A Comparison of the Line-Interception, Variable-Plot and Loop Methods as Used to Measure Shrub-Crown Cover

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Determining the percentage of ground covered by shrubby vegetation is an integral part of range inventory and of range condition and trend studies. Measurement of plant cover is used in making site descriptions and in studying brush control, seeding, and grazing management. A change in plant cover often reflects a change in management practices.

No accurate method of measuring plant cover has been devised. In most instances only an estimation of plant cover is made. However, Smith (1944) showed that cover estimates vary significantly among individuals on different days and even on the same day. Many range technicians, land managers, and ecologists have recognized the need for a rapid, accurate, and easy-to-use method of measuring plant cover.

The loop procedure of the Parker 3-Step Method is used widely in condition and trend studies. A ¾-inch loop is utilized to obtain the plant density index, a frequency measurement. Recently, Johnston (1957) employed the loop procedure to measure basal area cover in grassland vegetation. He found this method detected fewer species and gave more variable data than either the line-interception or vertical-point-quadrat methods. The literature contains no other studies concerning the relationship between the plant-density-index and actual plant cover.

Another widely used procedure for determining ground cover is the line-interception method described by Canfield (1941). Johnston (1957) found this method to be more time-consuming but detected more species by its use than by either the loop or the point-quadrat method. Savage (1940) found the line-interception method suitable for use in dune vegetation of the Southern Great Plains. Hormay (1949) discussed the use of this method for estimating density and yield of California bunchgrasses. Hanson (1950) found the line-interception method superior to others in mixed vegetation but inferior to some in dense grassland.

The variable-plot method (Cooper, 1957) is a new procedure used to estimate shrub-crown cover. Cooper compared the variable-plot method with the line-interception and complete-tally methods in the shrub type of southern Arizona. The variable-plot method was faster and easier to apply and gave cover values which closely approximated the estimates obtained by the other sampling techniques.

It was the purpose of this study to compare methods of estimating shrub crown cover as used by different observers in stands of varying shrub cover and species composition. Each method was then evaluated in terms of the "true cover" as calculated from actual shrub measurements.

Procedure

Four sites were selected for study, (1) Sweetwater Flat, (2) Quail Canyon, (3) Calico Mountain, and (4) Spanish Springs Valley, all located in northwestern Nevada. Spanish Springs Valley (Fig. 1) is dominated by big sagebrush (*Artemisia tridentata* Nutt.) The Sweetwater Flat site (Fig. 2) was plowed and seeded to crested wheatgrass in 1950. This site now supports a sparse stand of big sagebrush. The Quail Canyon site (Fig. 3) is dominated by shadscale (*Atriplex confertifolia* (Torr.) S. Wats.); the Calico Mountain site (Fig. 4) by whitesage (*Eurotia lanata* (Pursch) Moq.).

At each site a plot of 10,000 square feet (100 x 100 feet) was selected for uniformity of vegetation type and topography. This main plot was divided into subsampling areas of a number and size assumed necessary to obtain adequate measurements of shrubs for calculating "true cover". The number and size of these sampling units were as follows: four 25 x 25-foot subsampling areas at Calico Mountain and Spanish Springs Valley and four 25 x 50-foot subsampling areas at Quail Canyon. The entire main plot at Sweetwater Flat was sampled. The shrubs on each sampling unit were measured with a yardstick with 3 observers concurring on each measurement. Dead portions of the crown were excluded. Two measurements were re-

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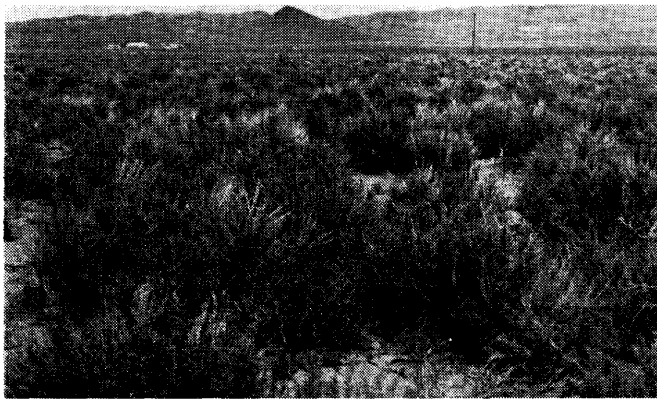

FIGURE 1. A dense stand of big sagebrush characterizes the study location in Spanish Springs Valley.

