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NARROW SOILS AND INTRICATE SOIL PATTERNS IN SOUTHERN NEW ENGLAND

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ABSTRACT

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Narrow bands of soils, 5 to 30 m wide, are common in southern New England immediately bordering wet areas, along drainageways, and where soil parent materials overlap or grade into one another. On the basis of detailed observations along 16- and 19-km trenches across representative landscapes, soil bodies less than 30 m wide occupy about 20% of the southern New England area. Yet on recently published soil survey maps such narrow soils seldom are delineated because of scale limitations, and the delineated areas less than 30 m wide occupy only about 1% of mapped areas. Narrow soils in forested areas are often more important than their width would indicate because of their influence on site quality, land use and natural-vegetation distribution.

INTRODUCTION

Scale limits the amount of detail shown on published soil maps and unless the scale used is extremely large most mapping units include numerous soil bodies that are too small to delineate (Powell and Springer, 1965; McCormack and Wilding, 1969). County soil survey maps in New England are published at scales of 1:15840 or 1:20000, and in conjunction with these there are no large-scale maps of representative small areas to provide an idea of the complexity that exists within mapping units. To be sure, large-scale "on-site" unpublished maps are made of small areas where very detailed information is needed, but there are few published soil maps available showing all the detail that actually exists and there is a tendency, even among soil scientists, to think the pattern is simpler than it really is. To some extent, the soil pattern is masked in cultivated areas by reason of the mixing and smoothing caused by cultural operations and so intricate patterns tend to be most marked in forested areas. Mader (1963) called attention to the local variability of soils in forested areas of the Northeast and pointed out that this is an important problem needing evaluation in soil-site studies. Papers dealing with soil variability have recently been reviewed by Beckett and Webster (1971).

During 1939—41 a soil map at the scale of 1:2400 (1 inch equals 200 ft.)

was made of the Harvard Forest as a means of finding the degree of detail needed for forest soil studies (Goodlett, 1960). In spite of the large scale — unusually large for that period — the maps were not entirely satisfactory to the foresters who tried to use them. Later, intricate soil patterns at the borders of drainageways and on lower slopes of the Harvard Forest were mapped on a 3.2-ha tract (Lyford et al., 1963) at a scale of 1:792 and an effort was made to relate growth and distribution of individual tree species to the soils. Only a few broad tree—soil relationships were found but the study did call particular attention to the lack of enough map space to delineate intricate soil patterns such as those caused by treethrow mounds and pits. This lack of space, however, was balanced to some degree because our understanding of tree—soil relationships was too imperfect to make use of such extreme detail. Subsequent studies of tree root development and distribution (Lyford and Wilson, 1966; Lyford and MacLean, 1966; Wilson, 1970; Horsley and Wilson, 1971) have provided background for better understanding of the importance of narrow soils and intricate soil patterns on tree growth.

It is the purpose of this report to show that soil bodies narrower than 30 m are common in most parts of southern New England, can occupy up to 20% of some landscapes, and often occur in intricate patterns that feasibly cannot be shown on published soil maps but may have considerable importance in forest soil studies, particularly those dealing with tree root systems.

METHODS

Detailed examination of soils in trenches and small experimental areas was made on or near the Harvard Forest in central Massachusetts, in the vicinity of Concord and Sudbury in eastern Massachusetts, and near Northwood and Fremont in southeastern New Hampshire. Surficial materials in these areas are acid sandy glacial drift derived principally from granitoid and schistose rocks. Landform, surficial geology, forest vegetation, land use and soils on or near these places are described by Mott and Fuller (1967), Upham (1969), and Van der Voet (1959).

Both organic and mineral soils occur in these areas. Organic soils were not differentiated below the order (Histosol) level inasmuch as all are wet. Mineral soils cover the whole moisture gradient from dry to wet and 31 soil series were identified (Table I). Slope and stoniness phases were not distinguished on the maps, but somewhat poorly drained variants were differentiated in view of the importance of moisture gradient to kind and distribution of vegetation.

For discussion purposes the soil series were grouped into seven natural drainage classes (Soil Survey Staff, 1951) and these were further grouped into three broad moisture classes: dry, moist and wet, as shown in Table I.

