

Estimation of Vegetation-Type Areas by Linear Measurement

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Maps are very useful in providing a picture of the location of vegetation types, but mapping as a method for determining type areas may be inadequate or costly. The measurement of vegetation-type areas by means of line surveys is discussed in the following article, and the method is tested in connection with detailed studies on plots. The results indicate that the method has important advantages over mapping.

UNLESS a map can be checked on the ground, a false impression of its accuracy may be gained. A map purports to show the true area in a vegetation type, but actually its reliability depends much upon the mapper. Even in timber surveys, where the mapping of types is comparatively easy, there is often much discrepancy in classification of types along the common boundary and in the amount of detail shown in strips mapped by different men. An alert crew leader can correct these tendencies in timber surveys. However, in surveys designed to determine changes in areas over a period of time, there is often no opportunity to check the first mapping when the data are used. For example, in conjunction with methods-of-cutting studies, the traditional procedure for determining the changes in brush cover and reproduction stocking resulting from different systems of marking and logging is to map the area, or a sample of it, before logging, immediately following logging, and again after a certain period of time. The areas are planimetered and the differences between maps are attributed to treatment effects. Actually the differences are affected by an appreciable lack of consistency between mappers, and it is not possible to segregate the part contributed by this cause.

Unless expense is no consideration, all parts of an area cannot be examined closely, hence judgment enters into mapping to a considerable extent. Even assuming that judgment as to classification may be correct, or at least unbiased, there is still the difference in the ability of different men to delineate boundaries on a map as they see them on the ground. These personal factors, inherent in mapping, are difficult to evaluate.

LINEAR MEASUREMENT

When ground surveys are used, a promising alternative to mapping is to estimate vegetation-

type areas by application of the linear-measurement method, by which distances through each type are measured along parallel survey lines. These linear measurements are converted to an area basis by using a factor which depends upon the spacing of lines, and the result is taken as an estimate of area in the type.

The linear-measurement method is well adapted to detailed studies of brush and reproduction cover on sample plots. The lines are staked at the first examination and remeasurements are made along these same lines. A carefully defined classification allows little chance of discrepancy between results obtained by different men working independently, and the changes shown by periodic remeasurements will be very close to the true changes along these particular lines. The source of error is thus limited almost entirely to sampling, and this can be evaluated by well-known procedures. The standard error attached to the estimate of area shows how reliable the estimate is, freed from opinion.

The amount of detail recorded along lines can be as much as desired. Distances across brush crowns too small to map can be included, brush composition can be measured by individual species, and open areas can be classified by several criteria used in studying incidence of reproduction. To record such data on a map and then to measure the areas by planimetering would be expensive and difficult. Such detailed map records might be confined to quadrats, but these too would have some of the same disadvantages that apply to the mapping of larger areas. The adequacy of quadrat sampling would be rather difficult to determine.

The linear-measurement method lends itself well to estimating the degree of stocking when the tree-area ratio has been determined. Rather than a fixed area, say anywhere from a milliacre to four milliacres per seedling, the area assigned could vary according to size of seedling. For trees taller than 4½ feet, the standard of full stocking could be based on a method such as has

¹Appreciation is extended to the Work Projects Administration for assistance rendered by statistical workers employed on Project No. 765-08-3-16.

been derived by Chisman and Schumacher,² whereby the space allotted to a tree varies according to diameter at breast height. Any segment of line within an area so allotted would be classed as representing stocked area, and it follows that the proportion of total area stocked by trees of different sizes or ages would be determined.

In connection with applying the linear-measurement method of sampling, the following questions arise: What length of line should be used as a sampling unit? What arrangement of sampling units gives the best accuracy? For a given total length of line—(a) What is the accuracy of estimate of the area in a vegetation type? (b) Given the smallest change in vegetation type area that is considered important, what is the chance of detecting such a change?

