50	3.00	3.00	3.50	2.00
20	4.00	2.50	4.00	3.00	2.00	2.00
21	5.00	7.50	10.00	9.00	4.00	9.00
22	4.00	5.00	4.00	4.00	7.00	3.00
23	6.00	6.00	4.00	6.00	1.50	4.00
30	55.50	23.50	35.70	30.20	68.60	51.30
31	.17	.33	.67	.36	.81	.81
33	.36	1.53	.22	.39	3.25	5.38
34	.35	.11	.08	.19	.36	1.30
38	5.30	6.80	5.10	7.30	4.30	4.80
45	.29	1.00	.01	1.50	.20	.10
62	20.00	13.00	16.00	18.00	20.00	38.00

Table 4 (concl.).

CHARACTER NUMBER	SOIL NUMBER				
	96	99	100	101	102
1	4.00	4.00	6.00	2.00	3.00
2	5.00	6.00	10.00	22.00	12.00
3	20.00	42.00	36.00	22.00	52.00
5	.00	7.00	.00	.00	10.00
10	.00	4.00	6.00	6.00	.00
11	.00	.00	.00	.00	9.00
12	100.00	100.00	100.00	100.00	100.00
13	.00	.00	.00	.00	.00
15	.50	15.00	15.00	1.00	6.00
16	2.50	3.00	3.00	3.00	2.50
20	4.00	4.00	4.00	5.00	3.00
21	8.30	9.50	9.00	8.00	10.00
22	4.50	3.50	4.00	2.00	3.00
23	6.50	5.00	6.00	2.00	4.00
30	33.50	65.00	51.50	48.70	34.00
31	.24	1.11	1.39	.64	.92
33	.54	2.72	3.45	1.46	.79
34	.19	.58	.49	1.80	.30
38	4.70	5.00	4.80	4.70	6.90
45	.00	.10	.10	.00	.60
62	14.00	30.00	43.00	6.10	35.00

Table 5. Data for fifty-nine soils transformed to give each character a range from 0 to 1000.

CHARACTER NUMBER	SOIL NUMBER					
	2	3	4	5	8	9
1	285.70	142.90	1000.00	142.90	714.30	428.60
2	157.90	92.10	157.90	842.10	78.90	78.90
3	386.00	184.20	175.40	842.10	298.20	315.80
5	200.00	750.00	.00	400.00	1000.00	.00
10	1000.00	571.40	428.60	428.60	.00	571.40
11	444.40	.00	.00	.00	.00	.00
12	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00
13	.00	.00	.00	.00	.00	.00
15	600.00	333.30	33.30	66.70	33.30	133.30
16	555.50	777.70	777.70	444.40	666.60	777.70
20	400.00	400.00	200.00	300.00	400.00	400.00
21	214.30	285.80	285.80	285.80	142.90	571.40
22	300.00	200.00	.00	400.00	300.00	400.00
23	250.00	166.70	.00	416.70	166.70	1000.00
30	477.90	473.50	336.30	60.50	907.10	401.20
31	649.30	477.60	343.30	1000.00	37.30	.00
33	162.90	392.60	724.50	1000.00	108.30	55.50
34	84.00	386.60	191.20	205.90	65.10	79.80
38	500.00	478.30	913.00	326.10	532.60	173.90
45	5.40	5.40	416.30	5.40	157.70	.00
62	723.30	673.30	290.70	1000.00	372.10	186.00

Table 5 (cont.).

CHARACTER NUMBER	SOIL NUMBER					
	10	11	15	17	18	19
1	428.60	428.60	571.40	714.30	1000.00	571.40
2	157.90	157.90	210.50	78.90	157.90	157.90
3	350.90	403.50	52.60	157.90	193.00	280.70
5	1000.00	600.00	.00	400.00	.00	400.00
10	.00	.00	428.60	.00	.00	571.40
11	.00	.00	.00	.00	.00	.00
12	272.70	1000.00	1000.00	1000.00	1000.00	1000.00
13	.00	.00	.00	.00	.00	.00
15	133.30	133.30	200.00	200.00	33.30	.00
16	777.70	555.50	333.30	444.40	777.70	777.70
20	600.00	500.00	400.00	400.00	200.00	200.00
21	714.30	428.60	285.80	242.90	71.40	285.80
22	200.00	400.00	400.00	200.00	200.00	200.00
23	416.70	500.00	166.70	250.00	83.30	.00
30	915.90	373.20	405.60	531.00	435.10	561.90
31	425.40	246.30	544.80	141.80	522.40	455.20
33	133.80	61.60	236.80	105.60	199.80	272.00
34	199.60	29.40	237.40	156.50	180.70	142.90
38	456.50	413.00	434.80	739.10	739.10	369.60
45	10.90	5.40	5.40	266.40	87.00	8.20
62	418.60	837.20	383.70	290.70	337.20	372.10

Table 5 (cont.).

CHARACTER NUMBER	SOIL NUMBER					
	21	23	27	29	31	34
1	.00	714.30	142.90	142.90	1000.00	428.60
2	78.90	131.60	289.50	236.80	210.50	52.60
3	52.60	701.80	526.30	122.80	43.90	105.30
5	.00	1000.00	.00	.00	.00	500.00
10	714.30	.00	.00	714.30	.00	.00
11	.00	.00	.00	.00	222.20	.00
12	1000.00	1000.00	1000.00	1000.00	1000.00	.00
13	.00	.00	.00	.00	.00	352.90
15	133.30	66.70	186.70	133.30	66.70	1000.00
16	333.30	444.40	333.30	333.30	1000.00	333.30
20	200.00	200.00	800.00	600.00	800.00	600.00
21	500.00	142.90	1000.00	357.10	571.40	571.40
22	200.00	200.00	200.00	600.00	400.00	200.00
23	333.30	166.70	750.00	833.30	833.30	500.00
30	53.10	432.20	848.10	28.00	806.80	330.40
31	82.10	440.30	574.60	903.00	.70	395.50
33	80.50	170.80	544.00	215.70	17.60	468.30
34	367.60	44.10	189.10	123.90	58.80	54.60
38	130.40	434.80	239.10	304.30	217.40	87.00
45	2.70	12.20	.00	5.40	15.80	2.70
62	73.30	534.90	290.70	302.30	232.60	755.80

Table 5 (cont.).

CHAR-ACTER NUMBER	SOIL NUMBER					
	35	39	40	42	44	46
1	142.90	.00	.00	428.60	428.60	142.90
2	78.90	26.30	263.20	1000.00	236.80	289.50
3	.00	122.80	368.40	.00	.00	.00
5	.00	.00	.00	.00	.00	.00
10	1000.00	.00	500.00	785.70	785.70	.00
11	.00	.00	.00	.00	222.20	555.50
12	324.70	1000.00	1000.00	1000.00	1000.00	441.60
13	588.20	.00	.00	.00	.00	.00
15	66.70	333.30	333.30	66.70	66.70	166.70
16	333.30	.00	111.10	777.70	333.30	1000.00
20	300.00	.00	500.00	200.00	900.00	400.00
21	.00	285.80	285.80	285.80	.00	428.60
22	400.00	800.00	800.00	200.00	900.00	200.00
23	.00	666.70	833.30	.00	83.30	166.70
30	233.00	17.70	54.50	843.70	871.70	620.90
31	573.10	328.40	344.80	584.30	477.60	565.70
33	999.10	77.50	53.70	78.30	88.90	76.60
34	325.60	16.80	.00	145.00	16.80	96.60
38	565.20	326.10	326.10	771.70	21.70	717.40
45	21.80	.00	5.40	397.00	27.20	38.10
62	872.10	.00	88.40	302.30	465.10	534.80

Table 5 (cont.).

CHARACTER NUMBER	SOIL NUMBER					
	48	50	52	55	57	58
1	142.90	142.90	142.90	142.90	142.90	.00
2	236.80	394.70	131.60	210.50	342.10	210.50
3	122.80	.00	736.80	140.40	122.80	105.30
5	.00	.00	.00	.00	.00	.00
10	857.10	.00	.00	.00	.00	.00
11	.00	.00	.00	.00	.00	.00
12	1000.00	1000.00	714.30	1000.00	1000.00	1000.00
13	.00	588.20	.00	.00	.00	.00
15	200.00	66.70	733.30	66.70	66.70	133.30
16	333.30	333.30	111.10	444.40	555.50	333.30
20	400.00	400.00	400.00	300.00	800.00	500.00
21	285.80	571.40	428.60	285.80	285.80	285.80
22	600.00	200.00	200.00	400.00	400.00	600.00
23	166.70	166.70	250.00	333.30	500.00	166.70
30	199.10	53.10	42.80	209.40	516.20	97.30
31	835.80	626.90	243.30	746.30	649.30	604.50
33	300.20	610.90	707.70	819.50	27.30	40.50
34	92.40	1000.00	804.60	338.20	75.60	46.20
38	282.60	108.70	695.70	65.20	826.10	956.50
45	5.40	38.10	.00	2.70	592.70	255.60
62	523.30	500.00	616.20	604.70	570.00	616.20

Table 5 (cont.).

CHAR-ACTER NUMBER	SOIL NUMBER					
	61	62	63	64	66	67
1	.00	571.40	714.30	285.70	428.60	.00
2	26.30	105.30	131.60	157.90	263.20	447.40
3	.00	298.20	140.40	105.30	315.80	157.90
5	.00	800.00	800.00	700.00	.00	.00
10	571.40	571.40	.00	428.60	571.40	714.30
11	.00	.00	.00	.00	.00	.00
12	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00
13	.00	.00	.00	.00	.00	.00
15	66.70	33.30	66.70	66.70	33.30	.00
16	555.50	333.30	333.30	777.70	666.60	333.30
20	400.00	800.00	600.00	400.00	200.00	200.00
21	.00	571.40	571.40	142.90	385.70	.00
22	800.00	400.00	400.00	500.00	100.00	500.00
23	166.70	500.00	500.00	166.70	.00	166.70
30	405.60	354.00	575.20	362.80	508.80	427.70
31	410.40	201.50	37.30	167.90	574.60	649.30
33	13.20	.00	34.30	778.20	565.10	263.20
34	29.40	16.80	102.90	29.40	111.30	113.40
38	1000.00	782.60	978.30	1000.00	304.30	717.40
45	119.60	29.90	1000.00	804.80	.00	16.30
62	616.20	314.00	570.00	558.10	348.80	360.50

Table 5 (cont.).

CHAR-ACTER NUMBER	SOIL NUMBER					
	68	69	71	72	73	74
1	428.60	1000.00	142.90	285.70	285.70	142.90
2	368.40	184.20	894.70	184.20	131.60	210.50
3	52.60	263.20	.00	403.50	157.90	210.50
5	600.00	500.00	.00	850.00	600.00	850.00
10	428.60	428.60	.00	571.40	428.60	.00
11	.00	.00	777.70	.00	.00	.00
12	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00
13	.00	.00	.00	.00	.00	.00
15	33.30	66.70	66.70	866.70	200.00	66.70
16	555.50	444.40	555.50	666.60	333.30	555.50
20	300.00	200.00	400.00	400.00	400.00	400.00
21	142.90	285.80	285.80	285.80	285.80	285.80
22	400.00	200.00	250.00	350.00	200.00	200.00
23	166.70	166.70	125.00	416.70	333.30	250.00
30	401.20	479.40	442.50	501.50	283.20	452.80
31	649.30	470.10	529.90	489.60	634.30	330.60
33	188.40	314.30	130.30	211.30	138.20	96.00
34	182.80	197.50	241.60	92.40	193.30	100.80
38	717.40	521.70	782.60	282.60	869.60	913.00
45	5.40	5.40	5.40	5.40	2.70	10.90
62	418.70	314.00	720.90	383.70	500.00	511.60

Table 5 (cont.).

CHAR-ACTER NUMBER	SOIL NUMBER					
	76	77	78	79	80	84Ā
1	714.30	142.90	142.90	428.60	1000.00	428.60
2	263.20	.00	.00	26.30	184.20	105.30
3	140.40	140.40	175.40	508.80	982.50	105.30
5	850.00	.00	.00	.00	1000.00	600.00
10	.00	714.30	.00	785.70	785.70	.00
11	.00	.00	.00	.00	.00	.00
12	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00
13	.00	705.90	1000.00	.00	.00	.00
15	66.70	66.70	66.70	66.70	66.70	200.00
16	555.50	555.50	1000.00	555.50	1000.00	555.50
20	400.00	.00	200.00	400.00	400.00	400.00
21	214.30	428.60	.00	285.80	.00	285.80
22	500.00	600.00	.00	700.00	600.00	400.00
23	416.70	833.30	.00	500.00	166.70	583.30
30	473.50	.00	22.10	480.80	795.00	333.30
31	373.10	828.40	107.50	26.10	116.40	223.90
33	95.10	107.40	43.10	156.70	369.80	265.00
34	126.10	250.00	537.80	8.40	14.70	87.10
38	456.50	260.90	65.20	173.90	260.90	565.20
45	111.50	5.40	5.40	152.30	32.60	5.40
62	407.00	767.40	104.70	581.40	488.40	453.50

Table 5 (cont.).

CHAR-ACTER NUMBER	SOIL NUMBER					
	86	87	88	89	91	95
1	714.30	142.90	714.30	428.60	285.70	428.60
2	210.50	315.80	276.30	184.20	263.20	105.30
3	43.90	263.20	622.80	289.50	1000.00	263.20
5	.00	.00	.00	.00	600.00	800.00
10	.00	428.60	571.40	.00	928.60	.00
11	222.20	1000.00	1000.00	.00	.00	388.90
12	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00
13	.00	.00	.00	.00	.00	.00
15	66.70	20.00	33.30	133.30	66.70	866.70
16	1000.00	444.40	555.50	555.50	666.60	333.30
20	800.00	500.00	800.00	600.00	400.00	400.00
21	142.90	500.00	857.10	714.30	.00	714.30
22	400.00	600.00	400.00	400.00	1000.00	200.00
23	833.30	833.30	500.00	833.30	83.30	500.00
30	806.80	334.80	529.50	433.60	1000.00	744.80
31	.70	126.90	380.60	149.30	486.60	491.80
33	17.60	120.60	5.30	20.20	272.00	459.50
34	58.80	8.40	2.10	25.20	60.90	258.40
38	217.40	543.50	173.90	434.80	.00	108.70
45	15.80	54.40	.90	81.60	10.90	5.40
62	232.60	151.20	186.00	209.30	232.60	441.90

Table 5 (concl.).

CHAR-ACTER NUMBER	SOIL NUMBER				
	96	99	100	101	102
1	428.60	428.60	714.30	142.90	285.70
2	131.60	157.90	263.20	578.90	315.80
3	350.90	736.80	631.60	386.00	912.30
5	.00	700.00	.00	.00	1000.00
10	.00	571.40	857.10	857.10	.00
11	.00	.00	.00	.00	1000.00
12	1000.00	1000.00	1000.00	1000.00	1000.00
13	.00	.00	.00	.00	.00
15	33.30	1000.00	1000.00	66.70	400.00
16	444.40	555.50	555.50	555.50	444.40
20	800.00	800.00	800.00	1000.00	600.00
21	614.30	785.70	714.30	571.40	857.10
22	500.00	300.00	400.00	.00	200.00
23	916.70	666.70	833.30	166.70	500.00
30	482.30	946.90	747.80	706.50	489.70
31	59.70	649.30	709.00	361.90	571.60
33	33.50	225.40	289.60	114.40	55.50
34	25.20	107.40	88.20	363.40	48.30
38	87.00	152.20	108.70	87.00	565.20
45	.00	5.40	5.40	.00	32.60
62	162.80	348.80	500.00	70.90	407.00

Table 6. Data for fifty-nine soils standardized to give each character a mean of zero and a variance of unity.

CHARACTER NUMBER	SOIL NUMBER					
	2	3	4	5	8	9
1	-.336	-.830	2.139	-.830	1.149	.159
2	-.341	-.678	-.341	3.167	-.746	-.746
3	.403	-.370	-.404	2.149	.066	.134
5	-.256	1.201	-.786	.274	1.864	-.786
10	1.867	.638	.229	.229	-.999	.638
11	1.344	-.385	-.385	-.385	-.385	-.385
12	.283	.283	.283	.283	.283	.283
13	-.286	-.286	-.286	-.286	-.286	-.286
15	1.515	.514	-.611	-.486	-.611	-.236
16	.092	1.077	1.077	-.401	.584	1.077
20	-.234	-.234	-1.124	-.679	-.234	-.234
21	-.606	-.311	-.311	-.311	-.901	.867
22	-.349	-.806	-1.721	.109	-.349	.109
23	-.447	-.738	-1.321	.136	-.738	2.175
30	.098	.081	-.434	-1.469	1.709	-.190
31	.933	.242	-.298	2.344	-1.529	-1.679
33	-.285	.657	-.033	3.147	-.509	-.725
34	-.399	1.267	.191	.272	-.504	-.423
38	.187	.113	1.602	-.409	.299	-.931
45	-.405	-.405	1.726	-.405	.385	-.433
62	1.389	1.155	-.631	2.681	-.251	-1.120

Table 6 (cont.).

CHARACTER NUMBER	SOIL NUMBER					
	10	11	15	17	18	19
1	.159	.159	.654	1.149	2.139	.654
2	-.341	-.341	-.071	-.746	-.341	-.341
3	.268	.470	-.874	-.471	-.336	-.001
5	1.864	.804	-.786	.274	-.786	.274
10	-.999	-.999	.229	-.999	-.999	.638
11	-.385	-.385	-.385	-.385	-.385	-.385
12	-3.452	.283	.283	.283	.283	.283
13	-.286	-.286	-.286	-.286	-.286	-.286
15	-.236	-.236	.014	.014	-.611	-.736
16	1.077	.092	-.893	-.401	1.077	1.077
20	.656	.211	-.234	-.234	-1.124	-1.124
21	1.456	.278	-.311	-.488	-1.196	-.311
22	-.806	.109	.109	-.806	-.806	-.806
23	.136	.427	-.738	-.447	-1.030	-1.321
30	1.742	-.295	-.174	.297	-.063	.413
31	.032	-.688	.512	-1.109	.422	.152
33	-.404	-.700	.018	-.520	-.134	.162
34	.237	-.700	.445	-.000	.133	-.075
38	.038	-.111	-.037	1.006	1.006	-.260
45	-.377	-.405	-.405	.949	.018	-.391
62	-.034	1.921	-.197	-.631	-.414	-.251

Table 6 (cont.).

