Variable Plot, Square Foot Plot, and Visual Estimate for Shrub Crown Cover Measurements[1]

H. G. FISSER

Instructor in Range Management, Division of Plant Science, University of Wyoming, Laramie, Wyoming.

Range management procedures often require an estimation of shrub cover for complete evaluation of vegetation characteristics. Survey studies conducted over large areas necessitate rapid estimation. However, procedures associated with reduced time requirements are often inexact and variable. Since the inherent characteristics of a survey study often require evaluation by several workers with varying degrees of ability and experience, an acceptable cover estimation method must be accurate, rapid, and consistent among individuals.

The study reported here was conducted in the Big Horn Basin of western Wyoming by University of Wyoming personnel.[2] Three men evaluated three types of shrub cover with three methods of estimation—visual estimate, square-foot plot, and variable plot. The object of this evaluation was to compare the three methods and to appraise the re-

---

[1] *Published with approval of the Director, Wyoming Agricultural Experiment Station, as Journal Paper No. 165.*

[2] *Acknowledgement is extended to graduate students Clayton Williams and Otto Schipporeit for their assistance and interest in this investigation.*

lationship of data acquired by different personnel.

Review of Literature

Estimates of vegetation cover for range inventry studies were originated in 1907 by Jardine. His method, known as the reconnaissance method, was used on a team basis and consisted of estimating percentage of ground cover and the percentage composition of the species in the vegetation (Pickford, 1940). Although widely adopted, the method has been criticized, since accuracy of results depended largely upon the judgment and observational powers of the individuals using it (Smith, 1944).

A number of plot sizes have been developed for cover estimation procedures (Brown, 1954). Armstrong (1907) used a frame one square foot in area and subdivided into 144 square inches by cord stretched across the frame. He counted squares of bare surface and squares occupied by vegetation. With practice and care, he was able to obtain accurate estimates of cover by examining 6 to 10 frames on a representative portion of turf. However, the method is not altogether satisfactory since estimation of tall plants is difficult and location by "random" throws tends to be biased (Greig-Smith, 1957).

The variable plot method was first proposed by Bitterlich (1948) in Austria. By this system, timber-volume estimates were obtained without establishing plot boundary lines. Basically, the procedure consisted of viewing all trees visible from a given point and counting all those whose diameters appeared greater than a hand-held angle gauge. The total count divided by the number of sampling points, multiplied by a constant derived for a given angle, gave an estimate of average basal area per acre. Grosenbaugh (1952) introduced the method to American foresters. Subsequent modifications have been developed to permit use of the method on shrub and grass types.

Cooper (1957) conducted variable plot studies on shrub types of southern Arizona. Modifications were developed for the direct conversion of shrub counts to percent cover data through division-factor constants for various sighting angles as projected by different crossarm lengths. A comprehensive derivation of variable plot principles and factor equations was presented. Variable plot studies were compared with direct shrub cover measurements and line interception data in three vegetation types. The variable plot estimates closely approximated the other methods in shrub stands of less than 35 percent cover and were much less time consuming.

Kinsinger, *et al.* (1960) compared different vegetation types of northern Nevada to evaluate variations of line interception, variable plot, and loop methods of shrub cover estimation as developed by different observers. Differences between observers and between plots of a vegetation type were negligible by variable plot analysis. Individual shrubs were difficult to distinguish when cover was more than 20 percent.

Hyder and Sneva (1960) constructed an apparatus of angle iron for application of variable plot studies on bunchgrass range of Oregon. Basal cover estimates were significantly greater by variable plot than by line intercept; however, the differences were not consistent among species. Differences between observers were slight. Reduction of reading time appeared to be the greatest advantage of the variable plot method.

