USE OF THE POINT-INTERCEPT TRANSECT IN MICHIGAN SOIL SURVEYS

Thesis for the Degree of M. S.
MICHIGAN STATE UNIVERSITY

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1968

ABSTRACT

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IN MICHIGAN SOIL SURVEYS

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A means of estimating the proportions of the several soils which normally comprise the mapping units of a soil survey is essential in order to prepare an adequate descriptive legend of the units and make suggestions for the proper use or management of the soils. The proportions of the soils in mapping units are often difficult to estimate because of complex topography, thickness of vegetation, and individual differences among soils mappers. Previous attempts in Michigan to estimate mapping unit compositions were inadequate for routine use because of inaccurate results and/or excessive time needed.

In this study point-intercept and line-intercept transects were used to estimate the soils composition of 20 mapping units in 3 study areas. The study areas were completely mapped before transects were made. Observations of soil type were made at regular intervals or continuously along transects and the numbers or lengths of each soil encountered were tabulated to give the kinds and proportions of soils in each mapping unit.

Results indicate that transects give the required information on mapping unit compositions with a reasonable expenditure of time. The compositions of some mapping units can be reliably

estimated by experienced field men. Other units are too small to justify even the moderate expense of using transects. The best use of transects can be made in complex units which occupy a significant portion of a survey area.

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A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Soil Science

1968

ACKNOWLEDGMENTS

The author expresses appreciation to Dr. Eugene P. Whiteside for his guidance during the course of this study.

Acknowledgment is due Sheldon Holcomb and Glenn Bedell, both of the Soil Conservation Service, United States Department of Agriculture, for assistance with field work, and Josephine Gibbs for helpful suggestions and final preparation of the manuscript.

For introducing the author to soil survey as a career and for training, guidance and examples during the formative years, special thanks are given Stan Alfred and Ken Mettert.

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I

The Problem of Defining Soil Mapping Unit Compositions in Michigan and the Objectives of the Study

The initial purpose of a soil survey is to classify and delineate the soils of an area. Usually the pattern of occurrence of soils belonging to different taxonomic units is too complex to precisely delineate each kind of soil. As a result other kinds of soils are included along with the soil which is being delineated. These other kinds of soils are called inclusions, and though they commonly make up a smaller proportion of a delineation than the soil it is desired to delineate (that soil which gives the delineation a name) they are often of major importance in the ultimate purpose of soil surveys, that of making suggestions for the proper use or management of the soils. To serve this last purpose adequately, a descriptive legend must be compiled as the survey proceeds to record the various kinds of soils in each mapping unit, describe the characteristics of these soils, record their proportions, and describe the areal relationships among these soils.

Sometimes the proportions of the different soils in mapping units are difficult to estimate. Topography may be complex, vegetation may mask soil differences, and ideas of individual mappers differ greatly as to what is the composition of areas they delineate.

Transects appear to be an objective means of obtaining information about mapping unit compositions. The objectives of this study therefore are to:

1) use transects experimentally in several areas to determine mapping unit compositions,
2) assess in what situations the method is most useful, and

3) recommend other methods for situations where something better than transects can be used (either better in terms of adequate estimates for less cost or more accurate estimates at a reasonable cost).

II

Literature Review

Literature relating directly to the use of transects and other methods for estimating compositions of soil mapping units has been limited. During recent years there have been some excellent articles and notes on the subject, however.

Wilding, Jones, and Schafer (1965) studied 10 randomly located profiles in each of 24 mapping delineations in Ohio. The series involved were Miami, Celina, and Crosby. They found that the most variable morphological properties were horizon thickness, depth to carbonates, loess thickness, depth to mottling, pH, and class of structure. The soils in the 24 delineations were correctly classified as to series 42 percent of the time, as to type 39 percent of the time, as to parent material 88 percent of the time, as to erosion 94 percent of the time, and as to drainage class 65 percent of the time.

In glacial landscapes drainage inclusions comprise significant proportions of the mapping units. This is due to the change of drainage class with only slightly different slope attributes: forms, lengths, gradients, and aspects. In conclusion Wilding, Jones and Schafer propose that the definition of mapping units specify the several dominant soils but not attempt to specify percentages of the different soils. They feel the latter is necessary because only a small portion of the landscape is ever directly sampled even in the most intensive surveys.

Powell and Springer (1965) used point-intercept transects in Georgia to investigate the percentage composition of mapping units of the Cecil, Appling, and Lloyd series which comprised 80 percent of the particular area investigated. They made 518 stops along transects in 16 randomly selected 160-acre blocks. The stops were 100 feet apart.

Slope was mapped correctly 91 percent of the time, surface texture 82 percent, erosion 77 percent, series 74 percent, type 64 percent, and all the preceding factors combined 59 percent. The mapping was judged reliable as most of the pedons could be similarly interpreted even though classified differently.

White (1966) in a note challenging the validity of transects for estimating the composition of soil mapping units constructed 8 models of areas with 2 different soils present in different patterns and proportions. The actual percent of each soil present in each of the models was then measured and also estimated by line-intercept transects. Although the estimates by transects were close to the actual measured percentages his statistical analysis estimated an impractically large length of transects necessary to estimate the percentage composition of mapping units similar to the models within 5 percent of the true value with a .95 confidence interval.

White recommends that since most soils have visible landscape characteristics the simplest estimation method is to delineate and measure the areas of the different soils within several delineations of a mapping unit or make visual estimates. If no such relation to landscape can be discerned soil associations or land types are recommended as mapping units.

Young (1965) has used point-intercept transects both as a basis for making delineations of mapping units in woodland areas and for estimating their compositions. He feels that this procedure of integrating mapping and sampling procedures provides more reliable soils information at less cost than conventional methods.

Johnson (1961) has set forth a recommended procedure for both line-intercept and point-intercept transects. A short discussion of the situations in which each procedure is most useful is given and examples with results are cited.

III

Description of Study Areas

EATON COUNTY

The delineations of the mapping units investigated in Eaton County are located on the Lansing moraine and its associated till plain. The predominant texture of this till is loam. Thin to thick areas of sandy loam till and wind-deposited sands are also present. Occasional organic deposits occupy old filled lakes or depressions.

The dominant soil series are those developed in loam till. They are the well-drained Miami, the moderately well-drained Celina*, the somewhat poorly drained Conover, and the poorly drained Brookston series. The well-drained Owosso series (developed in sandy loam drift over loam till) occurs in patches throughout the area. The Carlisle series is the commonest deep organic soil. Other associated series include Metamora and Spinks.

Land use in the area is general farming but the Lansing suburbs are steadily encroaching. Dairy and beef cattle are common. Cash crops include corn, soybeans and wheat.

* The Celina series as used here is now a variant in the fine-loamy family and is not in the fine family as the series is now defined.

GENESEE COUNTY

The study area in Genesee County is on the till plain associated with the Fowler moraine. Again the predominant texture of the till is loam.

The dominant series include Celina*, Conover, and Brookston. Metamora is an important associate.

Land use is general farming with livestock and crops as in Eaton County. The influence of the suburbs of Flint is more evident and much of the land is idle.

* The Celina series as used here is now a variant in the fine-loamy family and is not in the fine family as the series is now defined.

DELTA COUNTY

The portion of Delta County chosen for this transect study is a lake-modified till plain with numerous dunes and glacial lake shorelines. The dominant till texture ranges from sandy loam to loam. Limestone and dolomite bedrock at shallow depths are common in the area.

Soil series include the somewhat poorly drained Mackinac and the poorly drained Angelica, both developed in loam till. The somewhat poorly drained Sundell and the poorly drained Ruse, developed in sandy loam and loam tills over shallow bedrock are extensive. The Roscommon series, a poorly drained sand, and the Tawas and Linwood series (shallow organic soils) also are common. Associated series are Eastport, Croswell, Au Gres, and Onaway. For a tentative classification of these series see the listing in the Appendix, page 73.

IV

Methods Used to Measure Mapping Unit Composition

PREVIOUSLY USED METHODS AND THEIR RESULTS

Comprehensive cooperative evaluations of soil surveys in Michigan with the object of estimating the various soils in the mapping units were begun in 1961 by Don Franzmeier of the Michigan Agricultural Experiment Station and Don McCormack of the United States Department of Agriculture, Soil Conservation Service. The objectives of those early studies included:

1) evaluating the choice of soil type name for a mapping unit and the accuracy of the slope of this unit,
2) evaluating the effectiveness of the pattern created in making the delineations for showing landscape features,
3) comparing several delineations of the mapping units with the corresponding mapping unit descriptions in the descriptive legend, and,
4) making suggestions for more accurate and efficient soil mapping.

The procedure used, briefly, was as follows. Each soil scientist in a study area chose several of his field sheets with mapping completed and representing a variety of soils and landscapes. To these field sheets he attached a transparent acetate overlay and traced the approximate routes of all traverses which were made in the process of completing these soils maps.

These field sheets were then given to Franzmeier or McCormack to evaluate according to the objectives previously stated. Sample areas were chosen from each soil scientist's field sheets where different soil associations were mapped. Within these areas soil observations were made at frequent intervals, the observations were recorded on the overlay, and the kind, depth, texture, and sometimes reaction of each horizon were recorded in a notebook.

Delineations which appeared to be erroneous or unnecessary were examined in greater detail (more observations were made) than other areas which appeared to be mapped satisfactorily. This was done in order to find what the mapper originally saw and to determine if the soil actually was different from that mapped.

A complete soil map symbol, usually including the soil series, surface texture, slope, and erosion was assigned to each observation. This name was chosen in accordance with the state soil mapping legend.

The ability of the maps to portray the landscape was evaluated subjectively. If the soil scientist making the evaluation could locate himself readily from the lines inked onto the field sheet the landscape was judged as well drawn. If trouble was encountered in locating positions the landscape was poorly drawn. If the latter was thought to be the case an alternate set of lines was suggested for the area based on stereoscopic examination of the aerial photographs.

This evaluation procedure was used in the progressive survey areas of Charlevoix, Delta, Gladwin, Lapeer, Leelanau, and Shiawassee counties as well as with farm mapping in Genesee and Isabella counties. The distribution of these areas throughout the state gave a range of observations including many soil associations and landforms.

In general it was concluded that soil scientists were doing an adequate job of showing the relation of soils to landscape features by means of delineations, drainageways, etc. This was judged as being desirable because of the usual complexity of glaciated terrain as regards texture and lithology of parent materials and the variability of drainage classes over short distances.

First observing landscape type, delineating the landform, predicting what soil will occur in that delineation, checking the prediction by observing soil profiles, and finally selecting a mapping unit name for each delineation is a sound approach to soil mapping in these nonuniform areas. An alternate approach of observing soils, selecting a mapping unit, and making the delineations solely on the basis of the profile observations can be used in more homogeneous areas or featureless landscapes but is generally less desirable because of reduced accuracy and the additional time usually required (more observations per unit area are normally needed if profile observations are used as the sole basis for soil boundaries).

Most commonly, however, soil scientists use a combination of the above alternatives as a basis for making delineations and quite often use additional criteria. Simultaneous observations of landscapes, aerial photos, soil profiles, and vegetation should all be combined in arriving at a decision as to where soil boundaries are to be placed on soil maps.

A summary of the soil map evaluations made in 1961 is given in Table 1. It lists the counties in which progressive surveys were being conducted in 1961, the physiographic or geomorphic areas sampled within each county, the number of observations made within each physiographic area, and the percentage of soil type observations that corresponded to the series names (the capitalized portion of the soil type name) of the mapping units evaluated.

For example, in Charlevoix County 135 observations were made on moraines in the delineations of several mapping units. At only 41 percent of these observations did the series name at the observation point and the series name of the delineation in which the observation was made agree. Table 2 is an additional breakdown of the data on which Table 1 is based. It lists the total number of observations made in each county and the percentage of times that the management group, the surface texture (the uncapitalized portion of the soil type name), and the drainage class of an observation agreed with the management group, the surface texture, and the drainage class of the mapping unit name of the delineation in which the observation was made.

Past practice has presumably allowed a maximum proportion of 15 percent of other soils (inclusions) in a set of delineated soil bodies named as a phase or a soil type. As stated on page 277 of the Soil Survey Manual (Soil Survey Staff, 1951), ". . . any single soil name stands for a specially defined unit in the taxonomic system of classification; but that same

TABLE 1.

Summary of 1961 soil map evaluations by percentages of series found at observation sites that agreed with the mapping unit names of the soil map delineations in which observations were made. Soil observations were made after mapping was completed.