TABLE I

Classification of soil series identified in this study

Broad moisture class	Natural drainage class	Soil series	Subgroup	Family*
dry	excessively drained	Hinckley	Entic Haplorthods	sandy-skeletal
		Jaffrey	Entic Haplorthods	sandy-skeletal
		Windsor	Entic Haplorthods	sandy
	somewhat excessively drained	Agawam	Entic Haplorthods	coarse-loamy over sandy or sandy-skeletal
		Brimfield	Entic Lithic Haplorthods	loamy
		Brookfield	Entic Haplorthods	coarse-loamy
		Gloucester	Entic Haplorthods	sandy-skeletal
		Hollis	Entic Lithic Haplorthods	loamy
		Merrimac	Entic Haplorthods	sandy
		Shapleigh	Entic Lithic Haplorthods	sandy
	well drained	Charlton	Entic Haplorthods	coarse-loamy
		Enfield	Entic Haplorthods	coarse-silty over sandy or sandy-skeletal
		Essex	Entic Fragiorthods	sandy
		Paxton	Entic Fragiorthods	coarse-loamy
moist	moderately well drained (and somewhat poorly drained variants)	Acton	Aquentic Haplorthods	sandy-skeletal
		Deerfield	Aquentic Haplorthods	sandy
		Ninigret	Aquentic Haplorthods	sandy
		Scituate	Aquentic Fragiorthods	coarse-loamy over sandy or sandy skeletal
		Sudbury	Aquentic Haplorthods	sandy
		Sutton	Aquentic Haplorthods	coarse-loamy
		Woodbridge	Aquentic Fragiorthods	coarse-loamy
wet	poorly drained	Au Gres (Mesic variant)	Entic Haplaquods	sandy
		Leicester	Typic Haplaquepts	coarse-loamy
		Raynham	Aeric Haplaquepts	coarse-silty, non-acid
		Ridgebury	Aeric Fragiaquepts	coarse-loamy
		Rumney	Aeric Fluvaquents	coarse-loamy, acid
		Saugatuck	Aeric Haplaquods	sandy, ortstein
		Walpole	Aeric Haplaquepts	sandy
		Wareham	Mollic Psammaquents	
	very poorly drained	Peat or Muck	Histosols (Order level)	
		Scarboro	Typic Humaquepts	sandy
		Whitman	Typic Fragiaquepts	coarse-loamy

*Classification as given in "Soil Series of the United States, Puerto Rico and the Virgin Islands: Their Taxonomic Classification". Soil Survey Staff, Soil Conservation Service, U.S. Department of Agriculture, Washington, D.C., August, 1972. All families are mixed and mesic so these terms are not listed in the family column.

Trench studies

Detailed diagrams were made in 1964 of soil bodies exposed in a 19.3-km segment of a cable line trench (19-km trench), mostly in glacial till. This trench passed in an east—west direction through a portion of the Harvard Forest across the prevalent north—south landform trend.

In 1968 soil bodies were diagrammed in a 16.1-km segment of a north—south gas line trench (16-km trench) mostly in stratified drift of former glacial lakes in the vicinity of Concord and Sudbury in eastern Massachusetts. The two trenches were principally in forested areas, and although the upper 20 cm or so of all soils along the trenches were disturbed by clearing and trench-digging operations, the lower horizons remained intact and soil series could be identified. Survey markers showing distances were available at frequent intervals along the newly excavated trenches, and soil boundaries were located with a maximum error of about 3 m. Soil boundaries and names together with general slope, location of roads, fields, bedrock and other features were plotted on cross-section paper at a horizontal scale of 1:1200 and a vertical scale of 1:120.

Soil maps

Soil maps in several degrees of detail were made of a portion of a small watershed at the Harvard Forest and of two areas in New Hampshire. Soil boundary locations in these small plots were based on auger borings after a study of the soil characteristics in pits and trenches. Mapped areas were precisely gridded into 3.05, 6.10, 15.24 or 30.48 m squares. Scale of mapping varied from 1:60 (1 inch equals 5 ft.) to 1:1200.

RESULTS

Trench studies

The 16- and 19-km trenches provided information about the width and sequence of soil bodies in continuous transects across whole landscapes. The lengths involved and the fact that the trenches crossed representative landforms and soil areas makes it unlikely that the samples are biased or too short (White, 1966). As a matter of fact, samples of these lengths were needed before the writer himself was completely convinced that soil bodies narrower than 30 m are common on both glacial till and sandy glaciofluvial deposits.

A representative sequence of soils along the 19-km trench is shown in Fig. 1. This diagram illustrates that soils vary a good deal from place to place both in width and sequence. Where there are two or more contrasting parent materials in close juxtaposition, as in many wet areas, there often is a rather complicated intermingling of soils over a fairly short distance and all detail

