An Application of the Point-Centered Quarter Method to the Sampling of Grassland Vegetation[1]

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The point-centered quarter method, which belongs to a family of methods usually designated as "distance measurement methods," was developed by Cottam and Curtis (1956) for use in the sampling of tree and sapling compositions of woodlands in the northern Prairie-Forest Border Region. The method was first applied to grassland studies by the author in western North Dakota during the summer of 1958 and it is presently in use in that area. This method offers a means of taking rapid, quantitative samples of grassland vegetation which are free from subjective estimates and which yield data in terms of both species compositions and species densities. Densities are in terms of aerial shoots per unit area; a shoot is defined as a stem plus its appendages (Arber 1941; Foster 1949). The shoot has been selected as the organismal unit to avoid the necessity of distinguishing individual plants in the field.

Three native grassland stands in western North Dakota were sampled in June and August of 1959 in order to evaluate the characteristics and merits of the method when applied to grassland vegetation and it is the purpose of this paper to report that study. The great diversity of grassland types suggests, however, that the general applicability of the method should not be assumed until trials are made on a variety of other grassland types. This paper describes the method so that it may be tested by other workers on other grasslands.

Distance measurement methods are based upon the thesis that the measurement of the distances between plants is a more efficient sampling tool in the field than area methods of direct density (plants or shoots per unit area) measurement. This would appear particularly true in grassland vegetation, where difficulty is often encountered in distinguishing individuals and where high densities often make the direct counting of individuals or shoots, even in small sample areas, impractical. Many distance measuring methods have appeared since 1947 when Cottam introduced the random pairs method, the original member of this family. The works of Curtis (1950), Skellam (1952), Cottam, Curtis and Hale (1953), Clark and Evans (1954), Hopkins (1954), Moore (1954), Morisita (1954), Cottam and Curtis (1956), Greig-Smith (1957) and Lindsay, Barton and Miles (1958) are of particular importance in tracing the development of this family of methods.

The plant names used in this paper follow Stevens (1950).

Procedures

Field Procedure

All stands sampled in the present study were located in the South Unit of Theodore Roosevelt National Memorial Park, Billings County, North Dakota. The grassland vegetation of this area has been described by Hanson and Whitman (1938) and Dix (1958). The sampled stands had been ungrazed for at least 4 years and free from fire for 25 or more years.

In applying the point-centered quarter method to grassland vegetation, a technique developed by Evans and Love (1957) has been modified for use in locating the central point of each sampling unit. A single pin (surveyor's arrow) is placed vertically into the soil, guided by a small notch cut into the toe of the sampler's boot. The area around the point is then divided into quarters by drawing two imaginary lines through the pin; one line is drawn parallel with the line of traverse while the second is drawn at right angles to the first (Figure 1). The establishment of these lines is aided by filing four small marks on the pin in such a way that each mark is 90° from its nearest neighbor. Within each quarter of the sampling unit the closest living shoot to the point is recorded by species and the distance from the point to the closest shoot is measured to the nearest centimeter. Thus, each sampling unit consists of four shoots and four measured distances. The recording of field data is greatly facilitated by employing a previously prepared data form (Figure 2).

The distance from the point to all herbaceous shoots is measured from the base of the pin to the emergence of the shoot from the soil. Shrubs, half-shrubs and other woody plants are measured from any vertical level on the pin to the closest living portion of the plant in a particular quarter of the sampling unit.

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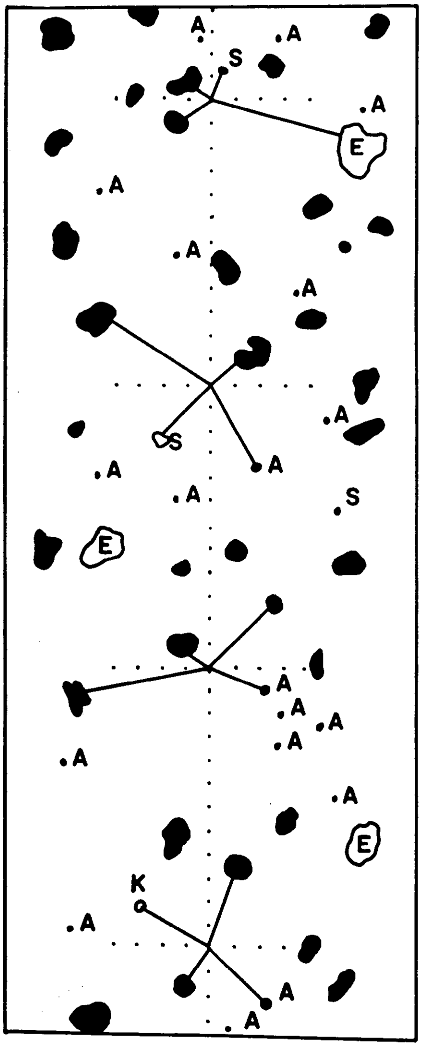