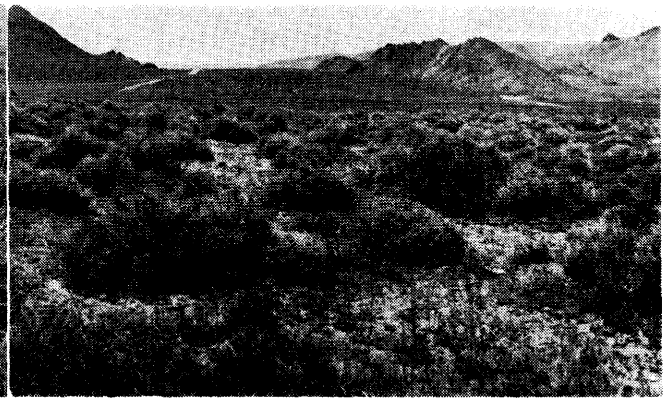

FIGURE 3. The Quail Canyon sampling area is dominated by shadscale with annual forbs and grasses seasonally abundant.

corded for each shrub and the crown area calculated by the ellipse formula, $A = \pi ab$, where a and b are lengths of major and minor radii, respectively.

Crown area calculated by this method has a high positive correlation (.99) with data obtained by mapping shrub crowns to scale and planimetering the crown areas (unpublished data, U. S. Forest Service, 1947). The cover calculated by the ellipse formula is referred to as "true cover" in this paper and was used as the standard for evaluating the accuracy of the line-interception, variable-plot, and loop methods.

Six 100-foot transect lines were established in each main plot. These transects originated from, and were perpendicular to, adjacent sides of the plot at the 25, 50- and 75-foot points. These lines were used for the loop-procedure and line-interception methods. The variable plots were located at 6 of the transect intersection points (Fig. 5).

The 3 observers recorded the data for each method on the same plot at each location before calculating shrub cover or comparing results.

Results and Discussion

The analysis of variance was calculated for the line-interception, variable-plot and loop methods as used by the 3 observers at 4 locations. Differences among methods and locations and their interaction were highly significant.

Each observer had used and was familiar with the line-interception and loop procedures. Approximately one-half day was spent in becoming familiar with the variable-plot technique and comparing individual observers. Transect lines and variable-plot locations were not moved until all observers had recorded their readings. These factors contributed to the low variation among observers. Since there were no significant observer differences estimates for all individuals for each method at each location were averaged together with the means from the ellipse-formula method (Table 1). Statistical analyses of these averages are presented in Table 2.

FIGURE 2. Sweetwater Flat, once plowed and seeded to crested wheatgrass, now supports a sparse stand of big sagebrush.

Significant differences among locations were expected, since selected sites varied widely in shrub cover.

The mean percent cover value for the 4 methods (Table 1) was analyzed by Duncan's multiple range test (Duncan, 1955). This test revealed that mean cover over all locations for the line-interception and ellipse-formula methods was not significantly different. The variable-plot and loop-procedure gave significantly higher mean-cover values than either the line-interception or the ellipse-formula method. The loop-procedure method gave a significantly higher mean value than the variable-plot method.

The 4 methods gave variable results at different locations (Table 1). At each location where the shrub crown cover was greater than 5 percent, the loop-procedure gave the highest average ground-cover percentage. Duncan's multiple range test (Duncan, 1955) revealed that, when crown cover was 5 percent or less, any of the methods tested gave cover values which did not differ significantly from the measured or "true cover" shown

Table 1. Multiple range test of mean percent shrub cover for 4 methods of estimation at 4 locations[1]

Location	Ellipse formula	Line interception	Variable plot	Loop procedure
Sweetwater Flat	4.1[a]	4.1[a]	5.0[a]	4.9[a]
Spanish Springs	20.9[a]	20.6[a]	23.4[b]	27.3[c]
Quail Canyon	10.8[a]	13.6[b]	13.8[b]	16.0[c]
Calico Mountain	18.8[b]	13.9[a]	20.7[b,c]	21.8[c]
Mean for Methods	13.6[a]	13.0[a]	15.7[b]	17.5[c]

[1] Any two means **at any one** location with different superscripts are significantly different at the .05 level.

as the ellipse method in Table 1. In such instances the most rapid method of crown-cover estimation would be the most logical choice. The data show that as shrub cover increases, the differences among methods become greater (Table 1). At Sweetwater Flat, cover varied from 4 to 5 percent, and there were no significant differences among the 4 methods. However, at the Spanish Springs location, where the dominant shrub is the same and the cover is 4 to 5 times as heavy, the differences among methods were significant and showed their general characteristic tendency of revealing high or low estimates. At the Spanish Springs and Quail Canyon sites the loop procedure gave cover values significantly larger than those obtained by the other 3 methods. At Calico Mountain variable plot data were not significantly different from the cover values obtained by the ellipse method or loop procedure, although the latter two differed significantly from each other.