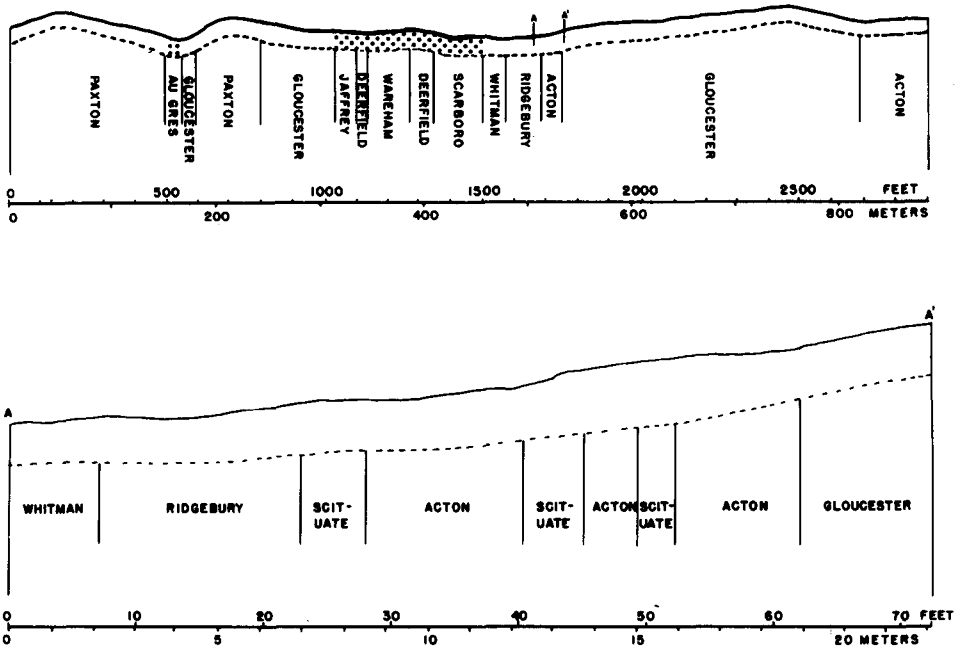


Fig.1. Sequence of soil series along a 0.9-km section of the 19-km trench as mapped at a scale of 1:1200. Stippling shows the location of sand and gravel deposits. The lower diagram shows the location of soil series in the 22-m section *A—A'* as mapped at a scale of 1:12.

cannot be shown even at the scale of 1:1200. A short section (*A—A'*, Fig.1) mapped at a scale of 1:12 illustrates this.

The very narrow character of soil bodies in some places was substantiated many times in the long trenches and also from a detailed study of five short trenches at the Harvard Forest, each extending from dry soils on knolls to wet soils in organic deposits. In each of three 30—36 m long trenches five soils were identified and in each of two 24 m long trenches four soils occurred.

Frequency of soil body occurrence in each of the two long trenches, as grouped by width and moisture classes, is shown in Fig.2. An interesting feature of these diagrams is the high proportion of soil bodies less than 20 m in width irrespective of moisture class.

Soil maps

The trench studies show there are many narrow soils in the ordinary landscapes of southern New England but do not show the pattern of narrow soils and their relationships to one another: soil maps are required for this.

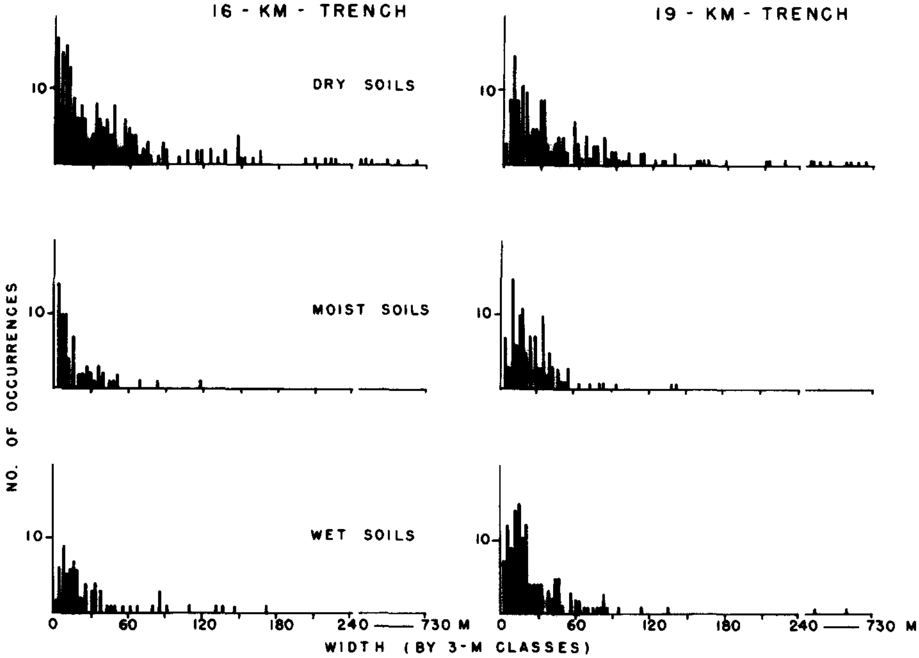


Fig.2. Percent frequency of occurrence of soils along two trenches by widths and broad moisture classes.