County	Physiographic Area	Number of Observations	Series Correct Percent
Charlevoix	Drumlins	69	75
	Moraines	135	41
	Total	204	52
Delta	Total	227	53
Gladwin	Lakebed	161	26
	Moraine	77	43
	Total	238	32
Lapeer	Lakebed	43	49
	Moraine	116	35
	Total	159	39
Leelanau	Outwash	33	85
	Moraine	85	33
	Total	118	47
Shiawassee	Lakebed	123	26
	Lake-washed till plain	54	50
	Moraine	95	45
	Total	272	37
Average	Drumlins	69	75
	Moraine	508	39
	Lakebed	327	29
	Outwash	33	85
	Lake-washed till plain	54	50
	Total	1218	39

TABLE 2.

Summary of 1961 soil map evaluations by percentages of management group, surface texture, and drainage class found at observation sites that agreed with mapping unit names. Soil observations were made after mapping was completed.

		Percent Correct		
County	Total Observations	Management Group	Surface Texture	Drainage Class
Charlevoix	204	63	63	100
Delta	227	62	74	78
Gladwin	238	42	51	74
Lapeer	159	47	58	96
Leelanau	118	65	65	100
Shiawassee	272	56	55	83
Average	1218	55	61	86

TABLE 3.

Summary of 1962-1964 soil map evaluations by percentages of series found at observation sites that agreed with mapping unit names. Soil observations were made at the same time mapping was done.

		Percent Correct	
Date	County	Series	Management Group
1962	Gladwin	86	
1962	Delta	76	
1962	Genesee	87	94
1963	Emmet	71	81
1964	Genesee	86	

name, applied to a mapping unit, stands for that defined taxonomic unit plus a small proportion of other units, up to about 15 percent, that cannot be excluded in practical cartography."

It is apparent from Tables 1 and 2 that the only set of characteristics associated with the names of the mapping units studied which comes close to meeting the 85 percent criterion is drainage class. Soils of the same series, management group, or surface texture all fall considerably below the 85 percent level. Of course, combinations of these, as for example series and surface texture (soil type), produce even lower percentages of the taxonomic units mentioned in the mapping unit names and correspondingly higher percentages of inclusions of other taxonomic units.

The preliminary conclusions were that the medium and low intensity soil maps being made in 1961 were taxonomically and practically less accurate than previously believed, or at least less accurate than had been generally acknowledged. With this information the next step involved measures to improve soil survey practices to remove the discrepancies between theory and practice.

The steps subsequently pursued included:

1) a search for methods of improving the accuracy of soil mapping so as to reduce the proportions of inclusions within mapping units,
2) defining mapping units more accurately (this could be done by using more liberal and realistic limits for inclusions and by using more soil complexes and

soil associations as mapping units, i.e., mentioning more than one soil in a mapping unit name because it is recognized as impractical to separate them due to their complex pattern of occurrence or the lack of importance of the separation from a use standpoint), and,

3) additional studies of mapping unit composition to see if the results of the 1961 studies were accurate and also typical of other similar geomorphic areas.

The methods of improving accuracy of soil mapping consist of further training of soil scientists in various aspects of soil classification and mapping and the development of new equipment and techniques to aid soil scientists in examining soils. Included are improved aerial photographs such as infra-red and leaf-off photos designed to show more soil and vegetative differences, more efficient arrangements of traverses and borings, adoption of a more precise and comprehensive classification system, and most recently, introduction of power augers to permit deeper and more thorough examination of soil profiles accessible to the trucks on which these augers are mounted. The redefinition of mapping units and the expanded use of soil associations and soil complexes is discussed later in Chapter V.

The 1961 soil map evaluations were followed up by more extensive studies designed to provide information on the soils in some mapping units and additional notes were made relating to various other characteristics of those mapping units. These studies were begun in 1962 and with minor variations were continued in 1963 and 1964.

An important difference between the 1962 to 1964 and the 1961 studies was that the 1961 studies (previously discussed) were conducted after the field sheets were mapped and all delineations drawn. The 1962 to 1964 studies were conducted concurrent with the mapping of field sheets. This meant that in these later studies the delineations and the evaluation of the delineations were based on the same soil observations. An outline of the procedure as used in 1964 follows.

1) The locations of soil observations were put on a transparent overlay sheet attached to each aerial photo. Consecutive numbers were used to identify each boring on each overlay. Thus as the soil scientist mapped he recorded his observations of the soil on the overlay and numbered them. He concurrently made delineations on the aerial photo and when finished he had not only the completed soil map but a record of all the observations he made and used as a basis for drawing and naming the delineations on his map.

2) A 3 x 5-inch file card was used to record data about each soil observation made. Data included:

    a) the mapping unit symbol of the delineation in which the observation was made (often this was not immediately known but was filled in as soon as the delineation was named),

    b) the location number for the observation as shown on the overlay followed by the complete identification symbol (soil type, slope, and erosion) for the taxonomic unit observed,

c) a brief thumbnail description of the soil profile at each observation point (color, texture, thickness, etc., for the major horizons),

d) other features pertaining to the delineation in which the observation was made such as land use, and,

e) mapper's initials and photo number.

The method as outlined above was intended to provide data about kinds of taxonomic units within the mapping units and other characteristics of mapping units which could be used in the routine conduct of soil surveys and ultimately in the correlation of the mapping units and the writing of soil survey reports. For these reasons the studies were regarded as of more than academic interest. The procedure had the potential of improving mapping efficiency by holding the number of mapping units to a minimum, encouraging wise selection of sites for recording observations, providing consistency among party members and between parties, and making possible a better description, if not better delineations, of the mapping units shown on soil maps.

The results obtained and the counties in which the procedure was used are shown in Table 3. Only the results pertaining to percentage compositions by series and management groups represented in the mapping unit names are given. Other benefits such as increased knowledge about the character of mapping units are mentioned in a following paragraph.

The initial objection to the procedure used from 1962 to 1964 was that too much time was required to complete the necessary operations. The estimate of the time used over that normally spent mapping a 4-section field sheet at medium intensity was 15 to 18 hours or about 25 percent.

It was also felt that the field notes taken at each observation point were often not specific and detailed enough to either make an evaluation of the concepts of different soil scientists or to adequately characterize the mapping units. However, where the procedure was used rigorously it did have worthwhile features in the training of soil scientists and in the description of the taxonomic units involved. Whether these improvements were justification for the increased expense was not investigated.

A more-serious objection can be made to the use of data obtained by this procedure for estimation of the percentages of the taxonomic units included in the mapping units as is done in Table 3. It is apparent in Table 3 that there was a considerably greater uniformity of the mapping units according to these studies than in the results obtained in the 1961 studies, Tables 1 and 2. The average percent agreement with the mapping unit names, by series and management groups, were 39 percent and 55 percent, respectively, in 1961 and 76 percent and 90 percent, respectively, in 1962 to 1964.

A follow up study conducted in late 1964 in Genesee County indicated that these differences did not actually reflect a difference in the purity of mapping units evaluated by the different studies. Independent observations made on several completed field sheets gave estimates of the series inclusion percentages for several mapping units that were much higher than the equivalent percentages estimated by tabulation of the observations made during the completion of the soil maps.

The results of some of this check procedure are shown in Table 4 and were obtained as follows. Several delineations were chosen on the completed soils maps of each of the soil scientists participating in the Genesee County soil survey (these maps were some of those on which the 1964 study was made during the mapping). The observations recorded on the overlays of these field sheets during the course of mapping were tabulated for each of the chosen delineations. Next additional observations were made by another soil scientist independently repeating the mapping of these areas using the same mapping and recording procedure. The additional independent observations made within the original delineations were then tabulated and the percentage of those observations within each delineation agreeing as to series with the name of the mapping unit originally assigned to the delineation was calculated for both tabulations. The averages of these calculated percentages for all delineations by individual mappers are shown in Table 4.

Based on the observations made by all the soil scientists as they completed the soil maps 64 percent of the area (assuming the proportions of observations are proportional to areas) was labeled with the correct series, 36 percent was incorrect and thus consisted of recognized mapping inclusions. The second set of independent observations (those made by another mapper on the same area) indicated that actually only 36 percent of the checked area was labeled correctly. This figure applies only to the selected delineations but it is in close agreement with

TABLE 4.

Comparison of 1964 Genesee County soil map evaluations by percentages of series found at observation sites that agreed with mapping unit names. Soil observations were made at the same time mapping was done for lines A, B, C and D and after mapping was completed for lines titled Independent Observer. All observations reported on each pair of lines (whether by mappers A, B, C, D or Independent Observer) were made in the same delineations.

Mapper	No. of Observ.	Ave.Acres Per Observ.	Series Correct Percent
A (original mapper)	53	6.0	57
Independent Observer	51	6.7	20
B (original mapper)	9	17.7	100
Independent Observer	29	5.5	60
C (original mapper)	8	10.0	62
Independent Observer	16	5.0	33
D (original mapper)	8	10.0	75
Independent Observer	10	8.0	60
Total			
A,B,C,D (original mappers)	78	8.2	64
Independent Observers	106	6.2	36

the average for all similar observations, 39 percent, observed in 1961, Table 1. For the entire study area in Genesee County in which observations were made in the course of mapping the tabulated portion correct as to series averaged 86 percent in 1964 (Table 3). This result is in general agreement with the 76 to 87 percent average obtained in similar studies there and elsewhere in 1962 to 1964. It is evident that the recording of all observations while mapping gives a strong bias to the homogeneity of the names of the mapping units that is not born out in independent observations made after the delineations are made.

But, how else does the mapper know the composition of the units unless he does an independent sampling after delineation?

Out of these studies came the suspicion (among some soil scientists) that perhaps neither method, that of recording and tabulating as to mapping unit observations made while mapping, or recording and tabulating as to mapping unit observations made after mapping was completed, was adequate to accurately estimate the various taxonomic inclusions contained in soil mapping units, especially in areas with complex soil patterns such as are common in glaciated terrain. Certainly both methods had deficiencies.

An obvious bias is encountered if the same observations that determine what the delineation is called and exactly where its boundaries are placed are used to estimate the taxonomic units in all delineations comprising a mapping unit in an area. This bias favors a high estimate of the series mentioned in the mapping unit names, and probably this is why the 1962 to 1964 estimates of the series named in the mapping units are suspiciously high and agree well with the earlier requirement of 85 percent purity of the mapping units or the presumed allowance of ". . . up to about 15 percent, that cannot be excluded in practical cartography." How else could a surveyor know their composition except by what he saw when mapping, unless an independent sampling of some kind were used?

The other methods (numerous observations made after mapping is completed or using observations of another mapper when making another map of the same area) also have shortcomings. Random observations throughout delineations, with all possible locations having equal opportunity for sampling should give accurate estimates of composition provided an adequately large sample is taken. The total sample sizes used in such studies discussed previously probably were adequate in most instances, but may have fallen down for purposes of inclusion estimates in not being random.

Still needed then was a method to accurately estimate what specific soil mapping units actually contained. From theoretical considerations it seemed desirable that any observations be made independently of actual mapping and that observations be the equivalent of a random sample. Also the time seemed at hand for some procedure which could be used in day-to-day soil survey work. So the method must be efficient with respect to use of time and materials by soil survey personnel.

Transect methods were considered and seemed to fulfill the above requirements. Before use, a check on the effectiveness of point-intercept transect and line-intercept transect methods was desired. Random transects or point observations seemed impractical as to time and equipment. The following sections deal with the trial use of transects with the objective of analyzing the mapping units to determine their component taxonomic units for purposes of naming or renaming mapping units and making recommendations as to their use or management.

EXPERIMENTAL USE OF THE POINT-INTERCEPT TRANSECT METHOD

In each county several mapping units were of particular importance because of their large areal extent and wide distribution. Many other mapping units were also present but they comprised only a small acreage and/or existed in only a few delineations. Because the study was exploratory in nature the extensive, widely distributed soils were selected for analysis by transects. These units provided ample area for a large number or length of transects without the necessity of bunching or crossing transects.

It was believed that a sufficient length of transects should be made and that those transects should be distributed so as to give an accurate measure of the average composition of all delineations of each mapping unit as it occurred within a particular physiographic position in a county. Consequently, transects were distributed over a representative sample of delineations of characteristic sizes and shapes within the range of similar physiographic situations in each survey area. By comparing the variability of a smaller number or shorter length of transects similarly distributed the necessary length or number of such transects to determine the composition of a mapping unit with a given degree of accuracy might then be estimated.

The variation within a single small delineation or several closely spaced delineations of the same unit may be much greater or much smaller than the significant variation encountered if the unit is of larger extent as individual delineations and/or if delineations are more widely distributed. For example, a few delineations of a given mapping unit may exist which are incredibly complex in composition, no component comprising over 10 percent of the total. At the opposite extreme may be other delineations of that mapping unit which have no apparent inclusions. However, it is unlikely that either situation could exist uniformly in a mapping unit of large acreage and with many widely spaced delineations. Thus the effort to chose units which were of large extent and consisted of several delineations well distributed throughout the representative physiographic situation for each unit. Such a choice should give results approximating an average composition of all the delineations of the mapping unit being investigated.

