Application of the Line Interception Method in Sampling Range Vegetation

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The line interception method as herein described is designed for measuring density and composition of herbaceous vegetation and shrubs. It is based primarily on the line transect. However, it incorporates a new technique for obtaining an inventory of the vegetation by line measurement of individual plants on a randomly selected sample. It appears to offer a practical, rapid and statistically sound means for sampling vegetation on both large and small range areas, as well as on small plots used in detailed and intensive studies. Field tests have demonstrated that subjective influences are largely eliminated as factors affecting inventories so obtained. The method while primarily developed for range studies should also serve equally well to measure minor vegetation and stands of reproduction in forests.

THE line interception method may be defined as a method of sampling vegetation based on the measurement of all plants intercepted by the vertical plane of randomly located lines of equal length. The method, as outlined in the foregoing definition, is in effect a streamlined model of the line transect.[2] New features which have been added to the line transect include schemes for the measurement of plants and randomization to insure a statistically sound basis of sampling. After a period of extensive testing, the line interception method is now recommended for consideration along with other methods commonly used in making botanical inventories and ecological appraisals of plant populations.

Description of the Method

The line interception method is based on a foundation comprised of three basic considerations which are enumerated as follows:

1. The sampling unit is a line transect which is visualized as having length and vertical dimensions only. No lateral dimension, or width, is included.
2. The direct measurement of the intercept of the plants through which a vertical plane of the line must pass.
3. The random basis of the estimate obtained through randomization in the locations of the sampling units.

The sampling unit.—The course of the line that constitutes the sampling unit of the line interception method is laid out in the manner illustrated in Figure 1, A. Equipment needed for laying out the sampling unit includes a multiple-strand wire line 3/64-inch in diameter and two stout ½-inch iron pins 18 inches or more long, used for pegging the line in place. The pins should be pointed at one end to facilitate driving. The wire line should be equipped with iron rings securely fastened at both of its ends. These rings should be large enough to slip easily over the pins. When stretched tight and pegged in place, this wire marks the course of the line of the sampling unit to be measured. A 2-pound hammer for use in driving the pins completes the equipment.

Direct measurement of vegetation.—One of the principal advantages of the line interception method is that it is a method of sampling vegetation which is based on actual measurement of the plants growing on randomly located and clearly defined sampling units.

By direct measurement of small samples it is proposed to obtain estimates of known reliability concerning the vegetation, its composition, density, and ecological structure.

A measurement of density is made on all plants growing directly over or directly under the line. This measurement includes only the intercept of the vegetation encountered, as illustrated in Figure 1, B.

Equipment required for making measurements of density and composition of the vegetation is an ordinary ruler or a 5-foot collapsible steel pocket tape. The graduation of the measuring device may be either English or metric. A ruler or steel tape, marked in feet and tenths on one edge and in the metric graduations on the other edge, probably is best for all purposes. A tatum holder or a clipboard of suitable size for holding

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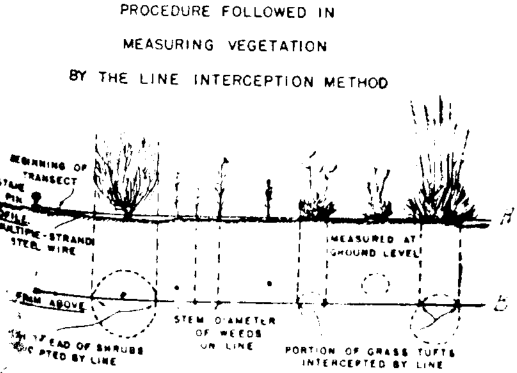
[1] Maintained by the Forest Service, U. S. Department of Agriculture, for Arizona, New Mexico, and West Texas, with headquarters at Tucson, Arizona.

[2] Weaver and Clements. Plant ecology. First edition, p. 23. McGraw-Hill. 1929.

the forms on which the measurements are recorded will contribute to neatness in field records.

The random sample.—The locations of all lines to be measured (sampling units) are determined by random selection. This device of randomization is used instead of purposive selection in order that all hidden factors which may influence the values of the sample may be eliminated through the free operation of the laws of chance. In this category the two most common unrecognized sources of bias are the influence of invisible differences of place (soil fertility, etc.) and the inherent human tendency toward prejudiced decisions that is present to some degree in almost all cases of personal judgment. In a randomly selected sample each possible place, whether good, poor, or about average in quality, has an equal and independent chance of being selected each time a location is made.