In the present study the answers to these questions are sought for an area of 31.2 acres in the mixed-conifer timber type, located in the Stanislaus National Forest. The area was mapped before and after logging in 1929, and again in 1935 after five growing seasons. The maps showed areas in reproduction, in high brush, bearmat (*Chamaebatia foliolosa* Benth.), and open. Full stocking of reproduction was taken as one or more established seedlings or saplings per mill-acre, including sugar pine (*Pinus lambertiana* Dougl.), ponderosa pine (*P. ponderosa* Dougl.), white fir (*Abies concolor* Lindley and Gordon), and California incense-cedar (*Libocedrus decurrens* Torr.). The principal species of high brush were greenleaf manzanita (*Arctostaphylos patula* Greene), whitethorn (*Ceanothus cordulatus* Kell.), deerbrush (*C. integrerrimus* H. & A.), littleleaf ceanothus (*C. parvifolius* Trel.), and Sierra chinquapin (*Castanopsis sempervirens* Dudley).

The 31.2 acres consisted of three plots, each treated differently in cutting. These plots are referred to subsequently as Plots A, B, and C. In Figure 1, Plot A is shown as mapped before logging and 5 years after logging.

The long sides of the plots extended generally at right angles to the elevational contours, and the sampling lines were taken parallel to these sides. On the maps the lines were drawn 3.3 feet apart by scale through each of the three plots for the 1929 (before logging) and the 1935 mapping. Distances through the four classes of cover were scaled and recorded by half-foot units.

When these distances were converted to an area basis, it was found that they differed by less than 0.6 percent from the areas as planimetered for each type in a plot. Since this discrepancy is not greater than would be expected from repeated measurements by planimetry, the area based on lines of this spacing is taken as that to which sample estimates will tend.

ESTIMATION OF AREA

The variability between lines with respect to distance through a vegetation type will govern the number of lines needed to estimate to a given accuracy, or, conversely, the accuracy obtained with a given number of lines. This variability between all lines taken in the plot shown in Figure 1, 1929 mapping, is expressed by the standard deviations shown in Table 1. Other things being equal, such as ease of taking the sample, the best sampling is obtained by using the sampling unit and arrangement of sampling units which gives the smallest standard deviation. Therefore, if total line length is limited to 192 chains in sampling Plot A, the best sampling is obtained by taking two 12-chain units at random within each of the eight 1- by 12-chain blocks.

The method of selecting lines for a sample from a single block is as follows: Since 20 is the total number of lines 3.3 feet apart possible in a block of this size, numbers are assigned to the lines consecutively from 1 to 20, inclusive, and marked on cards, from which, after thorough shuffling, two are drawn at random. The same procedure is followed in selecting sample lines from the other blocks. The estimated standard deviation is calculated from the following formula:

$$(S.D.)^2 = \frac{S(x_1 - x_2)^2}{n} \dots \dots \dots (1)$$

where

S.D. = standard deviation

S = sum over all blocks

*x*₁, *x*₂ = the respective values obtained from the two sampling units in a block

n = the number of sampling units

If time and funds allow for measurements along 384 chains of line, the best method of sampling indicated in Table 1 is to take two 12-chain lines at random within each of sixteen 1½- by 12-chain blocks. Thus, the area is divided into one-half as many blocks as there are sampling units.

²Chisman, H. H. and F. X. Schumacher. On the tree-area ratio and certain of its applications. Jour. Forestry 38:311-317. 1940.