Mapping units may blanket several different physiographic situations. For example, Conover loam, 0-2 percent slopes, uneroded or slightly eroded, commonly occurs as large delineations on till plains of many square miles extent. This mapping unit also occurs as much smaller delineations in complex morainic systems, however, and the composition of this same unit in these two situations is often observed to be significantly different. It was therefore decided that all transects for a mapping unit would be placed in as similar physiographic situations as possible. Then if different physiographic units of soil had different compositions, they might be named accordingly.

Aerial photograph field sheets with mapping completed were then selected which contained the chosen mapping units in similar physiographic positions. Overlays were fastened to these field sheets and transects of lengths varying from 1/8 to 1/2 mile were penciled onto the overlays through delineations of the various mapping units selected for study. A point can be made for the random location and direction of transects within delineations in such a situation. However, after some debate a more systematic approach to this problem was taken. The transects were placed: 1) in either a north-south or east-west direction, and 2) when possible in locations where local landmarks were available to help steer the soil scientist making observations along the transect in the field.

The arbitrary directions of north-south and east-west were chosen because such features as roads and field boundaries are commonly oriented in these directions. This further assists the soil scientist in following the transects in the field. A choice of directions was specified in order that where there was an observable pattern in the landscape or on the aerial photo terrain would be crossed at nearly right angles to that pattern. Such a situation is particularly common in moraines where several ridges may parallel each other separated by depressions. If a mapping unit in question occupies the entire ridge portion of the topography, differences in soil composition would be expected between the flank portions and the crests of the ridges. Much less variability would be expected lengthwise along the flanks or the crests of the ridges. In such a situation the soil scientist would want to sample the full range of variation in the unit by crossing the ridge, rather than paralleling the more homogeneous flanks or crests.

Such physiographic situations also occur on lake plains, outwash plains, and till plains, although they are more common in areas with more pronounced topography such as moraines, eskers, kames, and stream valleys. Of course with a choice of only two directions topography can seldom be crossed at exactly right angles, but one can always avoid nearly paralleling it.

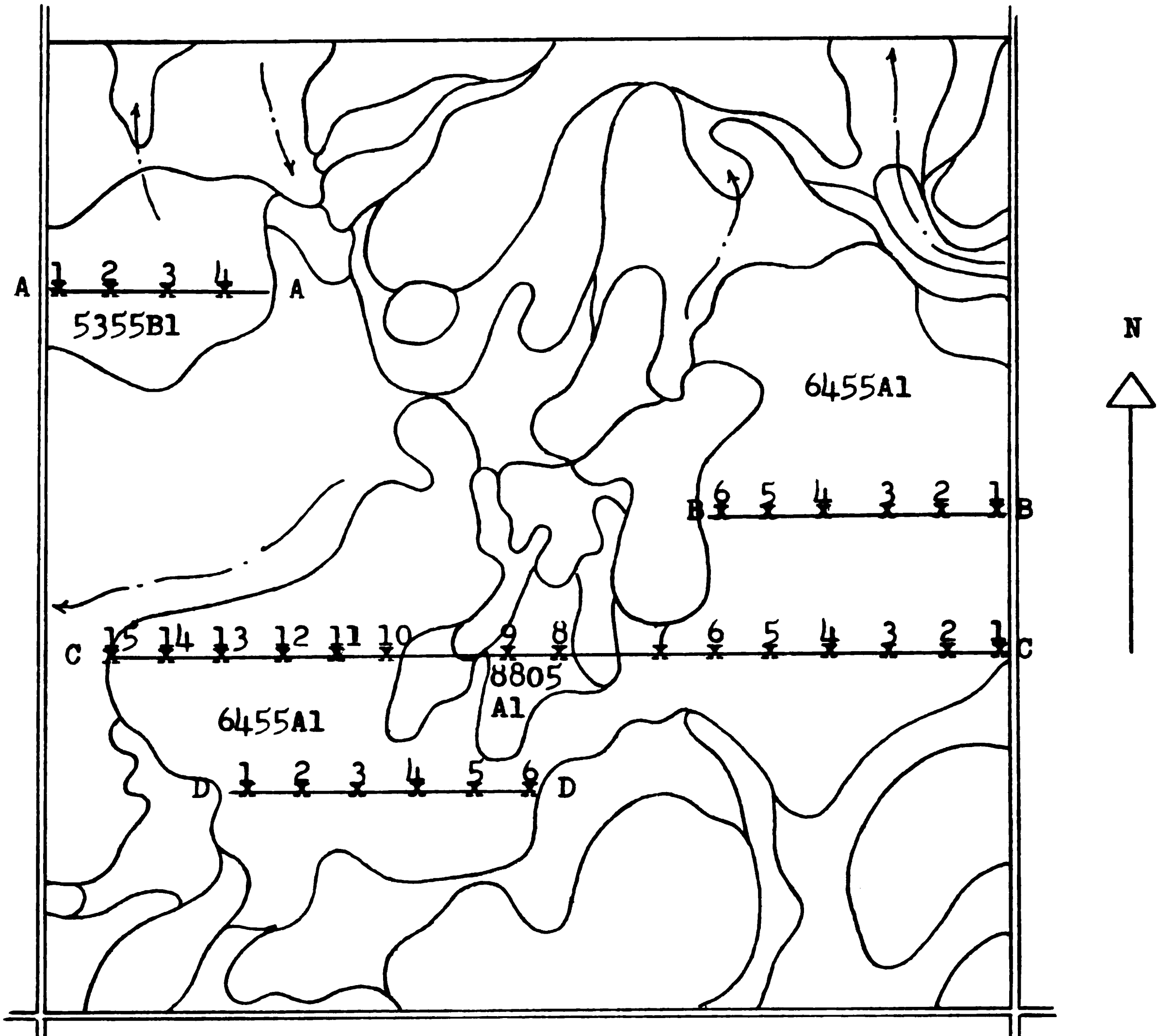
In order for a method of determining mapping unit composition to be successful from the practical viewpoint the use of field time must be reasonably efficient. By placing transects in positions where landmarks can be used as guides in following the transects considerable time is saved in locating beginning points and in taking compass bearings to determine direction to follow. Roads and fence rows also help in determining direction without compass aid. By using pairs of parallel transects observations can be made going from and returning to the car. Transects on all units being evaluated on a field sheet should be completed consecutively to avoid unnecessary travel expense and time.

Large forested areas presented some problems with regard to locating and following transect lines. In general such areas required more time than agricultural areas to sample with transects because of the more involved pacing and compass work required.

Transects were located on the overlays from 660 feet to 1320 feet apart where delineations were large enough to accomodate more than one. All transects within any one delineation were drawn parallel to one another. The location of the first observation on each transect was also marked on the overlays, and it was determined that subsequent observations would be spaced 330 feet apart along each transect. These rather arbitrary spacings were chosen as giving reasonably wide distribution of observations throughout the mapped areas with a reasonable expenditure of time, which would be necessary if the method were to be adaptable to routine survey use.

In practice a soil scientist took the field sheet and overlay into the field, located the initial observation point on a transect, and determined the soil at that point as to series, type and phase. He then paced off 330 feet intervals along the transect line and made subsequent determinations of the soils at each of those points. This procedure is illustrated by the example shown in Figure 1.

Each transect and its observations were numbered and the results recorded on a field form (Table 5). After completing the transects on the selected field sheets the soil scientist returned to his office and transferred the data from the field forms to a summary form (Table 6) for each mapping unit. This summary lists the identity of each soil phase encountered, the number of times each soil phase was observed, the total number of observations made in the mapping unit, and the percentage of the total number of observations that each phase comprised. From this basic data the percentages of each soil type found (disregarding erosion and slope) and the percentage of each soil series found (disregarding surface texture, slope and erosion) was also calculated. The examples given in Tables 5 and 6 illustrate these data and computations.



Scale: 5 inches = 1 mile

Legend

8805A1 — Mapping Delineation (on Field Sheet)

Road

A 1 2 3 4 A — Transect (on Overlay)

Section Line Not on Road

3 — Observation Point (on Overlay)

Intermittent Stream, Unclassified.

FIGURE 1.

Sample procedure used for locating transects and observation points on overlays over previously mapped aerial photo field sheets. See Tables 5 and 6 for tabulated results.

TABLE 5.

Sample field form used to record observations in the field along point-intercept transects. See Figure 1 and Table 6 for origin and summarization of data, respectively.

FIELD FORM FOR COMPOSITION OF MAPPING UNITS

Area: Eaton County — Date: 5-20-65

Photo No.: Sample — Observer: Lyle Linsemier

Transects: Point-Intercept

Transect and Stop No.	Mapping Unit	Obser-vation	Transect and Stop No.	Mapping Unit	Obser-vation
A-1	5355B1	5355B1	C-7	6455A1	8805A1
2	"	5355A1	8	8805A1	8805A1
3	"	6455A1	9	"	8805A1
4	"	5355B1	10	6455A1	8182A1
			11	"	6455A1
B-1	6455A1	6455A1	12	"	6455A1
2	"	6455A1	13	"	6455A1
3	"	6455A1	14	"	6455A1
4	"	6455A1	15	"	6453A1
5	"	6455A1			
6	"	6455A1	D-1	6455A1	6455A1
			2	"	6455A1
C-1	6455A1	6455A1	3	"	6453A1
2	"	6455A1	4	"	6455A1
3	"	6455A1	5	"	6455A1
4	"	6455A1	6	"	8745A1
5	"	8805A1			
6	"	6455A1			

TABLE 6.

Sample summary form* used to convert field form data to percentage composition of mapping units. See Figure 1 and Table 5 for origin of data.

SUMMARY FORM ON COMPOSITION OF MAPPING UNITS

Area: Eaton County

Mapping Unit: 6455A1 (Conover loam, 0-2 percent slopes, slightly eroded)

Transects: Point-Intercept

Observed units.	Number of stops (or length)	% Composition by:		
		Phase	Type	Series
6455A1	19	76	76	84**
6453A1	2	8	8	--**
8182A1	1	4	4	4
8745A1	1	4	4	4
8805A1	2	8	8	8
Total	25	100	100	100

* The summary forms actually compiled in this study contained the results of many more transects and observations than does this sample form which contains only the 3 sample transects and their 25 observations occuring in 6455A1 delineations shown in Figure 1 and Table 5.

** 6455A1 and 6453A1 are mapping units of Conover loam and Conover sandy loam, respectively. Hence, they are combined in the series column.

It is apparent that all transects and observations shown in Figure 1 do not appear in the summary form, Table 6. Transect A is in a delineation of the 5355B1 mapping unit and thus does not appear in Table 6 which contains only observations made in delineations of the 6455A1 mapping unit. Similarly, observations 8 and 9 of transect C fall in a delineation of 8805A1 and are not recorded in Table 6. In actual practice additional summary forms would be made for the 5355B1 and the 8805A1 mapping units.

Use of this data assumes that the number of observations of each kind of soil within all mapping delineations studied is proportional to the area of each soil within the mapping unit. This is believed by the author to be true. The method has been used for many years for such purposes as estimation of plant species composition on range lands and in other ecological studies and with thin sections to determine the composition of rocks. Mathematical proof of the validity of the method has been given by Chayes (1956).

EXPERIMENTAL USE OF THE LINE-INTERCEPT TRANSECT METHOD

In the Eaton County study area line-intercept transects were also made along the same routes as the point-intercept transects. Line-intercept transects are logically more accurate than point-intercept transects because of the larger sample taken by examining the soil continuously along a line rather than at spaced points. However, so much time is required to make line-intercept transects (unless a trench prepared for other uses than soil survey, such as a pipeline, is available) that this method is impractical for routine soil survey use. If the point-intercept transects produce approximately the same results as line-intercept transects, a possible objection to the use of point-intercept transects would be eliminated.

The line-intercept transects were made by examining the soil every few yards (10 to 20) along the transect route with an auger since open trenches were not available. Beginning and ending points for each transect were the first and last observations used for the point-intercept transects. Pacing was used to determine distances between soil changes. As was expected considerably more time was required to complete a line-intercept transect than for a point-intercept transect along the same route. The time spent for line-intercept transects varied from 4 to 6 times that used for point-intercept transects.