FIGURE 1. A hypothetical map of a grassland area illustrating the application of the method. The vertical dotted line indicates the line of traverse. The intersection of the four solid lines indicates the location of the point of the sampling unit. The area around the point was divided into four 90° quarters by drawing a line (dotted horizontal line) at right angles to the line of traverse. The solid lines indicate measured distances from points to shoots. Four sampling units are illustrated and the data is recorded in Figure 2. "A"= *Agropyron smithii;* "K" = *Koeleria cristata;* "E" = *Eurotia lanata;* "S" = *Stipa viridula; solid black* = *Bouteloua gracilis.*

Under this regime, a single woody plant may occasionally be measured two or more times when it appears in more than one quarter of a sampling unit. When a woody shoot overtops herbaceous shoots, only the former is measured. When a shoot touches the pin, a distance of zero is recorded.

The positions of the points in the field are determined objectively by pacing a predetermined number of steps along a compass line and placing the pin into the soil in the manner described above. The number of points required to adequately sample the vegetation is discussed below.

All sampling in the present study was done by a two-man team—a sampler and a recorder. While this method may be easily applied by an individual, a two-man team appears more efficient since the time required to record distances usually limits the speed of the method.

Laboratory Calculations

The homogeneity of each stand was tested by employing the method suggested by Curtis and McIntosh (1951). The number of shoots of the major species in each stand was segregated into four groups in which each segregate represented an approximately equal areal portion of the stand. Using the number of shoots contained in each of the four segregate groups, a Chi-square test for homogeneity (Snedecor 1956) was applied. All Chi-square values for the stands used in this study were found to be within the expected 5 percent level and all stands were accepted as homogenous.

Cottam, Curtis and Hale (1953) have shown that, when the point-centered quarter method is applied, the mean distance between points and shoots is equal to the square root of the mean area, if individual species are disregarded. The mean distance between shoots is found by summing the individual measured distances and dividing the sum by four times the number of points used. Further, the mean distance squared is equal to the mean area while density is equal to the reciprocal of the mean area, or, to put density in terms of shoots per square meter, 10,000 (the number of sq. cms. in 1 sq. m.) over the mean distance squared.

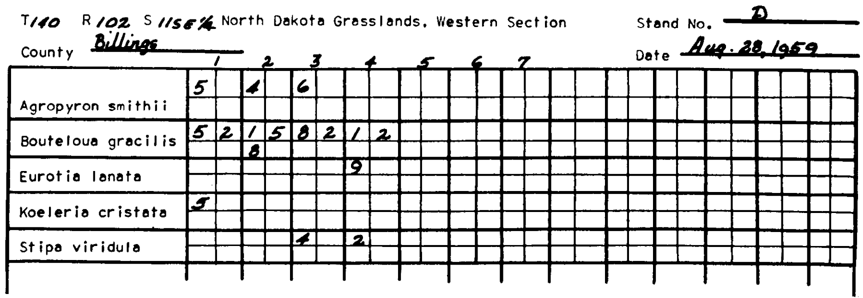
Table 1 may be used to demonstrate these calculations (p. 65).

In order to find the absolute densities for the individual species of the stand, the total density is multiplied by the relative densities of the individual species. Again, from Table 1, the absolute density for blue grama *(Bouteloua gracilis)* is calculated to be 295.85 shoots per square meter (0.565 x 523.64).

The adequacy of the sampling was judged by employing the suggestion of Cottam and his colleagues (Cottam, *et. al.* 1953 and Cottam and Curtis 1956) that approximately 30 individuals of a particular species must be encountered in the total sample before reasonable accuracy is obtained for that species.

An importance value which is independent of distance measurements may also be obtained from data collected with this method. Relative frequencies and

FIGURE 2. Data form used to record field sampling. Four measurements are made in each sampling unit. Data are from Figure 1.