The first step in sampling an area of vegetation is to decide whether the distribution of the sampling units will be governed by pure chance (completely random, and let the locations fall where they may) or whether the distribution of sampling units within the area will be restricted. When pure chance is relied upon, there may be occasions when one part of the area apparently receives more than its share of the sampling-unit locations. If this condition is present, the psychological effect of an apparently lopsided distribution of sampling units is not likely to be one that would tend to increase confidence in the outcome of the sample. On the other hand, the equalizing effect of a restricted distribution of sampling units tends to prevent an apparent disproportional spread in sampling-unit locations. The best equalizing effect is achieved with a representative sample. This type of sample is one in which the area is divided into a number of equal-sized compartments and each compartment assigned the same number of sampling units. In this manner visible grounds for distrust can be eliminated. From a statistical viewpoint, representative sampling is a sound practice and usually increases the reliability of the sample as measured by statistical tests. Compartments in the representative sampling scheme may be of any desired size.



1.—Sketch showing a segment of the measured (sampling unit). *A*, As it would appear to the observer in the field. *B*, The projected intercept of each plant to be measured.

There are several ways in which the random location of sampling units may be determined. One way that has been used with success is based on the intersection of perpendiculars erected from randomly located points on the x and y axes of rectangular coordinates. This method is illustrated in Figure 2.

A compartment taken from a representative sample is shown in Figure 2. It represents one section of land in which the two allotted sampling units have been located. Although a section of land is used as an example, the area of the compartment is not an essential point. Whether a few feet or several hundred acres are involved, the procedure to be followed in locating sampling units is the same. The axes of the coordinates are laid out on the south and west boundaries of the compartment. Then the location of each sampling unit is determined independently from two randomly located points—one on the abscissa and one on the ordinate. The intersection of perpendiculars (broken lines, Fig. 2), erected from these points on the x and the y axes, designates the beginning of the sampling unit. In Figure 2 the distances are indicated in chains and links.[3] Example: Sampling unit No. 1 is "up" (north) 18 chains and 42 links, and "over" (east) 66 chains and 51 links, both distances determined by separate randomization and reckoned from the zero of the coordinates. From these locations the sampling units are laid out in a predetermined cardinal direction. The process is repeated for each sampling unit until all locations have been determined.

Such field experience as is now available indicates that within large areas sampling units may be located in the field by rough surveying methods without impairment of the essential randomness of the sample. In this respect, provided a

[3] A surveyor's chain contains 66 feet and is subdivided into 100 links of 7.92 inches each. Also, 80 chains equal 1 mile. Any other system of linear measurement may be used instead of the surveyor's chain.

consistent standard of accuracy is maintained, the hand compass and pacing appears to be sufficiently accurate for this purpose. In order, however, that the choice of the exact beginning point of the sampling unit may not be subjectively influenced it is recommended that the ultimate, chain or fractional chain, of the course be measured with a tape-measure.

Basis of the Linear Sample

How the line is laid out may be described as a simple operation, but why the sampling unit of this form is preferred requires a more thorough explanation. In the first place it has been observed by various workers that size and conformation of plots influence the efficiency of the sample. [In general, oblong and oval plots have proved to be more efficient than square or round plots of equal area.] Length apparently is the factor that gives the oblong plots their superiority.[4] Personally conducted tests indicate that length of plot contributes greatly to the amount and the reliability of information obtained from the sample. In using a line as the unit of sampling, this factor (length) is developed to the maximum. It is also reasoned that a line, by virtue of its greater length, not only increases the likelihood of encountering *a greater number of plants* but also increases the chances of encountering *more kinds of herbage* than would be expected in the shorter more compact rectangular plot. It is a matter of common observation that unusual conditions in the distribution of vegetation seldom follow straight lines; therefore, the chance of measuring a disproportionate share of the unusual, such as the occasional group or family of plants, is reduced by using a long, narrow sampling unit.