These results were recorded on a field form with headings identical to Table 5. However, transect identification letters were indicated in the first column and the mapping unit through which the transect was made was entered in the second column. The soils observed and the length of each observation was noted in the third column. An example of a field form for line-intercept transects is shown in Table 7. The summary form and method used was the same as for the point-intercept transects except that length of each unit (observation) was substituted for a stop and the total lengths of transect in each kind of soil for the number of stops or observations. Total lengths of transects through a mapping unit were used to calculate the percent of each kind of soil. Table 8 is an example of a summary form for line-intercept transects.

TABLE 7.

Sample field form used to record observations in the field along line-intercept transects. See Table 8 for summarization of data.

Area: Eaton County Date: 5-20-65

Photo No.: Sample Observer: Lyle Linsemier

Transects: Line-Intercept

Transect and Stop No.	Mapping unit	Observation
A	5355B1	5355B1-300*
A		5355A1-330
A		6455A1-170
A		5355B1-190
B	6455A1	6455A1-1650
C	6455A1	6455A1-1300
C		8805A1- 50
C		6455A1- 600
C		8805A1- 30
C	8805A1	8805A1- 330
C	6455A1	8182A1- 100
C		6455A1-1430
C		6453A1- 120
D	6455A1	6455A1- 420
D	6455A1	6453A1- 280
D	6455A1	6455A1- 880
D		8745A1- 70

* Numbers following dashes in this column indicate the length in feet each observation occupied along a particular transect.

TABLE 8.

Sample summary form used to convert field form data to percentage composition of mapping units. See Table 7 for origin of data.

SUMMARY FORM ON COMPOSITION OF MAPPING UNITS.

Area: Eaton County

Mapping Unit: 6455A1 (Conover loam, 0-2 percent slopes, slightly eroded)

Transects: Line-intercept

Observed units.	Number of stops (or length)	% Composition by:		
		Phase	Type	Series
6455A1	6280 feet	91	91	97
6453A1	400 feet	6	6	--
8182A1	100 feet	1	1	1
8745A1	70 feet	1	1	1
8805A1	80 feet	1	1	1
Total	6930 feet	100	100	100

V

Results, Discussion and Conclusions

MAPPING UNIT COMPOSITION ESTIMATES FROM POINT-INTERCEPT TRANSECT AND LINE-INTERCEPT TRANSECT STUDIES

Point-intercept transect studies were conducted in 1965 in 3 survey areas, Eaton County of the Tri-County (Clinton, Eaton and Ingham) soil survey, Genesee County and Delta County, Results of these studies are given individually in this section.

Immediately after the results obtained with point-intercept transects in Eaton County are given the results obtained using line-intercept transects in that county. These line-intercept transects were run along identical routes and at the same time as the point-intercept transects.

Eaton County Point-Intercept Transects

The following series of Tables 9A to 9I list the taxonomic units (soil types) found within the delineations of each of the 9 mapping units sampled by point-intercept transects. In the first column from left to right in each of these tables all observations are represented. The second column represents only every other observation but uses all the transects. The third column represents all the observations made on every other transect. Thus the second and third columns are attempts to estimate what percentages of the different taxonomic units might have been arrived at had a sample only half as large as that actually taken been used.

TABLE 9.

A listing by soil types of percentage estimates of the major taxonomic units of 9 mapping units in Eaton County. Estimates are by point-intercept transects.

TABLE 9A.

Carlisle muck, 0-2 percent slopes, slightly eroded

Soil Types Found	All Transects (51 obs.)	All Transects, Alternate Observations (25 obs.)	Alternate Transects (28 obs.)
Carlisle muck	85 percent	84 percent	86 percent
Linwood muck	11 "	12 "	10 "
Others	4 "	4 "	4 "

Proposed Name: No change.

TABLE 9B.

Owosso sandy loam, 2-6 percent slopes, slightly eroded

Soil Types Found	All Transects (36 obs.)	All Transects, Alternate Observations (14 obs)	Alternate Transects (24 obs.)
Owosso sandy loam	53 percent	43 percent	49 percent
Miami loam	19 "	29 "	12 "
Miami sandy loam	10 "	7 "	8 "
Celina loam	5 "	7 "	8 "
Brady sandy loam	5 "	7 "	8 "
Others	8 "	7 "	15 "

Proposed Name: Owosso-Miami sandy loams, 2-6 percent slopes, slightly eroded.

TABLE 9C.

Miami loam, 2-6 percent slopes, slightly eroded

Soil Types Found	All Transects (23 obs.)
Miami loam	70 percent
Celina loam	13 "
Owosso sandy loam	9 "
Others	8 "

Proposed Name: No change

TABLE 9D.

Miami loam, 2-6 percent slopes, moderately eroded

Soil Types Found	All Transects (28 obs.)
Miami loam	49 percent
Celina loam	22 "
Owosso sandy loam	15 "
Miami sandy loam	10 "
Others	4 "

Proposed Name: Miami loam, 2-6 percent slopes, slightly eroded*.

* This change is desirable because 49 percent of the unit is slightly eroded and only 28 percent is moderately eroded (Table 10). Thus, on the basis of these observations this unit and the preceding unit (Table 9C) should be combined. The avoidance of duplicate mapping units is an obvious advantage of having accurate estimates of mapping unit compositions. As this name change is not due to series composition, it is not mentioned in the discussion.

TABLE 9E.

Miami loam, 6-12 percent slopes, moderately eroded

Soil Types Found	All Transects (47 obs.)	All Transects, Alternate Observations (25 obs.)	Alternate Transects (25 obs.)
Miami loam	64 percent	72 percent	76 percent
Owosso sandy loam	19 "	20 "	16 "
Miami sandy loam	11 "		
Others	6 "	8 "	8 "

Proposed Name: No change

TABLE 9F.

Celina loam, 0-2 percent slopes, slightly eroded

Soil Types Found	All Transects (41 obs.)	All Transects, Alternate Observations (19 obs.)	Alternate Transects (26 obs.)
Celina loam	47 percent	37 percent	50 percent
Conover loam	47 "	58 "	42 "
Others	6 "	5 "	8 "

Proposed Name: Celina-Conover loams, 0-2 percent slopes, slightly eroded.

TABLE 9G.

Celina loam, 2-6 percent slopes, slightly eroded

Soil Types Found	All Transects (70 obs.)	All Transects, Alternate Observations (33 obs.)	Alternate Transects (28 obs.)
Celina loam	59 percent	67 percent	71 percent
Miami loam	18 "	9 "	6 "
Conover loam	16 "	18 "	17 "
Others	7 "	6 "	6 "

Proposed Name: No change

TABLE 9H.

Conover loam, 0-2 percent slopes, slightly eroded

Soil Types Found	All Transects (129 obs.)	All Transects, Alternate Observations (69 obs.)	Alternate Transects (56 obs.)
Conover loam	78 percent	77 percent	82 percent
Celina loam	7 "	6 "	6 "
Brookston loam	7 "	7 "	5 "
Others	8 "	10 "	7 "

Proposed Name: No change

TABLE 9I.

Brookston loam, 0-2 percent slopes, slightly eroded

Soil Types Found	All Transects (48 obs.)	All Transects, Alternate Observations (26 obs.)	Alternate Transects (26 obs.)
Brookston loam	76 percent	73 percent	80 percent
Conover loam	13 "	23 "	12 "
Brookston sandy loam	7 "		
Others	4 "	4 "	8 "

Proposed Name: No change

Eaton County Line-Intercept Transects

Table 10 lists the percentages of the major taxonomic units (comprising more than 5 percent) of 7 mapping units as estimated by the measurement of length intercepts along transect lines. For purposes of comparison the estimates obtained from point-intercept transects are shown in parentheses after each line-intercept estimate.

TABLE 10.

Comparison of 2 transect methods of estimating percentages of major taxonomic units in mapping units: by length intercepts and by numbers of observations. (Percentages by numbers of observations are in parentheses.)

Taxonomic Units Observed	Percentage Compositions of Mapping Units Listed						
	3493B1	4505B1	4505B2	4505C2	5355B1	6455A1	8805A1
3493B1	51(45)						
3493C1	8(3)			8(11)			
4503B1	6(8)		8(10)				
4503C2				12(7)			
4505B1	21(14)	68(61)	25(21)				
4505B2		8(9)	23(28)				
4505C1				8(13)			
4505C2				46(38)	8(11)		
5355B1		17(13)	23(18)		47(52)		
6455A1					19(15)	79(75)	
8805A1							81(76)

Legend

3493 - Owosso sandy loam

4503 - Miami sandy loam

4505 - Miami loam

5355 - Celina loam

6455 - Conover loam

8805 - Brookston loam

A - 0-2 percent slopes

B - 2-6 " "

C - 6-12 " "

1 - slightly eroded

2 - moderately eroded

Genesee County Point-Intercept Transects

Only point-intercept transects were made in Genesee County. Tables 11A to 11D list by soil type the taxonomic units found within each of the 4 mapping units sampled. All observations are represented in these tables and no tabulation by alternate observations or alternate transects is attempted.

TABLE 11.

A listing by soil types of percentage estimates of the major taxonomic units of 4 mapping units in Genesee County. Estimates are by point-intercept transects.

TABLE 11A.

Celina loam, 2-6 percent slopes, slightly eroded

Soil Types Found (43 observations)	
Celina loam	37 percent
Conover loam	52 "
Owosso sandy loam	7 "
Others	4 "

Proposed Name: Conover-Celina loams, 2-6 percent slopes, slightly eroded

TABLE 11B.

Conover loam, 0-2 percent slopes, slightly eroded

Soil Types Found (77 observations)	
Conover loam	83 percent
Brookston loam	6 "
Metamora loamy sand	5 "
Others	6 "

Proposed Name: No change

TABLE 11C.

Conover loam, 2-6 percent slopes, slightly eroded

Soil Types Found (62 observations)	
Conover loam	84 percent
Brookston loam	5 "
Others	11 "

Proposed Name: No change

TABLE 11D.

Brookston loam, 0-2 percent slopes, slightly eroded

Soil Types Found (39 observations)	
Brookston loam	77 percent
Conover loam	8 percent
Metea loamy fine sand, Humic Gley variant	5 "
Others	10 "

Proposed Name: No change

Delta County Point-Intercept Transects

Only point-intercept transects were made in Delta County. Tables 12A to 12G list by soil type or groups of soil types the taxonomic units found within each of the 7 mapping units sampled. All observations are represented in these tables and no tabulation by alternate observations or alternate transects is attempted.

TABLE 12.

A listing by soil types or groups of soil types of percentage estimates of the major taxonomic units of 7 mapping units in Delta County. Estimates are by point-intercept transects.

TABLE 12A.

Angelica soils

Soil Types Found (38 observations)	
Angelica sandy loam and loam	74 percent
Linwood peat and muck	18 "
Mackinac loam	5 "
Others	3 "

Proposed Name: Angelica-Linwood complex

TABLE 12B.

Sundell sandy loam

Soil Types Found (51 observations)	
Bonduel sandy loam	76 percent
Mackinac loam	10 percent
Ruse sandy loam	8 "
Others	6 "

Proposed Name: No change

TABLE 12C.

Linwood and Cathro soils

Soil Types Found (57 observations)	
Linwood and Cathro peats and mucks	74 percent
Tawas peat and muck	12 "
Lupton peat and muck	7 "
Angelica sandy loam and loam	5 "
Others	2 "

Proposed Name: No change

TABLE 12D.

Mackinac loam

Soil Types Found (21 observations)	
Mackinac loam	90 percent
Angelica sandy loam and loam	10 "

Proposed Name: No change

TABLE 12E.

Roscommon sand

Soil Types Found (37 observations)	
Roscommon sand	65 percent
Tawas peat and muck	10 "
Au Gres sand and loamy sand	8 "
Croswell sand	5 "
Linwood peat and muck	5 "
Others	7 "

Proposed Name: No change

TABLE 12F.

Tawas soils

Soil Types Found (45 observations)	
Tawas peat and muck	71 percent
Roscommon sand	18 "
Lupton peat and muck	9 "
Others	2 "

Proposed Name: Tawas-Roscommon complex

TABLE 12G.

Ruse sandy loam

Soil Types Found (50 observations)	
Ruse sandy loam	76 percent
Linwood peat and muck	12 "
Bonduel sandy loam	8 "
Others	4 "

Proposed Name: Ruse-Linwood complex

DISCUSSION

This section deals with the adequacy of the naming of the mapping units sampled with transects. In all 3 study areas combined, 20 mapping units were investigated. On the basis of percentage composition estimates by point-intercept transects 13 of these were named adequately.