Soil maps along the 19-km trench. Soil maps of three farms crossed by the 19-km trench were made by the Soil Conservation Service in 1958 and 1964 before there was knowledge either of the trench or the trench location, and they provide an unusually good opportunity to compare independently made detailed soil maps with soil locations as identified in the trench. The coincidence of soil bodies mapped on aerial photos at the scale of 1:15840 with soil bodies plotted along the trench at a scale of 1:1200 (Fig.3) is extraordinarily good; certainly as good as could be expected considering that the soils were ideally exposed in the trench whereas the soil surveyor used a spade or auger and for the most part was mapping in forested areas.

Soil maps of small tracts. Fig.4 shows an ultradetailed soil map (all soil boundaries located with an accuracy of 3 m) of an 8 ha experimental field in Northwood, Rockingham County, New Hampshire. This map made at a scale of 1:1200 using a 30.48-m grid required about four hours per ha. Two small wet depressions occur in this field and the pattern of narrow soil bodies surrounding these wet spots was easily mapped on the large scale but could not be shown on the published 1:20,000 soil map (Van der Voet, 1959) except by means of wet-spot symbols.

Another ultradetailed map was made of an 1.6-ha area along a drainage-

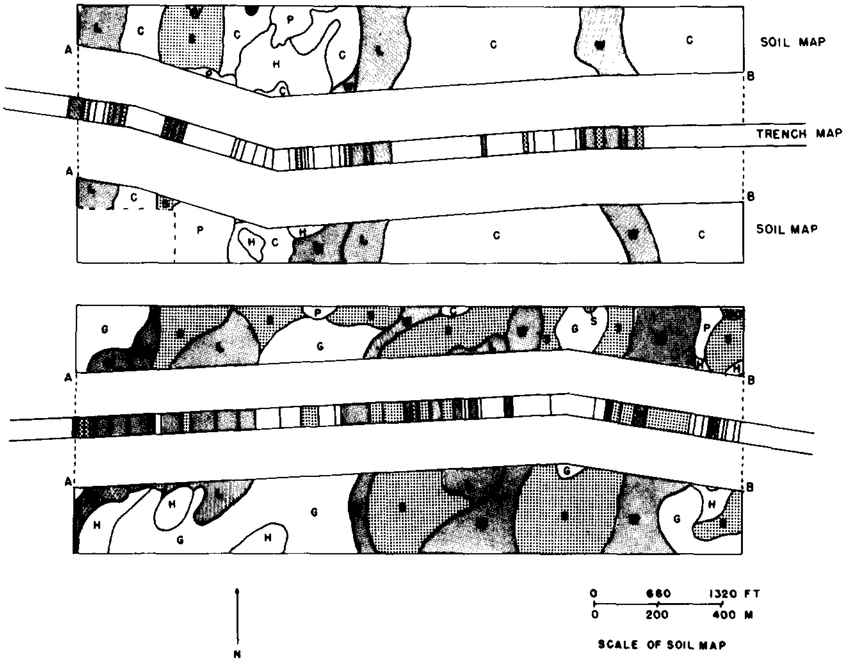


Fig.3. Exploded diagrams of soils in two areas along the 19-km trench showing, in the center portion of each area, the soils as mapped in great detail along the trench at a scale of 1:1200, and, on either side (separated along trench line *A—B* for easy comparison), the soils as mapped on aerial photos at a scale of 1:15840. Lightly stippled areas are wet soils, strongly stippled areas are moist soils, unstippled areas are dry soils. Symbols stand for soil series. *A* = Acton; *C* = Charlton; *G* = Gloucester; *H* = Hollis; *L* = Leicester; *M* = Muck; *MS* = Marsh; *P* = Paxton; *S* = Sutton; *W* = Whitman.

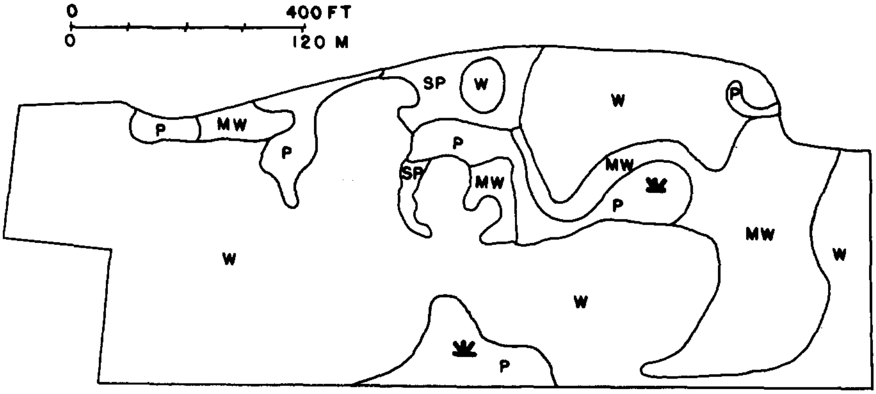


Fig.4. Ultradetailed soil map of 8 ha experimental field in Northwood, N.H., made at a scale of 1:1200. The published map of the same area shows only the two wet-spot symbols. *W* = well; *MW* = moderately well; *SP* = somewhat poorly; *P* = poorly; *VP* = very poorly drained soils.