CHARACTER NUMBER	SOIL NUMBER					
	21	23	27	29	31	34
1	-1.325	1.149	-.830	-.830	2.139	.159
2	-.746	-.475	.334	.064	-.071	-.880
3	-.874	1.612	.940	-.605	-.907	-.672
5	-.786	1.864	-.786	-.786	-.786	.539
10	1.048	-.999	-.999	1.048	-.999	-.999
11	-.385	-.385	-.385	-.385	.480	-.385
12	.283	.283	.283	.283	.283	-4.852
13	-.286	-.286	-.286	-.286	-.286	1.553
15	-.236	-.486	-.035	-.236	-.486	3.015
16	-.893	-.401	-.893	-.893	2.063	-.893
20	-1.124	-1.124	1.547	.656	1.547	.656
21	.572	-.901	2.634	-.017	.867	.867
22	-.806	-.806	-.806	1.023	.109	-.806
23	-.156	-.738	1.301	1.592	1.592	.427
30	-1.497	-.074	1.488	-1.591	1.333	-.456
31	-1.349	.092	.632	1.953	-1.676	-.088
33	-.623	-.253	1.277	-.069	-.881	.967
34	1.162	-.619	.179	-.180	-.538	-.561
38	-1.080	-.037	-.707	-.484	-.781	-1.228
45	-.419	-.370	-.433	-.405	-.351	-.419
62	-1.647	.509	-.631	-.577	-.903	1.540

Table 6 (cont.).

CHAR-ACTER NUMBER	SOIL NUMBER					
	35	39	40	42	44	46
1	-.830	-1.325	-1.325	.159	.159	-.830
2	-.746	-1.015	.199	3.976	.064	.334
3	-1.076	-.605	.335	-1.076	-1.076	-1.076
5	-.786	-.786	-.786	-.786	-.786	-.786
10	1.867	-.999	.434	1.252	1.252	-.999
11	-.385	-.385	-.385	-.385	.480	1.776
12	-3.185	.283	.283	.283	.283	-2.585
13	2.778	-.286	-.286	-.286	-.286	-.286
15	-.486	.514	.514	-.486	-.486	-.111
16	-.893	-2.371	-1.879	1.077	-.893	2.063
20	-.679	-2.014	.211	-1.124	1.992	-.234
21	-1.490	-.311	-.311	-.311	-1.490	.278
22	.109	1.938	1.938	-.806	2.396	-.806
23	-1.321	1.010	1.592	-1.321	-1.030	-.738
30	-.822	-1.630	-1.492	1.471	1.576	.635
31	.626	-.358	-.292	.671	.242	.597
33	3.143	-.635	-.733	-.632	-.589	-.639
34	.931	-.769	-.862	-.064	-.769	-.330
38	.410	-.409	-.409	1.118	-1.452	.932
45	-.320	-.433	-.405	1.626	-.292	-.236
62	2.084	-1.989	-1.576	-.577	.183	.508

Table 6 (cont.).

CHARACTER NUMBER	SOIL NUMBER					
	48	50	52	55	57	58
1	-.830	-.830	-.830	-.830	-.830	-1.325
2	.064	.873	-.475	-.071	.604	-.071
3	-.605	-1.076	1.746	-.538	-.605	-.672
5	-.786	-.786	-.786	-.786	-.786	-.786
10	1.457	-.999	-.999	-.999	-.999	-.999
11	-.385	-.385	-.385	-.385	-.385	-.385
12	.283	.283	-1.184	.283	.283	.283
13	-.286	2.778	-.286	-.286	-.286	-.286
15	.014	-.486	2.015	-.486	-.486	-.236
16	-.893	-.893	-1.879	-.401	.092	-.893
20	-.234	-.234	-.234	-.679	1.547	.211
21	-.311	.867	.278	-.311	-.311	-.311
22	1.023	-.806	-.806	.109	.109	1.023
23	-.738	-.738	-.447	-.156	.427	-.738
30	-.949	-1.497	-1.536	-.910	.242	-1.331
31	1.683	.843	-.700	1.323	.933	.753
33	.278	1.552	1.949	2.407	-.841	-.787
34	-.353	4.644	3.568	1.000	-.446	-.608
38	-.558	-1.154	.857	-1.303	1.304	1.751
45	-.405	-.236	-.433	-.419	2.641	.893
62	.455	.346	.889	.835	.673	.889

Table 6 (cont.).

CHAR-ACTER NUMBER	SOIL NUMBER					
	61	62	63	64	66	67
1	-1.325	.654	1.149	-.336	.159	-1.325
2	-1.015	-.610	-.475	-.341	.199	1.143
3	-1.076	.066	-.538	-.672	.134	-.471
5	-.786	1.334	1.334	1.069	-.786	-.786
10	.638	.638	-.999	.229	.638	1.048
11	-.385	-.385	-.385	-.385	-.385	-.385
12	.283	.283	.283	.283	.283	.283
13	-.286	-.286	-.286	-.286	-.286	-.286
15	-.486	-.611	-.486	-.486	-.611	-.736
16	.092	-.893	-.893	1.077	.584	-.893
20	-.234	1.547	.656	-.234	-1.124	-1.124
21	-1.490	.867	.867	-.901	.101	-1.490
22	1.938	.109	.109	.566	-1.264	.566
23	-.738	.427	.427	-.738	-1.321	-.738
30	-.174	-.367	.463	-.334	.214	-.091
31	-.028	-.869	-1.529	-1.004	.632	.933
33	-.899	-.953	-.812	2.238	1.364	.126
34	-.700	-.769	-.295	-.700	-.249	-.238
38	1.900	1.155	1.826	1.900	-.484	.932
45	.187	-.278	4.754	3.741	-.433	-.349
62	.889	-.523	.673	.617	-.360	-.306

Table 6 (cont.).

CHARACTER NUMBER	SOIL NUMBER					
	68	69	71	72	73	74
1	.159	2.139	-.830	-.336	-.336	-.830
2	.738	-.206	3.436	-.206	-.475	-.071
3	-.874	-.068	-1.076	.470	-.471	-.269
5	.804	.539	-.786	1.466	.804	1.466
10	.229	.229	-.999	.638	.229	-.999
11	-.385	-.385	2.640	-.385	-.385	-.385
12	.283	.283	.283	.283	.283	.283
13	-.286	-.286	-.286	-.286	-.286	-.286
15	-.611	-.486	-.486	2.515	.014	-.486
16	.092	-.401	.092	.584	-.893	.092
20	-.679	-1.124	-.234	-.234	-.234	-.234
21	-.901	-.311	-.311	-.311	-.311	-.311
22	.109	-.806	-.578	-.120	-.806	-.806
23	-.738	-.738	-.884	.136	-.156	-.447
30	-.190	.103	-.035	.186	-.633	.004
31	.933	.212	.453	.290	.873	-.349
33	-.181	.336	-.419	-.087	-.386	-.559
34	.144	.225	.468	-.353	.202	-.307
38	.932	.261	1.155	-.558	1.453	1.602
45	-.405	-.405	-.405	-.405	-.419	-.377
62	-.034	-.523	1.378	-.197	.346	.400

Table 6 (cont.).

CHARACTER NUMBER	SOIL NUMBER					
	76	77	78	79	80	84A
1	1.149	-.830	-.830	.159	2.139	.159
2	.199	-1.150	-1.150	-1.015	-.206	-.610
3	-.538	-.538	-.404	.873	2.687	-.672
5	1.466	-.786	-.786	-.786	1.864	.804
10	-.999	1.048	-.999	1.252	1.252	-.999
11	-.385	-.385	-.385	-.385	-.385	-.385
12	.283	.283	.283	.283	.283	.283
13	-.286	3.392	4.924	-.286	-.286	-.286
15	-.486	-.486	-.486	-.486	-.486	.014
16	.092	.092	2.063	.092	2.063	.092
20	-.234	-2.014	-1.124	-.234	-.234	-.234
21	-.606	.278	-1.490	-.311	-1.490	-.311
22	.566	1.023	-1.721	1.481	1.023	.109
23	.136	1.592	-1.321	.427	-.738	.718
30	.081	-1.696	-1.613	.109	1.288	-.445
31	-.178	1.653	-1.247	-1.574	-1.211	-.778
33	-.563	-.513	-.776	-.311	.563	.134
34	-.168	.514	2.099	-.816	-.781	-.382
38	.038	-.632	-1.303	-.931	-.632	.410
45	.145	-.405	-.405	.357	-.264	-.405
62	-.088	1.595	-1.500	.726	.292	.129

Table 6 (cont.).

CHARACTER NUMBER	SOIL NUMBER					
	86	87	88	89	91	95
1	1.149	-.830	1.149	.159	-.336	.159
2	-.071	.469	.266	-.206	.199	-.610
3	-.907	-.068	1.310	.033	2.754	-.068
5	-.786	-.786	-.786	-.786	.804	1.334
10	-.999	.229	.638	-.999	1.662	-.999
11	.480	3.505	3.505	-.385	-.385	1.128
12	.283	.283	.283	.283	.283	.283
13	-.286	-.286	-.286	-.286	-.286	-.286
15	-.486	-.661	-.611	-.236	-.486	2.515
16	2.063	-.401	.092	.092	.584	-.893
20	1.547	.211	1.547	.656	-.234	-.234
21	-.901	.572	2.045	1.456	-1.490	1.456
22	.109	1.023	.109	.109	2.853	-.806
23	1.592	1.592	.427	1.592	-1.030	.427
30	1.333	-.439	.292	-.069	2.058	1.100
31	-1.676	-1.169	-.148	-1.079	.278	.299
33	-.881	-.459	-.931	-.870	.162	.931
34	-.538	-.816	-.850	-.723	-.527	.561
38	-.781	.336	-.931	-.037	-1.526	-1.154
45	-.351	-.151	-.428	-.010	-.377	-.405
62	-.903	-1.283	-1.120	-1.012	-.903	.075

Table 6 (concl.).

CHAR-ACTER NUMBER	SOIL NUMBER				
	96	99	100	101	102
1	.159	.159	1.149	-.830	-.336
2	-.475	-.341	.199	1.817	.469
3	.268	1.746	1.343	.403	2.418
5	-.786	1.069	-.786	-.786	1.864
10	-.999	.638	1.457	1.457	-.999
11	-.385	-.385	-.385	-.385	3.505
12	.283	.283	.283	.283	.283
13	-.286	-.286	-.286	-.286	-.286
15	-.611	3.015	3.015	-.486	.765
16	-.401	.092	.092	.092	-.401
20	1.547	1.547	1.547	2.437	.656
21	1.043	1.750	1.456	.867	2.045
22	.566	-.349	.109	-1.721	-.806
23	1.884	1.010	1.592	-.738	.427
30	.114	1.858	1.111	.956	.142
31	-1.439	.933	1.173	-.223	.620
33	-.816	-.029	.234	-.484	-.725
34	-.723	-.271	-.376	1.139	-.596
38	-1.228	-1.005	-1.154	-1.228	.410
45	-.433	-.405	-.405	-.433	-.264
62	-1.229	-.360	.346	-1.658	-.088

Table 7. Correlation matrix for fifty-nine soils based on standardized characters.

SOIL NUMBER	SOIL NUMBER							
	2	3	4	5	8	9	10	11
2	1.000	.337	-.070	.124	-.280	-.209	-.261	-.027
3	.337	1.000	.051	.159	.124	-.268	.137	.099
4	-.070	.051	1.000	-.210	.307	-.079	-.091	-.238
5	.124	.159	-.210	1.000	-.432	-.404	-.201	.113
8	-.280	.124	.307	-.432	1.000	-.013	.344	.308
9	-.209	-.268	-.079	-.404	-.013	1.000	.001	.071
10	-.261	.137	-.091	-.201	.344	.001	1.000	.167
11	-.027	.099	-.238	.113	.308	.071	.167	1.000
15	.147	-.009	.239	.054	-.263	-.357	-.435	-.399
17	-.314	-.082	.663	-.540	.688	-.060	.058	.062
18	-.095	.032	.802	-.100	.374	-.182	-.077	-.107
19	.159	.452	.556	.025	.405	-.084	.060	-.162
21	.015	.153	-.004	-.158	-.387	.407	-.311	-.411
23	.009	.160	.191	.215	.588	-.288	.149	.460
27	-.335	-.234	-.369	.096	-.243	.201	.254	-.034
29	.102	-.227	-.400	.254	-.741	.148	-.375	-.227
31	-.397	-.366	.102	-.575	.349	.640	.240	.151
34	.085	.071	-.271	.031	-.159	-.130	.539	.134
35	.214	.314	-.016	.355	-.311	-.411	.022	-.230
39	-.101	-.410	-.351	-.043	-.324	.208	-.421	-.139
40	-.027	-.518	-.529	.033	-.476	.335	-.416	-.120
42	.000	-.067	.444	.117	.033	-.216	-.082	-.402
44	.192	-.218	-.346	-.158	.015	-.114	-.207	-.116
46	.176	.118	.124	-.094	-.036	-.184	.517	-.066
48	.479	.096	-.263	.452	-.657	-.307	-.491	-.253
50	-.257	.257	-.041	.280	-.399	-.257	-.124	-.258
52	.033	.287	-.057	.317	-.316	-.259	.007	-.052
55	-.049	.296	-.199	.679	-.447	-.316	-.252	-.093
57	-.178	-.227	.162	-.059	-.036	-.219	-.063	.080
58	.064	-.099	.013	.160	-.276	-.448	-.326	.172
61	.287	.106	.017	-.114	-.020	-.189	-.331	.065
62	-.204	-.224	-.020	-.414	.280	.231	.149	.287
63	-.376	-.215	.409	-.368	.449	-.034	.099	.239
64	-.156	.181	.461	.020	.315	-.209	-.111	-.024
66	.179	.293	.414	.406	-.091	-.173	-.121	-.398

Table 7 (cont.).

SOIL NUMBER	SOIL NUMBER							
	2	3	4	5	8	9	10	11
67	.290	.031	-.008	.435	-.324	-.405	-.473	-.419
68	.069	.302	.272	.243	.141	-.521	-.128	-.142
69	-.065	.077	.613	-.013	.404	-.167	-.014	-.143
71	.167	-.031	.016	.322	-.201	-.426	-.140	-.023
72	.418	.393	-.247	-.057	.109	.069	.088	.045
73	.284	.397	.146	.115	-.053	-.452	-.082	.080
74	-.088	.388	.120	-.009	.481	-.335	.234	.422
76	-.447	-.082	.139	-.182	.678	-.072	.156	.378
77	.150	.067	-.179	.161	-.469	.122	-.282	.052
78	-.151	.215	.191	-.167	.021	.067	-.102	-.204
79	.134	-.186	-.128	-.126	.089	.512	-.262	.277
80	.030	.109	.153	-.013	.626	.154	.131	.222
84A	-.327	.125	-.039	-.171	.428	.206	.054	.535
86	-.300	-.276	.023	-.525	.386	.567	.140	.108
87	.036	-.521	-.245	-.220	-.217	.381	-.205	-.136
88	.081	-.532	-.113	-.275	-.115	.355	.042	-.069
89	-.510	-.585	-.104	-.427	.008	.728	.114	.217
91	.100	-.057	-.288	.092	.226	.041	-.030	-.116
95	.112	.182	-.300	-.100	.064	-.044	.249	.061
96	-.489	-.584	-.364	-.366	.018	.706	.082	.220
99	.173	.019	-.387	-.192	.015	.244	.341	.061
100	.305	-.175	-.300	-.055	-.316	.355	.052	-.012
101	-.079	-.012	-.078	-.041	-.167	.123	.095	-.383
102	.147	-.184	-.245	-.022	.036	-.040	.255	.226

Table 7 (cont.).

SOIL NUMBER	SOIL NUMBER							
	15	17	18	19	21	23	27	29
2	.147	-.314	-.095	.159	.015	.009	-.335	.102
3	-.009	-.082	.032	.452	.153	.160	-.234	-.227
4	.239	.663	.802	.556	-.004	.191	-.369	-.400
5	.054	-.540	-.100	.025	-.158	.215	.096	.254
8	-.263	.688	.374	.405	-.387	.588	-.243	-.741
9	-.357	-.060	-.182	-.084	.407	-.288	.201	.148
10	-.435	.058	-.077	.060	-.311	.149	.254	-.375
11	-.399	.062	-.107	-.162	-.411	.460	-.034	-.227
15	1.000	.077	.353	.147	.141	-.165	-.117	.276
17	.077	1.000	.552	.122	-.141	.335	-.213	-.564
18	.353	.552	1.000	.581	-.336	.366	-.394	-.362
19	.147	.122	.581	1.000	-.026	.407	-.321	-.416
21	.141	-.141	-.336	-.026	1.000	-.419	.081	.257
23	-.165	.335	.366	.407	-.419	1.000	-.240	-.439
27	-.117	-.213	-.394	-.321	.081	-.240	1.000	.159
29	.276	-.564	-.362	-.416	.257	-.439	.159	1.000
31	-.184	.265	.199	-.006	-.123	-.201	.196	-.202
34	-.164	-.137	-.285	-.339	-.190	-.065	.129	-.082
35	.210	-.296	-.056	.054	-.009	-.154	-.233	.063
39	.117	-.098	-.294	-.510	.312	-.170	.022	.497
40	.005	-.328	-.545	-.661	.304	-.340	.132	.699
42	.206	.093	.312	.354	-.031	-.158	-.185	-.147
44	.343	-.227	-.202	-.099	-.204	-.287	-.105	.230
46	-.259	-.102	.174	.077	-.337	-.227	-.079	-.271
48	.533	-.621	-.239	-.015	.146	-.283	-.128	.696
50	.354	-.178	-.032	-.072	.446	-.225	.163	.108
52	.143	.003	-.104	-.271	.278	.011	.184	-.078
55	.302	-.425	-.015	-.004	.041	-.082	.228	.308
57	-.075	.240	.042	-.384	-.327	-.256	.054	.151
58	.150	.048	-.011	-.419	-.220	-.154	-.189	.286
61	.149	.005	.050	-.076	-.170	-.213	-.512	.172
62	-.118	.323	-.200	-.200	.037	.125	.063	.075
63	-.162	.725	.095	-.205	-.115	.118	-.109	-.300
64	-.165	.415	.191	.135	-.139	.052	-.370	-.253
66	.267	-.174	.380	.753	.064	.112	.101	-.148

Table 7 (cont.).