The whitesage type at Calico Mountain and the shadscale type at Quail Canyon were difficult to sample because of the large number of plants with partially dead crowns. These portions of dead crowns were not recorded and, therefore, were excluded from the cover values as estimated by the line-interception, ellipse-formula, and loop procedures. Percent of ground cover estimated by the variable-plot method depends upon observing a portion of the living crown on both sides of the cross arm. Therefore, central portions of dead crowns were unavoidably included in the variable plot data, thus inflating the cover values obtained by this method. The inclusion of dead crown in data obtained by the variable-plot method contributed to the higher cover values for this method compared with "true cover". Should some procedure be devised for reducing the variable-plot results by the amount of dead crown area, the cover values obtained by this method would be more comparable to "true cover". Even without some factor to reduce the variable-plot data by the amount of dead crown, estimation by this method did not differ significantly from either the line-interception or ellipse-formula methods, except at one location.

Table 2. Analysis of variance for data in Table 1.

Source of variation	Degrees of freedom	Mean squares
Location	3	1412.9**
Method	3	93.4**
Location x method	9	56.9**
Error	72	12.4
Total	87	

**Denotes significance at the .01 level

The cover values obtained by the line-interception method were significantly different from those of the ellipse-formula method at Quail Canyon and Calico mountain where there were numerous partially dead shrub crowns. At Sweetwater Flat and Spanish Springs the 2 methods gave similar values. At one of these sites the shrub cover was low and at the other it was high, but there was very little dead crown at either site. These results indicate that the line-interception method will give results comparable to the ellipse-formula method over a wide range of shrub crown cover provided that few partially dead crowns are present.

The difficulty with any estimating method is the problem of obtaining a sufficient number of observations to sample adequately the population being studied. The number of plots necessary to sample each study site adequately depends upon the amount of variation in shrub cover. An analysis of observer and plot variations is presented in Table 3. The coefficient of variation among plots and the number of plots necessary to sample the vegetation within 20 percent of the mean with 95 percent confidence were calculated (Snedecor, 1946).

Variation among plots was significant with the loop-procedure and line-interception methods at all locations (Table 3). Observer differences were significant at 1 location with each of these 2 methods.

The coefficient of variation is an indication of the magnitude of variability among individual plots.

Because of the high variability among plots, a large sample is necessary to estimate crown cover by the line-interception and loop-procedure methods. Within the limits of accuracy established in this study, it would require from 14 to 104 plots to

Table 3. Analysis of observer and sample unit (transect or variable plot) variability, coefficient of variation (C.V.), and sample size when using 3 methods of estimating shrub-crown cover at 4 locations.

Method and Source	Degrees of freedom	Mean squares, C.V., and sample size at: Sweet-water Flat	Spanish Springs	Quail Canyon	Calico Moun-tain
Loop-procedure:					
Observers	2	.06	5.16*	2.16	6.89
Sample Unit	5	14.62**	97.87**	132.40**	41.42**
Obs. x Sample unit	10	.06	0.83	0.77	4.42
C.V.		78.0%	36.2%	71.9%	29.5%
Sample size[1]		100	22	85	14
Variable-plot:					
Observers	2	0.36	3.83	1.84	0.10
Sample unit	5	0.40	20.79**	1.34	3.18
Obs. x Sample unit	10	0.19	1.74	1.02	3.64
C.V.		12.6%	19.5%	8.4%	8.6%
Sample size[1]		3	6	1	1
Line-interception:					
Observers	2	0.01	1.97	2.36**	1.75
Sample unit	5	10.66**	51.00*	92.51**	33.91**
Obs. x Sample unit	10	0.08	14.61	0.31	2.66
C.V.		75.5%	34.7%	70.7%	41.9%
Sample size[1]		104	20	83	29

[1]Number of plots necessary to sample within 20 percent of the mean with 95 percent confidence.

*Denotes significance at .05 level.

**Denotes significance at .01 level.

sample adequately the shrub cover by these 2 methods, assuming a valid estimate of the population variation can be obtained from the 6 samples taken. Perhaps 6 samples were not sufficient to predict normal population variation; however, many studies lack even this degree of sampling intensity.

The line-interception method was the most accurate of the methods studied when compared with "true cover", although a large sample is needed for the estimate of cover to be reliable. The results of this study indicate when shrub cover exceeds 5 percent, estimates by the loop-procedure method are unreliable irregardless of the size of sample taken because of the significantly higher cover values obtained compared with "true cover".

Among-plot variation when sampling with the variable-plot method was significant at only one location (Table 3). There were no significant observer differences at any location for this method. The coefficient of variation for the variable-plot method was considerably lower than either of the other 2 methods. Therefore, this method was considered the most reliable and the number of plots needed to sample shrub cover adequately was small and did not exceed the number of plots used in this study.