way in Fremont, Rockingham County, New Hampshire, and is shown in Fig. 5. This map, made at a scale of 1:300 using a 15.24-m grid, is based on the examination of soils in numerous soil pits. Superimposed on this are the soil boundaries shown on the published soil map. Simplicity of the published soil map as compared with the complexity of the ultradetailed maps in striking. Nevertheless, the published soil maps may be just as accurate as the ultradetailed maps; this depends on how the mapping units are defined and described.

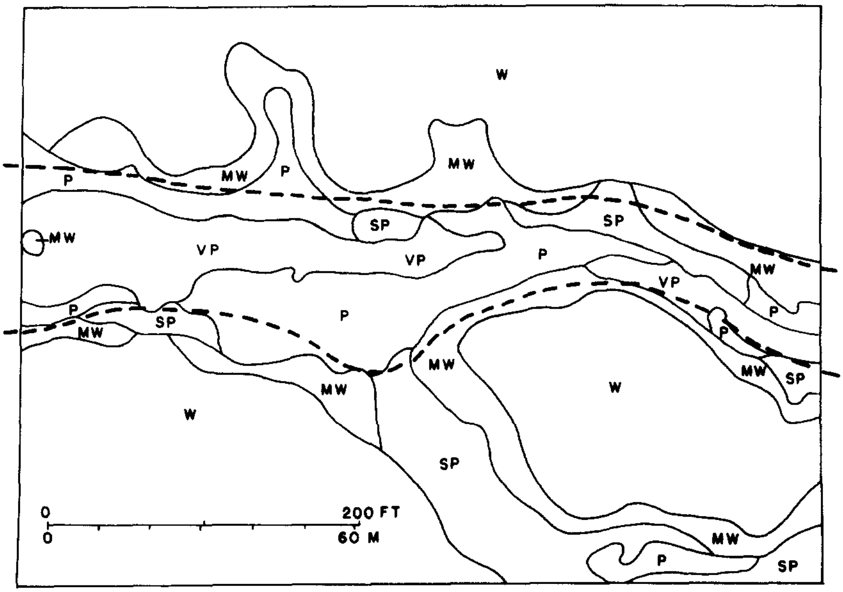


Fig.5. Ultradetailed soil map of 1.6 ha area in Fremont, N.H., made at a scale of 1:300. The dashed lines are the soil boundaries shown on the published soil map. Letter symbols are the same as in Fig.4.

A near-ultimate soil map (no lack of map space, all soil boundaries plotted with an accuracy of 0.3 m) of a 2.4-ha watershed on the Harvard Forest is shown in Fig.6. This was made in part at a scale of 1:60 and in part at 1:240, and a 6.10-m grid was used except in areas of great complexity where a 3.05-m grid was necessary. Approximately 10 to 20 soil examinations with an auger are required in each 6.10 X 6.10 m square in order to trace out soil boundaries with an accuracy of 0.3 m. At the 1:60 scale there is sufficient space on the map to plot individual stumps and stones as well as the exact location of each soil examination. At the 1:120 scale, space is somewhat limited and the mapper finds himself justifying certain shortcuts solely because of lack of map space.

Available time rather than space on the map is the major limitation for the near-ultimate soil map. Approximately one half hour is required to map the