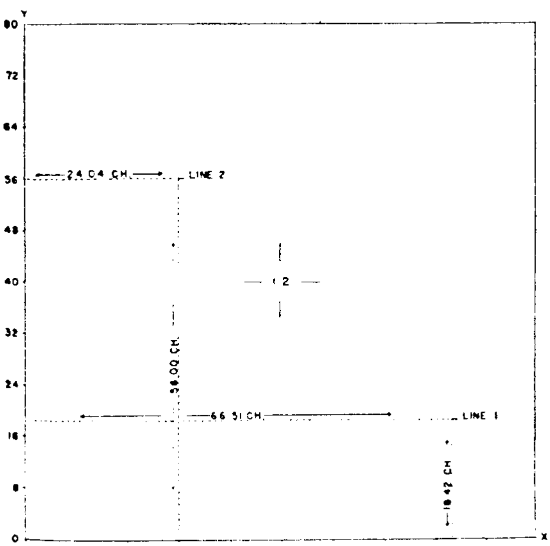


Fig. 2.—Showing the manner in which random locations are made from points on the x and y axes of rectangular coordinates.

Length of line.—The various lengths of line that may be required to give a reliable sample under all of the many conditions that are encountered in sampling range vegetation have not as yet been determined. It is known that the scarcity or abundance of plants and the degree of heterogeneity in their distribution influence the length of line requirement. Such information as is now on hand indicates that a 50-foot line is long enough for sampling areas with 5 to 15 percent ground cover, whereas in sparsely vegetated areas, with from ½ to 3 percent ground cover, a line 100 feet long gives the best results.

Experience with the 50- and 100-foot lines does, however, suggest an empirical rule; that is, the length of line which can be marked out and measured within a 15-minute period by a pair of reasonably efficient workers is more than likely to be a line of sufficient length.

Numbers of lines.—The number of observations required for a reliable sample varies with the heterogeneity of the vegetation rather than with the size of the area. In any event, to provide sufficient data for the estimate of experimental error, not less than 16 sampling units should be measured for each area to be sampled. Preliminary statistical tests (relative magnitude of standard error and Fisher's "t"),[5] made with 16 or more observations, will give an indication of how large the sample should be in order to attain a given degree of reliability. Computation of the sample mean and its standard error can be accomplished quickly in the field if necessary. In the majority of cases range samples attain a high degree of statistical reliability with less than 100 sampling units. It should be noted that the size of the area has relatively little effect on the number of lines required for a reliable sample. It is usually a bit startling at first to learn that a plot ¼-acre in area may require as many lines for the same degree of precision as does a grazing allotment containing many hundreds of acres.

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[4] Dendrinos, Ath. D. The question of the shape of plots in field experimentation. Translation of Extrait du Bulletin de l'Association internationale des selectionneurs de plantes, Vol. IV, No. 1.

[5] Fisher, R. A. Statistical methods for research workers. 7th Edition. Oliver and Boyd, London. 1938.

Measurement Technique

Density and composition.—As indicated in Figure 1-B, linear measurements are made of the intercepts of vegetation through which the vertical projection of the line must pass. Density of grasses, grass-like plants, rosette-forming plants, and weeds are measured on the line at the ground surface. There are several reasons for designating this region of these plants as the point where measurements should be made. These are:

1. The ground surface is a definite point and readily located.
2. Measurements made at the ground surface give a measure of the plant in terms of ground occupied to the exclusion of the other plants.
3. Plants are more compact at the ground surface.
4. Compression or expansion of the tuft during the process of measurement is less likely to occur.
5. Grazed plants are as readily measured as are the ungrazed ones.
6. Dead and living portions of the tuft can be recognized easily and measured separately.
7. Stage of plant development affects the area covered by the basal portion of these plants less than it does the area of the spread higher up on the plant.
8. Whether the plant is measured during a period of active growth or in a dormant stage should make little difference in the ground surface measurements.
9. The composition estimate based on such measurements is not influenced by the relative height, brightness of color, or other characteristic that contributes to the conspicuousness of the plants.
10. By this method of sampling, the relatively scarce plants (both large and small) have a proportionally equal chance of being included in the sample.[6]