Marquette University — Plant Ecology Form No. 10

T 140 R 102 S 115E¼ North Dakota Grasslands, Western Section — Stand No. D

County Billings — Date Aug. 28, 1959

	1		2		3		4		5		6		7	
Agropyron smithii	5		4		6									
Bouteloua gracilis	5	2	1 8	5	8	2	1	2						
Eurotia lanata							9							
Koeleria cristata	5													
Stipa viridula					4		2							

$$\text{Mean Distance} = \frac{d_1 + d_2 + d_3 \ldots\ldots\ldots d_n}{4 \times \text{number of points used}} = \frac{874}{4 \times 50} = 4.37 \text{ cms.}$$

$$\text{Mean Area} = \text{mean distance}^2 = (4.37)^2 = 19.1 \text{ sq. cms. per shoot}$$

$$\text{Total Density} = 1/19.1$$

or, to put the density in terms of shoots per square meter,

$$\text{Total Density} = \frac{10{,}000}{19.1} = 523.64 \text{ shoots per square meter.}$$

densities may be calculated from the number of points of occurrence (each point is considered a quadrat) and the number of shoots, respectively. The two relative values for each species are then added to give an importance value (Table 1). While importance values calculated in this way may be of limited value in some grassland work, they may be highly desirable in certain studies—e.g., in savannah vegetation when it is desired to make use of some method which will permit direct comparisons between tree, shrub and herbaceous synusia. When the point-centered quarter method is applied to woodland vegetation, it is customary (Cottam and Curtis 1956) to calculate an importance value which is the sum of the relative frequency, density and dominance values for each species. The importance values for trees will sum to 300 percent (relative frequency + relative density + relative dominance) while the importance values for herb, shrub and sapling measurements will sum to 200 percent (relative frequency + relative density). Whitford and Salamun (1954) have suggested that sapling data may be made directly comparable to tree data by multiplying the importance value of each sapling species by 1.5 to bring the sum to the same 300 percent as the importance value for trees. The same method would appear applicable to herb and shrub data.

Results

Stand A was first sampled on June 29 by employing 50 sampling units and the results of that sampling are given in Table 1. Of the nine species detected, only two proved adequately sampled. Further, it appeared that while a prohibitive number of sampling units would be required to adequately sample the third ranked species, winter fat *(Eurotia lanata)*, it suggested that an adequate sample of the first and second ranked species might be obtained with fewer sampling units. A second sampling of the stand was therefore made (Table 2) by employing 25 units distributed over the same total area and this gave an adequate sample for blue grama but not for western wheatgrass *(Agropyron smithii)*. A third sampling of 25 units was made in the stand and again only blue grama proved to be adequately sampled. It was concluded from this study that 25 sampling units gave an adequate sample for the first ranked species in this grassland type; that approximately 30-35 sampling units were required to adequately determine the density of the recond ranked species; and that a very large number of sampling units would be required to adequately sample the lesser ranked species.

In order to evaluate the influence of seasonal differences upon data obtained with the point-centered quarter method, Stand A was sampled again on August 28, approximately two months after the first sampling, and the results are given in Table 3. Comparisons between Tables 1 and 3 show a striking similarity in the values for the first and second ranked species. The inadequately sampled lesser species show large variations which are probably attributable to

Table 1. Species densities and importance values for Stand A. The stand was sampled on June 29, 1959 by employing fifty sampling units (200 shoots). An asterisk has been placed before the adequately sampled species. The stand has a southwest exposure and a slope of 11°.

Species	Number of Points	Number of Shoots	Sum of Distances	Relative Frequency	Relative Density	Importance Value	Absolute Density (Shoots per sq. M.)
**Bouteloua gracilis*	40	113	474	43.96	56.50	100.46	295.85
**Agropyron smithii*	29	60	239	31.87	30.00	61.87	157.09
Eurotia lanata	6	9	43	6.59	4.50	11.09	23.56
Stipa comata	4	6	28	4.39	3.00	7.39	15.70
Stipa viridula	4	4	28	4.39	2.00	6.39	10.47
Sphaeralcea coccinea	4	4	36	4.39	2.00	6.39	10.47
Artemisia frigida	2	2	12	2.19	1.00	3.19	5.23
Muhlenbergia cuspidata	1	1	10	1.09	0.50	1.59	2.62
Erysimum parviflorum	1	1	4	1.09	0.50	1.59	2.62
TOTAL	91	200	874	99.96	100.00	199.96	523.64

Table 2. Species densities and importance values for Stand A on June 29, 1959 employing 25 sampling units. An asterisk has been placed before the adequately sampled species.