SOIL NUMBER	SOIL NUMBER							
	15	17	18	19	21	23	27	29
67	.389	-.294	.029	.100	.027	-.154	-.270	.360
68	.403	.079	.434	.423	-.187	.254	-.515	.075
69	.480	.474	.690	.654	-.053	.571	-.251	-.294
71	.098	-.133	.099	-.084	-.153	-.147	-.105	-.100
72	-.174	-.092	-.211	.106	.069	.226	-.130	-.029
73	.268	.188	.111	.022	.013	.265	-.203	.191
74	-.313	.380	.139	.099	-.291	.441	-.172	-.375
76	-.007	.497	.373	.128	-.393	.532	-.364	-.228
77	.079	-.420	-.120	-.074	.267	-.144	-.205	.437
78	-.097	.050	.207	.210	.309	-.035	-.237	-.211
79	-.164	-.122	-.215	-.003	.085	-.044	-.187	.027
80	-.246	.124	.278	.578	-.301	.591	-.362	-.442
84A	-.244	.400	.115	-.169	-.195	.278	-.152	-.129
86	-.252	.227	.186	-.043	-.204	-.207	.052	-.174
87	-.257	-.151	-.320	-.413	.232	-.369	.083	.212
88	-.146	-.148	-.167	-.103	.108	-.145	.295	.057
89	-.326	.168	-.173	-.444	.113	-.278	.517	.117
91	-.098	-.296	-.126	.295	-.131	.226	-.120	-.013
95	-.020	.058	-.253	-.134	.116	.141	.410	-.190
96	-.289	.000	-.346	-.495	.092	-.258	.553	.205
99	-.177	-.124	-.385	-.119	.027	.055	.530	.029
100	.105	-.277	-.277	-.189	.052	-.189	.446	.289
101	.047	-.209	-.260	.061	.346	-.358	.465	.068
102	-.447	-.039	-.262	-.199	-.063	.309	.287	-.149

Table 7 (cont.).

SOIL NUMBER	SOIL NUMBER							
	31	34	35	39	40	42	44	46
2	-.397	.085	.214	-.101	-.027	.000	.192	.176
3	-.366	.071	.314	-.410	-.518	-.067	-.218	.118
4	.102	-.271	-.016	-.351	-.529	.444	-.346	.124
5	-.575	.031	.355	-.043	.033	.117	-.158	-.094
8	.349	-.159	-.311	-.324	-.476	.033	.015	-.036
9	.640	-.130	-.411	.208	.335	-.216	-.114	-.184
10	.240	.539	.022	-.421	-.416	-.082	-.207	.517
11	.151	.134	-.230	-.139	-.120	-.402	-.116	-.066
15	-.184	-.164	.210	.117	.005	.206	.343	-.259
17	.265	-.137	-.296	-.098	-.328	.093	-.227	-.102
18	.199	-.285	-.056	-.294	-.545	.312	-.202	.174
19	-.006	-.339	.054	-.510	-.661	.354	-.099	.077
21	-.123	-.190	-.009	.312	.304	-.031	-.204	-.337
23	-.201	-.065	-.154	-.170	-.340	-.158	-.287	-.227
27	.196	.129	-.233	.022	.132	-.185	-.105	-.079
29	-.202	-.082	.063	.497	.699	-.147	.230	-.271
31	1.000	-.072	-.512	-.205	-.111	-.041	.150	.158
34	-.072	1.000	.464	-.076	-.096	-.349	-.144	.295
35	-.512	.464	1.000	-.133	-.182	-.059	.052	.155
39	-.205	-.076	-.133	1.000	.806	-.284	.000	-.410
40	-.111	-.096	-.182	.806	1.000	-.230	.234	-.467
42	-.041	-.349	-.059	-.284	-.230	1.000	.049	.274
44	.150	-.144	.052	.000	.234	.049	1.000	-.120
46	.158	.295	.155	-.410	-.467	.274	-.120	1.000
48	-.571	-.088	.384	.273	.365	.079	.430	-.199
50	-.286	.125	.425	.013	-.131	-.025	-.222	-.075
52	-.456	.356	.354	.107	.012	-.315	-.413	-.095
55	-.372	.077	.430	.104	-.064	-.161	-.066	-.099
57	.025	-.148	-.154	-.064	.047	.306	.120	.206
58	-.405	-.135	.079	.288	.249	.081	.063	.092
61	-.246	-.287	.213	.201	.187	.088	.380	.096
62	.222	-.105	-.332	.033	.247	-.263	.067	-.319
63	.123	-.038	-.221	.013	-.095	.091	-.118	-.086
64	-.192	-.117	.227	-.069	-.199	.197	-.108	.020
66	-.196	-.211	.249	-.392	-.479	.396	-.164	.059

Table 7 (cont.).

SOIL NUMBER	SOIL NUMBER							
	31	34	35	39	40	42	44	46
67	-.588	-.423	.313	.213	.256	.541	.255	-.049
68	-.357	-.372	.128	-.092	-.205	.505	.043	.071
69	.000	-.188	.000	-.188	-.424	.169	-.184	-.243
71	-.098	-.170	.007	-.192	-.184	.524	.016	.517
72	-.178	.276	-.173	.126	.123	-.161	-.093	-.148
73	-.554	-.074	.131	.033	-.059	-.020	-.284	-.077
74	-.186	-.159	-.153	-.206	-.320	.081	-.376	.175
76	.284	-.166	-.363	.041	-.132	.026	.047	-.165
77	-.293	.117	.438	.352	.204	-.221	-.115	-.094
78	.018	.021	.261	-.104	-.229	-.034	-.253	.037
79	.185	-.163	-.016	.164	.306	-.249	.385	-.367
80	.176	-.179	-.091	-.301	-.229	-.045	.160	-.191
84A	.264	.049	-.209	.226	.020	-.411	-.288	-.155
86	.921	-.141	-.442	-.209	-.060	-.010	.268	.169
87	.276	-.227	-.273	.395	.475	-.086	.132	.165
88	.462	-.128	-.417	-.020	.160	-.128	.208	.155
89	.692	-.068	-.626	.265	.370	-.199	-.151	-.098
91	-.103	-.280	-.047	.090	.218	.026	.510	-.260
95	-.002	.449	-.172	.152	-.093	-.377	-.206	-.028
96	.696	-.037	-.537	.244	.464	-.382	.161	-.279
99	.129	.355	-.361	.023	.161	-.301	.012	-.156
100	.204	.354	-.209	.069	.295	-.215	.160	-.186
101	.183	-.179	-.192	-.409	-.008	.341	.200	-.039
102	-.006	.072	-.431	.049	.046	-.248	-.265	.226

Table 7 (cont.).

SOIL NUMBER	SOIL NUMBER							
	48	50	52	55	57	58	61	62
2	.479	-.257	.033	-.049	-.178	.064	.287	-.204
3	.096	.257	.287	.296	-.227	-.099	.106	-.224
4	-.263	-.041	-.057	-.199	.162	.013	.017	-.020
5	.452	.280	.317	.679	-.059	.160	-.114	-.414
8	-.657	-.399	-.316	-.447	-.036	-.276	-.020	.280
9	-.307	-.257	-.259	-.316	-.219	-.448	-.189	.231
10	-.491	-.124	.007	-.252	-.063	-.326	-.331	.149
11	-.253	-.258	-.052	-.093	.080	.172	.065	.287
15	.533	.334	.143	.302	-.075	.150	.149	-.118
17	-.621	-.178	.003	-.425	.240	.048	.005	.323
18	-.239	-.032	-.104	-.015	.042	-.011	.050	-.200
19	-.015	-.072	-.271	-.004	-.384	-.419	-.076	-.200
21	.146	.446	.278	.041	-.327	-.220	-.170	.037
23	-.283	-.225	.011	-.082	-.256	-.154	-.213	.125
27	-.128	.163	.184	.228	.054	-.189	-.512	.063
29	.696	.108	-.078	.308	.151	.286	.172	.075
31	-.571	-.286	-.456	-.372	.025	-.405	-.246	.222
34	-.088	.125	.356	.077	-.148	-.135	-.287	-.105
35	.384	.425	.354	.430	-.154	.079	.213	-.332
39	.273	.013	.107	.104	-.064	.288	.201	.033
40	.365	-.131	.012	-.064	.047	.249	.187	.247
42	.079	-.025	-.315	-.161	.306	.081	.088	-.263
44	.430	-.222	-.413	-.066	.120	.063	.380	.067
46	-.199	-.075	-.095	-.099	.206	.092	.096	-.319
48	1.000	.138	-.022	.438	.005	.372	.400	-.200
50	.138	1.000	.542	.607	-.113	.006	-.266	-.398
52	-.022	.542	1.000	.406	-.190	.080	-.187	-.222
55	.438	.607	.406	1.000	-.077	.094	-.111	-.608
57	.005	-.113	-.190	-.077	1.000	.694	.396	.056
58	.372	.006	.080	.094	.694	1.000	.694	.078
61	.400	-.266	-.187	-.111	.396	.694	1.000	.074
62	-.200	-.398	-.222	-.608	.056	.078	.074	1.000
63	-.398	-.212	-.098	-.354	.595	.350	.148	.388
64	-.073	-.164	-.051	.053	.418	.357	.400	-.007
66	.233	.171	-.002	.397	-.314	-.332	-.252	-.453

Table 7 (cont.).

SOIL NUMBER	SOIL NUMBER							
	48	50	52	55	57	58	61	62
67	.637	.050	-.058	.204	.154	.411	.541	-.246
68	.313	.038	-.223	.080	.065	.285	.373	-.018
69	-.119	.001	-.028	-.029	-.416	-.362	-.274	.092
71	.052	.195	.005	.123	.245	.317	.093	-.319
72	.057	-.289	.043	-.149	-.362	-.276	-.130	-.045
73	.234	.058	.202	-.005	.126	.434	.299	.324
74	-.347	-.146	-.019	-.229	.226	.340	.254	.330
76	-.342	-.224	-.375	-.198	.063	-.001	.013	.286
77	.422	.399	-.003	.303	-.118	.170	.225	-.257
78	-.217	.577	.108	.062	-.184	-.195	-.125	-.310
79	.115	-.402	-.205	-.188	-.119	-.097	.316	.127
80	-.229	-.479	-.267	-.265	-.405	-.466	-.026	.085
84A	-.408	-.192	-.040	-.025	-.025	.082	.110	.325
86	-.539	-.321	-.475	-.342	.119	-.353	-.083	.106
87	-.093	-.224	-.205	-.238	.003	.033	.060	.169
88	-.141	-.257	-.281	-.335	-.156	-.279	-.331	.258
89	-.452	-.235	-.202	-.356	.198	-.054	-.221	.431
91	.225	-.337	-.255	-.084	-.276	-.248	.160	-.091
95	-.198	.111	.316	.172	-.375	-.360	-.548	-.121
96	-.346	-.188	-.206	-.247	.073	-.213	-.278	.431
99	-.087	-.278	.059	-.210	-.233	-.396	-.434	.162
100	.175	-.242	.051	-.073	-.195	-.328	-.338	.018
101	-.013	.201	-.023	-.140	.014	-.348	-.393	.105
102	-.299	-.216	.046	-.252	-.115	-.058	-.377	.225

Table 7 (cont.).

SOIL NUMBER	SOIL NUMBER							
	63	64	66	67	68	69	71	72
2	-.376	-.156	.179	.290	.069	-.065	.167	.418
3	-.215	.181	.293	.031	.302	.072	-.031	.393
4	.409	.461	.414	-.008	.272	.613	.016	-.247
5	-.368	.020	.406	.435	.243	-.013	.322	-.057
8	.449	.315	-.091	-.324	.141	.404	-.201	.109
9	-.034	-.209	-.173	-.405	-.521	-.167	-.426	.069
10	.099	-.111	-.121	-.473	-.128	-.014	-.140	.088
11	.239	-.024	-.398	-.419	-.142	-.143	-.023	.045
15	-.162	-.165	.267	.389	.403	.480	.098	-.174
17	.725	.415	-.174	-.294	.079	.474	-.133	-.092
18	.095	.191	.380	.029	.434	.690	.099	-.211
19	-.205	.135	.753	.100	.423	.654	-.084	.106
21	-.115	-.139	.064	.027	-.187	-.053	-.153	.069
23	.118	.052	.112	-.154	.254	.571	-.147	.226
27	-.109	-.370	.101	-.270	-.515	-.251	-.105	-.130
29	-.300	-.253	-.148	.360	.075	-.294	-.100	-.029
31	.123	-.192	-.196	-.588	-.357	.000	-.098	-.178
34	-.038	-.117	-.211	-.423	-.372	-.188	-.170	.276
35	-.221	.227	.249	.313	.128	.000	.007	-.173
39	.013	-.069	-.392	.213	-.092	-.188	-.192	.126
40	-.095	-.199	-.479	.256	-.205	-.424	-.184	.123
42	.091	.197	.396	.541	.505	.169	.524	-.161
44	-.118	-.108	-.164	.255	.043	-.184	.016	-.093
46	-.086	.020	.059	-.049	.071	-.243	.517	-.148
48	-.398	-.073	.233	.637	.313	-.119	.052	.057
50	-.212	-.164	.171	.050	.038	.001	.195	-.289
52	-.098	-.051	-.002	-.058	-.223	-.028	.005	.043
55	-.354	.053	.397	.204	.080	-.029	.123	-.149
57	.595	.418	-.314	.154	.065	-.416	.245	-.362
58	.350	.357	-.332	.411	.285	-.362	.317	-.276
61	.148	.400	-.252	.541	.373	-.274	.093	-.130
62	.388	-.007	-.453	-.246	-.018	.092	-.319	-.045
63	1.000	.619	-.397	-.250	-.083	.031	-.119	-.268
64	.619	1.000	.079	.151	.187	.008	-.068	-.133
66	-.397	.079	1.000	.270	.219	.465	.068	-.030

Table 7 (cont.).

SOIL NUMBER	SOIL NUMBER							
	63	64	66	67	68	69	71	72
67	-.250	.151	.270	1.000	.642	.006	.390	-.121
68	-.083	.187	.219	.642	1.000	.437	.361	-.019
69	.031	.008	.465	.006	.437	1.000	-.144	-.026
71	-.119	-.068	.068	.390	.361	-.144	1.000	-.340
72	-.268	-.133	-.030	-.121	-.019	-.026	-.340	1.000
73	.092	.070	-.061	.336	.580	.255	.094	.117
74	.302	.295	-.174	.073	.477	.058	.250	.071
76	.395	.174	-.334	-.172	.444	.412	-.049	.028
77	-.255	-.169	-.033	.176	.024	-.153	-.124	-.092
78	-.180	-.039	.110	-.139	-.056	.000	-.048	-.036
79	.103	.133	-.147	-.068	-.408	-.171	-.438	-.026
80	-.078	.141	.208	-.123	.057	.383	-.365	.248
84A	.291	.267	-.421	-.327	.097	.079	-.176	.154
86	.062	-.100	-.261	-.420	-.270	-.126	-.035	-.104
87	-.017	-.123	-.319	.031	-.281	-.359	.324	-.270
88	-.126	-.445	-.051	-.320	-.445	-.083	.134	-.223
89	.278	-.209	-.408	-.500	-.547	-.277	-.216	-.177
91	-.299	-.058	.141	.285	.045	.004	-.298	.240
95	-.095	-.308	-.023	-.463	-.345	.059	-.106	.498
96	.129	-.326	-.461	-.520	-.639	-.326	-.325	-.152
99	-.203	-.470	-.060	-.416	-.471	-.131	-.461	.674
100	-.323	-.536	.023	-.278	-.508	-.117	-.382	.482
101	-.232	-.348	.233	.011	-.153	-.132	.112	-.050
102	-.017	-.328	-.182	-.313	-.261	-.129	.249	.129

Table 7 (cont.).

SOIL NUMBER	SOIL NUMBER							
	73	74	76	77	78	79	80	84A
2	.284	-.088	-.447	.150	-.151	.134	.030	-.327
3	.397	.388	-.082	.067	.215	-.186	.109	.125
4	.146	.120	.139	-.179	.191	-.128	.153	-.039
5	.115	-.009	-.182	.161	-.167	-.126	-.013	-.171
8	-.053	.481	.678	-.469	.021	.089	.626	.428
9	-.452	-.335	-.072	.122	.067	.512	.154	.206
10	-.082	.234	.156	-.282	-.102	-.262	.131	.054
11	.080	.422	.378	.052	-.204	.277	.222	.535
15	.268	-.313	-.007	.079	-.097	-.164	-.246	-.244
17	.188	.380	.497	-.420	.050	-.122	.124	.400
18	.111	.139	.373	-.120	.207	-.215	.278	.115
19	.022	.099	.128	-.074	.210	-.003	.578	-.169
21	.013	-.291	-.393	.267	.309	.085	-.301	-.195
23	.265	.441	.532	-.144	-.035	-.044	.591	.278
27	-.203	-.172	-.364	-.205	-.237	-.187	-.362	-.152
29	.191	-.375	-.228	.437	-.211	.027	-.442	-.129
31	-.554	-.186	.284	-.293	.018	.185	.176	.264
34	-.074	-.159	-.166	.117	.021	-.163	-.179	.049
35	.131	-.153	-.363	.438	.261	-.016	-.091	-.209
39	.033	-.206	.041	.352	-.104	.164	-.301	.226
40	-.059	-.320	-.132	.204	-.229	.306	-.229	.020
42	-.020	.081	.026	-.221	-.034	-.249	-.045	-.411
44	-.284	-.376	.047	-.115	-.253	.385	.160	-.288
46	-.077	.175	-.165	-.094	.037	-.367	-.191	-.155
48	.234	-.347	-.342	.422	-.217	.115	-.229	-.408
50	.058	-.146	-.224	.399	.577	-.402	-.479	-.192
52	.202	-.019	-.375	-.003	.108	-.205	-.267	-.040
55	-.005	-.229	-.198	.303	.062	-.188	-.265	-.025
57	.126	.226	.063	-.118	-.184	-.119	-.405	-.025
58	.434	.340	-.001	.170	-.195	-.097	-.466	.082
61	.299	.254	.013	.225	-.125	.316	-.026	.110
62	.324	.330	.286	-.257	-.310	.127	.085	.325
63	.092	.302	.395	-.255	-.180	.103	-.078	.291
64	.070	.295	.174	-.169	-.039	.133	.141	.267
66	-.061	-.174	-.334	-.033	.110	-.147	.208	-.421

Table 7 (cont.).