Shrubs and half-shrubs, on the other hand, are measured on the crown-spread intercept. This different point of measurement definitely places the browse sample in a separate statistical universe. The apparent discrepancy in the designated regions of measurement on the grasses and weeds and the browse plants is a condition that is shared by all methods that are commonly used in the measurement of forage plant densities. Insofar as the line interception method is concerned, plants may be measured at any point occurring within the vertical plane of the line. In this particular case the aim has been to designate a point at which a consistent degree of accuracy in measurement can be maintained. The ground-level measurement of grasses and weeds and the crown-spread measurement of shrubs meet this specification. A measure in terms of absolute density (degree of complete occupancy of the ground surface) is obtained for grasses and weeds. Browse measurements are not always so definite as that for grasses and weeds. In very dense stands of browse where the crown cover is closed, the crown spread should represent the absolute density. But in sparse stands of browse this condition would not be true. On the other hand, stem diameter of browse is obviously a poor measure of forage cover. Crown-spread measurements do, however, give a good estimate of the relative abundance of the browse and the amount of ground beneath the shelter of such plants.

Use of either standard systems of measurement is largely a matter of personal preference. The foot scale is the logical method to use when the line to be measured is in terms of feet. On the other hand, for the sake of consistency, a line laid out in metric units demands metric measurement of the vegetation.

Measurement of individual plants should be read to the nearest one-hundredth of a foot or the nearest ¼ centimeter as the case may be. All measurements are recorded by species or classes on an appropriate form.

Field records.—Unless each species of plants is recorded separately, data obtained by the line interception method may easily become a confusing array of figures. Confusion and errors may be avoided by using a suitable form and thereon recording the measurements of plants as they are made in the field. A reproduction of a form used for recording data obtained in sampling density and composition is presented in Figure 3. This field sheet contains all of the data pertaining to one sampling unit comprised of a line 50 feet long. Measurements were made in feet and the readings were recorded to the nearest one-hundredth of a foot. Different species of plants and the different classes of vegetation are entered in separate columns in the record. Note that all the numerical data on the sheet can be summed quickly.

Field and office personnel requirements.—The personnel requirements for field work are com-

[6] Klapp, E. Methods of studying grassland stands. (Translation of an article in Rep. 3rd. Grassl. Conf. Zurich. pp. 193-202. Zurich, 1934.)

paratively low in regard to numbers of men and their previous training. Two men constitute a field crew of maximum efficiency. In an emergency, small areas can be handled by one man working alone. The education and training requirements for field crews include but two essentials. A field examiner should be able to identify the common plants of the region in which he proposes to work and should be able to use an ordinary foot ruler or a metric scale in making linear measurements. Training of a crew in the use of the line interception method ordinarily can be completed in 1 day in the field at most. In most cases a little practice in measuring the plants is all the training that is necessary to develop skilled operators. The choice of office personnel must be based on more exacting standards in education and training. In this case, a fair knowledge of arithmetic and statistical procedure is essential. A competent statistical clerk equipped with a calculating machine can complete the compilation and computations necessary for a statistical analysis of the data included in a sample of moderate size (40 to 80 sampling units) within the period of 1 working day.

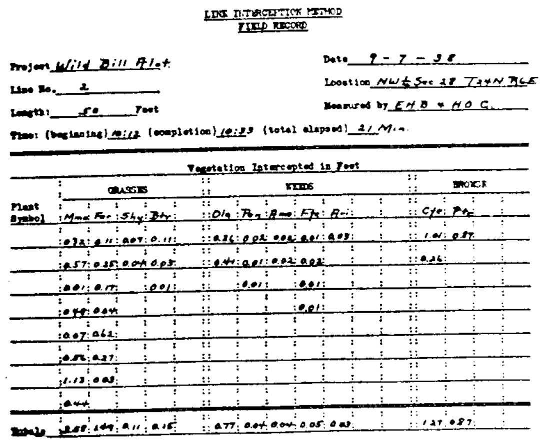
Application of the Method

It has been the aim during the development of the line interception method to devise a means of sampling areas of vegetation based on actual measurement of the plants concerned, these measurements to be made in a manner that insured reliable estimates of plant density and vegetational composition and, by slight adaptations, to obtain measurements of forage productivity and the degree of grazing use. Also included in this objective were the goals of increased accuracy and lower costs of sampling, the over-all purpose being to perfect a usable and economically feasible method of measuring herbaceous vegetation that would be workable under conditions encountered in the collection of quantitative and qualitative ecological data on extensive areas such as are commonly used in large-scale grazing experiments.