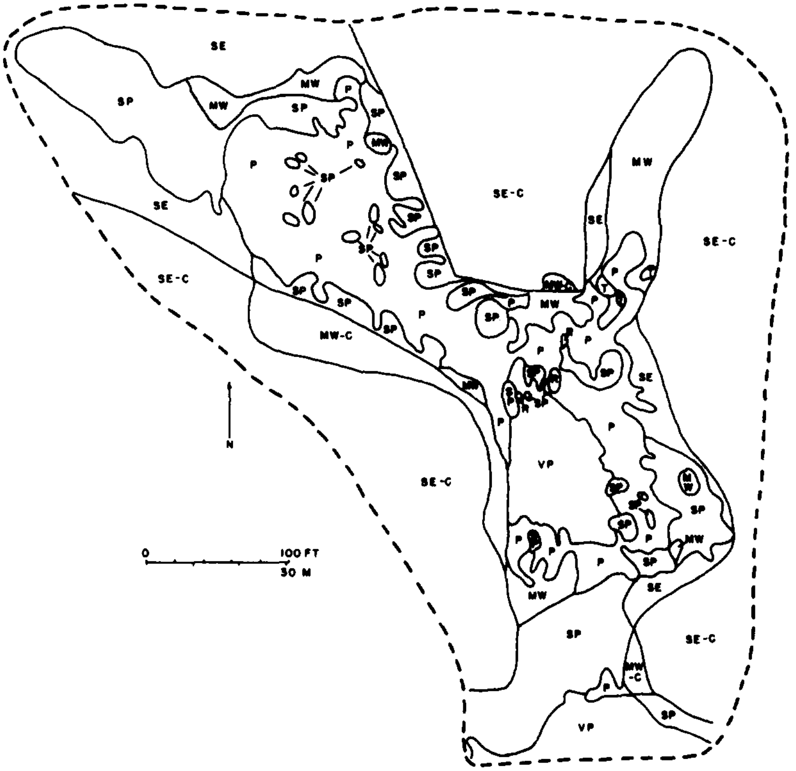


Fig.6. Near-ultimate soil map of a 2.4 ha tract at the Harvard Forest.*SE-C* = somewhat excessively drained, formerly cultivated soils; *SE* = somewhat excessively drained soils; *MW-C* = moderately well drained, formerly cultivated soils; *MW* = moderately well drained soils; *SP* = somewhat poorly drained soils; *P* = poorly drained soils; *VP* = very poorly drained soils; *R* = recent treethrow mounds.

soils in each 6.10 X 6.10 m square in forested areas or about 136 h per ha. Mapping is a good deal more rapid if the areas have been cultivated previously because microrelief is eliminated by plowing and harrowing and the complexity due to mounds and pits is eliminated.

The 1939—41 Harvard Forest soil map of this same area is superimposed on the near-ultimate soil map in Fig.7. The kinds of soils mapped in 1939—41 had broad ranges and were defined to cover three moisture classes rather than the six natural drainage classes shown on the near-ultimate soil map. The correspondence between the two maps is reasonably close considering that the reference points used on the 1939—41 map were paths and stonewalls rather than a precisely surveyed and staked grid and that distances from the reference points were determined by pacing.

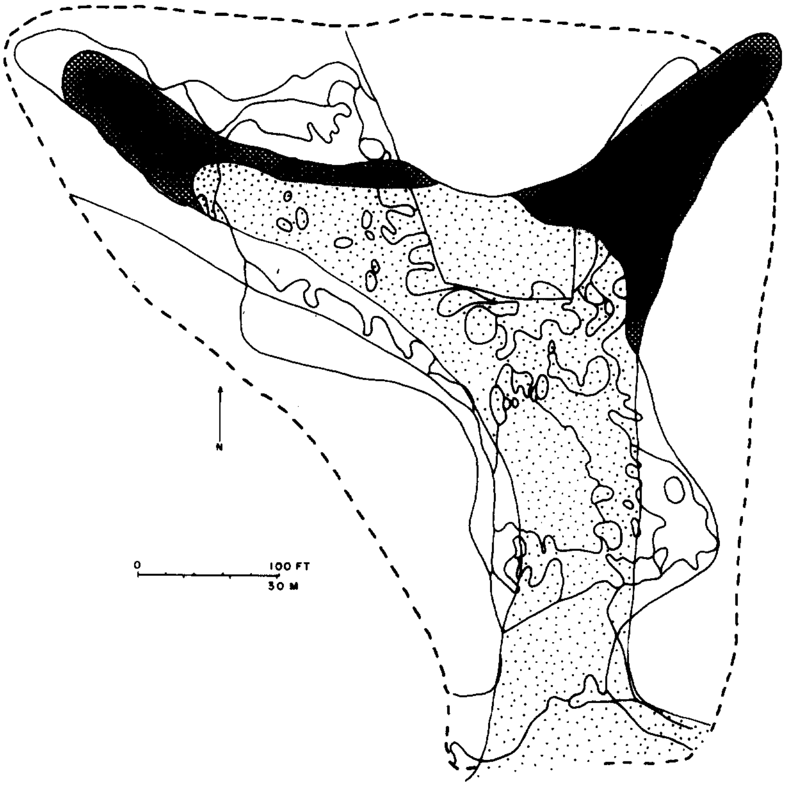


Fig.7. The 1939—41 Harvard Forest soil map of area shown in Fig.6 superimposed on the near-ultimate soil map. Lightly stippled: wet soils; cross hatched: moist soils; plain: dry soils.

DISCUSSION

Roots of some red maples at the Harvard Forest extend outward from the tree base for at least 24 m and some red oaks at least 15 m. Conceivably then, root systems of many large forest trees can occupy areas 30—50 m in diameter, and in those areas where soil patterns are intricate and soil bodies narrow an individual tree root can grow in four or five different kinds of soil. To illustrate this possibility a hypothetical situation is shown in Fig.8.