SOIL NUMBER	SOIL NUMBER							
	73	74	76	77	78	79	80	84A
67	.336	.073	-.172	.176	-.139	-.068	-.123	-.327
68	.580	.477	.444	.024	-.056	-.408	.057	.097
69	.255	.058	.412	-.153	.000	-.171	.383	.079
71	.094	.250	-.049	-.124	-.048	-.438	-.365	-.176
72	.117	.071	.028	-.092	-.036	-.026	.248	.154
73	1.000	.622	.093	.130	-.147	-.452	-.308	.223
74	.622	1.000	.397	-.199	-.035	-.392	.015	.509
76	.093	.397	1.000	-.198	-.098	-.076	.355	.612
77	.130	-.199	-.198	1.000	.457	.166	-.266	-.022
78	-.147	-.035	-.098	.457	1.000	-.135	.004	-.066
79	-.452	-.392	-.076	.166	-.135	1.000	.502	-.007
80	-.308	.015	.355	-.266	.004	.502	1.000	.088
84A	.223	.509	.612	-.022	-.066	-.007	.088	1.000
86	-.537	-.125	.294	-.290	.091	.212	.245	.287
87	-.255	-.162	-.165	-.045	-.142	.163	-.219	.006
88	-.395	-.365	-.203	-.225	-.153	.139	.008	-.318
89	-.335	-.100	.059	-.118	-.133	.180	-.190	.287
91	-.372	-.236	.062	-.111	-.100	.504	.691	-.305
95	.006	-.035	-.032	-.182	-.120	-.312	-.207	.170
96	-.487	-.292	.070	-.132	-.130	.336	-.033	.207
99	-.102	-.166	-.200	-.265	-.243	-.005	.063	-.100
100	-.223	-.539	-.364	-.076	-.302	.190	-.023	-.235
101	-.210	-.218	-.378	-.367	.073	-.167	-.089	-.582
102	.072	.248	-.051	-.267	-.188	-.265	-.089	-.022

Table 7 (cont.).

SOIL NUMBER	SOIL NUMBER							
	86	87	88	89	91	95	96	99
2	-.300	.036	.081	-.510	.100	.112	-.489	.173
3	-.276	-.521	-.532	-.585	-.057	.182	-.584	.019
4	.023	-.245	-.113	-.104	-.288	-.300	-.364	-.387
5	-.525	-.220	-.275	-.427	.092	-.100	-.366	-.192
8	.386	-.217	-.115	.008	.226	.064	.018	.015
9	.567	.381	.355	.728	.041	-.044	.706	.244
10	.140	-.205	.042	.114	-.030	.249	.082	.341
11	.108	-.136	-.069	.217	-.116	.061	.220	.061
15	-.252	-.257	-.146	-.326	-.088	-.020	-.289	-.177
17	.227	-.151	-.148	.168	-.296	.058	.000	-.124
18	.186	-.320	-.167	-.173	-.126	-.253	-.346	-.385
19	-.043	-.413	-.103	-.444	.295	-.134	-.495	-.119
21	-.204	.232	.108	.113	-.131	.116	.092	.027
23	-.207	-.369	-.145	-.278	.226	.141	-.258	.055
27	.052	.083	.295	.517	-.120	.410	.553	.530
29	-.174	.212	.057	.117	-.013	-.190	.205	.029
31	.921	.276	.462	.692	-.103	-.002	.696	.129
34	-.141	-.227	-.128	-.068	-.280	.449	-.037	.355
35	-.442	-.273	-.417	-.626	-.047	-.172	-.537	-.361
39	-.209	.395	-.020	.265	.090	.152	.244	.023
40	-.060	.475	.160	.370	.218	-.093	.464	.161
42	-.010	-.086	-.128	-.199	.026	-.377	-.382	-.301
44	.268	.132	.208	-.151	.510	-.206	.161	.012
46	.169	.165	.155	-.098	-.260	-.028	-.279	-.156
48	-.539	-.093	-.141	-.452	.225	-.198	-.346	-.087
50	-.321	-.224	-.257	-.235	-.337	.111	-.188	-.278
52	-.475	-.205	-.281	-.202	-.255	.316	-.206	.059
55	-.342	-.238	-.335	-.356	-.084	.172	-.247	-.210
57	.119	.003	-.156	.198	-.276	-.375	.073	-.233
58	-.353	.033	-.279	-.054	-.248	-.360	-.213	-.396
61	-.083	.060	-.331	-.221	.160	-.548	-.278	-.434
62	.106	.169	.258	.431	-.091	-.121	.431	.162
63	.062	-.017	-.126	.278	-.299	-.095	.129	-.203
64	-.100	-.123	-.445	-.209	-.058	-.308	-.326	-.470
66	-.261	-.319	-.051	-.408	.141	-.023	-.461	-.060

Table 7 (cont.).

SOIL NUMBER	SOIL NUMBER							
	86	87	88	89	91	95	96	99
67	-.420	.031	-.320	-.500	.285	-.463	-.520	-.416
68	-.270	-.281	-.445	-.547	.045	-.345	-.639	-.471
69	-.126	-.359	-.083	-.277	.004	.059	-.326	-.131
71	-.035	.324	.134	-.216	-.298	-.106	-.325	-.461
72	-.104	-.270	-.223	-.177	.240	.498	-.152	.674
73	-.537	-.255	-.395	-.335	-.372	.006	-.487	-.102
74	-.125	-.162	-.365	-.100	-.236	-.035	-.292	-.166
76	.294	-.165	-.203	.059	.062	-.032	.070	-.200
77	-.290	-.045	-.225	-.118	-.111	-.182	-.132	-.265
78	.091	-.142	-.153	-.133	-.100	-.120	-.130	-.243
79	.212	.163	.139	.180	.504	-.312	.336	-.005
80	.245	-.219	.008	-.190	.691	-.207	-.033	.063
84A	.287	.006	-.318	.287	-.305	.170	.207	-.100
86	1.000	.292	.325	.537	.025	-.110	.609	.051
87	.292	1.000	.698	.415	-.042	-.028	.415	-.167
88	.325	.698	1.000	.433	.060	.106	.505	.197
89	.537	.415	.433	1.000	-.238	.044	.888	.277
91	.025	-.042	.060	-.238	1.000	-.201	.019	.184
95	-.110	-.028	.106	.044	-.201	1.000	.074	.625
96	.609	.415	.505	.888	.019	.074	1.000	.355
99	.051	-.167	.197	.277	.184	.625	.355	1.000
100	.114	-.107	.248	.300	.095	.395	.385	.822
101	.166	.023	.342	.133	.104	-.046	.249	.318
102	-.093	.479	.624	.211	-.089	.455	.169	.331

Table 7 (cont.).

SOIL NUMBER	SOIL NUMBER		
	100	101	102
2	.305	-.079	.147
3	-.175	-.012	-.184
4	-.300	-.078	-.245
5	-.055	-.041	-.022
8	-.316	-.167	.036
9	.355	.123	-.040
10	.052	.095	.255
11	-.012	-.383	.226
15	.105	.047	-.447
17	-.277	-.209	-.039
18	-.277	-.260	-.262
19	-.189	.061	-.199
21	.052	.346	-.063
23	-.189	-.358	.309
27	.446	.465	.287
29	.289	.068	-.149
31	.204	.183	-.006
34	.354	-.179	.072
35	-.209	-.192	-.431
39	.069	-.409	.049
40	.295	-.008	.046
42	-.215	.341	-.248
44	.160	.200	-.265
46	-.186	-.039	.226
48	.175	-.013	-.299
50	-.242	.201	-.216
52	.051	-.023	.046
55	-.073	-.140	-.252
57	-.195	.014	-.115
58	-.328	-.348	-.058
61	-.338	-.393	-.377
62	.018	.105	.225
63	-.323	-.232	-.017
64	-.536	-.348	-.328
66	.023	.233	-.182

Table 7 (concl.).

SOIL NUMBER	SOIL NUMBER		
	100	101	102
67	-.278	.011	-.313
68	-.508	-.153	-.261
69	-.117	-.132	-.129
71	-.382	.112	.249
72	.482	-.050	.129
73	-.223	-.210	.072
74	-.539	-.218	.248
76	-.364	-.378	-.051
77	-.076	-.367	-.267
78	-.302	.073	-.188
79	.190	-.167	-.265
80	-.023	-.089	-.089
84A	-.235	-.582	-.022
86	.114	.166	-.093
87	-.107	.023	.479
88	.248	.342	.624
89	.300	.133	.211
91	.095	.104	-.089
95	.395	-.046	.455
96	.385	.249	.169
99	.822	.318	.331
100	1.000	.286	.050
101	.286	1.000	.054
102	.050	.054	1.000

Table 8. Distance matrix based on standardized characters.

Soil No.	Soil Number							
	2	3	4	5	8	9	10	11
2	0.000	0.820	1.283	1.469	1.294	1.257	1.472	1.000
3	0.820	0.000	1.163	1.443	1.029	1.220	1.200	0.880
4	1.283	1.163	0.000	1.882	1.068	1.320	1.519	1.268
5	1.469	1.443	1.882	0.000	1.938	1.923	1.935	1.487
8	1.294	1.029	1.068	1.938	0.000	1.185	1.124	0.880
9	1.257	1.220	1.320	1.923	1.185	0.000	1.368	1.001
10	1.472	1.200	1.519	1.935	1.124	1.368	0.000	1.156
11	1.000	0.880	1.268	1.487	0.880	1.001	1.156	0.000
15	0.869	0.845	0.963	1.507	1.044	1.057	1.340	0.896
17	1.162	0.993	0.730	1.860	0.618	1.061	1.231	0.863
18	1.196	1.067	0.586	1.739	0.923	1.250	1.409	1.076
19	0.918	0.700	0.806	1.554	0.805	1.044	1.205	0.919
21	1.279	1.132	1.317	1.909	1.408	0.953	1.602	1.271
23	1.121	0.981	1.127	1.510	0.743	1.296	1.251	0.755
27	1.422	1.330	1.642	1.613	1.474	1.198	1.282	1.207
29	1.089	1.206	1.519	1.472	1.575	1.094	1.607	1.158
31	1.538	1.473	1.385	2.187	1.128	0.869	1.337	1.169
34	1.624	1.595	1.973	2.042	1.813	1.781	1.284	1.526
35	1.531	1.435	1.786	1.683	1.922	1.974	1.821	1.738
39	1.516	1.573	1.691	1.991	1.578	1.238	1.852	1.367
40	1.286	1.453	1.672	1.751	1.536	1.025	1.722	1.206
42	1.424	1.436	1.198	1.725	1.481	1.642	1.705	1.588
44	1.188	1.380	1.662	1.894	1.342	1.417	1.664	1.287
46	1.181	1.166	1.306	1.839	1.335	1.412	1.039	1.221
48	0.803	0.965	1.353	1.317	1.427	1.254	1.577	1.071
50	1.779	1.423	1.774	1.705	1.943	1.846	1.908	1.712
52	1.505	1.306	1.686	1.615	1.783	1.738	1.706	1.493
55	1.203	0.951	1.417	1.135	1.447	1.366	1.551	1.112
57	1.258	1.240	1.223	1.685	1.269	1.369	1.454	1.060
58	1.128	1.147	1.263	1.579	1.329	1.398	1.569	0.951
61	1.058	1.107	1.317	1.811	1.252	1.335	1.638	1.076
62	1.168	1.121	1.240	1.838	0.964	0.991	1.223	0.828
63	1.719	1.598	1.309	2.192	1.241	1.613	1.628	1.332
64	1.475	1.247	1.165	1.771	1.249	1.609	1.695	1.363
66	0.961	0.834	0.921	1.362	1.120	1.143	1.347	1.081

Table 8.--Continued

Soil No.	Soil Number							
	2	3	4	5	8	9	10	11
67	0.978	1.048	1.243	1.378	1.311	1.331	1.608	1.182
68	0.923	0.749	0.975	1.407	0.942	1.213	1.282	0.891
69	1.047	0.919	0.765	1.583	0.829	1.132	1.275	0.962
71	1.257	1.349	1.499	1.492	1.566	1.691	1.688	1.324
72	0.779	0.762	1.346	1.579	1.061	1.081	1.246	0.932
73	0.839	0.713	1.048	1.489	1.041	1.196	1.269	0.811
74	1.068	0.765	1.093	1.598	0.774	1.196	1.131	0.686
76	1.125	0.919	1.047	1.611	0.621	1.033	1.139	0.659
77	1.355	1.380	1.719	1.714	1.812	1.427	1.873	1.370
78	1.915	1.636	1.700	2.370	1.783	1.733	2.029	1.830
79	1.012	1.112	1.296	1.695	1.075	0.781	1.473	0.831
80	1.356	1.291	1.441	1.788	0.994	1.386	1.507	1.231
84A	1.041	0.803	1.089	1.596	0.768	0.856	1.164	0.551
86	1.442	1.373	1.384	2.121	1.038	0.874	1.377	1.130
87	1.263	1.510	1.588	1.914	1.479	1.066	1.650	1.284
88	1.289	1.594	1.594	1.979	1.515	1.196	1.545	1.346
89	1.288	1.247	1.254	1.846	1.092	0.574	1.229	0.836
91	1.350	1.421	1.770	1.740	1.335	1.469	1.657	1.437
95	1.110	1.042	1.547	1.714	1.243	1.309	1.250	1.103
96	1.440	1.409	1.522	1.951	1.203	0.653	1.348	0.966
99	1.176	1.263	1.737	1.825	1.425	1.298	1.296	1.260
100	1.093	1.364	1.691	1.713	1.613	1.241	1.524	1.304
101	1.369	1.287	1.509	1.811	1.480	1.284	1.457	1.440
102	1.278	1.459	1.733	1.776	1.477	1.533	1.415	1.246

Table 8.--Continued

Soil No.	Soil Number							
	15	17	18	19	21	23	27	29
2	0.869	1.162	1.196	0.918	1.279	1.121	1.422	1.089
3	0.845	0.993	1.067	0.700	1.132	0.981	1.330	1.206
4	0.963	0.730	0.586	0.806	1.317	1.127	1.642	1.519
5	1.507	1.860	1.739	1.554	1.909	1.510	1.613	1.472
8	1.044	0.618	0.923	0.805	1.408	0.743	1.474	1.575
9	1.057	1.061	1.250	1.044	0.953	1.296	1.198	1.094
10	1.340	1.231	1.409	1.205	1.602	1.251	1.282	1.607
11	0.896	0.863	1.076	0.919	1.271	0.755	1.207	1.158
15	0.000	0.728	0.765	0.668	0.905	0.963	1.177	0.845
17	0.728	0.000	0.692	0.795	1.108	0.828	1.327	1.309
18	0.765	0.692	0.000	0.663	1.329	0.899	1.543	1.367
19	0.668	0.795	0.663	0.000	1.408	0.767	1.335	1.210
21	0.905	1.108	1.329	1.048	0.000	1.372	1.398	1.100
23	0.963	0.828	0.899	0.767	1.372	0.000	1.443	1.393
27	1.177	1.327	1.543	1.335	1.398	1.443	0.000	1.218
29	0.845	1.309	1.367	1.210	1.100	1.393	1.218	0.000
31	1.260	1.125	1.238	1.248	1.528	1.479	1.323	1.508
34	1.605	1.679	1.871	1.758	1.832	1.721	1.697	1.764
35	1.461	1.776	1.731	1.566	1.743	1.790	1.985	1.663
39	1.124	1.290	1.508	1.453	1.043	1.450	1.590	1.086
40	1.033	1.283	1.531	1.391	1.049	1.423	1.343	0.728
42	1.250	1.361	1.279	1.189	1.621	1.583	1.710	1.598
44	1.003	1.350	1.458	1.258	1.511	1.496	1.540	1.193
46	1.193	1.236	1.173	1.120	1.508	1.415	1.500	1.482
48	0.618	1.215	1.206	0.934	1.064	1.217	1.334	0.627
50	1.379	1.687	1.690	1.603	1.438	1.804	1.612	1.594
52	1.344	1.473	1.629	1.588	1.440	1.542	1.512	1.629
55	0.838	1.257	1.186	1.037	1.196	1.216	1.196	1.008
57	1.062	1.007	1.215	1.265	1.508	1.363	1.303	1.148
58	0.867	1.003	1.153	1.184	1.285	1.226	1.447	1.005
61	0.944	1.095	1.179	1.111	1.326	1.326	1.691	1.137
62	0.927	0.828	1.219	1.046	1.188	1.031	1.218	1.091
63	1.495	1.050	1.525	1.577	1.774	1.491	1.722	1.778
64	1.370	1.150	1.349	1.286	1.674	1.424	1.793	1.632
66	0.688	0.985	0.824	0.443	1.051	0.975	1.184	1.156

Table 8.--Continued

Soil No.	Soil Number							
	15	17	18	19	21	23	27	29
67	0.717	1.116	1.091	0.911	1.113	1.184	1.458	0.928
68	0.561	0.811	0.762	0.615	1.135	0.848	1.385	0.978
69	0.588	0.660	0.596	0.517	1.126	0.681	1.340	1.210
71	1.216	1.405	1.363	1.349	1.609	1.505	1.596	1.500
72	0.936	1.031	1.214	0.903	1.209	0.970	1.292	1.131
73	0.621	0.765	0.935	0.803	1.049	0.845	1.270	0.927
74	0.873	0.700	0.952	0.814	1.192	0.766	1.308	1.239
76	0.719	0.612	0.801	0.756	1.219	0.691	1.320	1.115
77	1.312	1.633	1.585	1.431	1.423	1.587	1.751	1.171
78	1.675	1.664	1.615	1.567	1.515	1.795	2.117	1.957
79	0.927	1.035	1.214	0.948	1.122	1.115	1.375	1.115
80	1.409	1.334	1.303	1.046	1.780	1.035	1.781	1.744
84A	0.705	0.609	0.879	0.797	1.045	0.798	1.199	1.019
86	1.202	1.068	1.175	1.190	1.468	1.411	1.401	1.429
87	1.240	1.307	1.518	1.393	1.274	1.531	1.386	1.197
88	1.323	1.425	1.542	1.367	1.510	1.510	1.261	1.396
89	0.938	0.858	1.156	1.089	1.063	1.197	0.920	1.038
91	1.362	1.556	1.573	1.217	1.675	1.322	1.655	1.502
95	1.089	1.148	1.418	1.200	1.355	1.175	1.040	1.386
96	1.078	1.068	1.372	1.260	1.154	1.321	0.961	1.093
99	1.332	1.414	1.648	1.369	1.618	1.390	1.020	1.401
100	1.250	1.489	1.602	1.406	1.628	1.530	1.106	1.246
101	1.157	1.367	1.515	1.202	1.213	1.558	1.090	1.329
102	1.498	1.443	1.660	1.478	1.703	1.287	1.298	1.582