Efficiency of this method has proved to be extremely high in several cases where it has been tried by members of the staff of the Southwestern Forest and Range Experiment Station.[7]

Laboratory and field tests for reliability of the method made under controlled conditions include the checking of estimates obtained from line samples against known areas on maps and the remeasurement of lines in the field. Such discrepancies as were revealed by these comparisons were slight in all instances.

An example of the application of the line interception method is presented in Table 1. These data represent a summary of all the measurements obtained in sampling a cattle range in northern Arizona. In this example the sum of information obtained from a grazing allotment of approximately 25,000 acres has been reduced to a few essential statistics. The sample, on which the summary is based, contains a total of 88 sampling units which were distributed at the rate of 2 per section.[8]


LINE INTERCEPTION METHOD
FIELD RECORD

Project Wild Bill Plot
Line No. 2
Length: 50 Feet
Date 9-7-38
Location NW¼ Sec 28 T24N R6E
Measured by EHB + HOC
Time: (beginning) 10:12 (completion) 10:33 (total elapsed) 21 Min.

Vegetation Intercepted in Feet

Plant Symbol	Grasses				Weeds							Browse		
	Mme	Fer	Shy	Bty	Ola	Pen	Bmo	Fjx	Br			Cfe	Pty	
	0.32	0.11	0.07	0.11	0.26	0.02	0.02	0.01	0.03			1.01	0.27	
	0.57	0.25	0.04	0.05	0.44	0.01	0.02	0.02				0.26		
	0.01	0.17		0.01		0.01		0.01						
	0.44	0.04						0.01						
	0.07	0.62												
	0.86	0.27												
	1.13	0.03												
	0.44													
Totals	3.88	1.49	0.11	0.16	0.77	0.04	0.04	0.05	0.03			1.27	0.27	

Fig. 3.—A reproduction of field notes showing the arrangement of the form used and the manner in which the measurements are recorded in the field.

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[7]Among those who have tried this method in the field and have assisted its development, the following should be given particular mention:

Bert R. Lexen (1937) proposed the use of one-dimensional transect for sampling ranges and preparing working plans and a description of the method.

M. J. Culley (1937) used Lexen's one-dimensional transect method in sampling pastures of the Santa Rita Experimental Range. Although the transect locations were not completely randomized and the measurement of grass was not made at ground level, this work afforded information that was later used in the development of the line interception method.

H. O. Cassidy, E. H. Bomberger, and Canfield (1938) sampled the Wild Bill Allotment, a range area of 25,000 acres in the ponderosa pine forest of northern Arizona, by the line interception method.

K. W. Parker (1938) used the line interception method in sampling vegetation on shrub control experimental plots in Arizona and New Mexico.

George Glendening, K. A. Valentine, and R. H. Canfield (1939) sampled vegetation on numerous ranger study plots (100 × 100 feet) located on all national forests in Arizona and New Mexico. Twenty 50-foot lines per plot obtained highly significant results in all cases.

[8]A standard United States G.L.O. section is 1 square mile in area and contains 640 acres.

Table 1.—Office Summary of Eighty-eight 50-Foot Sampling Units. (Means of All Measurements By Species and Forage Classes in Feet, Percent of Ground Occupied, and Percent of Composition)

	Muhlenbergia montana	*Festuca arizonica*	Minor grasses	Weeds	Total herbaceous vegetation	Browse
Mean feet ± σ_m[1]	**4.55±.33**	1.88±.20	0.94±.13	0.91±.11	8.28±.54	0.06±.023
Ground occupied (percent)	**9.10**	3.76	1.88	1.82	16.56	0.12
Composition (percent)	**55.00**	22.70	11.30	11.00	100.00	......

[1]All the estimates test highly significant at the 1-percent level or higher excepting browse which falls just below the 1-percent level of Fisher's "t."

A summary of the kind presented in Table 1 contains all the essential information from the sample that can be expressed in mathematical form. Line 1 shows the sample means in averages expressed in linear feet for all species or classes of plants encountered. In this final summation the principal grasses have been treated individually, while less abundant scattered grasses have been grouped under the heading "Minor grasses." Weeds of a wide variety containing no dominant or otherwise important species are represented by another group. Browse plants, for similar reasons, are also treated as a group without regard to species. The reliability of these estimates is indicated by their accompanying standard errors.