Changes are recommended in the names of the other 7 units so that their compositions will conform to guidelines set forth in Soils Memorandum-66 concerning application of the soil classification system in naming mapping units. This memorandum is issued by the United States Department of Agriculture, Soil Conservation Service, which is primarily responsible for the coordination of such criteria on a nationwide basis. A preliminary draft had been reviewed by all cooperators in the National Cooperative Soil Survey, and it incorporates the recent experiences and observations on the variability of mapping units in various parts of the United States. This memorandum is reproduced in the Appendix starting on page 74.

The guidelines in this memorandum replace the inadequate 15 percent criterion set forth in the Soil Survey Manual (see page 16). These guidelines are quite practical and provide a needed systematic approach to the naming of mapping units. The naming of mapping units as phases of soil series, complexes, associations, undifferentiated groups, and variants are discussed. Each of these is defined as to pattern of occurrence of component soils and the permissible percentages of different soils included.

Permissible percentages allowed in each of these kinds of soil mapping units but not mentioned in the unit name depends on the similarity of the soils. For example, a unit may be named as a phase of a soil series with one phase mentioned in the unit name when only 50 percent of the unit actually consists of that phase. Another 25 to 50 percent of the unit may consist of closely similar phases. However, there cannot be more than 25 percent of a closely similar series or more than 10 percent of a strongly contrasting soil without indicating its presence in the name. If these criteria are not met and the pattern of component soils is too intricate to allow further delineation of component soils the name of a complex should be used. Definitions and examples of terms such as "strongly contrasting" and "closely similar" are included in the memorandum.

It should be noted that the transect estimates of mapping unit components reported here apply only to delineations within a small portion of each of the 3 survey areas. Hence the results, including the naming of mapping units, can apply only to these areas. Similar data for additional areas must be obtained by some reliable means of estimation, transect or otherwise, before units covering entire survey areas can be accurately named. This points up the necessity for making composition estimates of mapping units a continuing process as the survey proceeds. Estimates based on only a small portion of a survey area are likely to be inaccurate as regards the entire area because of different topography, different parent materials (for example loam textured tills of 2 moraines having different source areas), etc. Estimates made only after considerable mapping is completed are also undesirable. It may be found that a considerable range exists among the delineations of a unit and that 2 or more distinct kinds of delineations exist as regards percentages of component soils as indicated by some previously unobserved features. If considerable mapping has been completed before this is discovered much time consuming rechecking of delineations may be necessary to adequately name the delineations.

Eaton County

Of 9 mapping units investigated in the Eaton County study area 2 have soils of different taxonomic units in proportions unsuitable for naming as phases of soil series. The component soils occur in patterns too intricate to allow them to be delineated at the scale being used, so these mapping units should be named as complexes.

It is proposed that the mapping unit Celina loam, 0-2 percent slopes, slightly eroded (a phase of a soil series) be changed to Celina-Conover loams, 0-2 percent slopes, slightly eroded (a complex). Celina and Conover represent parallel families of like subgroups (subgroups having a common limit) and in the aggregate total more than 75 percent of the delineations. In this respect the unit qualifies for naming as a phase of a soil series. However, neither series comprises 50 percent of the total necessitating a complex.

The Owosso unit is 53 percent Owosso series and has enough soils similar to Owosso for an aggregate total of 87 percent. However, Miami soils (loam and sandy loam) comprise 29 percent of this unit. There are no strongly contrasting soils individually comprising more than 10 percent or collectively more than 25 percent of this unit. It should therefore be renamed Owosso-Miami sandy loams.

Similar reasoning to that for the Owosso is applicable to the 3 Miami units and the Celina loam, 2-6 percent slopes, slightly eroded unit. However, in these cases no one of the similar soils makes up over 25 percent of a unit and their names should not be changed.

The Carlisle muck, Conover loam, and Brookston loam units are more than 75 percent Carlisle, Conover, and Brookston series, respectively. There are no strongly contrasting soils comprising more than 10 percent of these units.

All observations (the first column in Table 9) are used in considering the choice of names for the Eaton County mapping units. It is noted by comparing the 3 columns in Table 9 that the choice of names will vary in some units depending upon which column is used (for example Table 9F). On this basis it is recommended that a minimum of 50 well distributed observations be made when using point-intercept transects for estimation of a mapping unit's components. Little variation is encountered in composition estimates after 50 observations are obtained (for example Tables 9A, 9G, and 9I).

The results obtained using line-intercept transects are too similar to results from point-intercept transects to justify the extra effort and time required for line-intercept transects. Only when special situations exist, such as an open trench as the result of pipe line installation, is the line-intercept transect recommended.

Genesee County

Four mapping units were studied in Genesee County. Three of these have proportions of component soils suitable for naming them as phases of soil series. These include the 2 Conover units and the Brookston unit. All have dominant soils of one taxonomic unit comprising more than 75 percent of the delineations and none has a strongly contrasting soil comprising more than 10 percent.

The other unit should be named as a complex since its composition is not suitable for a phase of a soil series and the pattern of occurrence is too intricate to allow the component soils to be further delineated.

The Celina loam, 2-6 percent slopes, slightly eroded mapping unit should be renamed Conover-Celina loams, 2-6 percent slopes, slightly eroded. The Conover and Celina series represent parallel families of like subgroups and together comprise more than 75 percent of this unit. The dominant soil, Conover, comprises more than 50 percent but the other soil, Celina, comprises more than 25 percent, hence the use of a complex.

Delta County

The nature of the Delta County soil survey makes the varied use of mapping units named as complexes, associations, undifferentiated groups, and phases of soil series quite useful. While the topography is subdued soil patterns are complicated and are commonly masked by vegetation.

Seven units were investigated. Three of the units were named as undifferentiated groups prior to this study. The Angelica soils unit consisted of 2 soil types, Angelica sandy loam and loam. The transects estimate approximately 20 percent of a strongly contrasting soil, Linwood peat, so an Angelica-Linwood complex is more appropriate.

Another undifferentiated group, Linwood and Cathro soils, seems adequately named on the basis of transect estimates. The third undifferentiated group, Tawas soils, is described as containing Tawas peat and muck. The strongly contrasting soil, Roscommon sand, comprises nearly 20 percent of the unit, so Tawas-Roscommon complex is a better name.

The remaining 4 units were originally named as phases of soil series (soil types). Three of these, Bonduel sandy loam, Mackinac loam, and Roscommon sand have percentages of named soils and similar soils exceeding 75 percent with only small percentages of strongly contrasting soils. Thus they need no change. The other, Ruse sandy loam, has more than 75 percent of Ruse soils, but also has more than 10 percent of a strongly contrasting soil, Linwood peat. It should be named Ruse-Linwood complex.

CONCLUSIONS

The use of point-intercept transects for estimating the percentages of different soils occurring in the various delineations of mapping units in soil surveys is practical for most situations. Their practicality is very evident when one considers other methods which have been used in Michigan to arrive at similar estimates.

It is not suggested that every mapping unit in a survey area be examined with transects. Note that many of the units investigated in this study are adequately named as phases of soil series and consist of 75 percent or more of a single series. Such units can be adequately characterized by estimates of experienced field men. In some survey areas such units may include 50 percent of the legend and perhaps as much as 70 percent of the area. Of course, there is much variability among survey areas with respect to complexity of mapping units. The areas sampled in this study represent relatively homogeneous areas. More complex areas could have been chosen within the same study areas; that they were not chosen should not lead the reader to believe that mapping unit complexes are rare in Michigan. Units actually named as complexes were rare until several years ago, but this was due to the failure to recognize them rather than because they did not exist.

Other major units with a less homogeneous composition should be sampled with transects at various intensities depending on the situation. A few units may be very complex but component soils may be associated with characteristic topographic positions. Such situations can often be estimated visually with sufficient accuracy. Usually there are no topographic, vegetative, or other clues, and in these situations the transect is most useful.

As with many other aspects of a soil survey the successful use of transects depends on the good judgment of the party members. Any method of estimation if misused or unjustifiably used can result in the discouragement or disenchantment of those concerned. A good job is now being done in naming many mapping units as is evidenced by the 13 units adequately named of the 20 investigated. There is always room for improvement and transects can improve this phase of soil survey activity (more accurate characterization and naming of units).

Anything which can give us with reasonable cost more precise estimates in descriptive legends of what the delineations of a mapping unit contain is a valuable contribution to a soil survey program. The more we can say with reasonable assurance about the composition of a mapping unit the more precisely we can define the properties of that unit and the more precisely we can say how that unit should be managed for particular purposes or how suitable it would be for a particular use.

The use of a means by which reliable estimates of the proportions of different soils can be made can result in more accurate maps with experience and the adjustment of delineations or names to fit the landscapes involved. Confusion and the feeling of futility which may accompany mapping in complex areas with ill defined units can also be alleviated. Even the acknowledgment that we cannot say much very definite about a few mapping units is sometimes helpful. On-site investigation of small areas for any purpose is desirable on medium intensity soil surveys in Michigan.

VI

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VII

Appendices

LIST OF SOIL SERIES ENCOUNTERED AND THEIR TENTATIVE CLASSIFICATION*

Angelica	Mollic Haplaquepts; fine-loamy, mixed, nonacid, frigid
Au Gres	Entic Haplaquods; sandy, mixed, frigid
Bonduel=Sundell	Entic Haplaquods; coarse-loamy, mixed, frigid
Brady	Aquollic Hapludalfs; coarse-loamy, mixed, mesic
Brookston	Typic Argiaquolls; fine-loamy, mixed, non-calcareous, mesic
Carlisle	Histosol
Cathro	Histosol
Celina=Celina, variant	Typic Hapludalfs; fine-loamy, mixed, mesic
Conover	Udollic Ochraqualfs; fine-loamy, mixed mesic
Croswell	Entic Haplorthods; sandy, mixed, frigid
Linwood	Histosol
Lupton	Histosol
Mackinac	Alfic Haplaquods; fine-loamy, mixed, frigid
Metamora	Udollic Ochraqualfs; fine-loamy, mixed, mesic
Metea	Arenic Hapludalfs; fine-loamy, mixed, mesic
Miami	Typic Hapludalfs; fine-loamy, mixed, mesic
Owosso	Typic Hapludalfs; fine-loamy, mixed, mesic
Ruse	Lithic Haplaquepts; loamy, mixed, nonacid, frigid
Roscommon	Mollic Psammaquents; sandy, mixed, frigid
Tawas	Histosol

* Soil Survey Staff, U. S. Dep. Agr., Soil Cons. Serv., Placement of series midwest region July, 1967, 1967. (as amended January, 1968)

UNITED STATES DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

Washington, D.C., 20250

October 9, 1967

SOILS MEMORANDUM-66

Re: Application of the Soil Classification System in Developing or Revising Series Concepts and in Naming Mapping Units

This memorandum establishes Soil Conservation Service policy for using the soil classification system adopted January 1, 1965.

It is SCS policy to use the soil classification system in developing and revising series concepts and in naming mapping units. Further, it is SCS policy to use the system in soil survey publications, standard series descriptions, and other documents. (We do not expect to rewrite soil survey manuscripts completed before January 1, 1965, simply to use the new terminology. Nor should extensive remapping of soils be necessary if current mapping is accurate and can be clearly interpreted.)

This memorandum outlines interim guides for applying the system in developing and revising series concepts and in naming mapping units. The substance of the guides is to be included in a correlation manual now being prepared. Until it is issued, use these guides. Use Soils Memorandum SCS-11 (Rev.) as a guide in preparing and revising series descriptions.

The classification system has not been fully tested as yet. The testing follows from placing series in the system, revising series concepts, and naming mapping units at all stages of soil surveys. Testing may bring out deficiencies in the definitions and differentiae for classes in the family and higher categories. If such deficiencies are found, they must be corrected as soon as possible. They may indicate need for changes either in the system or in the guides for its application. For example, if use of the system requires proposing a large number of new series, this indicates that the criteria for classes in the family or higher categories need to be reviewed and may need to be modified.

Bring any indications of deficiencies to the attention of the principal soil correlators and the Director, Soil Classification Correlation.

AO (Sufficient copies for all soil scientists)

DEVELOPMENT AND REVISION OF SERIES CONCEPTS

Not all presently established and tentative series will fit into the soil classification system. Most of those series were proposed or established within previous systems of classification, which did not use present criteria. Adjustments in series concepts are therefore necessary. Guides for modifying series concepts and for developing concepts of new series follow.

1. Accumulation at the series level of differentiae of higher categories.

Criteria for distinguishing series include all criteria for setting apart classes in higher categories. The differentiae for orders, suborders, great groups, subgroups, and families all come into play in revising the concepts and definitions of established and tentative series and in developing concepts of new series. For practical purposes, attention can be given in work on series concepts to the differentiae for subgroups and families. Those differentiae include the criteria for distinguish-orders, suborders, and great groups.