Table 8.--Continued

Soil No.	Soil Number							
	31	34	35	39	40	42	44	46
2	1.538	1.624	1.531	1.516	1.286	1.424	1.188	1.181
3	1.473	1.595	1.435	1.573	1.453	1.436	1.380	1.166
4	1.385	1.973	1.786	1.691	1.672	1.198	1.662	1.306
5	2.187	2.042	1.683	1.991	1.751	1.725	1.894	1.839
8	1.128	1.813	1.922	1.578	1.536	1.481	1.342	1.335
9	0.869	1.781	1.974	1.238	1.025	1.642	1.417	1.412
10	1.337	1.284	1.821	1.852	1.722	1.705	1.664	1.039
11	1.169	1.526	1.738	1.367	1.206	1.588	1.287	1.221
15	1.260	1.605	1.461	1.124	1.033	1.250	1.003	1.193
17	1.125	1.679	1.776	1.290	1.283	1.361	1.350	1.236
18	1.238	1.871	1.731	1.508	1.531	1.279	1.458	1.173
19	1.248	1.758	1.566	1.453	1.391	1.189	1.258	1.120
21	1.528	1.832	1.743	1.043	1.049	1.621	1.511	1.508
23	1.479	1.721	1.790	1.450	1.423	1.583	1.496	1.415
27	1.323	1.697	1.985	1.590	1.343	1.710	1.540	1.500
29	1.508	1.764	1.663	1.086	0.728	1.598	1.193	1.482
31	0.000	1.905	2.247	1.747	1.544	1.668	1.400	1.372
34	1.905	0.000	1.535	1.899	1.827	2.240	1.939	1.522
35	2.247	1.535	0.000	1.968	1.905	1.991	1.778	1.661
39	1.747	1.899	1.968	0.000	0.696	1.937	1.556	1.741
40	1.544	1.827	1.905	0.696	0.000	1.752	1.257	1.668
42	1.668	2.240	1.991	1.937	1.752	0.000	1.588	1.384
44	1.400	1.939	1.778	1.556	1.257	1.588	0.000	1.548
46	1.372	1.522	1.661	1.741	1.668	1.384	1.548	0.000
48	1.623	1.702	1.381	1.166	0.964	1.396	0.996	1.353
50	2.034	1.941	1.575	1.869	1.848	1.911	1.970	1.830
52	2.061	1.600	1.605	1.682	1.634	2.071	2.009	1.744
55	1.628	1.651	1.361	1.328	1.317	1.630	1.411	1.387
57	1.389	1.855	1.859	1.560	1.322	1.273	1.311	1.228
58	1.622	1.783	1.643	1.166	1.081	1.456	1.304	1.238
61	1.595	1.942	1.571	1.270	1.176	1.496	1.111	1.288
62	1.175	1.732	1.877	1.371	1.081	1.600	1.257	1.443
63	1.598	2.043	2.204	1.843	1.752	1.701	1.795	1.756
64	1.747	2.021	1.695	1.795	1.710	1.514	1.681	1.570
66	1.395	1.742	1.472	1.462	1.386	1.179	1.343	1.172

Table 8.--Continued

Soil No.	Soil Number							
	31	34	35	39	40	42	44	46
67	1.670	1.929	1.450	1.181	1.045	1.098	1.149	1.294
68	1.389	1.763	1.519	1.303	1.201	1.077	1.174	1.117
69	1.272	1.722	1.621	1.386	1.358	1.304	1.340	1.325
71	1.654	2.033	1.878	1.801	1.650	1.157	1.554	1.092
72	1.395	1.474	1.762	1.361	1.168	1.503	1.335	1.338
73	1.487	1.623	1.520	1.239	1.137	1.381	1.338	1.195
74	1.372	1.698	1.706	1.360	1.293	1.365	1.429	1.091
76	1.073	1.666	1.767	1.256	1.173	1.342	1.172	1.232
77	1.878	1.832	1.471	1.467	1.441	1.931	1.732	1.690
78	1.941	2.141	1.882	1.942	1.999	2.091	2.125	1.843
79	1.206	1.762	1.675	1.256	1.019	1.601	1.035	1.459
80	1.457	2.079	1.999	1.960	1.740	1.723	1.477	1.728
84A	1.080	1.525	1.648	1.098	1.042	1.502	1.274	1.170
86	0.442	1.907	2.137	1.650	1.434	1.610	1.254	1.303
87	1.279	1.998	2.037	1.287	1.058	1.676	1.384	1.333
88	1.156	2.001	2.224	1.737	1.434	1.759	1.400	1.436
89	0.807	1.679	2.004	1.157	0.949	1.552	1.359	1.283
91	1.708	2.177	1.975	1.687	1.427	1.694	1.150	1.789
95	1.428	1.388	1.896	1.491	1.450	1.781	1.557	1.423
96	0.831	1.743	2.091	1.216	0.938	1.735	1.267	1.504
99	1.441	1.590	2.144	1.776	1.466	1.825	1.542	1.650
100	1.389	1.605	2.039	1.773	1.396	1.764	1.446	1.675
101	1.386	1.985	2.000	1.841	1.459	1.337	1.354	1.512
102	1.610	1.878	2.274	1.792	1.588	1.876	1.801	1.444

Table 8.--Continued

Soil No.	Soil Number							
	48	50	52	55	57	58	61	62
2	0.803	1.779	1.505	1.203	1.258	1.128	1.058	1.168
3	0.965	1.423	1.306	0.951	1.240	1.147	1.107	1.121
4	1.353	1.774	1.686	1.417	1.223	1.263	1.317	1.240
5	1.317	1.705	1.615	1.135	1.685	1.579	1.811	1.838
8	1.427	1.943	1.783	1.447	1.269	1.329	1.252	0.964
9	1.254	1.846	1.738	1.366	1.369	1.398	1.335	0.991
10	1.577	1.908	1.706	1.551	1.454	1.569	1.638	1.223
11	1.071	1.712	1.493	1.112	1.060	0.951	1.076	0.828
15	0.618	1.379	1.344	0.838	1.062	0.867	0.944	0.927
17	1.215	1.687	1.473	1.257	1.007	1.003	1.095	0.828
18	1.206	1.690	1.629	1.186	1.215	1.153	1.179	1.219
19	0.934	1.603	1.588	1.037	1.265	1.184	1.111	1.046
21	1.064	1.438	1.440	1.196	1.508	1.285	1.326	1.188
23	1.217	1.804	1.542	1.216	1.363	1.226	1.326	1.031
27	1.334	1.612	1.512	1.196	1.303	1.447	1.691	1.218
29	0.627	1.594	1.629	1.008	1.148	1.005	1.137	1.091
31	1.623	2.034	2.061	1.628	1.389	1.622	1.595	1.175
34	1.702	1.941	1.600	1.651	1.855	1.783	1.942	1.732
35	1.381	1.575	1.605	1.361	1.859	1.643	1.571	1.877
39	1.166	1.869	1.682	1.328	1.560	1.166	1.270	1.371
40	0.964	1.848	1.634	1.317	1.322	1.081	1.176	1.081
42	1.396	1.911	2.071	1.630	1.273	1.456	1.496	1.600
44	0.996	1.970	2.009	1.411	1.311	1.304	1.111	1.257
46	1.353	1.830	1.744	1.387	1.228	1.238	1.288	1.443
48	0.000	1.532	1.530	0.848	1.174	0.872	0.909	1.152
50	1.532	0.000	1.328	1.164	1.779	1.673	1.912	1.871
52	1.530	1.328	0.000	1.261	1.739	1.513	1.750	1.663
55	0.848	1.164	1.261	0.000	1.315	1.131	1.317	1.454
57	1.174	1.779	1.739	1.315	0.000	0.742	1.038	1.142
58	0.872	1.673	1.513	1.131	0.742	0.000	0.679	1.086
61	0.909	1.912	1.750	1.317	1.038	0.679	0.000	1.151
62	1.152	1.871	1.663	1.454	1.142	1.086	1.151	0.000
63	1.762	2.141	1.962	1.838	1.060	1.347	1.537	1.243
64	1.462	2.001	1.825	1.461	1.141	1.237	1.233	1.411
66	0.863	1.496	1.492	0.853	1.302	1.214	1.251	1.219

Table 8.--Continued

Soil No.	Soil Number							
	48	50	52	55	57	58	61	62
67	0.643	1.621	1.582	1.028	1.134	0.860	0.809	1.217
68	0.767	1.529	1.549	0.990	1.039	0.859	0.879	0.947
69	1.031	1.586	1.494	1.094	1.323	1.221	1.255	0.952
71	1.343	1.656	1.751	1.368	1.270	1.215	1.425	1.562
72	1.012	1.776	1.480	1.221	1.325	1.260	1.260	1.060
73	0.812	1.526	1.336	1.036	1.022	0.774	0.920	0.790
74	1.119	1.672	1.488	1.181	1.011	0.849	0.966	0.825
76	1.059	1.659	1.619	1.119	1.036	1.003	1.069	0.799
77	1.167	1.481	1.826	1.303	1.621	1.398	1.395	1.617
78	1.880	1.466	1.975	1.754	2.006	1.910	1.911	1.974
79	0.982	1.877	1.653	1.243	1.251	1.167	0.982	0.995
80	1.556	2.246	2.000	1.673	1.734	1.769	1.567	1.355
84A	1.007	1.609	1.428	0.986	1.052	0.908	0.971	0.759
86	1.533	2.013	2.016	1.539	1.284	1.517	1.420	1.198
87	1.331	1.957	1.847	1.509	1.375	1.321	1.356	1.177
88	1.463	2.043	1.976	1.669	1.544	1.620	1.713	1.200
89	1.218	1.756	1.626	1.290	1.052	1.110	1.265	0.789
91	1.295	2.170	2.016	1.573	1.692	1.660	1.437	1.490
95	1.318	1.622	1.368	1.197	1.506	1.487	1.653	1.271
96	1.314	1.838	1.741	1.367	1.245	1.316	1.420	0.896
99	1.423	2.010	1.686	1.582	1.536	1.669	1.754	1.247
100	1.294	1.982	1.697	1.515	1.513	1.643	1.711	1.337
101	1.316	1.620	1.730	1.480	1.401	1.579	1.672	1.251
102	1.607	2.041	1.753	1.680	1.551	1.558	1.801	1.277

Table 8.--Continued

Soil No.	Soil Number							
	63	64	66	67	68	69	71	72
2	1.719	1.475	0.961	0.978	0.923	1.047	1.257	0.779
3	1.598	1.247	0.834	1.048	0.749	0.919	1.349	0.762
4	1.309	1.165	0.921	1.243	0.975	0.765	1.499	1.346
5	2.192	1.771	1.362	1.378	1.407	1.583	1.492	1.579
8	1.241	1.249	1.120	1.311	0.942	0.829	1.566	1.061
9	1.613	1.609	1.143	1.331	1.213	1.132	1.691	1.081
10	1.628	1.695	1.347	1.608	1.282	1.275	1.688	1.246
11	1.332	1.363	1.081	1.182	0.891	0.962	1.324	0.932
15	1.495	1.370	0.688	0.717	0.561	0.588	1.216	0.936
17	1.050	1.150	0.985	1.116	0.811	0.660	1.405	1.031
18	1.525	1.349	0.824	1.091	0.762	0.596	1.363	1.214
19	1.577	1.286	0.443	0.911	0.615	0.517	1.349	0.903
21	1.774	1.674	1.051	1.113	1.135	1.126	1.609	1.209
23	1.491	1.424	0.975	1.184	0.848	0.681	1.505	0.970
27	1.722	1.793	1.184	1.458	1.385	1.340	1.596	1.292
29	1.778	1.632	1.156	0.928	0.978	1.210	1.500	1.131
31	1.598	1.747	1.395	1.676	1.389	1.272	1.654	1.395
34	2.045	2.021	1.742	1.929	1.763	1.722	2.033	1.474
35	2.204	1.695	1.472	1.450	1.519	1.621	1.878	1.762
39	1.843	1.795	1.462	1.181	1.303	1.386	1.801	1.361
40	1.752	1.710	1.386	1.045	1.201	1.358	1.650	1.168
42	1.701	1.514	1.179	1.098	1.077	1.304	1.157	1.503
44	1.795	1.681	1.343	1.149	1.174	1.340	1.554	1.335
46	1.756	1.570	1.172	1.294	1.117	1.325	1.092	1.338
48	1.762	1.462	0.863	0.843	0.767	1.031	1.343	1.012
50	2.141	2.001	1.496	1.621	1.529	1.586	1.656	1.776
52	1.962	1.825	1.492	1.582	1.549	1.494	1.751	1.480
55	1.838	1.461	0.853	1.028	0.990	1.094	1.368	1.221
57	1.060	1.141	1.302	1.134	1.039	1.323	1.270	1.325
58	1.347	1.237	1.214	0.860	0.859	1.221	1.215	1.260
61	1.537	1.233	1.251	0.809	0.879	1.255	1.425	1.260
62	1.248	1.411	1.219	1.217	0.947	0.952	1.562	1.060
63	0.000	1.082	1.728	1.730	1.490	1.474	1.838	1.640
64	1.082	0.000	1.355	1.370	1.231	1.368	1.696	1.445
66	1.728	1.355	0.000	0.867	0.774	0.683	1.312	1.024

Table 8.--Continued

Soil No.	Soil Number							
	63	64	66	67	68	69	71	72
67	1.730	1.370	0.867	0.000	0.609	1.007	1.148	1.152
68	1.490	1.231	0.774	0.609	0.000	0.645	1.091	0.925
69	1.474	1.368	0.683	1.007	0.645	0.000	1.410	0.994
71	1.838	1.696	1.312	1.148	1.091	1.410	0.000	1.536
72	1.640	1.445	1.024	1.152	0.925	0.994	1.536	0.000
73	1.414	1.304	0.904	0.793	0.518	0.747	1.247	0.881
74	1.328	1.216	0.995	0.958	0.621	0.884	1.192	0.957
76	1.230	1.232	1.007	1.035	0.588	0.660	1.307	0.901
77	2.027	1.855	1.454	1.376	1.362	1.503	1.798	1.491
78	2.300	2.085	1.644	1.838	1.721	1.719	2.045	1.815
79	1.471	1.338	1.074	1.113	1.101	1.072	1.632	1.063
80	1.804	1.523	1.292	1.550	1.304	1.154	1.912	1.206
84A	1.309	1.196	0.955	1.015	0.693	0.769	1.333	0.827
86	1.629	1.648	1.352	1.510	1.281	1.271	1.566	1.308
87	1.695	1.670	1.414	1.294	1.315	1.416	1.278	1.410
88	1.817	1.943	1.391	1.611	1.486	1.380	1.497	1.454
89	1.350	1.527	1.147	1.272	1.113	1.082	1.487	1.110
91	2.002	1.729	1.336	1.292	1.328	1.393	1.899	1.244
95	1.660	1.692	1.203	1.501	1.255	1.131	1.546	0.836
96	1.538	1.725	1.316	1.424	1.306	1.249	1.678	1.245
99	1.808	1.878	1.395	1.649	1.462	1.388	1.877	0.823
100	1.886	1.910	1.366	1.593	1.480	1.389	1.825	0.981
101	1.892	1.863	1.140	1.333	1.292	1.336	1.490	1.326
102	1.744	1.882	1.525	1.674	1.465	1.464	1.430	1.286

Table 8.--Continued

Soil No.	Soil Number							
	73	74	76	77	78	79	80	84 A
2	0.839	1.068	1.125	1.355	1.915	1.012	1.356	1.041
3	0.713	0.765	0.919	1.380	1.636	1.112	1.291	0.803
4	1.048	1.093	1.047	1.719	1.700	1.296	1.441	1.089
5	1.489	1.598	1.611	1.714	2.370	1.695	1.788	1.596
8	1.041	0.774	0.621	1.812	1.783	1.075	0.994	0.768
9	1.196	1.196	1.033	1.427	1.733	0.781	1.386	0.856
10	1.269	1.131	1.139	1.873	2.029	1.473	1.507	1.164
11	0.811	0.686	0.659	1.370	1.830	0.831	1.231	0.551
15	0.621	0.873	0.719	1.312	1.675	0.927	1.409	0.705
17	0.765	0.700	0.612	1.633	1.664	1.035	1.334	0.609
18	0.935	0.952	0.801	1.585	1.615	1.214	1.303	0.879
19	0.803	0.814	0.756	1.431	1.567	0.948	1.046	0.797
21	1.049	1.192	1.219	1.423	1.515	1.122	1.780	1.045
23	0.845	0.766	0.691	1.587	1.795	1.115	1.035	0.798
27	1.270	1.308	1.320	1.751	2.117	1.375	1.781	1.199
29	0.927	1.239	1.115	1.171	1.957	1.115	1.744	1.019
31	1.487	1.372	1.073	1.878	1.941	1.206	1.457	1.080
34	1.623	1.698	1.666	1.832	2.141	1.762	2.079	1.525
35	1.520	1.706	1.767	1.471	1.882	1.675	1.999	1.648
39	1.239	1.360	1.256	1.467	1.942	1.256	1.960	1.098
40	1.137	1.293	1.173	1.441	1.999	1.019	1.740	1.042
42	1.381	1.365	1.342	1.931	2.091	1.601	1.723	1.502
44	1.338	1.429	1.172	1.732	2.125	1.035	1.477	1.274
46	1.195	1.091	1.232	1.690	1.843	1.459	1.728	1.170
48	0.812	1.119	1.059	1.167	1.880	0.982	1.556	1.007
50	1.526	1.672	1.659	1.481	1.466	1.871	2.246	1.609
52	1.336	1.488	1.619	1.826	1.975	1.653	2.000	1.428
55	1.036	1.181	1.119	1.303	1.754	1.243	1.673	0.986
57	1.022	1.011	1.036	1.621	2.006	1.251	1.734	1.052
58	0.774	0.849	1.003	1.398	1.910	1.167	1.769	0.908
61	0.920	0.966	1.069	1.395	1.911	0.982	1.567	0.971
62	0.790	0.825	0.799	1.617	1.974	0.995	1.355	0.759
63	1.414	1.328	1.230	2.027	2.300	1.471	1.804	1.309
64	1.304	1.216	1.232	1.855	2.085	1.338	1.523	1.196
66	0.904	0.995	1.007	1.454	1.644	1.074	1.292	0.955