Species	Number of Points	Number of Shoots	Importance Value	Absolute Density (shoots per sq. M.)
**Bouteloua gracilis*	21	59	104.28	323.67
Agropyron smithii	14	25	55.04	137.15
Eurotia lanata	4	6	14.57	32.92
Four other species	8	10	26.11	54.87
TOTAL	47	100	200.00	548.61

large sampling errors, rather than to differences in seasonal variations.

Time trials in Stand A showed the rate of sampling with the point-centered quarter method to be a consistent 50 sampling units per hour in this vegetation type.

For comparative purposes, studies were made on two additional grassland stands in western North Dakota. One stand (B) was located contiguously with Stand A but, due to its direct southern exposure, was more xeric than the original stand. When 50 sampling units were used to sample Stand B, blue grama was found (Table 4) to have a density which was 42 percent higher than the density for the same species in Stand A while the total density for all species was 28 percent higher in the more xeric stand. Blue grama accounted for 76 percent of the vegetation in Stand A. In Stand B, blue grama was the only species adequately sampled with 50 sampling units. The very high density of this species, the low densities of the remaining species, and the small amount of mulch present, permitted sampling to occur at the comparatively rapid rate of 67 sampling units per hour.

The third site had a north-northeast exposure and a slope of 18°. This stand (C) was less xeric than either of the other stands; it supported a greater number of species and had a thick mulch cover. When 50 sampling units were employed on the stand only little bluestem *(Andropogon scoparius)* proved to be adequately sampled. Fifty additional sampling units were distributed over the area and the results pooled with the original to form a single sample of 100 units (Table 4). This table shows that a total of 32 species were detected in the sampling and that, of these, six were species adequately sampled. The comparatively slow sampling rate of 37 units per hour in this stand was due to the necessity of removing large quantities of mulch before the exact locations of the emergence of the shoots from the soil could be determined. The total density of plants in this stand was approximately midway between the total densities for Stand A and B.

Some differences that may be encountered in various grassland types within the same general area are shown by comparisons between the three stands. Stand B occurred on the most xeric site of the study and this condition was reflected in the very high density for a single species, blue grama, the low densities of all other species and the small amount of mulch on the grassland floor. The least xeric site was Stand C which showed a high total number of species, a comparatively large number of important species (6), the absence of a single species with a density far higher than that for the other species, and a thick

Table 3. Species densities and importance values for Stand A on August 29, 1959. Fifty sampling units were employed in obtaining the sample. An asterisk has ben placed before the adequately sampled species.

Species	Number of Points	Number of Shoots	Importance Value	Absolute Density (shoots per sq. M.)
**Bouteloua gracilis*	43	116	105.20	322.23
**Agropyron smithii*	27	53	56.10	147.22
Stipa viridula	7	13	14.20	36.11
Eurotia lanata	5	6	8.50	16.67
Stipa comata	4	7	7.90	19.45
Five other species	5	5	8.00	13.90
TOTAL	91	200	199.90	555.58

Table 4. Species densities and importance values for Stand B. Fifty sampling units were used in sampling the stand. An asterisk has been placed before the adequately sampled species. The stand has southern exposure and a slope of 14°.

Species	Number of Points	Number of Shoots	Importance Value	Absolute Density (shoots per sq. M.)
**Bouteloua gracilis*	47	152	137.84	513.51
Eurotia lanata	13	29	31.60	97.97
Agropyron smithii	6	8	11.89	27.03
Plantago purshii	4	5	7.76	16.89
Six other species	6	6	10.86	20.28
TOTAL	76	200	199.95	675.68

Table 5. Species densities and importance values for Stand C. The stand was sampled by employing 100 sampling units. An asterisk has been placed before the adequately sampled species. The stand has a north northeast exposure and a slope of 18°.

Species	Number of Points	Number of Shoots	Importance Value	Absolute Density (shoots per sq. M.)
**Andropogon scoparius*	41	89	39.69	132.88
**Bouteloua curtipendula*	38	58	30.60	86.58
**Stipa viridula*	30	46	24.22	68.66
**Bouteloua gracilis*	21	43	19.67	64.16
**Carex filifolia*	22	31	17.34	46.24
**Muhlengergia cuspidata*	19	35	16.81	53.22
Juniperus horizontalis	7	22	8.24	31.34
Stipa comata	7	9	4.96	11.95
Carex eleocharis	7	7	4.71	10.47
Calamovilfa longifolia	4	8	3.70	11.95
Twenty-two other species	42	52	30.27	74.71
TOTAL	238	400	200.21	591.09

mulch mat. While Stand A was intermediate between the other two stands and showed intermediate characteristics, it was more closely related to Stand B than to Stand C.