Advantages and disadvantages of the various methods of sampling were noted during the course of this study. The ellipse-formula method, although accurate, is time-consuming and should, therefore, be used only when accurate estimations of shrub cover are necessary.

In addition to the extremely variable data obtained when using the line-interception and loop-procedure methods, is the time consumed in stretching and rewinding the steel tape. It is also doubtful that the tape used for permanent transects in shrubby vegetation can be relocated exactly for subsequent readings.

The variable-plot method is rapid and easy to learn and use. However, when vegetative cover is 20 percent or more, it is difficult to distinguish individual shrubs growing close together. This may account for the significant plot variation at the Spanish Springs site (Table 3). Where crown cover is dense, it may be necessary for the observer to leave the point of observation and determine whether there is only 1 large shrub or several small ones in a particular clump. Another man working with the observer can point out the individual plants when the observer is in doubt. In either instance, time and manpower are utilized. Cooper (1957) also found the method unreliable in shrub cover of 35 percent or greater. As a research tool, the variable-plot technique cannot be used to study minute vegetational changes. This method may have distinct advantages for use by land management agencies in inventory work. These agencies seldom have the time or personnel to establish enough transect lines in order to get an adequate sample of vegetative cover.

Summary and Conclusions

Three methods of estimating shrub-crown-cover were compared by 3 observers in 4 locations in northwestern Nevada.

A uniform area of 10,000 square feet was selected at each location. Shrub cover was estimated by the line-interception, variable-plot, and loop-procedure methods. Sampling procedure is explained.

A fourth method was used to determine "true cover" and was included in some comparisons by means of Duncan's multiple range test. "True cover" was

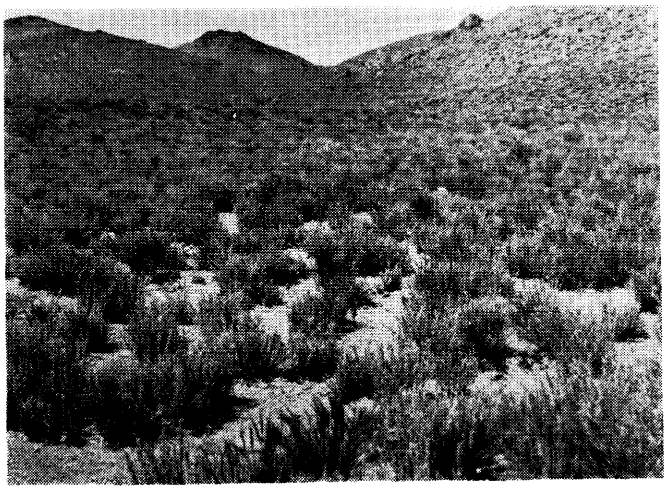

FIGURE 4. Whitesage, protected from grazing for 20 years, is the dominant shrub on the Calico Mountain sampling area.

used as a standard to evaluate the accuracy of 3 methods of estimation.

The data were analyzed, using standard statistical procedures.[2] Significant differences were found among locations, methods of estimating shrub cover, and the methods x location interaction.

The line-interception method gave shrub values which were comparable to "true cover" as calculated by the ellipse-formula method.

Cover values obtained by the loop-procedure method were significantly higher than "true cover".

Cover values obtained when estimating by the different methods varied widely from location to location.

When using the loop-procedure or the line-interception methods a large sample is needed because of plot variability.

Among-plot variation was significant at all locations with the loop-procedure and line-interception methods but it was significant at only 1 location with the variable-plot method.

The variable-plot method has high precision because of low variability between plots. However, cover estimates by this method are higher than "true cover" partly because of dead shrub crowns. A modification of this method to exclude dead crowns from the cover estimate will increase the accuracy and usefulness of the variable-plot method.

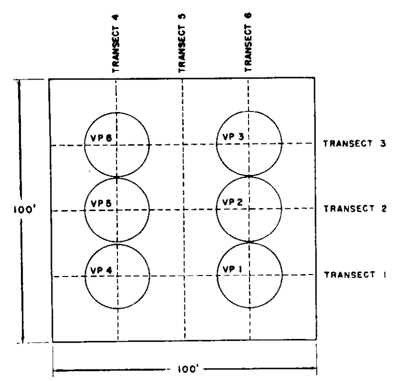

FIGURE 5. Schematic drawing showing transects 1, 2, and 3 running through the plot east to west, and 4, 5, and 6 through the plot north to south; variable plots (VP) 1 through 6 located equidistant 25′ inside the plot boundary where the east-west transects intersect the north-south transects.

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