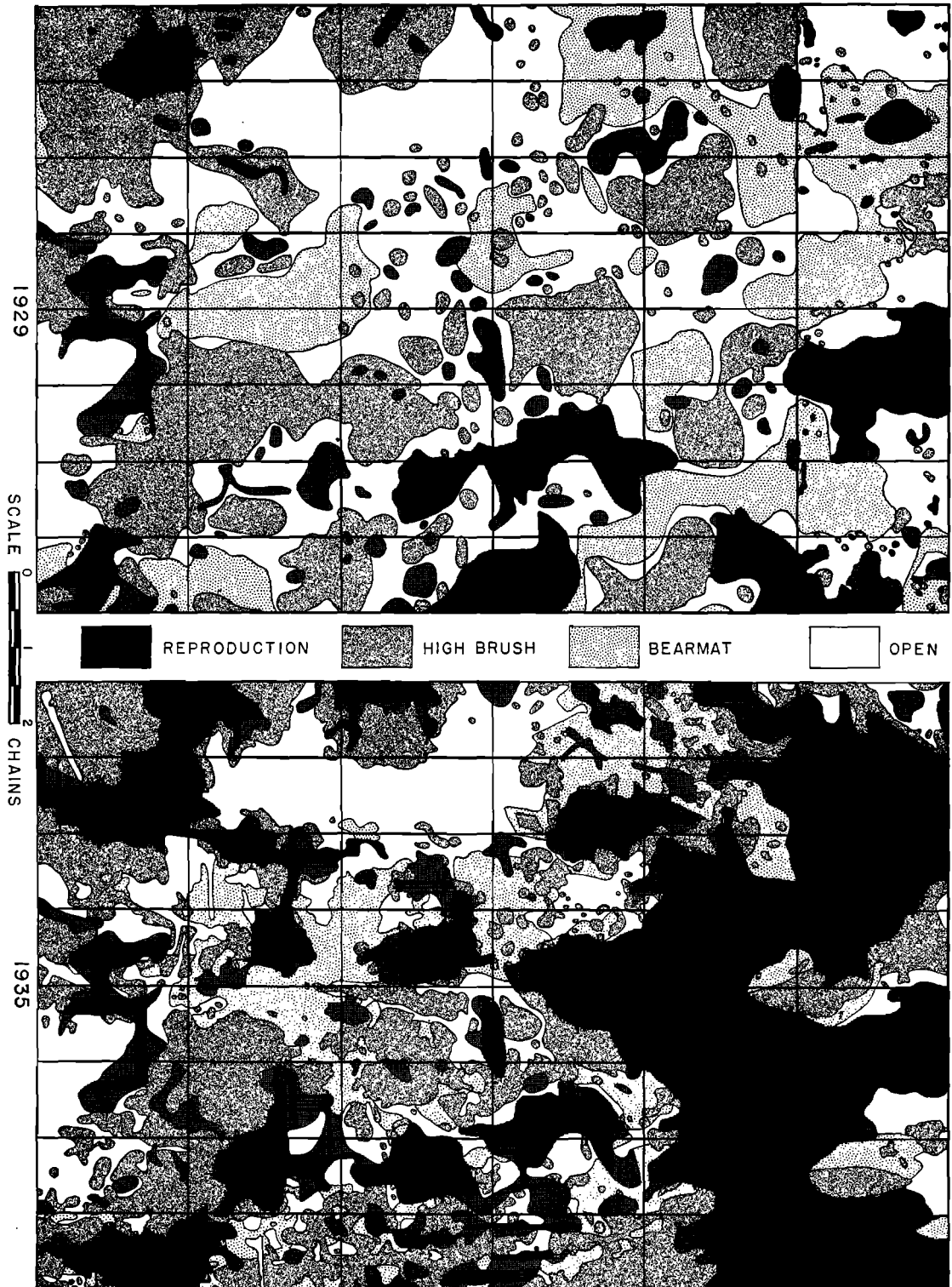


Fig. 1.—Vegetation-type maps of Plot A; mapped before logging in 1929, and five seasons after logging in 1935.

TABLE 1.—BASIS FOR SELECTION OF SAMPLING UNIT SIZE AND ARRANGEMENT
Based on lines spaced 3.3 feet apart in Plot A

Sampling unit	Degrees of freedom ¹	Vegetation type			
		Reproduction	High brush	Bearmat	Open
		Standard deviation ²	Standard deviation ²	Standard deviation ²	Standard deviation ²
12-chain line	159	68	64	55	60
4-chain line	479	61	69	72	64
2-chain line	959	58	70	63	66
Total variability					
12-chain line	152	35	40	31	42
4-chain line	472	51	63	68	60
2-chain line	952	53	67	61	64
Variability within 1-by 12-chain blocks ³					
12-chain line	144	26	31	24	31
4-chain line	464	49	62	67	58
2-chain line	944	52	60	60	63
Variability within ½-by 12-chain blocks ⁴					

¹The number of observations less the number of means from which deviations are calculated.²In terms of half-foot units per 2 chains. The squares of the standard deviations are the mean squares in analysis of variance.³Containing twenty 12-chain lines per block.⁴Containing ten 12-chain lines per block.TABLE 2.—ACCURACY OF SAMPLE ESTIMATES OF VEGETATION-TYPE AREAS
Based on Plots A, B, and C with a total area of 31.2 acres