In general the soil patterns likely to influence root and tree growth strongly in southern New England are ones with marked moisture changes, as at the bases of long slopes or along drainageways. Ideally soil patterns at the bases of long uniform slopes consist of parallel narrow bands of increasingly wetter soils. In the actual landscapes this ideal is seldom achieved, because the narrow bands tend to be discontinuous or to narrow or widen abruptly as a result of local soil variations. For example, the soils around the wet spots in Fig.4 and along the drainageway in Fig.5 are not of equal width, and there is

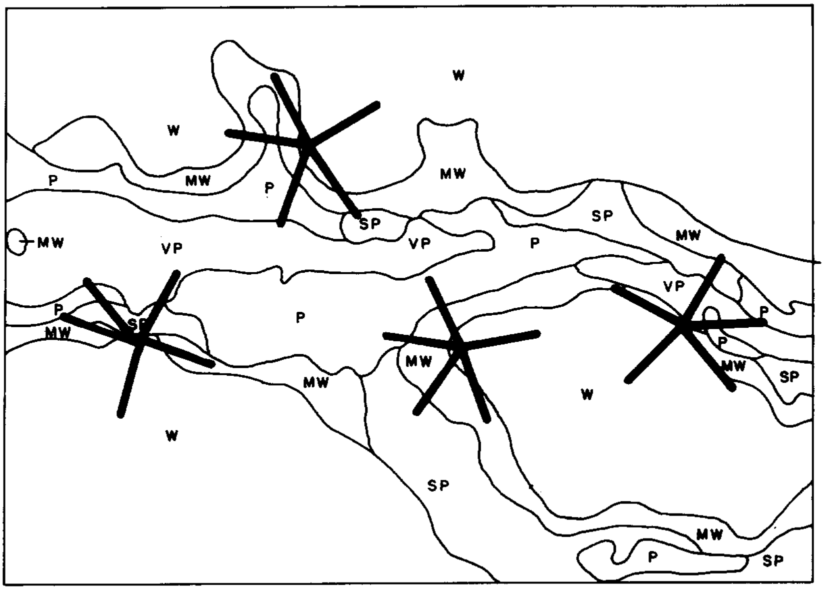
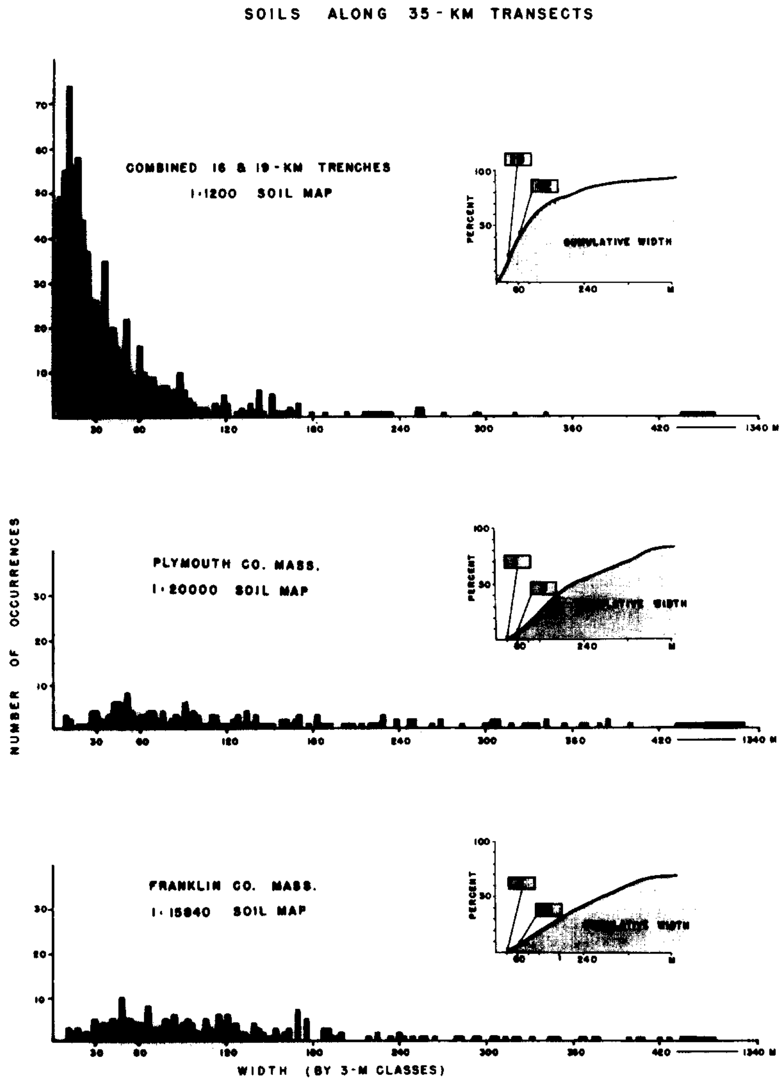


Fig.8. The 1.6-ha tract at Fremont, N.H. (Fig.5), showing locations of four imaginary trees, all on the same soil and each with roots 15.2 m in length. Tree locations are chosen to show how some trees can extend their roots into and across as many as four different soils depending on the soil pattern. (Root widths greatly exaggerated for visual emphasis.)

some discontinuity. This means that a single long root of a tree growing at the edge of a well drained soil could grow successively through well and moderately well drained soils into a poorly drained soil, whereas an adjacent root of the same tree could grow directly from a well into a poorly drained soil.