2. Series control section.

The phrase "series control section" refers to that part of the profile to be considered in distinguishing series within families. Dimensions of the series control section for three sets of soils are as follows:

Cryic soils - From the mineral surface to whichever is shallower of (a) a depth of 30 inches (75 cm) or (b) a depth of 10 inches (25 cm) below a level at which soil temperature is 0° C about 2 months after the summer solstice.

Very shallow soils - From the mineral surface to a lithic or paralithic contact if thickness of the regolith is 14 inches (35 cm) or less.

All other mineral soils (Orders 1 through 9) - From a depth of 10 inches (25 cm) to (a) a lithic contact, a paralithic contact, petrocalcic horizon, or duripan if it is within a depth of 40 inches (1 m); (b) a depth of 40 inches (1 m) if the regolith is thicker than that but the named diagnostic horizons and subjacent Cca horizons are not; or (c) the bottom of the named diagnostic horizons and any subjacent Cca horizon if the thickness of both the named diagnostic horizons and the regolith exceeds 40 inches (1 m) but not below a depth of 80 inches (2 m). (Note that calcic and gypsic horizons and duripans are diagnostic only if their upper boundaries are within a depth of 40 inches (1 m). Salic horizons are diagnostic if the upper boundary is within 30 inches (75 cm) of the surface. Diagnostic horizons are defined in the 7th Approximation and the 1967 Supplement, and the Cca horizon is defined in the 1962 supplement to the Soil Survey Manual.)

The depth limits for Cryic soils were chosen so that some part of a profile can serve as a series control section in soils that never thaw to depths of more than a few inches. If the limits for "all other mineral soils" (which exclude the upper 10 inches) were applied to Cryic soils, some would lack a series control section.

The depth limit of 14 inches (35 cm) was chosen for very shallow soils so that the minimum thickness of the series control section for slightly deeper soils would be large enough to be reliably identified and described. For example, if the regolith is 15 inches deep to rock, the series control section for "all other mineral soils" applied and the part of the profile between 10 and 15 inches becomes the series control section. This part forms a layer thick enough to be identified and described.

The depth limit of 14 inches (35 cm) does not require that this be a maximum within a series as does the depth limit of 20 inches (50 cm) for lithic subgroups. Pedons both shallower and deeper than 14 inches may be in the same series so long as they do not have characteristics requiring them to be classified in different families.

Soil characteristics outside the series control section that are not differentiae for families or subgroups may be the bases for distinguishing phases, which are discussed in the Soil Survey Manual, pp. 289-299.

3. Establishing norms and class limits for series.

In revising or developing series concepts, systematic procedures are essential. They reduce possibilities of recognizing more series than are necessary to organize and present existing knowledge about soil behavior and genesis. They are especially important after a shift from one classification system to another because of the changes in class criteria. In any shift of systems, habits of thinking about soils must be modified, which requires extra effort.

The distinctions between any one series and its competitors must be large enough to be recorded clearly and comprehended readily. Each series should stand on its own. Determining that it does is also simplified by a systematic procedure for assembling and evaluating information about soils.

First, assemble and study available information on the soils of a series for which the concept is to be modified or the soils for which a new series is to be proposed. This study may show that some essential information is lacking. If so, gather this information. Without it, you cannot classify the soils satisfactorily or prepare adequate series descriptions.

Next, array the available information on morphology, composition, and geographic distribution of the soils under consideration. This eases the task of reviewing existing concepts of series and arriving at possible concepts for new series.

First study the arrayed information to sharpen the norms and class limits for series already on the books. This is necessary because those series were recognized within earlier systems of classification. Their concepts and definitions must now be modified to fit the new system. Record and examine the ranges in characteristics allowed in the past. Also record in notes the known limits between the series under study and any competing series. These latter series include members of the same family and memebers of adjacent families, i.e., those which share common limits with the series under study. Examples of competing series in adjacent families in neighboring subgroups are the Fayette series (Typic Hapludalfs) and the Downs series (Mollic Hapludalfs). When the definitions of either of these two series is modified, the definitions of both are affected and the limits between them must be spelled out in revised descriptions. If the concept of either series is changed, the concepts of both are modified.

When a new series is to be proposed, no norm and range in characteristics have been specified for it previously. Setting up a new series, however, introduces possibilities for conflict and overlapping with already recognized series. Consequently, part of the process of deciding on the need for a new series must be the recording of known limits between it and competing series. Record these limits in the same way as you do in revising concepts of established series.

Select a pedon as a norm for a series class on the basis of the arrayed data on morphology, composition, and geographic distribution of the soils under consideration--assuming that all essential information is now at hand. No one pedon is likely to be central for all ranges, but where it falls in those ranges is important. Give preference to pedons in the central parts of the ranges in characteristics and geographic occurrence. Consider the ranges in morphology, composition, and distribution collectively.

The pedon selected as a norm for a series becomes the "typifying pedon" in a draft series description. It is a reference specimen to illustrate the central concept for the series. Along with other very similar pedons, it forms the nucleus for the series class. If the pedon selected to typify a series has one or more characteristics unusual for the series class, record these in special notes in the section of the description labeled "Remarks".

After selecting a typifying pedon, spell out the permissible ranges in characteristics. In doing this, use the arrayed information on morphology and composition of the soils. The hard core of this information consists of the profile descriptions and laboratory characterization analyses. Also use supplementary notes on relief and other features to the extent that they apply. One example of supplementary notes is a record of thickness of solum at several sites. Only part of the full set of properties of any soil is considered in its classification. Thus, not all observable soil characteristics are necessarily definitive for a series class. Emphasize in the statement of range in characteristics the definitive properties for a given series.

After a norm has been selected and a statement of range in characteristics prepared for a series, the concept thus developed must be tested further. Check the norm and ranges in characteristics against the class limits for the family and subgroup in which the series is placed. The ranges specified for the series must not cross the limits of the family to which the series belongs. Also compare the norm and ranges of the series with those of other series in the same family and with those in adjacent families. Adjacent families are others which share a limit or limits with the family in which the series is classified. Those families may be in the same or in different subgroups as the one in which the series is placed. Testing series concepts in this way often brings out the need for modifying either or both the norm and the range in characteristics.

The distinctions in definitive characteristics of the norms for the series being defined and the competing series should be clearly larger than normal errors of observation and the ranges in characteristics should not overlap.

4. Recognition of new series.

Strict application of family class limits is now required in defining soil series. This will exclude some soils that were parts of defined series in the past. This will also raise questions about proposing new series for some soils in survey areas in regions with little previous mapping. The bases for applying family class limits and for making judgments on proposing new series are therefore discussed on these pages.

Soils that fall outside class limits of families in the system are to be handled at the series level in one of three ways.

(1) Some will fit into other already defined series. Such soils present few problems because they can be classified in series that have been defined.

(2) Some will not fit into any already defined series but are extensive and different enough to warrant establishing new series. These soils can be classified with few problems.

New series will need to be proposed. The procedures for selecting norms and defining ranges in characteristics given on pp. 4-7 are to be followed. Requirements for recognition of new series are discussed on p. 5.

(3) Some will not fit any already defined series and are not extensive and different enough to warrant establishing new series; these soils in effect will be unnamed series. Such soils will give rise to many of the problems encountered in defining and differentiating series. Judgments on the recognition of new series for such soils are to be based on factors such as accuracy of observations and estimates, combined differences in characteristics, and acreages of soils. Each of these is discussed separately.

(a) Normal errors of observation. A first general guide is that soils for which a new series is being considered must differ appreciably in either or both morphology and composition from soils of already defined series. This means that differences in relevant characteristics must be larger than the normal errors of observation or estimate. Some examples of normal errors of observation and of tolerances to be allowed without setting up new series are given as further guides.

Identification of soil color in the field is subject to errors because of changes in the quality of light and in soil moisture and because of differences in the skill of individuals. Field observations must be made at different times of day and with differing soil moisture contents. Thus, they give rise to differences in matching as large as a full interval between chips in the color chart. The scatter in identification of soil color by one person looking at the same specimen at different times and under different conditions or by a group of individuals looking at the same specimen together is an example of "normal errors of observation". Under optimum field conditions, soil color can be matched to within one-half interval of a chip in the color chart. Given the exercise of care, the normal scatter of observations is plus or minus a half interval between chips on the same sheet or between chips of the same value and chroma on adjacent sheets. Color distinctions between the soils of two series must be larger than this normal scatter.

Comparisons of field estimates of textures with laboratory characterization data on several hundred soil samples indicate that texture can be estimates to within one-half a textural class as given in the chart for texture on p. 209 of the Soil Survey Manual. Thus, field estimates are commonly within plus or minus one-half class of the actual texture, though observational errors by highly qualified individuals are smaller. To set apart series based in part on differences in texture, the distinctions must be larger than the probable error of field estimates. This holds for the whole control section and any of its parts.

Most contrasting textures within the series control section are family criteria, which automatically become series criteria. The parts of the series control section that are of contrasting textures need to be thick enough to be identified reliably. Soils in which thin bands of contrasting texture are significant cannot be examined satisfactorily by using only a soil auger. Even in pits, some minimum thickness is required for reliable identification, somewhat greater near the bottom than near the top of the control section. The reliability of observations decreases with depth. A layer of loam 3 inches thick near the top of a control section that is mostly sand would be noted, as a rule. A layer of loam of the same thickness near the bottom of the same kind of control section would be missed as often as not. A thicker layer of loam, one about 6 inches thick, is required for reliable identification in the deeper part of the control section.

Mean annual soil temperature measurements may be in error by 1 or 2 degrees under optimum conditions. In fact, the thermometer may have this error. The probable error in annual soil temperature, if the value is obtained from continuous measurements for a full year, is about 1 degree, which means that the mean of those measurements is apt to differ from a 30-year average by 1 degree. Estimates based on 4 to 6 measurements in the same year have a larger probable error, as much as 2 degrees. Estimates of soil temperature based on meteorological records at a weather station in a nearby or distant city are subject to an error as large as 5 or 10 degrees unless the site of the station is comparable to that of the soil. Do not use the weather records from nearby or distant cities to estimate soil temperature unless you first establish that the sites of the station and soil are fully comparable.

A tolerance of at least 2 degrees in average annual temperature of soils is permissible without recognition of new series. A tolerance as large as 3 degrees may be considered. This should preclude establishing series of minor extent solely on the basis of temperature. A tolerance is necessary because the change in annual soil temperature can be gradual over broad belts, especially in large plains. Series need not be proposed for soils that fall outside the temperature limits of the family unless the 2- or 3-degree tolerance is exceeded.

More measurements of soil temperature are needed to improve the bases for its estimation. As more measurements become available, better guides than can be offered now should be possible.

(b) Combined differences in characteristics. Soil series are seldom set apart on the basis of differences in one characteristic. As a rule, the distinctions are in several characteristics and some are greater than others. If the magnitude of distinctions in morphology and composition are clearly greater than the normal errors of observation, justification for series is seldom a problem.

Problems arise in deciding whether a new series is needed if soils to be classified are outside but near the limits of an already defined series in two or more definitive characteristics. As one example, soils to be classified may have an annual temperature approximately 3 degrees below the limit for thermic families and also be marginal in texture of the control section between fine-loamy and coarse-loamy families. A series may have been defined for soils of a coarse-loamy thermic family but none for soils of a fine-loamy mesic family. Distinctions in temperature and in texture of the control section between the soils to be classified and the already defined series are believed to be real but only slightly larger than normal errors of observation. Do not propose a new series for soils of this kind. Rather, handle them as taxadjuncts, a word coined by adding the combining form tax-, denoting arrangement, as a prefix to the word adjunct.

Soils handled as taxadjuncts are considered adjuncts to but not parts of the series furnishing a name for their identification on maps. These soils are thus unclassified at the series level but are allowed to go under the name of a defined series. They are enough like the soils of the defined series in morphology, composition, and behavior so that little or nothing is gained by adding a new series. For each soil handled as a taxadjunct, include an appropriate footnote in each published survey to explain what has been done.

(c) Consideration of extent. The acreage of each kind of soil that falls outside the limits of any defined series is highly relevant to a decision on need for a new series. The known extent of a kind of soil outside the limits of any defined series should be 2000 acres or more before a new series is considered. Beyond that, be sure that soils for which a new series is being considered are clearly further outside the limits of any defined series than the normal errors of observation before a new series is proposed, even though extent of the soils equals or exceeds 2000 acres. Soils that are marginal to defined series, especially soils of minor extent, are to be handled as taxadjuncts, as explained in the two preceding paragraphs.

Soils with a total extent of less than 2000 acres outside the limits of any defined series have been handled in the past as variants or as mapping inclusions. The use of variants is not changed. Mapping inclusions are also to be used but with some modification, as explained later on pp. 9-10. Soils marginal to already defined series are also to be handled as taxadjuncts.