Vegetation type	Mean ¹	52 12-chain lines, 2 in each 1-by 12-chain block			104 12-chain lines, 2 in each ½-by 12-chain block		
		Standard deviation	Standard error	Sampling error ²	Standard deviation	Standard error	Sampling error ²
Reproduction	304	85	11	Percent of mean	69	6	Percent of mean
High brush	333	88	12	7.2	65	6	3.9
Bearmat	288	81	11	6.9	58	5	3.4
Open	659	115	15	7.3	81	7	3.5
				4.6			2.2

¹In terms of half-foot units per 12 chains.²Range from the mean, 19 in 20 trials.

In this study the blocks are rectangular in shape and the lines are all of equal length, but this is not necessary if lines are properly weighted in the calculations.

The accuracy of the sample estimate of area is determined from the following formula for the standard error of a mean:

$$(S.E.)^2 = \frac{(S.D.)^2}{n} - \frac{(S.D.)^2}{N} \dots \dots (2)$$

where

S.E. = standard error of a mean

S.D. = standard deviation

n = the number of sampling units

N = the number of sampling units possible

In the present study N is taken as the number of parallel lines possible with 3.3-foot spacing.

The three plots were comparable with respect to vegetation-type areas before cutting. The standard deviations for each type may therefore be based on the combined data from all plots.

The standard errors applicable to sampling 31.2 acres are shown in Table 2 for the two different intensities of sampling used. The sampling error is obtained by doubling the standard error and is expressed in percentage of the mean. It gives the range from the true mean expected in 19 out of 20 trials. The reduction in sampling error expected by doubling the intensity alone would be 29 percent. In this case the reduction amounts to about 50 percent because of the added precision gained by taking smaller blocks.

ESTIMATION OF CHANGE

In mapping vegetation types, the purpose is usually to determine changes in type areas over a period following treatment. In the present study these changes varied considerably in the plots representing the three different treatments.

Within plots the changes along lines tended to be greater if the initial distance through a type was large. The lines were equalized in this re-

TABLE 3.—CHANCE OF DETECTING A CHANGE OF 20 PERCENT IN VEGETATION-TYPE AREA BY TAKING LINEAR MEASUREMENTS ALONG TWO 12-CHAIN LINES PER 1- BY 12-CHAIN BLOCK

Vegetation type	Original distance through type ¹	Change of 20 percent ¹	Standard error of difference ¹	Probability of detecting change at 0.05 level of significance
		Plot A, 9.6 acres		
Reproduction	287	57	21	0.78
High brush	446	—89	17	0.99
Bearmat	284	—57	16	0.94
		Plot B, 10.8 acres		
Reproduction	291	58	25	0.68
High brush	300	—60	21	0.83
Bearmat	304	—61	14	0.99
		Plot C, 10.8 acres		
Reproduction	331	66	19	0.93
High brush	266	—53	22	0.70
Bearmat	276	—55	12	0.99

¹Number of half-foot units per 12-chain line.

TABLE 4.—CHANCE OF DETECTING A CHANGE OF 10 PERCENT IN VEGETATION-TYPE AREA BY TAKING LINEAR MEASUREMENTS ALONG TWO 12-CHAIN LINES PER 1/2- BY 12-CHAIN BLOCK

Vegetation type	Original distance through type ¹	Change of 10 percent ¹	Standard error of difference ¹	Probability of detecting change at 0.05 level of significance
		Plot A, 9.6 acres		
Reproduction	287	29	12	0.70
High brush	446	—45	10	0.99
Bearmat	284	—28	8	0.93
		Plot B, 10.8 acres		
Reproduction	291	29	13	0.65
High brush	300	—30	12	0.73
Bearmat	304	—30	8	0.96
		Plot C, 10.8 acres		
Reproduction	331	33	9	0.95
High brush	266	—27	12	0.65
Bearmat	276	—28	7	0.97

¹Number of half-foot units per 12-chain line.

spect by covariance analysis³ and the standard deviation of the change per line freed from this effect. In all cases a significant reduction in value of the standard deviation was obtained by this procedure. For future periodic changes in these plots, it is likely that the number of points at which a line enters or leaves a type will be useful as an independent variable in equalizing conditions along lines, since the number of such points will provide a relative measure of the perimeter or distance along which a type can either extend or decrease.