Table 8.--Continued

Soil No.	Soil Number							
	73	74	76	77	78	79	80	84A
67	0.793	0.958	1.035	1.376	1.838	1.113	1.550	1.015
68	0.518	0.621	0.588	1.362	1.721	1.101	1.304	0.693
69	0.747	0.884	0.660	1.503	1.719	1.072	1.154	0.769
71	1.247	1.192	1.307	1.798	2.045	1.632	1.912	1.333
72	0.881	0.957	0.901	1.491	1.815	1.063	1.206	0.827
73	0.000	0.531	0.762	1.315	1.765	1.128	1.491	0.651
74	0.531	0.000	0.668	1.528	1.723	1.159	1.387	0.564
76	0.762	0.668	0.000	1.470	1.747	0.968	1.141	0.470
77	1.315	1.528	1.470	0.000	1.565	1.355	1.927	1.360
78	1.765	1.723	1.747	1.565	0.000	1.847	2.063	1.676
79	1.128	1.159	0.968	1.355	1.847	0.000	1.084	0.884
80	1.491	1.387	1.141	1.927	2.063	1.084	0.000	1.286
84A	0.651	0.564	0.470	1.360	1.676	0.884	1.286	0.000
86	1.405	1.265	1.003	1.829	1.813	1.125	1.386	0.989
87	1.314	1.317	1.261	1.663	2.041	1.164	1.739	1.149
88	1.482	1.528	1.376	1.863	2.156	1.299	1.601	1.395
89	1.044	0.994	0.876	1.518	1.815	0.931	1.524	0.722
91	1.539	1.528	1.315	1.834	2.147	1.034	0.938	1.454
95	1.119	1.191	1.116	1.684	1.999	1.384	1.619	1.017
96	1.256	1.219	1.013	1.639	1.893	0.945	1.554	0.898
99	1.336	1.426	1.346	1.842	2.236	1.378	1.491	1.308
100	1.394	1.589	1.416	1.710	2.285	1.278	1.552	1.364
101	1.328	1.377	1.392	1.932	1.874	1.417	1.681	1.409
102	1.331	1.285	1.364	1.926	2.248	1.593	1.691	1.353

Table 8.--Continued

Soil No.	Soil Number							
	86	87	88	89	91	95	96	99
2	1.442	1.263	1.289	1.288	1.350	1.110	1.440	1.176
3	1.373	1.510	1.594	1.247	1.421	1.042	1.409	1.263
4	1.384	1.588	1.594	1.254	1.770	1.547	1.522	1.737
5	2.121	1.914	1.979	1.846	1.740	1.714	1.951	1.825
8	1.038	1.479	1.515	1.092	1.335	1.243	1.203	1.425
9	0.874	1.066	1.196	0.574	1.469	1.309	0.653	1.298
10	1.377	1.650	1.545	1.229	1.657	1.250	1.348	1.296
11	1.130	1.284	1.346	0.836	1.437	1.103	0.966	1.260
15	1.202	1.240	1.323	0.938	1.362	1.089	1.078	1.332
17	1.068	1.307	1.425	0.858	1.556	1.148	1.068	1.414
18	1.175	1.518	1.542	1.156	1.573	1.418	1.372	1.648
19	1.190	1.393	1.367	1.089	1.217	1.200	1.260	1.369
21	1.468	1.274	1.510	1.063	1.675	1.355	1.154	1.618
23	1.411	1.531	1.510	1.197	1.322	1.175	1.321	1.390
27	1.401	1.386	1.261	0.920	1.655	1.040	0.961	1.020
29	1.429	1.197	1.396	1.038	1.502	1.386	1.093	1.401
31	0.442	1.279	1.156	0.807	1.708	1.428	0.831	1.441
34	1.907	1.998	2.001	1.679	2.177	1.388	1.743	1.590
35	2.137	2.037	2.224	2.004	1.975	1.896	2.091	2.144
39	1.650	1.287	1.737	1.157	1.687	1.491	1.216	1.776
40	1.434	1.058	1.434	0.949	1.427	1.450	0.938	1.466
42	1.610	1.676	1.759	1.552	1.694	1.781	1.785	1.825
44	1.254	1.384	1.400	1.359	1.150	1.557	1.267	1.542
46	1.303	1.333	1.436	1.283	1.789	1.423	1.504	1.650
48	1.533	1.331	1.463	1.218	1.295	1.318	1.314	1.423
50	2.013	1.957	2.043	1.756	2.170	1.622	1.838	2.010
52	2.016	1.847	1.976	1.626	2.016	1.368	1.741	1.686
55	1.539	1.509	1.669	1.290	1.573	1.197	1.367	1.582
57	1.284	1.375	1.544	1.052	1.692	1.506	1.245	1.536
58	1.517	1.321	1.620	1.110	1.660	1.487	1.316	1.669
61	1.420	1.356	1.713	1.265	1.437	1.653	1.420	1.754
62	1.198	1.177	1.200	0.789	1.490	1.271	0.896	1.247
63	1.629	1.695	1.817	1.350	2.022	1.660	1.538	1.808
64	1.648	1.670	1.943	1.527	1.729	1.692	1.725	1.878
66	1.352	1.414	1.391	1.147	1.336	1.203	1.316	1.395

Table 8.--Continued

Soil No.	Soil Number							
	86	87	88	89	91	95	96	99
67	1.510	1.294	1.611	1.272	1.292	1.501	1.424	1.649
68	1.281	1.315	1.486	1.113	1.328	1.255	1.306	1.462
69	1.271	1.416	1.380	1.082	1.393	1.131	1.249	1.388
71	1.566	1.278	1.497	1.487	1.899	1.546	1.678	1.877
72	1.308	1.410	1.454	1.110	1.244	0.836	1.245	0.823
73	1.405	1.314	1.482	1.044	1.539	1.119	1.256	1.336
74	1.265	1.317	1.528	0.994	1.528	1.191	1.219	1.426
76	1.003	1.261	1.376	0.876	1.315	1.116	1.013	1.346
77	1.829	1.663	1.863	1.518	1.834	1.684	1.639	1.842
78	1.813	2.041	2.156	1.815	2.147	1.999	1.893	2.236
79	1.125	1.184	1.299	0.931	1.084	1.384	0.945	1.378
80	1.386	1.739	1.601	1.524	0.938	1.619	1.554	1.491
84A	0.989	1.149	1.395	0.722	1.454	1.017	0.898	1.308
86	0.000	1.226	1.280	0.872	1.576	1.465	0.854	1.495
87	1.226	0.000	0.871	0.997	1.635	1.419	1.068	1.629
88	1.280	0.871	0.000	1.097	1.597	1.369	1.109	1.367
89	0.872	0.997	1.097	0.000	1.565	1.180	0.413	1.220
91	1.576	1.635	1.597	1.565	0.000	1.657	1.523	1.454
95	1.465	1.419	1.369	1.180	1.657	0.000	1.285	0.879
96	0.854	1.068	1.109	0.413	1.523	1.285	0.000	1.275
99	1.495	1.629	1.367	1.220	1.454	0.879	1.275	0.000
100	1.460	1.593	1.325	1.221	1.527	1.096	1.273	0.594
101	1.355	1.485	1.288	1.215	1.546	1.467	1.223	1.317
102	1.660	1.178	0.989	1.317	1.744	1.103	1.446	1.239

Table 8.--Continued

Soil No.	Soil Number		
	100	101	102
2	1.093	1.369	1.278
3	1.364	1.287	1.459
4	1.691	1.509	1.733
5	1.713	1.811	1.776
8	1.613	1.480	1.477
9	1.241	1.284	1.533
10	1.524	1.457	1.415
11	1.304	1.440	1.246
15	1.250	1.157	1.498
17	1.489	1.367	1.443
18	1.602	1.515	1.660
19	1.406	1.202	1.478
21	1.628	1.213	1.703
23	1.530	1.558	1.287
27	1.106	1.090	1.298
29	1.246	1.329	1.582
31	1.389	1.386	1.610
34	1.605	1.985	1.878
35	2.039	2.000	2.274
39	1.773	1.841	1.792
40	1.396	1.459	1.588
42	1.764	1.337	1.876
44	1.446	1.354	1.801
46	1.675	1.512	1.444
48	1.294	1.316	1.607
50	1.982	1.620	2.041
52	1.697	1.730	1.753
55	1.515	1.480	1.680
57	1.513	1.401	1.551
58	1.643	1.579	1.558
61	1.711	1.672	1.801
62	1.337	1.251	1.277
63	1.886	1.892	1.744
64	1.910	1.863	1.882
66	1.366	1.140	1.525

Table 8.--Concluded

Soil No.	Soil Number		
	100	101	102
67	1.593	1.333	1.674
68	1.480	1.292	1.465
69	1.389	1.336	1.464
71	1.825	1.490	1.430
72	0.981	1.328	1.286
73	1.394	1.328	1.331
74	1.589	1.377	1.285
76	1.416	1.392	1.364
77	1.710	1.932	1.926
78	2.285	1.874	2.248
79	1.278	1.417	1.593
80	1.552	1.681	1.691
84A	1.364	1.409	1.353
86	1.460	1.355	1.660
87	1.593	1.485	1.178
88	1.325	1.288	0.989
89	1.221	1.215	1.317
91	1.527	1.546	1.744
95	1.096	1.467	1.103
96	1.273	1.223	1.446
99	0.594	1.317	1.239
100	0.000	1.352	1.466
101	1.352	0.000	1.581
102	1.466	1.581	0.000

Table 9. Correlations among twenty-one characters for fifty-nine soils based on standardized characters.

CHARACTER NUMBER	CHARACTER NUMBER							
	1	2	3	5	10	11	12	13
1	1.000	-.151	.155	.294	-.106	-.029	.087	-.209
2	-.151	1.000	.032	-.172	.098	.245	.140	-.196
3	.155	.032	1.000	.362	.158	.117	.116	-.204
5	.294	-.172	.362	1.000	-.177	-.058	-.061	-.185
10	-.106	.098	.158	-.177	1.000	-.079	.116	-.008
11	-.029	.245	.117	-.058	-.079	1.000	.004	-.111
12	.087	.140	.116	-.061	.116	.004	1.000	-.263
13	-.209	-.196	-.204	-.185	-.008	-.111	-.263	1.000
15	-.063	-.174	.267	.176	.022	.026	-.267	-.029
16	.414	.041	.014	.115	.001	.062	.009	.068
20	.106	.078	.158	-.015	-.048	.204	-.041	-.255
21	.017	.026	.241	.007	-.225	.304	-.101	-.121
22	-.202	-.115	.059	-.137	.304	-.030	.177	-.151
23	-.014	-.180	.130	-.113	-.167	.120	.080	-.112
30	.466	.136	.254	.318	.059	.116	-.014	-.388
31	-.343	.389	.026	-.116	.272	-.011	-.043	.068
33	-.165	.118	.149	.007	.115	-.206	-.264	.177
34	-.247	.083	-.120	-.183	-.120	-.163	-.094	.498
38	-.004	.104	-.300	.162	-.193	.013	.014	-.234
45	.148	.042	-.210	.101	-.130	-.123	.103	-.104
62	-.146	.090	.005	.189	.014	-.056	-.305	.144

Table 9 (cont.).

CHARACTER NUMBER	CHARACTER NUMBER							
	15	16	20	21	22	23	30	31
1	-.063	.414	.106	.017	-.202	-.014	.466	-.343
2	-.174	.041	.078	.026	-.115	-.180	.136	.389
3	.267	.014	.158	.241	.059	.130	.254	.026
5	.176	.115	-.015	.007	-.137	-.113	.318	-.116
10	.022	.001	-.048	-.225	.304	-.167	.059	.272
11	.026	.062	.204	.304	-.030	.120	.116	-.011
12	-.267	.009	-.041	-.101	.177	.080	-.014	-.043
13	-.029	.068	-.255	-.121	-.151	-.112	-.388	.068
15	1.000	-.224	.176	.354	-.128	.243	.089	.175
16	-.224	1.000	.003	-.169	-.256	-.150	.454	-.256
20	.176	.003	1.000	.488	.072	.424	.460	-.161
21	.354	-.169	.488	1.000	-.302	.569	.149	-.023
22	-.128	-.256	.072	-.302	1.000	.273	-.044	.007
23	.243	-.150	.424	.569	.273	1.000	-.030	-.206
30	.089	.454	.460	.149	-.044	-.030	1.000	-.178
31	.175	-.256	-.161	-.023	.007	-.206	-.178	1.000
33	.149	-.171	-.234	-.090	-.128	-.260	-.202	.373
34	.061	-.129	-.214	.036	-.446	-.305	-.349	.158
38	-.245	-.012	-.210	-.254	-.124	-.318	-.127	.001
45	-.187	.077	.033	-.081	.011	-.123	.071	-.206
62	.137	-.061	-.147	-.187	.002	-.240	-.159	.427

Table 9 (concl.).

CHARACTER NUMBER	CHARACTER NUMBER				
	33	34	38	45	62
1	-.165	-.247	-.004	.148	-.146
2	.118	.083	.104	.042	.090
3	.149	-.120	-.300	-.210	.005
5	.007	-.183	.162	.101	.189
10	.115	-.120	-.193	-.130	.014
11	-.206	-.163	.013	-.123	-.056
12	-.264	-.094	.014	.103	-.305
13	.177	.498	-.234	-.104	.144
15	.149	.061	-.245	-.187	.137
16	-.171	-.129	-.012	.077	-.061
20	-.234	-.214	-.210	.033	-.147
21	-.090	.036	-.254	-.081	-.187
22	-.128	-.446	-.124	.011	.002
23	-.260	-.305	-.318	-.123	-.240
30	-.202	-.349	-.127	.071	-.159
31	.373	.158	.001	-.206	.427
33	1.000	.433	-.114	-.043	.477
34	.433	1.000	-.121	-.137	.114
38	-.114	-.121	1.000	.549	.258
45	-.043	-.137	.549	1.000	.106
62	.477	.114	.258	.106	1.000

Table 10. Projection values for fifty-nine soils based on centroid-factor analysis of the matrix of correlations among twenty-one characters (Table 9).

Projection number	Soil Number					
	2	3	4	5	8	9
1	-0.383	-1.158	-0.955	-3.003	1.454	2.185
2	0.550	1.050	0.865	1.937	0.904	-1.875
3	1.024	-0.089	-3.157	2.784	-2.957	0.047
4	1.121	-0.815	-0.437	1.455	-0.389	-0.801
5	1.402	1.197	-0.383	1.598	0.890	-0.688
6	-0.005	0.130	-0.692	1.420	-0.125	-0.569
7	-0.069	0.359	0.430	2.392	-0.226	-0.119
8	-1.065	-0.125	0.784	0.297	0.278	1.112
9	0.325	-0.197	0.796	2.062	-0.323	0.158
10	0.248	-0.750	0.518	-0.375	-1.098	0.998

Table 10 (cont.).

Projection number	Soil Number					
	10	11	15	17	18	19
1	1.407	0.757	-0.859	0.402	-0.702	-0.414
2	2.665	0.358	-0.605	0.288	0.361	0.289
3	-0.128	-0.280	-0.056	-2.276	-2.518	-1.351
4	-1.790	-0.115	0.086	-0.640	-0.489	-0.271
5	0.441	0.248	-0.019	-0.730	0.311	1.276
6	-0.547	1.158	-0.206	0.433	-0.796	-1.051
7	-1.416	-0.680	0.631	-0.340	0.504	1.197
8	-0.685	0.080	-0.288	0.125	-0.153	-0.066
9	-1.205	0.857	-0.410	-0.429	1.459	0.456
10	0.408	-0.573	0.349	-0.347	0.123	-0.065

Table 10 (cont.).

Projection number	Soil Number					
	21	23	27	29	31	34
1	-0.681	0.297	1.551	-0.551	3.523	-0.422
2	-2.446	0.976	1.095	-2.107	-0.103	1.897
3	0.452	-1.346	2.409	1.986	-1.237	2.820
4	-1.355	-0.448	-0.461	1.047	-0.583	-3.757
5	-1.375	1.529	-1.667	-0.537	-1.322	1.111
6	-0.426	1.114	0.162	0.766	-2.206	1.012
7	1.168	1.217	0.995	0.332	-1.086	-3.371
8	-0.446	-0.743	1.095	-0.131	1.560	-1.403
9	-1.101	0.986	-1.025	-0.121	0.575	-1.868
10	-0.331	-1.357	1.212	1.483	1.348	0.748

Table 10 (cont.).

Projection number	Soil Number					
	35	39	40	42	44	46
1	-5.067	-0.161	0.670	-1.494	0.717	-0.507
2	-0.028	-3.861	-3.178	1.402	-1.488	1.700
3	1.661	0.727	1.653	-1.968	0.299	-0.418
4	-1.641	-0.139	1.137	2.418	2.577	-0.162
5	2.593	-1.101	-0.919	-0.580	1.204	-0.707
6	-0.322	2.249	1.415	-2.283	-1.499	-1.743
7	-1.712	-0.047	0.027	1.008	-0.722	-2.324
8	0.104	-1.691	-0.544	-0.009	0.519	-2.065
9	-0.611	-0.703	-0.971	0.375	-1.642	0.913
10	-1.394	-0.339	0.463	2.219	0.296	0.419

Table 10 (cont.).

Projection number	Soil Number					
	48	50	52	55	57	58
1	-1.668	-3.964	-2.331	-2.296	-0.412	-1.649
2	-1.351	-0.054	1.356	-0.251	0.541	-0.802
3	1.338	2.349	2.496	1.538	-1.050	-0.509
4	1.347	-3.207	-2.606	-0.764	1.808	1.521
5	0.898	-1.668	-0.609	0.261	-1.773	-1.182
6	0.403	-1.086	1.893	0.620	0.775	1.785
7	0.591	1.434	-.805	0.973	-1.818	-1.355
8	-0.514	0.936	-0.251	0.226	1.039	-0.763
9	-0.385	0.520	-1.182	0.467	-0.096	0.171
10	0.696	-1.822	-2.249	-0.583	1.140	-0.192

Table 10 (cont.).