Frequency determinations were also made on the three stands of the study by employing 40 1-M² quadrats distributed throughout each stand. The results for all species which had a frequency index value of 30 percent or more in any stand are given in Table 6. Comparisons between this table and Tables 1, 2, 3, 4, and 5 show a general agreement in the relative importance of most species when sampled with the two methods. The point-centered quarter method would appear, however, to be more sensitive in distinguishing between the relative importance of species with near equal ranks. For example, while the frequency index values for blue grama shows the species to be nearly as important in Stand A as in Stand B, the point-centered quarter method shows a 58 percent higher density for the species in Stand B. Again, in Stand C little bluestem and sideoats grama *(Bouteloua curtipendula)* had the same frequency values, but when the point-centered quarter method was used to sample the stand, the former species had a density 65 percent greater than the latter species. Frequency index determinations made from area quadrats, however, appear to yield a broad though general picture of the species composition spectrum and for this reason such determinations are highly valuable in establishing gross similarities and differences between stands.

Discussion

While the point-centered quarter method is not historically a descendant of the point quadrat method, it nevertheless appears to be a logical extension of that method when, as in the present study, it is applied to the sampling of grassland vegetation. The point quadrat method was introduced by the Australian ecologists Levy and Madden (1933) and has as its theoretical basis the principle that when the sample area becomes a point, the proportion of an infinitely large total number of sampling areas which are covered equals the cover of the species (Greig-Smith 1957). The point quadrat method has been widely applied in the sampling of grassland vegetation throughout the world and Brown (1954) suggests that the method has every prospect of becoming the accepted one in both survey and detailed analyses of grassland vegetation. Of the several variations of the point quadrat method which are now in use, the most widely applied appears to be the point-frame method in which 10 pins, spaced 2 inches apart, are arranged in a frame in such a way that they can be lowered into the vegetation and the contacts between the pins and shoots recorded.

Goodall (1952), in an exhaustive study of several varia-

Table 6. Frequency index values for the three stands of the study. Forty ¼-M² quadrats were used to sample each stand.

Species	Stand A	Stand B	Stand C
Agropyron smithii	75	27	10
Andropogon scoparius			85
Bouteloua curtipendula			85
Bouteloua gracilis	95	97	35
Carex filifolia	20	17	55
Koeleria cristata			30
Muhlenbergia cuspidata			47
Plantago purshii	15	40	
Sphaeralcea coccinea	37	22	10
Stipa viridula	30		70
Anemone patens			32
Eurotia lanata	57	67	
Hedeoma hispida	45	17	
Brauneria angustifolia			57
Aster laevis			37
Symphoricarpos occidentalis			40
Campanula rotundifolia			35
Anemone cylindrica			30
Linum lewisii			40
Total Number of Species in Quadrats	27	29	64

tions of the point quadrat method, concluded that: 1) a great economy in sampling time may be achieved by using a single pin as the sampling unit rather than a frame containing 10 pins; 2) when a single pin is used, the subconscious choice of placement of the pin is much greater than with frames of 10 pins and special care must be taken to avoid their subjective placement; 3) the diameter of the pins used in sampling may strongly affect the obtained estimates of vegetal composition. As applied in the present study, the point-centered quarter method appeared to take advantage of the first of Goodall's conclusions while avoiding the possible undesirable features of the second and third. Since the diameter of the pin used in the sampling was small (3 mm.), and since the number of times which the pin was intercepted by vegetation low (8 percent or less), the diameter of the pin would appear to be relatively insignificant. Furthermore, since four separate measurements were made at each point (one to the closest shoot in each quarter) the possibility of subjective selection of the distances to be measured was minimized. While it may be possible to subconsciously select a particular location for a point, the subjectivity concerned becomes greatly reduced when four separate distances are measured.

The present study shows that with the point-centered quarter method no *a priori* number of sampling units can be given as adequate to sample a given vegetation type, nor can the time required to make such a sample be given. It is suggested that when the point-centered quarter method is applied to grasslands, those species which are represented by 30 or more shoots may be considered as adequately sampled unless positive evidence exists to the contrary. The occurrence of 30 or more shoots in a sample may be easily determined in the field and such an occurrence may be accepted in the field as evidence that further sampling of that species is unnecessary.