The standard deviation of the change per line, using all lines, was taken in formula (2) to determine the standard errors to which sample estimates would tend. The criteria used for judging the successfulness of each method of cutting were arbitrarily set at a minimum increase of 20 percent in the area stocked with reproduction and a

minimum decrease of 20 percent in the brush and bearmat covered area. The changes, as mapped, varied greatly from 20 percent, particularly in the reproduction cover where the changes were +150 percent, +83 percent, and —27 percent for Plots A, B, and C, respectively. The corresponding standard errors shown in Table 3 are 21, 25, and 19. For this type and the brush and bearmat types as well, the standard errors were fairly constant within a type and bore no significant relation to the amount of change that occurred. They may therefore be applied to the changes of 20 percent which are to be detected. Following Neyman,⁴ the chances of detecting changes of this magnitude and in the directions indicated, were calculated and are shown in Table 3. The chance of detecting them with this intensity of sampling is reasonably good in most cases. If determination of either a positive or a

³Snedecor, G. W. Statistical methods applied to experiments in agriculture and biology. pp. 219-241. Ames, Iowa, 1937.

⁴Neyman, J. Lectures and conferences on mathematical statistics. pp. 60-61. The Graduate School of the U. S. Dept. Agriculture, Wash. 1937.

negative change is to be made, neither being specified in advance, the tables given by Tang⁵ would apply. The probabilities in that case would be somewhat lower.

If a change of 10 percent is taken as the least that is considered important, the results in Table 4 indicate that by taking two lines per $\frac{1}{2}$ - by 12-chain block, the chances of detection will be satisfactory in general. Surely very few treatments could be considered worthwhile if their effect on a vegetation-type area would be less than 10 percent.

DISCUSSION

So far as sampling experimental plots is concerned, the results based on maps of the Stanislaus plots indicate that the linear-measurement method is entirely feasible. A check on the application of the theory, based on 30 independent samples, showed that the spread of sample means about the true mean corresponded with the spread expected from the standard errors derived in this study. In field practice too, the method has proven to be entirely feasible. It was used in a northern California brushfield in 1939 to estimate the extent to which brush cover had come back on areas that had been cleared in 1936 by three different methods, i.e., by fire alone, by burning and then stripping with a bulldozer, and by bulldozer stripping alone. Distances across brush crowns were recorded by species, and measurements were taken to determine the average maximum height of each species. Without previous training or experience with the method, two men were able to run 2 miles of line a day, one-third of which was through the burned-unstripped area where brush up to 5 feet in height had taken control of most of the area and the dead stems from the original brush further impeded travel. The object was to measure the relative amount and kind of competition to planted seedlings on areas treated by the different methods. In methods-of-cutting plots in the pure pine type, the method has been used for the past 2 years in a total of ten 20-acre plots, each 10 by 20 chains in dimensions. At the start a grid of closely spaced lines was run through a plot, much the same as with the Stanislaus plot maps, to determine the best method of sampling and the intensity needed. It was found that the

longest line used, e.g., 20 chains, was at least as efficient as smaller sampling units. Before logging, the measurements included distance through various classes of brush, stocked areas, stockable areas, and unstockable areas. After logging additional detail was recorded, such as skid trails, litter disturbance, and areas burned over in slash disposal. On this work a two-man crew completed 2 to 3 miles of line a day. Tests obtained by having different men work independently showed almost perfect agreement in results.

Line sampling is much less costly than mapping. For the plot illustrated in Figure 1, it is apparent that 384 chains of line would give estimates of areas and changes within the limits of accuracy required for most purposes. The time required to take this amount of line would be about 3 days, as compared to mapping time of 10 to 12 days. The map would include more detail than is shown in Figure 1, but not as much as could be obtained by line sampling. Office compilation of data from line sampling can be accomplished more quickly and with less chance of error than is possible in drafting and planimetering maps.