That soil bodies bordering drainageways or at the bases of slopes tend to occur in long narrow strips with irregular boundaries is well known to all who map soils, but these investigators generally do not have time to work out the boundaries in detail nor could these detailed boundaries be plotted at a scale of 1:15840, the common mapping scale on aerial photos in southern New England, even if they were worked out. As a result there are not many published maps as detailed as the near-ultimate map shown in Fig.6.

Both the ultradetailed and near-ultimate soil maps show that an intricate soil pattern exists in many places and can be mapped. These examples also serve to reemphasize the well known fact that there must be some compromise between scale of map and amount of detail shown. Inability to show all detail on published soil survey maps is illustrated in Fig.9 which provides a comparison of soil widths and occurrences along three 35-km transects. One of the transects consists of all soil bodies mapped along the combined 16- and 19-km trenches. The other two transects are of all soil bodies mapped along 35-km lines drawn across recently published soil survey maps of Franklin Co. Mass. (Mott and Fuller, 1967) and Plymouth Co. Mass. (Upham, 1969).


SOILS ALONG 35-KM TRANSECTS

COMBINED 16 & 19-KM TRENCHES 1:1200 SOIL MAP

PLYMOUTH CO. MASS. 1:20000 SOIL MAP

FRANKLIN CO. MASS. 1:15840 SOIL MAP

Fig.9. Comparison of widths of soils as mapped in great detail along the combined 16- and 19-km trenches with widths as shown along 35-km transects on published soil survey maps of two counties in Massachusetts.

These two counties border the counties where the 16- and 19-km trenches were examined and have essentially the same soils as those along the trenches. In terms of number of occurrences, 56% of the soil bodies in the combined-trench-transect are less than 30 m wide, but in terms of cumulative total width (more easily understood if translated as area) only 19% are made up of soil bodies less than 30 m wide. For soils less than 60 m wide the cumulative total width is 42%. By contrast the cumulative-width curves for transects of published maps show only about 1% of the total width (area) made up of soil bodies less than 30 m wide and 6—7% for those less than 60 m wide. In fact, about half of these narrow occurrences are where the transect lines happen to cross locations where soil boundaries narrow as they pinch out. The other half represent long narrow soils along drainageways.

When using or making soil maps of forested areas in southern New England it is necessary to keep in mind the possibility of soil patterns so intricate in many places that they cannot be shown on published soil maps because of limitations of scale. Perhaps a major deficiency of the 1939—41 Harvard Forest soil map was not degree of detail shown or accuracy of boundaries but rather lack of some means to point out to map users the great complexity within some mapping units. This also may be a weakness in some present-day published soil survey reports. Often the soil mapper himself is not conscious of the complexity that exists because he has learned how to overlook it, or, as in the case of the writer, because he never has had occasion to map in such great detail.

Although all detail cannot possibly be shown on a county-size published soil map, the user should be warned in some manner of the complexity that may exist. To those familiar with the concept of the pedon as the basic soil entity (Simonson, 1968) the soil series name itself implies there is, or can be, a certain amount of complexity in a fine repeating pattern. Where the pattern is coarser the use of two or more series or phase names for a mapping unit is sometimes possible. Even though this calls attention to the complexity it has the disadvantage of a long name.

It is tempting to think that even if all detail cannot be shown on the soil map or if the mapping unit name cannot be completely connotative at least the true relationships can be described. Unfortunately, just as there are limitations of lack of space and time to make soil maps there are also limitations of space for published words and time to write them. Perhaps the best that realistically can be hoped for is to give the average map user a greater awareness than he has now of the complexity that does exist in many mapping units. Possibly this could be achieved by greater use of inserts of large-scale maps of representative portions of small-scale maps. This method is familiar to most readers because it is used so frequently in daily newspapers. Regrettably there is a tendency among users of maps, soil or otherwise, to consider any delineated area on a map as uniform, especially if it has a single color or a single symbol. All too frequently the accompanying description is not read carefully.

But whether or not intricate soil patterns are shown on soil maps or described in accompanying reports they do exist in many forested areas. For some tree species the intricacy may not be important. For other species, growth may be influenced greatly — or, to express it teleologically, "the tree knows it is there".

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