No study was made in this work of the time requirements and efficiencies of sampling methods other than the point-centered quarter method. It is not possible, therefore, to compare directly the time required to apply the point-centered quarter method with the time requirements of other commonly used grassland methods. However, some general comparisons may be justified. Whitman and Siggeirsson (1954), working in upland, native, ungrazed mixed-grass rangeland in western North Dakota, found that approximately one full day was required for a two-man team to sample the third-ranked species to an accuracy of 10 percent of the mean with the point-quadrat method while about four days were required to obtain the same accuracy with the line-intercept method. In comparison to these figures, the point-centered quarter method, as applied in the present study, yielded an adequate sample for six species in Stand C, vegetatively the most complex of the study areas, in approximately 2.6 hours of work for a two-man team. In Stand A, an adequate sample of the first ranked species was obtained in approximately 20 minutes, while one hour was required to sample the second ranked species. It would appear, therefore, that the rapid working rate of the point-centered quarter method would recommend it as a valuable sampling tool.

The sampling efficiency of the point-centered quarter method may be greatly increased by applying the technique of multi-phase sampling (Yates 1953). This technique is of particular value when quantitative information is desired on a number of species which differ widely in absolute densities. Under this regime, one or two species in a stand with apparently similar densities are selected for sampling in the first-phase and all remaining species are ignored. Thus, in Stand A, a survey of the stand would quickly establish blue grama and western wheatgrass as the most abundant species and they would be selected for first-phase sampling; in each sampling unit the distances from the point to the closest shoot of either of these species would be measured in each quarter, all other species being ignored. When 30 or more of each of these species are detected in the sample, they would be presumed adequately sampled. A new estimate would then be made and the species which seem likely to rank third, fourth or fifth in abundance would be sampled to the exclusion of all others, including blue grama and western wheatgrass, in the second-phase sample. When 30 or more shoots of each of these species have been detected in the sample they would be considered adequately sampled and, if desirable, a third-phase sampling would be initiated. The multiphase sampling technique may be continued to any level which appears practical for a particular study. The calculations for determining the absolute densities for the sampled species are made in the usual way (see PROCEDURES) but it is necessary to calculate the densities for each sample-phase separately. Overall species compositions (importance values) cannot, of course, be determined when multi-phase sampling is employed.

One objection which may be advanced to the application of the point-centered quarter method to grasslands is that the obtained density data are exactly true only for species which are randomly distributed. Anderson (1954) and Steiger (1930), have demonstrated, however, that randomness in grassland species is not always the case. Cottam and Curtis (1956) have indicated that, when populations are aggregated, the densities obtained with this method are below the actual density values. At the present time, no rapid, accurate method for measuring actual densities of aggregated species in grasslands has come to the attention of the author and the point-centered quarter method appears to suffer less from this shortcoming than do methods now in use. The sampling bias appears to be in only one direction and the added computational labor involved in determining actual densities does not appear to justify more time consuming methods for most grassland studies. In discussing the application of distance measurement methods to studies of pattern, Greig-Smith (1957) has concluded that where it is impossible to distinguish individuals, as is clearly the case in perennial grasslands, "it may be impossible by these techniques to analyse the distribution of all, or even a majority, of species present".

The need met by the point-centered quarter method as applied to grassland sampling is that of offering a means of making rapid, objective estimates of the vegetation which are expressed in terms of both species composition (importance values) and density. Since the measured distances are relatively small, minor differences in vegetation are readily detected, whether the differences are changes in time caused by livestock grazing, climatic shifts or some similar factor or differences in space caused by slope, exposure or edaphic dissimilarities.

Summary

The point-centered quarter method of sampling grassland vegetation yields data in terms of densities (shoots per unit area) and relative species compositions. In applying the method, a point is objectively established and the area around the point is divided into four quadrants. In each quadrant of the sampling unit, the distance to the closest living shoot is measured in centimeters and the species and the distance are recorded. Each sampling unit therefore consists of four measured distances to four shoots. The densities of individual species are calculated from the measured distances and an importance value (relative frequency + relative density) which is independent of the measured distances is determined.

The method was tested on three grassland stands in western North Dakota. One stand was sampled in June and again in August and no significant differences were found, indicating that the method is not sensitive to seasonal aspect. The method appeared to be more rapid than either the line intercept or point frame methods and is thought to be highly efficient in detecting slight differences between closely related stands or vegetal changes in time within a stand due to treatment or climatic shifts.

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