Projection number	Soil Number					
	61	62	63	64	66	67
1	-1.368	1.641	0.851	-1.558	-1.128	-2.178
2	-1.846	-0.291	1.423	1.060	0.429	-1.235
3	-1.362	-0.709	-3.166	-2.834	-0.225	-0.177
4	1.996	0.492	0.677	1.048	-0.219	1.930
5	0.534	-0.660	-1.943	0.441	0.867	0.394
6	0.807	0.829	2.407	1.754	-1.057	-0.049
7	-1.820	-0.171	-2.243	-1.597	1.739	0.797
8	-0.475	0.224	2.356	2.058	0.046	-1.097
9	-0.184	-0.899	-1.116	-0.540	0.386	-0.039
10	-0.443	0.047	-0.058	-0.825	0.432	0.119

Table 10 (cont.).

Projection number	Soil Number					
	68	69	71	72	73	74
1	-1.265	-0.243	-1.626	0.851	-1.060	-0.342
2	0.050	0.453	1.617	0.567	0.147	0.685
3	-1.101	-1.334	0.129	0.643	-0.360	-1.509
4	0.774	-0.595	1.986	-0.408	0.093	0.011
5	0.475	0.797	-2.075	1.566	-0.148	-0.376
6	-0.029	-0.205	-1.511	0.786	1.201	0.906
7	0.628	1.547	-0.119	0.381	0.286	-0.250
8	-0.968	-0.172	-2.114	-0.819	-1.184	-1.177
9	0.447	0.331	2.172	-0.761	-0.031	0.337
10	-0.012	-0.042	-0.585	0.537	-0.121	-0.908

Table 10 (cont.).

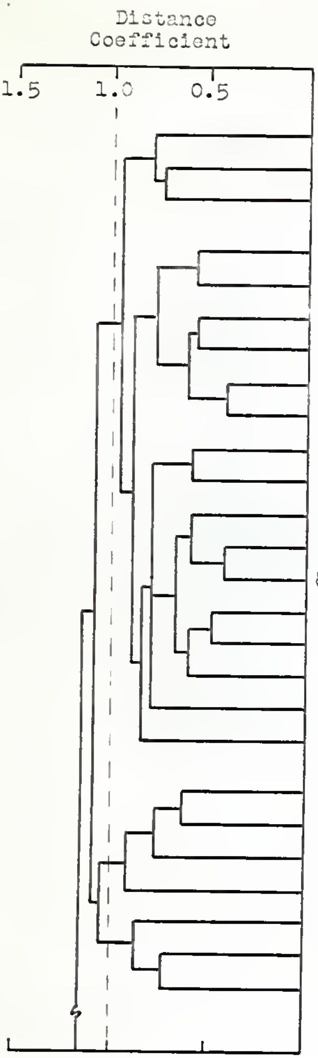
Projection number	Soil Number					
	76	77	78	79	80	84A
1	0.589	-2.454	-2.371	0.966	1.882	0.374
2	0.080	-2.704	-2.195	-1.695	0.970	-0.387
3	-1.538	1.865	-0.868	-0.182	-1.806	-0.813
4	0.019	-1.293	-4.452	0.755	0.649	-0.661
5	0.217	0.845	-0.219	1.203	3.934	-0.204
6	0.468	0.581	-3.058	0.203	-0.787	1.030
7	-0.051	-0.863	-0.194	-0.499	1.141	-0.552
8	-0.125	0.367	0.406	1.582	1.625	-0.283
9	0.350	2.406	1.995	-0.270	0.591	0.250
10	-0.325	-0.090	-2.511	-0.276	-1.189	-0.439

Table 10 (cont.).

Projection number	Soil Number					
	86	87	88	89	91	95
1	2.564	1.734	3.270	2.113	1.280	1.338
2	-0.651	-1.395	0.323	-0.926	-0.814	1.840
3	-1.457	0.846	1.369	-0.050	0.190	1.775
4	-0.177	1.632	1.306	-0.355	2.267	-1.636
5	-0.856	1.632	-1.546	-1.937	3.677	-0.077
6	-2.227	-0.626	-1.965	0.183	-0.824	1.038
7	-1.357	-0.825	0.434	-0.524	1.563	0.480
8	1.134	-0.935	-0.051	0.677	0.913	-0.945
9	0.502	0.885	0.899	-0.021	-0.915	-0.937
10	0.772	-0.742	0.167	1.006	-0.878	-0.124

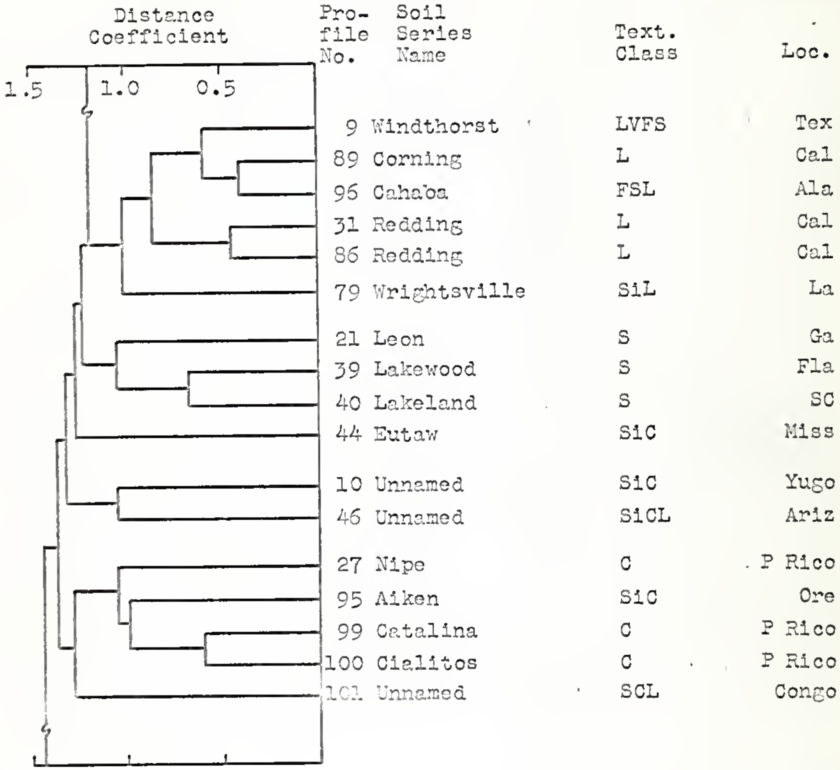
Table 10 (concl.).

Projection number	Soil Number				
	96	99	100	101	102
1	2.848	2.988	2.350	0.827	2.564
2	-1.632	1.863	1.089	0.543	2.547
3	0.556	2.321	2.894	1.082	1.579
4	-0.373	-0.394	0.162	0.417	0.793
5	-1.696	1.037	1.026	-1.295	-1.310
6	-0.162	0.623	0.151	-2.969	0.718
7	-0.401	0.704	0.501	1.979	0.507
8	1.150	0.416	1.143	0.914	-1.880
9	-0.572	-1.717	-0.987	-1.673	1.261
10	0.654	1.795	2.871	1.198	-1.223



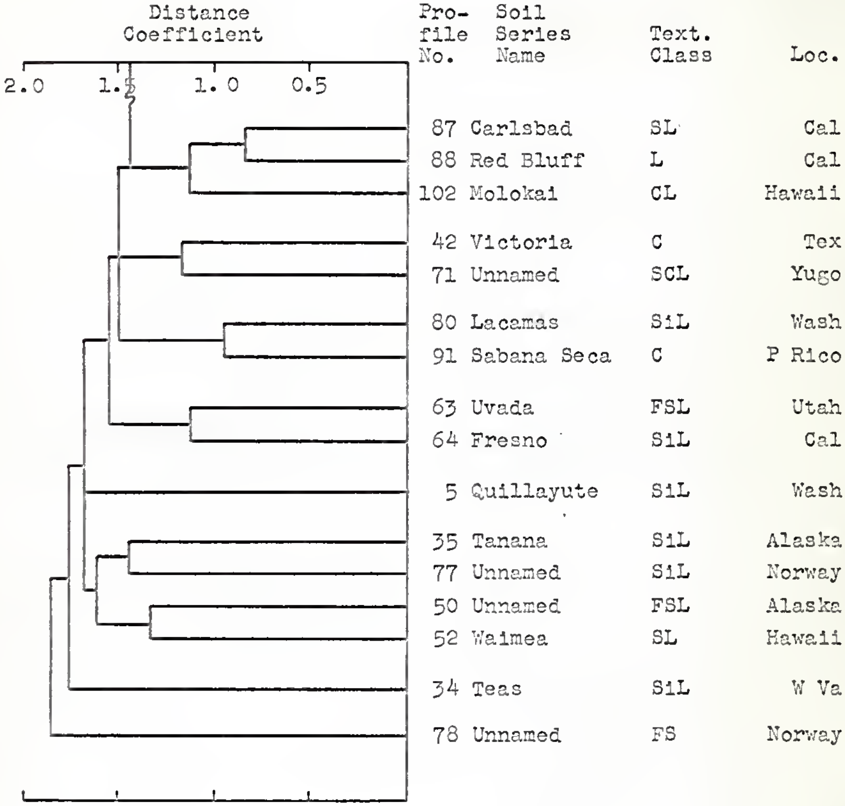
Pro-file No.	Soil Series Name	Text. Class	Loc.
2	Sharpsburg	SiCL	Neb
3	Eakin	SiL	SD
72	Shelby	CL	Iowa
4	Exline	FSL	ND
18	Exline	CL	ND
15	Williams	L	ND
69	Unnamed	SiL	SD
19	Tetonka	SiL	ND
66	Tetonka	SiCL	ND
8	Odin	SiL	Oregon
17	Rhoades	VFSL	SD
11	Alford	SiL	Indiana
76	New Mexico	L	ND
84A	Lansing	SiL	NY
68	Barnes	CL	ND
73	Morton	L	ND
74	Keith	L	Neb
23	Fillmore	SiL	Neb
62	Mohave	CSL	Ariz
29	Scituate	SL	NH
48	Erie	CL	NY
67	Webster	CL	Minn
55	Burton	L	Tenn
57	Mimbres	CL	NM
58	Blackhawk	SiL	Nev
61	Saltair	SiL	Utah

Fig. 4. Upper portion of distance dendrogram (Fig. 2).



Profile No.	Soil Series Name	Text. Class	Loc.
9	Windthorst	LVFS	Tex
89	Corning	L	Cal
96	Cahaba	FSL	Ala
31	Redding	L	Cal
86	Redding	L	Cal
79	Wrightsville	SiL	La
21	Leon	S	Ga
39	Lakewood	S	Fla
40	Lakeland	S	SC
44	Eutaw	SiC	Miss
10	Unnamed	SiC	Yugo
46	Unnamed	SiCL	Ariz
27	Nipe	C	P Rico
95	Aiken	SiC	Ore
99	Catalina	C	P Rico
100	Cialitos	C	P Rico
101	Unnamed	SCL	Congo

Fig. 5. Central portion of distance dendrogram (Fig. 2).



Pro-file No.	Soil Series Name	Text. Class	Loc.
87	Carlsbad	SL	Cal
88	Red Bluff	L	Cal
102	Molokai	CL	Hawaii
42	Victoria	C	Tex
71	Unnamed	SCL	Yugo
80	Lacamas	SiL	Wash
91	Sabana Seca	C	P Rico
63	Uvada	FSL	Utah
64	Fresno	SiL	Cal
5	Quillayute	SiL	Wash
35	Tanana	SiL	Alaska
77	Unnamed	SiL	Norway
50	Unnamed	FSL	Alaska
52	Waimea	SL	Hawaii
34	Teas	SiL	W Va
78	Unnamed	FS	Norway

Fig. 6. Lower portion of distance dendrogram (Fig. 2).

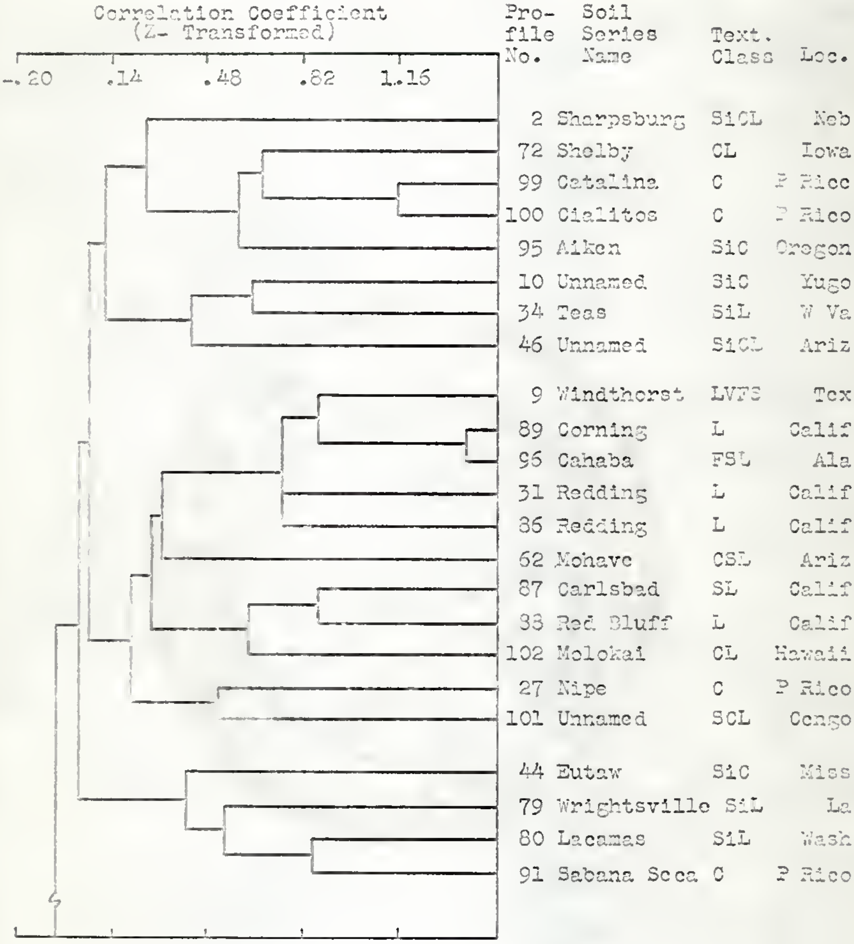
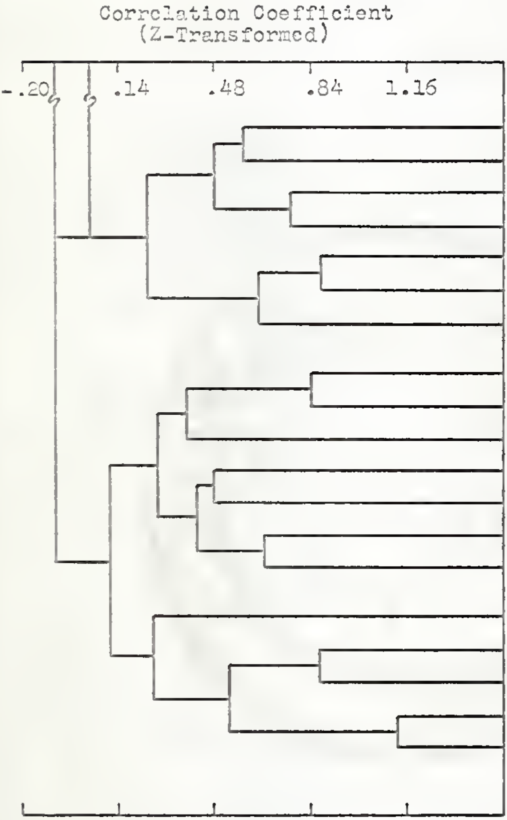


Fig. 7. Upper portion of correlation dendrogram (Fig. 3).

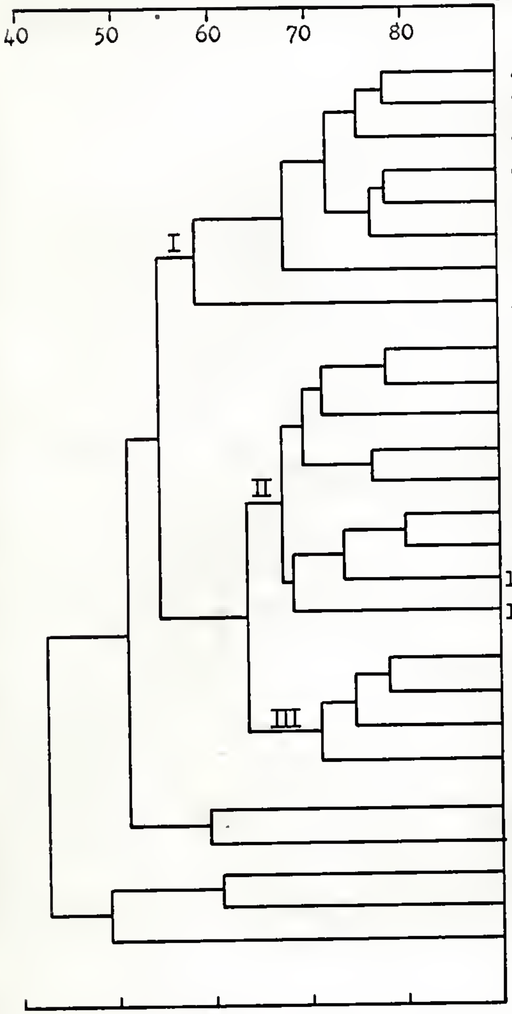
Profile No.	Soil Series Name	Text. Class	Loc.
3	Eakin	SiL	SD
73	Morton	L	ND
74	Keith	L	Neb
8	Odin	SiL	Ore
76	New Mexico	L	ND
23	Fillmore	SiL	Neb
11	Alford	SiL	Indiana
84A	Lansing	SiL	NY
17	Rhoades	VFSL	SD
63	Uvada	FSL	Utah
64	Fresno	SiL	Calif
4	Exline	FSL	ND
18	Exline	CL	ND
69	Unnamed	SiL	SD
19	Tetonka	SiL	ND
66	Tetonka	SiCL	ND
15	Williams	L	ND

Fig. 8. Central portion of correlation dendrogram (Fig. 3).