The second line in the table contains the computed percentages of the mean ground surface actually occupied by herbaceous plants and the percent ground covered by the crown spread of browse. This series of values is similar to density estimates and, subject to the usual adjustment for forage acre requirement, may be used for the same purposes. As an example, the 25,000-acre allotment from which this sample was obtained supports a ground cover of 9.1 percent of *Muhlenbergia montana.* The total compact acreage of this grass is computed as being equal to 9.1 percent of 25,000 acres, or the sum of 2,275 acres. Browse listed in the last column is regarded as a separate measurement. It belongs in a different statistical universe as previously indicated. This fact does not lessen the value of the information concerning the shrub population. As compared with other methods of shrub density estimates, it is pointed out that shrubs and grasses never have been measured on the same basis.

Extensions of the Method

By slight modification of the method to meet additional requirements, the line interception method may be extended into and combined with correlated measurements of forage utilization and forage volume. Although each of these measurements takes the method into a new and different sampling universe, the principles which apply to the special cases are exactly the same principles as govern the sampling of density and composition.

Forage utilization.—Estimates of forage use by grazing animals are based on samples comprised of measurements made on two planes; namely, the vertical height of grazed stubble and the horizontal intercept of the individual plants. Height measurements are separated into stubble-height classes on the basis of arbitrarily predetermined height-class intervals. Corresponding measurements of density are made on the intercept of the plants in the usual manner described for the line interception method.

Measurements of utilization are recorded on a form similar to the one illustrated in Figure 3, but the stubble height is separated into the desired number of height classes with each class heading a column as do the plant species in the form shown in Figure 3. Species are then listed down the extreme left-hand column of the form. Measurements are made in the following manner: Stubble height of each plant is measured to determine the class in which it belongs, then the intercept of the plant is measured in the usual way, and this intercept measurement is entered opposite the species name and in the column under the proper stubble-height class heading.

Forage volume.—Measurement of forage volume is also a special case. The essential measurements are the weight and composition of vegetation growing on a specified area. In order to obtain an area of sufficient size, this sampling unit is laid out in the form of a belt. The width of the belt is restricted as much as is possible thereby giving greater length to the sampling unit of a given area. Computation is facilitated if the size of the area included in each plot is restricted to multiples of one ten-thousandth of an acre (i. e. 4.356 square feet). Forage growing on this area is clipped, and the clippings are then segregated by species and weighed. When correlated density measurements are desired, the linear sampling unit is measured in the usual manner on a central line bisecting and running the full length of the belt.

In the measurement of forage volume, a heavy pair of office shears, paper bags for holding the clipped grass, and scales for weighing are all the additional equipment needed for this work.

Summary

The line interception method is a method of sampling vegetation based on the measurement of the intercept of plants growing on randomly located lines of equal length. Samples, from which are derived estimates of the density, composition, and ecological structure of the vegetation, involve only the linear measurements of the intercept of plants encountered on the line. Extensions of the method involving additional measurements include a means of sampling the degree of grazing use and the forage production. In taking grazing use samples, stubble height of plants growing on the line is an added measurement. Forage crop estimates are obtained by clipping and weighing the plants growing on a narrow belt. This belt is bisected by a line on which density measurements are also made in the usual manner.

Application of the line interception method in the field of range investigations has been determined by extensive trials. Results obtained in these investigations may be summed up as follows:

The method is equally efficient for either large or small areas. It can be used for a wide variety of measurements. Some of the uses in sampling vegetation for which the line interception method may be recommended are: measurement of density and composition of vegetation, forage production, and degree of forage utilization by livestock.

It is believed that the line interception method has considerable merit as a means of sampling vegetation. Some of its advantages are as follows:

Field measurements and office compilation of the data require less expenditure of time than most methods used in ecological and range studies. Two men comprise a field crew of maximum efficiency. A crew of this size can complete the measurement of 15 to 30 plots per day, depending on the amount of time consumed in travel. Office time required for compilation and reduction of data for a sample of 40 to 80 units is often less than 1-man day. The linear sampling unit approaches the ideal in shape of sampling plots, and the data obtained are based on actual measurements of the vegetation. Personnel engaged in application of the method requires no specialized knowledge to fit them for field work, and very little training is necessary to insure accurate consistent results. The method has a sound statistical basis, and the reliability of the results obtained may be determined by standard statistical procedure.