NAMING MAPPING UNITS

Mapping units recognized in field work are to be named as phases of soil series, soil types, complexes, soil associations, undifferentiated groups, variants, and miscellaneous land types. Most of the separations shown on detailed soil maps in the past have been named as phases of soil types. Some have been named as soil types. A few have been named as complexes, associations, undifferentiated groups, variants, or miscellaneous land types. The distinctions between these kinds of mapping units and the conventions for their use are explained in the remainder of the memorandum. Some modifications of past conventions are necessary under the new classification system.

Mapping inclusions

Mapping inclusions are normal components of all kinds of mapping units. Their nature and the past conventions for handling them are therefore discussed before the modified conventions are explained.

Few if any bodies of soil that can be delineated at mapping scales in detailed surveys consist of polypedons (equals soil individuals as used in the 7th Approximation) of one series class. The great bulk of the soil within each set of delineated bodies identified by a single phase or type name has been thought to consist of polypedons of one series. A small proportion has been known to fall outside the range of the series providing a name for the mapping unit. Recent detailed studies of mapping units have shown that the proportions of mapping inclusions are commonly greater than the 15 percent that have been allowed in mapping units named as phases of series. The proportions also will be increased by strict application of family class limits in defining series.

Mapping inclusions are polypedons or pedons of a series or phase different from the most extensive polypedons within delineated soil bodies composing a mapping unit. Such included soils are of three kinds.

The first kind consists of polypedons or pedons representing named series and differing significantly in one or more of morphology, composition, and behavior from the phase or phases providing a name for the mapping unit. The polypedons forming the inclusions are too small to be shown on the map and do not reach proportions that justify recognizing a complex.

The second kind consists of polypedons or pedons of named series of limited extent in a given survey area and so similar to those of the series providing a name or names for the mapping unit that little or nothing is gained by adding an extra series name.

The third kind consists of polypedons that differ significantly in one or more of morphology, composition, and behavior from those of the series providing a name or names for the mapping unit. The total acreage of this third kind is so small that its classification as a series is not warranted. The extent is usually tens of acres but may be a few hundred acres. Such soils were not classified into series in the past but were included with named series. This practice is to be continued, though it differs from the general practice for inclusions as explained in the next paragraph. If mapping units contain inclusions of this kind, this is to be recorded and the soils described in handbooks and soil survey manuscripts.

Except for the situation described in the preceding paragraph, the allowable proportions of inclusions are meant to apply to the bulk of the map entities, i.e., the segments of the soil mantle shown as individual delineations on maps. Thus, each delineated soil body is expected to have some of the included kinds of soil but not necessary all of them. At the same time, the contrasting minor kinds of soil do not occur in bodies large enough to be mapped separately.

This memorandum modifies the past practice of allowing maximum proportions of 15 percent as inclusions in a set of delineated bodies named as a phase or a soil type. That practice is described on p. 277 of the Soil Survey Manual. Higher proportions of soils similar to the most extensive kind or kinds in a mapping unit will now be allowed, as specified in the following pages. The new limits for allowable proportions of inclusions will be tested through use for several years and then continued or changed if necessary.

Definitions and examples of similar and dissimilar classes

Conventions for naming mapping units as phases of soil series and as soil types are explained later, partly on the basis of allowable proportions of soils of similar and dissimilar familes and subgroups. Definitions and examples are therefore given of "parallel families", "closely similar families", "like subgroups", and "unlike subgroups".

(a) Parallel families. Families are parallel if they are in different subgroups but are nearly equivalent in texture, mineralogy, and other family differentiae, as indicated by the same adjectives in their names. For example, coarse-loamy, siliceous, thermic Typic Hapludults and coarse-loamy, siliceous, thermic Aquic Haplustalfs are parallel families.

(b) Closely similar families. Families are closely similar if they are alike on one or more counts, as for example:

(1) Texture. Closely similar families have the same textural classes in comparable horizons though adjectives for particle size classes in their names differ. For example, two soils with cambic horizons of silt loam texture could belong to different particle-size families, one to a coarse-silty family and the other to a coarse-loamy family, but still be closely similar. Two soils having argillic horizons of loam texture could be closely similar though one might be in a fine-loamy family and the other in a coarse-loamy family.

(2) Carbonates. Soils with carbonates in only a part of the layer between 10 and 20 inches are considered closely similar to both nonacid and calcareous families.

(3) Temperature. Polypedons occurring next to or near one another in the same landscape may be assumed to have closely similar temperatures.

(4) Mineralogy. Neighboring polypedons with closely similar textures of the family control section can be presumed to have like mineralogy if actual data do not show that the mineralogies differ or if there are no known obvious differences in the soils.

(c) Like subgroups. Like subgroups are those that have common limits. Thus, a pair of like subgroups share a limit or limits. Examples of like subgroups follow:

Intergrades:

Typic Udifluvents and Fluventic Dystrochrepts
Aquic Hapludalfs and Typic Hapludalfs
Aquic Hapludults and Typic Hapludults
Aquic Hapludults and Aeric Ochraquults
Aeric Haplaquolls and Aquic Hapludolls
Aeric Haplaquolls and Typic Haplaquolls
Spodic Quartzipsamments and Entic Haplorthods
Typic Eutroboralfs and Typic Glossoboralfs
Typic Hapludults and Ultic Hapludalfs
Typic Hapludalfs and Mollic Hapludalfs

Extragrades:

Cumulic Hapludolls and Typic Hapludolls
Lithic Hapludolls and Typic Hapludolls if there is a lithic contact within 1 meter.

(d) Unlike subgroups. Unlike subgroups are pairs of subgroups separated in the system by a third subgroup. Examples of unlike subgroups follow:

Intergrades:

Aquic Hapludalfs and Typic Ochraqualfs (Aeric Ochraqualfs intervene)
Aquollic Hapludalfs and Typic Hapludalfs (Aquic Hapludalfs intervene)
Typic Argiudolls and Typic Hapludalfs (Mollic Hapludalfs intervene)

Extragrades:

Aquic Haploborolls and Typic Calciaquolls (Note that Aeric Calciaquolls intervene and that parallel families are rare.)
Lithic Hapludolls and Typic Hapludolls if there is no lithic contact within 1 meter.

(Note that several orders and great soil groups never occur together. Polypedons of Aridisols and Spodosols, for example, never occur together. The examples given for unlike subgroups were selected from those that can and do exist in close proximity.)

CONVENTIONS FOR NAMING MAPPING UNITS

1. Phases of soil series

Most series consist of a set of soils with ranges in soil slope, depth, stoniness, or other features significant to their use. Subdivisions according to differences in such features are recognized as phases. Some series lack such subdivisions and can be called monophase series, at least so far as is known now.

Phases are set apart in a soil survey area because of differences in behavior beyond those differences that can be related directly to soil series. Each phase should differ from every other phase in the same series in usefulness or response or both. Thus, for example, phase separations should carry with them differences in one or more of use suitability, management requirements for crop production, crop yields, forage production, site index, limitations for septic tanks, and suitability for road grades. Furthermore, the differences in behavior between any pair of phases of a single series should be larger than errors of estimate.

Mapping units set apart in field work are to be named as phases of soil series, including soil types considered as one kind of phase, provided they meet the requirements spelled out below under Alternative I or Alternative II.

> Alternative I. three-fourths or more of the polypedons fit within the phase of the series that provides the name for the mapping unit or fit in closely similar phases of the same series or of other series in closely similar families of the same subgroup, in parallel families of like subgroups, or in other families closely similar in behavior. The most extensive kind of soil must fall within the range of the phase providing the name for the mapping unit. As a rule, that kind constitutes more than half. The most extensive soil, however, may constitute no more than 35 percent of the mapping unit if 15 percent or more consists of a taxadjunct to the series. Each of the inclusions of soils of closely similar series may constitute as much as 25 percent of the mapping unit but their aggregate proportion must not exceed 50 percent. Minor proportions of strongly contrasting soils are also allowed as inclusions but none of them individually may constitute more than 10 percent and their aggregate proportion may not exceed 15 percent.

Further explanation of closely similar phases is given in this paragraph. Closely similar phases may belong to the same series, to other series in parallel families of like subgroups, to other series in closely similar families, or to taxadjuncts. Examples of closely similar phases within the same series are a pair of slope phases having a common gradient limit, e.g., Redding gravelly loam, 2 to 5 percent slopes and Redding gravelly loam, 5 to 9 percent slopes. Further examples of closely similar phases are a comparable pair in parallel families of like subgroups such as Enders sandy loam, 2 to 6 percent slopes (Typic Hapludults) and Helena sandy loam, 2 to 6 percent slopes (Aquic Hapludults).

> Alternative II. Three-fourths or more of the polypedons fit within a taxadjunct to the series that provides the name for the mapping unit or fit in other series in closely similar families of the same subgroup, in parallel families of like subgroups, or in other families closely similar in behavior, but the series providing the name does not occur in the survey area. The proportions of the most extensive kind of soil and of the similar and contrasting inclusions are the same as under Alternative I.

Alternative I covers the common situation that will be met in correlating soils of individual survey areas. Follow that alternative as usual practice.

Follow Alternative II only if the most extensive kind of soil in a mapping unit is a taxadjunct and the series providing the name is not represented in a survey area. For example, the most extensive kind of soil might fit a series in all respects except temperature. This is true of some soils in Maryland, just east of Washington, D. C. They fit series classified in thermic families except that temperatures are believed to be slightly below the mesic-thermic limit. Furthermore, the total acreage is small. A limited acreage in Prince Georges County, Maryland has therefore been correlated with the Hyde series, which is classified in a thermic family of Typic Umbraquults. The soils in question are being handled as taxadjuncts to the Hyde series.

Problems are to be expected in the use of family temperature limits because they are new criteria in the classification of soils. When correlating the soils of survey areas, check the family temperature limits against several kinds of boundaries. One kind consists of boundaries between land resource regions and areas. Other kinds are natural geographic features such as rivers and the margins of mountains. The geographic limit between a pair of otherwise similar series differing in temperature but having a common temperature limit may be made to coincide with the boundary of a land resource area or with some natural geographic feature without exceeding the tolerance of 2 or 3 degrees. The possibility of using such geographic limits in the correlation of soils should be examined wherever prospects seem favorable without assuming beforehand that the approach will work everywhere.

If a taxadjunct, on the basis of temperature or other characteristics, constitutes the most extensive soil in a mapping unit, name it accordingly. Add to the description of the mapping unit in the handbook or soil survey manuscript an explanation of the character of the taxadjunct, including a reference to a published soil survey that has a good description of the series used to provide a name for the mapping unit.

Maximum proportions of soils allowed as inclusions within a mapping unit named as a phase of a series may range from 15 to 50 percent, depending on the degree of contrast between included kinds of soils and the most extensive kind of soil. Inclusions of closely similar polypedons of named series, which may constitute as much as half of a mapping unit, should be marginal in properties to the polypedon of the most extensive series. The pedons of these inclusions should be as much like those of the dominant series as they are like the typifying pedon of the series in which they are classified.

Minor proportions of inclusions may consist of polypedons contrasting both in characteristics and behavior. If the contrast is great and the minor kinds of soil are of special importance, indicate them by defined spot symbols.

Insofar as practicable, mapping units should be designed to keep inclusions to a minimum. The dominant kind of soil should form as high a proportion of the mapping unit as is feasible at the field scale. Efforts should be made to design legends so that mapping units to be called phases will have 75 percent or more of the polypedons within one series. Keep in mind that the great bulk of inclusions should consist of soils that have properties combining to give responses to management for the growing of plants and to engineering manipulation similar to those of the most extensive kind of soil within the mapping unit.

Remember at all times that guides cannot substitute for judgment based on understanding the purposes of a soil survey and the ability of soil scientists to serve them.

a. Soil types. Although the soil type is no longer a category in the classification system, the term is not likely to disappear in the near future. Because of its changed status, some change in the convention for its use is also necessary.

In this memorandum, soil type refers to one kind of phase and to a way of naming mapping units.

As one kind of phase, the soil type is a subdivision of a series according to texture of the surface layer. If a series consists of soils having a range in texture extending over two or more textural classes, that range can be subdivided. Each subdivision is called a soil type.

As a way of naming mapping units, the soil type permits the use of textural class terms in phase names even if no subdivision of a series is made on the basis of texture of the surface layer. For example, silt loam is the only textural class of the surface layer of soils in the Monona series (Typic Hapludolls). No subdivision of the series on the basis of texture of the surface layer is therefore required. The expression "silt loam" is included, however, in phase names, e.g., Monona silt loam, 2 to 7 percent slopes.