If larger areas were under consideration, the intensity of sampling could be decreased with assurance of maintaining the same accuracy shown for 10-acre plots. In sampling areas in timber types the unit of measurement could be much coarser than in sampling brush and reproduction areas, since the boundaries are less definite. The difficulty of making boundary decisions would not be eliminated, but would be less than in mapping. The scale in Figure 1 could be changed from chains to miles and the corresponding average line spacing of one-quarter mile would give accurate estimates applicable to 96 square miles. If a map was needed to outline the location and extent of the major types, these and other features could be sketched in from the line survey with little loss of time.

The advantages of linear measurement compared to mapping will apply also in grazing studies made to estimate areas in different forage types, to estimate forage composition, condition, and density within types, and to detect changes occurring with time and treatment. Similarly in erosion surveys, vegetation cover and soil surface conditions and changes can be inventoried more easily, cheaply, and with less likelihood of bias from personal causes than by mapping on ground surveys.

⁵Tang, P. C. The power function of the analysis of variance tests with tables and illustrations of their use. Statistical Research Memoirs, Dept. Statistics, Univ. of London 2:126-149. 1938.

On range and watershed inspections, made to determine the efficacy of management practices in maintaining or improving forage yield and in controlling erosion, a small amount of time devoted to taking measurements along permanently staked lines would yield specific information

from which inferences could be made. Observations alone, extending over a period of time and thus likely to be made by different men, may not lead to detection and correct interpretation of soil and cover changes unless the changes are quite pronounced.

Growth-Form Variation in Black Locust and Its Importance in Farm Planting

Henry Hopp

The occurrence of distinctive growth-form variation among native tree species is a matter of frequent observation. Study of such variation offers the possibility of selecting promising types for the genetic improvement of tree planting stock. In the case of black locust (*Robinia pseudoacacia* L.), variation in growth-form is a notable character.

ELLIOTT (5) comments on the variability in black locust by saying that it is a very "capricious" tree, some open-grown trees being "tall" while others "separate and throw out branches low down." In many black locust stands, undesirable tree-form cannot apparently be attributed to adverse soil conditions, since even where growth is rapid and vigorous the trees may possess such a poor, crooked shape as to be of little financial value. In extreme cases, the trees are so crooked and forked that it is almost impossible to obtain even one straight fence post from an entire grove. There are, on the other hand, forms of black locust that grow straight and free of forks. Crumley's observations (4, pp. 290-294) indicate that such variation may be inherent. Judging from Hall's studies (8), it appears that stands of straighter, faster-growing forms may be more resistant to injury by the locust borer (*Cyrtene robiniae* Forst.) than crooked forms.

In order to evaluate the importance of growth-form variation as a basis for selecting genetic types, a large number of mature black locust stands have been examined in the eastern United States.¹ Most of the stands examined were located outside the native range of the species and had developed from old plantings. This exploratory study has shown that most black locust trees

can be classified into three major groups, based on the dominant character of the tree appearance regardless of site influences. These groups are designated by the writer as the pinnate, spreading, and palmate growth-forms. The terms describe the distinctive appearance of the forms when growing in the open.

In judging the genetic significance of the three growth-forms, it is necessary to rely on whatever field evidence can be accumulated from existing stands until such time as experimental plantings have matured. Hence special effort has been made to find tracts where two or three forms are growing side by side or within short distances of each other. So far, such instances have been found at fifteen different locations in ten states. At eight of these locations, the pinnate and spreading forms were present on the same area, while in the other seven locations, the spreading and palmate forms were found together.

Inquiry from the landowners as to the source of the stock revealed in two cases, at Sandwich, Mass., and New Bloomfield, Pa., that the forms had arisen from stock of separate origin. Although further evidence is desirable, these few instances are important in showing that the three different forms will develop under what are apparently comparable site conditions. As additional indication that their occurrence is not dependent on specific environments, it is also significant that these forms have been observed recurring on a variety of sites over a wide geographical range. Judging, therefore, from the evidence available, it seems likely that these

¹During the course of this survey many field technicians have aided the writer in locating stands for study and in making measurements. Since the number of people who helped in this investigation is so large that their names cannot be given separately, this means is taken to acknowledge their assistance and to thank them collectively.