Pro-file No.	Soil Series Name	Text. Class	Loc.
42	Victoria	C	Tex
71	Unnamed	SiCL	Yugo
67	Webster	CL	Minn
68	Barnes	CL	ND
57	Mimbres	CL	NM
58	Blackhawk	SiL	Nev
61	Saltair	SiL	Utah
5	Quillayute	SiL	Wash
55	Burton	L	Tenn
52	Waimea	SL	Hawaii
35	Tanana	SiL	Alaska
77	Unnamed	SiL	Norway
50	Unnamed	FSL	Alaska
78	Unnamed	FS	Norway
21	Leon	S	Ga
29	Scituate	SL	NH
48	Erie	CL	NY
39	Lakewood	S	Fla
40	Lakeland	S	SC

Fig. 9. Lower portion of correlation dendrogram (Fig. 3).

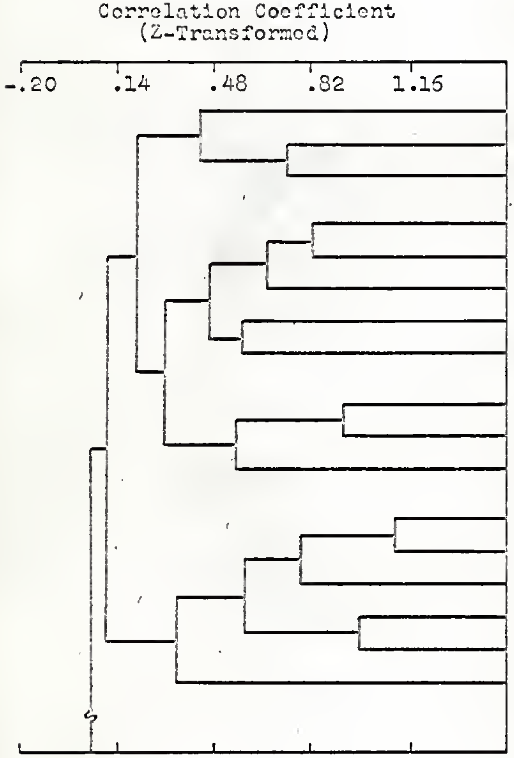


Profile No.	Soil Series Name	Text. Class	Loc.
42	Victoria	C	Texas*
71	Unnamed	SiCL	Yugo*
46	Unnamed	SiCL	Ariz*
64	Fresno	SiL	Cal*
74	Keith	L	Neb*
57	Mimbres	CL	N Mex*
61	Saltair	SiL	Utah
35	Tanana	SiL	Alaska
84	Hosmer	SiL	Indiana*
97	Ora	FSL	Miss*
40	Lakeland	S	SC
48	Erie	CL	NY
72	Shelby	CL	Iowa*
95	Aiken	SiC	Oregon*
99	Catalina	C	P Rico*
102	Molokai	CL	Hawaii*
101	Unnamed	SCL	Congo
79	Wrightsville	SiL	La*
80	Lacamas	SiL	Wash*
91	Sabana Seca	C	P Rico*
44	Eutaw	SiC	Miss*
52	Waimea	SL	Hawaii
50	Unnamed	FSL	Alaska
77	Unnamed	SiL	Norway
78	Unnamed	FS	Norway
39	Lakewood	S	Fla

Fig. 10. Taxonomic dendrogram based on sixty-one soil characters using weighted-pair-group method (reproduced from Sarkar, Bidwell, and Marcus, 1966). Asterisks indicate those soils which stayed in their respective groups as the number of characters was reduced. Soil profile numbers were changed to correspond to those found in 7th Approximation. Cophenetic correlation not computed.

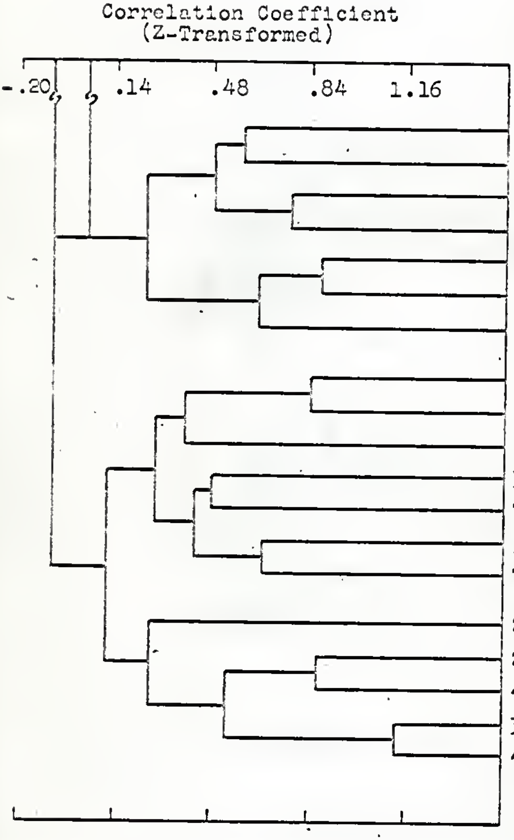
Pro-file No.	Mean Annual Precip. (Inches)	Mean Annual Temp. (F°)	Per-cent Slope
2	27.9	52	9
72	33.0	50	15
99	76.8	76	15
100	76.8	76	25
95	35.9	54	15
10	27.5	57	2
34	50.0	51	25
46	12.9	61	2.5
9	32.7	65	2
89	21.6	63	2
96	55	67	1
31	23.2	63	1
86	23.2	63	1
62	10.0	69	1
87	10.9	62	0
88	21.6	63	1
102	22.9	72	6
27	75.9	75	3
101	44.0	67	1
44	52.5	64	0
79	58.5	68	1
80	44.4	52	1
91	60.0	78	1

Fig. 11. Precipitation, temperature, and slope relationships for soils of Fig. 7.



Profile No.	Mean Annual Precip. (Inches)	Mean Annual Temp. (F°)	Percent Slope
3	18.2	46	5
73	13.7	43	3
74	16.9	48	1
8	9.5	47	0
76	15.4	40	0
23	22.7	51	1
11	41.7	55	2
84A	35.1	48	3
17	15.0	47	3
63	10.1	48	1
64	9.3	63	0
4	17.7	42	0.5
18	19.1	42	0
69	18.5	45	0
19	19.5	42	0
66	19.5	42	0
15	11.5	40	3

Fig. 12. Precipitation, temperature, and slope relationships for soils of Fig. 8.



Profile No.	Mean Annual Precip. (Inches)	Mean Annual Temp. (F°)	Percent Slope
42	28.0	71	0
71	24.1	53	0
67	28.3	45	0
68	19.5	42	1
57	9.2	60	1
58	8.8	49	2
61	19.5	52	1
5	115.9	49	1
55	54.2	57	1
52	40.9	65	12
35	13.4	28	1
77	25.8	33	1
50	67.8	40	0
78	25.8	33	0
21	47.7	69	2
29	41.1	47	2
48	35.1	48	3
39	53.5	71	5
40	46.2	64	5

Fig. 13. Precipitation, temperature, and slope relationships for the soils of Fig. 7.

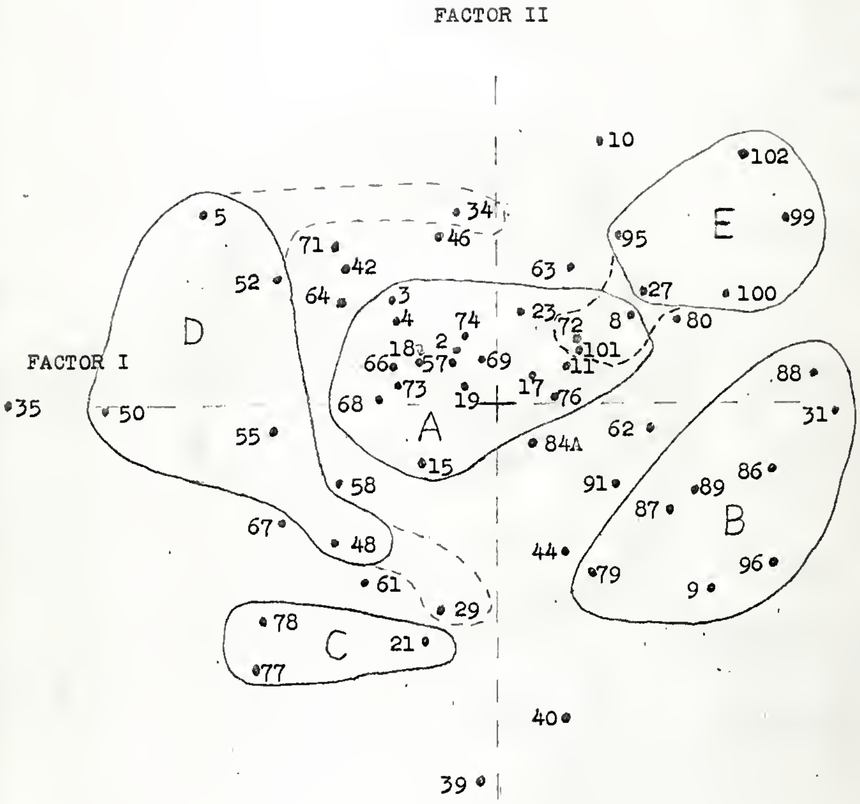


Fig. 14. Projections of fifty-nine soils onto centroid character axes I and II. Correlation between original distances (Table 8, Appendix) and distances computed from the first three factor projections (Table 10, Appendix) was .779 .

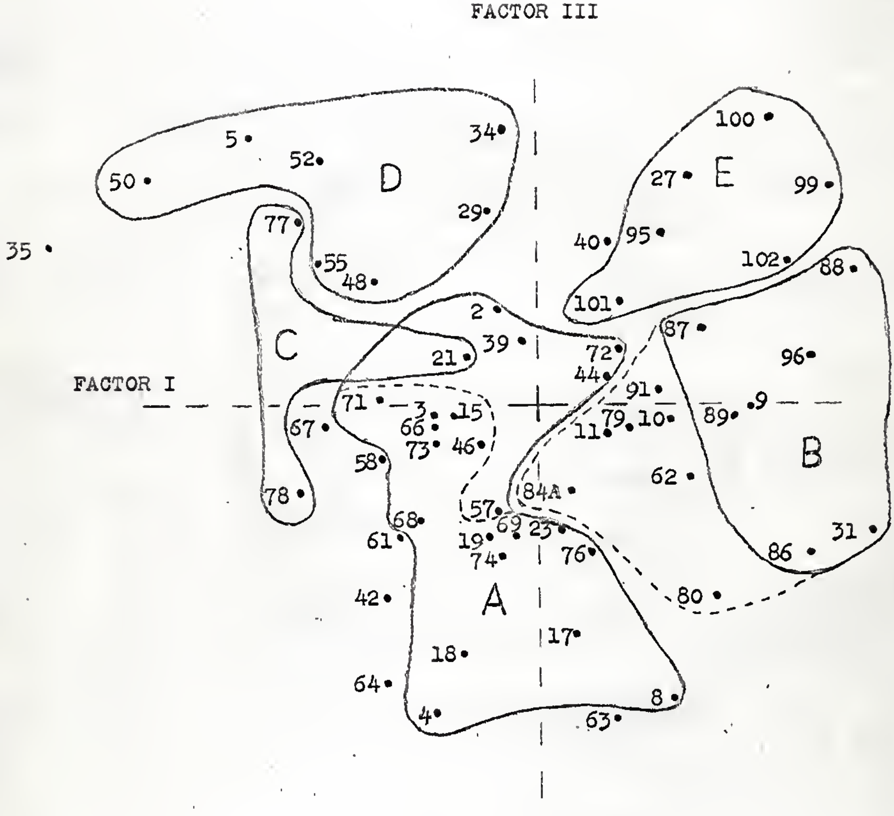


Fig. 15. Projections of fifty-nine soils onto centroid character axes I and III. This figure may be viewed as the third dimension of Fig. 14 (Appendix). Correlation between original distances (Table 8, Appendix) and distances computed from the first three factor projections (Table 10, Appendix) was .779.

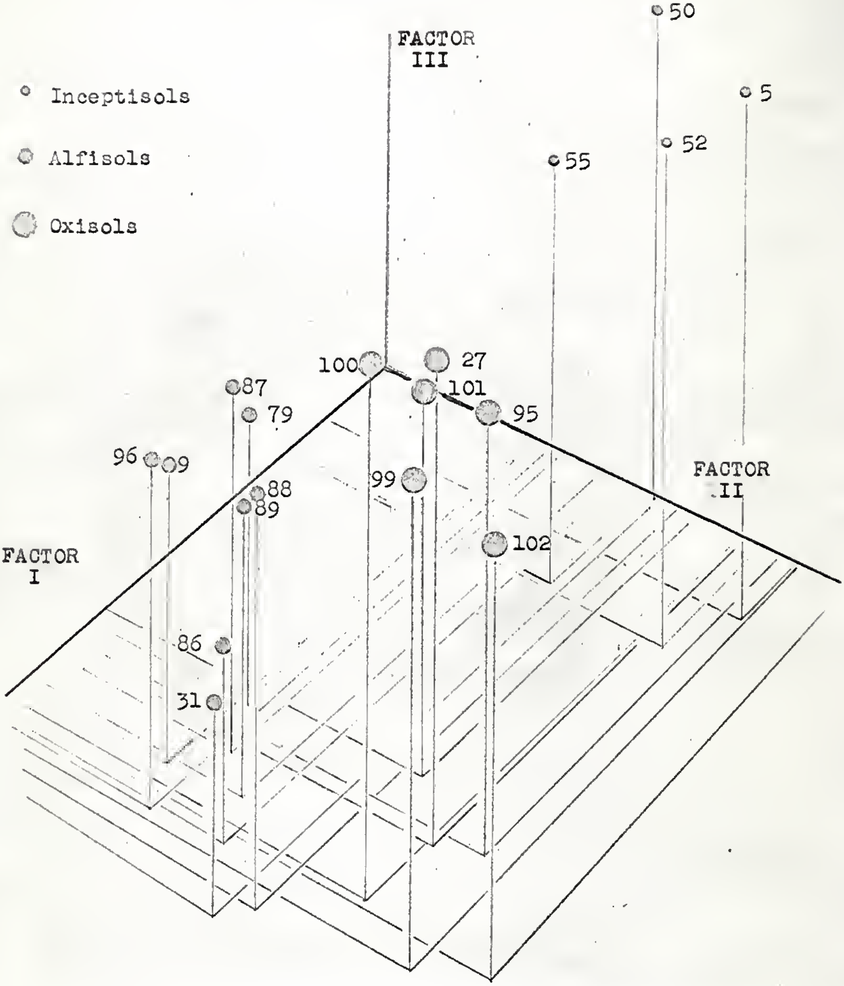


Fig. 16. Perspective representation of three-dimensional relationships among soils selected from Figs. 14 and 15. The centroid-character axes were reoriented and a value of 4 was added to all projections of Table 10, (Appendix).

APPLICATION OF CLUSTER ANALYSIS AND CENTROID FACTOR ANALYSIS TO THE NUMERICAL TAXONOMY OF SOME SOILS OF THE WORLD

by

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B. S., Kansas State University, 1961

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

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1967

Reawakening of interest in taxonomy in recent years, attributable to increased availability of electronic computers, prompted this statistical investigation in soil classification. New freedom of ideas and concepts in this vital discipline of taxonomy suggested numerous possibilities for exploration. Four aspects emphasized in this present analysis were as follows:

(1) The feasibility of using 21 objectively selected characteristics in a numerical classification of soils was determined.

(2) The usefulness and applicability of numerical procedures to soil classification was evaluated.

(3) Added experience in application of these numerical procedures was gained.

(4) The relationships among soils as indicated by two estimates of overall similarity and by factor analysis projections were investigated and evaluated critically.

Morphological and laboratory data for 59 modal soil profiles from nine Orders were selected from the publication, Soil Classification--A Comprehensive System: 7th Approximation. All characters were transformed to give each character a mean of zero and a variance of unity. Correlation and distance matrices were computed to obtain two estimates of the similarity of each individual soil to every other.

Relationships among soils as indicated by the correlation and distance matrices were summarized by the unweighted-pair-group method of cluster analysis using arithmetic averages.

Results of these cluster analyses were expressed in the form of dendrograms yielding heirarchic clusters of soils. The centroid-factor analysis which was applied to a matrix of correlations among the 21 characters yielded factor loadings for the 59 soils. Projections were then calculated, and all soils were plotted on rectangular-coordinate axes to express three-dimensional relationships among the soils.

Relationships among individual soils and groups, as indicated by the correlation dendrogram, the distance dendrogram, and the factor analysis projections were evaluated by five criteria:

(1) Comparisons were made of the relationships among soils as indicated by the three clustering techniques.

(2) Comparison with results of a previous numerical study of soils was made.

(3) Comparison with the present system of soil classification was made.

(4) Logical relationships based on knowledge of soil forming factors were evaluated.

(5) An objective criterion, known as cophenetic correlation, was used to determine how faithfully the two dendrograms represented their original matrices. An objective method of evaluating the factor analysis projections was also employed.

All three methods expressed essential agreement with some differences in the precision of the estimates. Some soils responded to each of the three methods in a different manner; and some soils showed no strong affinity for any cluster, regardless of method.

The correlation dendrogram expressed general relationships that agreed with those of a previous study; however, precise agreement was difficult to recognize. The problem of comparing the two studies precisely arose because the previous study comprised only 26 soils.

Comparison of results with the new classification as described in the 7th Approximation revealed many areas of agreement and certain specific areas of disagreement. In general, Mollisols, Alfisols, Inceptisols, Spodosols, and Oxisols were well separated into clusters. Vertisols and Aridisols showed almost as much affinity for Mollisols as for the soils of their own respective Orders, while Ultisols exhibited affinity for Alfisols and Oxisols. An Alaska Entisol exhibited much stronger affinity for an Alaska Inceptisol than it did for other Entisols, while a Spodosol and two Entisols of southeastern United States showed strong affinity for one another.

Twenty-one objectively selected characters were found to be sufficient to reveal logical relationships among soils and general structure of clusters within a group of 59 soils. Numerical taxonomy provided a means of incorporating objectivity and repeatability into the scientific investigation of complex relationships among soils. It is adaptable to large amounts of new soil data, and therefore is an invaluable tool for use in soil classification.