Include a textural class term in the name of each mapping unit identified by a single phase name.

Mapping units should not be separated solely on the basis of texture of the surface soil unless the textural differences are relevant to soil use, management, or engineering manipulation. Samples of surface layers from a set of delineated bodies named as one phase may have textures of four classes such as loam, silt loam, clay loam, and silty clay loam, though the full range in texture remains small. This holds, for example, if the texture range straddles the limits between those textural classes. Textures of individual samples might be scattered across but near the common limits for loam, silt loam, clay loam, and silty clay loam. An interchange of 3 percent in the relative proportions of sand, silt, and clay shifts the texture from one to any of the others in this set of four classes. Soil scientists cannot consistently distinguish two textural classes if the texture of the specimen is near their common limit. A somewhat larger range, for example an interchange of 5 percent, is necessary before consistent distinctions can be made. If consistent distinctions can be made and those do have meaning to usefulness of soils, mapping units are to be separated. On the other hand, if a mapping unit does have a range in texture of the surface layer crossing the limits between textural classes but not exceeding the range of one class or of a family particle-size class, use the name of the dominant textural class in the assigned phase name.

2. Complexes

Complexes are sets of delineated bodies having patterns of component polypedons so intricate that they cannot be mapped separately at normal field scales, mostly 1:15,840 or 4 inches equal 1 mile. The component polypedons generally represent two or more unlike subgroups or families. The soils of one subgroup may be most extensive but the proportions of less extensive soils within bodies that can be delineated exceed those allowable in mapping units named as phases of series or as soil types.

An inclusion not markedly different from the most extensive components of a complex may constitute as much as 25 percent without adding another series or phase name. No inclusion is to form as high a proportion of the complex as does each of the extensive components. No single component that contrasts sharply with the extensive component soils is to exceed 10 percent of the whole and the aggregate of these not more than 25 percent.

The first part of the name of a complex is to be formed chiefly from names of series. If a miscellaneous land type is a major component, its name is to be used as though it were the name of a series. One, two, or three series names may be used to form the first part of the name of a complex. The second part is to be a textural class term or the word "complex". A third part is necessary for those complexes subdivided on the basis of slope, erosion, stoniness, and the like.

As general practice, use a pair of series names joined by a hyphen in constructing the first part of the name for a complex.

Use three series names joined by hyphens only if all are essential to distinguish one complex from another in the same survey area. Never use more than three series names as the first part of the name of a complex. As many as three series names should be used sparingly.

Use a single series name plus the word "complex" to name a mapping unit if (a) only one of the major component soils has been classified and named at the series level or (b) the complex consists very largely of polypedons of one series and the proportions of those of all other series are small. Polypedons other than those of the dominant series might represent a half dozen series, each of limited extent.

If the dominant polypedons have surface layers differing in texture, the word "complex" is to be the second part.

If one of the dominant components is a miscellaneous land type, use the word "complex" as the second part.

For the third part of a name, if required, use the same kinds of terms for slope, erosion, etc. as is done for phases and soil types.

Always keep the names as short as possible yet distinctive for a survey area.

Examples of appropriate names for complexes are:

Sogn complex
Sharkey-Alligator clays
Aastad-Cresbard loams, undulating
Denton-San Saba clays, 2 to 5 percent slopes
Corning-Redding gravelly loams, 0 to 5 percent slopes
Gem-Springerville complex, 0 to 5 percent slopes
Lagonda-Clarinda complex, 7 to 11 percent slopes, eroded
Manor-Urban land complex, 8 to 15 percent slopes
Travessila-Rock outcrop complex
Skaggs-Duncan-Hughesville complex
Chipeta-Persayo-Rance complex, 2 to 10 percent slopes

For further discussion of soil complexes, see pp. 304-305 of the <u>Soil Survey Manual</u>.

3. Soil associations

Soil associations are sets of delineated bodies in which polypedons representing two or more series occur together with some regularity of pattern and are individually large enough to be mapped separately at usual field scales, mostly 1:15,840 or 4 inches equal 1 mile. Mapping units could be set apart and named as phases or types within the soil bodies delineated and named as soil associations, according to conventions already outlined.

The major or most extensive component soils of most associations are polypedons representing one, two, or three series. Soil associations in which the extensive polypedons represent two or three series are most common. In some associations, one or more miscellaneous land types are major components.

Every delineated body of a soil association has the same major components, whether they represent one, two, or three series or miscellaneous land types. The relative proportions of polypedons of those series, however, may differ appreciably from one delineated body to another. The pattern of occurrence of components is thus less uniform within mapping units that are soil associations than it is for complexes.

The components of an association may or may not be contrasting. The kinds of soils may represent different great groups or even different orders. On the other hand, they may all represent a single subgroup.

The proportions of inclusions in a soil association may be higher than allowed in mapping units named as phases, types, or complexes. No one inclusion is to constitute as high a proportion of the association as does the least extensive of the major components.

If soil associations are mapped in surveys of areas with low potentials for farming or other intensive uses, the inclusions need not be classified and named at the series level unless this has already been done in some other survey area. Instead, the inclusions can be identified in descriptions of the association as phases of families or subgroups. Do not use the names of these minor kinds of soils in naming associations.

The soil associations mapped in low-intensity surveys are more narrowly defined than those shown on general soil maps of counties. The patterns of occurrence of component soils and their relative proportions are more nearly the same from one delineated body to another for the narrowly defined associations. The same conventions in naming, however, are followed for the more narrowly and less narrowly defined associations. This may give rise to some confusion but a guide for naming soil associations at all levels of generalization has not yet been developed. Further instructions on this will be issued later.

The first part of the name of an association is to be formed chiefly from names of series. If a miscellaneous land type is a major component, its name is to be used as though it were the name of a series. One, two, or three series names may be used to form the first part of the name of an association.

If the names of two or three series or of one or two series and a miscellaneous land type form the first part of the name of an association, join those names with hyphens. As general practice, use one or two series names. Use three series names only if all are essential to distinguish one association from another in the same survey area. Never use more than three series names as the first part of the name of an association. As many as three series names should be used sparingly.

Use the word "association" as the second part of the name.

Names of some associations need a third part. Subdivision of associations on the basis of relief are required in places because of related differences in usefulness, management requirements, and the like. Identify such subdivisions by including a slope term such as level, undulating, rolling, moderately steep, or steep as the third part of the name. Slope phases are discussed further on pp. 290-293 of the Soil Survey Manual.

Examples of appropriate names for soil associations are:

Nokay-Peat association
Hibbing association, rolling
Cohoe-Kenai association, steep
Ruston-Cuthbert-Shubuta association, moderately steep

See also the discussion of soil associations on pp. 303-304 of the Soil Survey Manual.

4. Undifferentiated groups (combinations)

Undifferentiated groups or combinations are sets of delineated bodies in which polypedons representing two or more series occur together without regularity of pattern and are large enough to be mapped separately at usual field scales, mostly 1:15,840 or 4 inches equal 1 mile. Mapping units in which polypedons of one series are most extensive could be set apart within delineated areas of undifferentiated groups. Furthermore, these mapping units could be named as phases or types according to conventions outlined earlier.

In most undifferentiated groups, the most extensive component soils represent two or three series. Those groups in which the polypedons of two series are major components are the most common. A few have polypedons of a single series as the only major component but have polypedons of other series present in proportions too large to permit naming a mapping unit as a phase. In some undifferentiated groups, miscellaneous land types are major components, seldom more than one.

Every delineated body of an undifferentiated group has at least one of the major components and may have all of them. Each of the major components does not occur in every delineated body. Thus, undifferentiated groups lack the repeating soil pattern characteristic of soil associations.

The proportions of inclusions allowed in undifferentiated groups are comparable to those allowed in soil associations. No one of the inclusions is to reach as large a proportion as does the least extensive of the major components.

The kinds of soils in an undifferentiated group may belong to the same or to different subgroups. All the major soils, however, are similar enough in behavior so that separating them on a map is not important for the objective of a survey. In low-intensity surveys, some undifferentiated groups may consist of contrasting soils that respond in the same way to extensive management.

If undifferentiated groups are mapped in surveys of areas with low potentials for farming or other intensive uses, the inclusions need not be classified and named as series unless this has been done in some other survey area. Instead, the inclusions may be identified in the descriptions of undifferentiated groups as phases of families or subgroups. Do not use the names of these minor kinds of soils in naming undifferentiated groups.

The names of undifferentiated groups have two or three parts. The first part is usually formed from series names. The second part consists of the word "soils" or a textural class term. The third part is included, as required, for slope, erosion, stoniness, and the like.

As general practice, use two or three series names to form the first part of the name of an undifferentiated group. If two series names are used, connect them with the conjunction "and". If three series names are used, separate them by commas and use the conjunction "and" between the last two. Never use more than three series names.

Use a single series name only if polypedons of that series are such a large part of the mapping unit that those of other series constitute inclusions. An example is a mapping unit of severely eroded soils of one series which in the uneroded condition have A horizons of silt loam and B horizons of clay. Removal of the A horizon has been erratic, which leaves the texture of the surface layer as silt loam, silty clay loam, or clay. The pattern of occurrence of these is irregular yet the solum has not been truncated enough to exclude an appreciable part of the mapping unit from the series. The mapping unit is thus an undifferentiated group of soil types within one series. A single series name is then to be used to form the first part of that name of the undifferentiated group.

For the second part of the name of an undifferentiated group, use the word "soils" or the plural form of a textural class term.

Use the word "soils" if the most extensive polypedons belong to a single series, as already explained, or if the polypedons of two or three series have surface layers of different textural classes.

Use the plural form of a textural class term if the most extensive pedons represent two or three series and have surface layers of the same texture.

For the third part of a name, if required, use the same kinds of terms for slope, erosion, etc. as is done for phases and soil types.

If a miscellaneous land type is a major component of an undifferentiated group, the construction of its name must depart from the general practice. A two-part name must be used to identify both the classified soils and the miscellaneous land type. An example of a name for this kind of combination is Hagerstown soils and Stony land. If the miscellaneous land type is the more extensive, it is to be listed first, e.g., Stony land and Hagerstown soils.

Examples of appropriate names for undifferentiated groups are:

Steinauer soils, 12 to 18 percent slopes, severely eroded
Renshaw and Sioux soils, undulating
Boone and Chelsea loamy fine sands, 2 to 6 percent slopes
Memphis and Loring silt loams, 0 to 2 percent slopes
Gloucester and Charlton stony soils, 3 to 15 percent slopes
Shelby and Burchard soils, 3 to 5 percent slopes, eroded
Borup, Colvin, and Perella soils
Cuthbert, Dulac, and Ruston soils, 8 to 12 percent slopes

For further discussion of undifferentiated groups see pp. 305-306 of the <u>Soil Survey Manual</u>.

5. Variants

Some kinds of soils outside the ranges of defined series are too distinctive to be handled as taxadjuncts and too extensive to be correlated as mapping inclusions. Distinctions in morphology and composition are clearly larger than the normal errors of observation, being as great as is common between different series. Differences from soils of defined series are also readily evident in usefulness or behavior. The extent of these kinds of soils is ordinarily in hundreds rather than tens of acres but less than 2000 acres. Extent is thus too small to warrant establishing new series. Soils of this kind are to be correlated as variants.

The nature and use of variants is discussed on pp. 299-300 of the Soil Survey Manual. The guide provided in the Soil Survey Manual is repeated here so as to have the instructions in one place. Some additional instructions are also given.

Name mapping units as variants in much the same way you name phases of series. Include the word "variant" plus a modifier as part of the name of each mapping unit. Keep the modifier as short as possible yet distinctive in a survey area. One example of a name is Fullerton silt loam, thin solum variant, 2 to 7 percent slopes.

If possible, tie each variant to a series in the same subgroup, i.e., the subgroup in which soils constituting the variant are classified. This may not always be feasible. The soils of a variant may be the only representative of a subgroup in a survey area. In that situation, tie a variant to a series represented in the survey area, selecting the series of soils most like the variant in behavior.

Explain the placement of the variant in the classification system in footnotes in the soil handbook and soil survey manuscript.

6. Miscellaneous land types

Mapping units are named as miscellaneous land types provided they lack natural soil or consist of soils that are not classified for one reason or another. The nature of miscellaneous land types is discussed and definitions are given for many of them on pp. 306-311 of the Soil Survey Manual. Names other than those in the Soil Survey Manual are being tested for mapping units consisting of arable soils that cannot be classified into series. "Made land" is now held for largely nonarable fills. Work is in progress to develop names for mapping units of arable soils not classifiable into series.

/s/ D. A. Williams

*U. S. Government Printing Office: 1967 305-322/68