Procedure

Crown cover studies were conducted on three shrub types—Nuttal saltsage (*Atriplex nuttallii* S. Wats.), big sagebrush (*Artemisia tridentata* Nutt.), and greasewood (*Sarcobatus vermiculatus* (Hooki) Torr.). The sites were relatively uniform over an area approximately 200 feet in diameter and typical of much of the rangeland of western Wyoming. Saltsage (Figure 1) is a half-shrub, rarely over a foot in height with well defined plant units. The sagebrush (Figure 2) in this area is about 2.5 feet tall, while the greasewood (Figure 3) ranges from three to five feet in height. Individual bushes of the latter two species are, in many cases, not well defined.

Three observers collected individual data by three methods. Visual estimates were determined on a reconnaissance basis while standing in the study site and recorded in units of 5-percent crown cover. Cover data were obtained from transects of 10 frames, each a square foot in area. Each observer located plots independently of the others but within the general study area. Variable plot estimates were conducted from a single location point within each of the study sites.

A wooden angle gauge (Figure 4) was constructed similar to that described by Cooper (1957). The overall length, or the distance from eyepiece to crossarm, was 30 inches. Peephole diameter of the eyepiece was 5/32 of an inch. Four lengths of crossbar with division constants of 1, 2, 4, and 6 were used and individual readings obtained by each of the angles. The crossbars were easily exchanged but were held firmly in the cross lap cuts.

Before the reported study, survey procedures with the three methods were conducted throughout the region for two weeks. All observers were thus able to estimate shrub cover with reasonable uniformity. Emphasis was placed upon the concepts of recognizing the influence of plant growth form and height upon visual and square foot plot estimations. Variable

FIGURE 1. The saltsage site is characterized by the sparse stand of well-defined and easily identifiable plant units.

plot determinations involved the study of delineating plant units of various species.

Results and Discussion

Mean values of percent crown cover by shrub type as evaluated between methods and between observers are presented in Table 1. Differences between cover values of shrub types are not related and are of little importance as a measure of variation in this study. Determination of cover by visual estimate were equal by the three observers on the saltsage site but were extremely variable on the other two sites. This would appear to be a function of the growth form and height of the different species. Visual estimation must, of necessity, be considered a gross procedure with an expected high degree of variability between observes unless intensive training and checking procedures are conducted. Cover estimates from transects of square foot frames appear to be of little value for shrub cover determinations. Observer differences were great and the overall averages of cover by this method were much less than those by the other methods. It seems obvious that this method cannot be successfully applied to shrub cover determinations.

Mean cover values of variable plot data as presented in Table 1 indicate relatively close estimates between observers on given sites. Further evaluation of the data by standard statistical procedures (Ostle, 1956) yields interesting sources of variation. Mean squares for relation of variance to shrub types, gauge angles as determined by crossarm lengths, and observers are presented in Table 2. Shrub types introduced an expected highly significant variation in cover estimates. Other sources of significant variation in mean squares were crossarm lengths, observes, and the interaction between shrub types and gauge angles.

The highly significant variation in different crossarm lengths appeared to result from the higher average cover estimation values of the next to the longest crossarm length—that of 4-15/64 inches (Table 3). Interaction effects of the saltsage data tend to modify the deviation but appear to be of slight significance. Computation of the least significant difference (L. S. D.) shows the average crown cover value by this length to be significantly different from all others at the

FIGURE 2. The dense stand of big sagebrush is characteristic of much of the study area.

FIGURE 3. Many bottomland areas are dominated by greasewood.

5-percent probability level. The others are uniform and indicate little variation.

Effective sampling radius becomes larger with a smaller angle and thus, if a change in estimation occurs, one would expect it to be downward. This follows from the concept that, as the distance of measurable plants from the observer increases, the probability increases that hidden bushes will not be counted and that separate plant units will be combined into single counting units. Confirmation of this hypothesis is noted in the observed lower estimates of the shorter crossarms on the sagebrush and greasewood sites (Table 3).

The low estimates by the longest crossarm indicate other agents that can cause variation. The basic concept of the variable plot technique assumes a crown measurement procedure on a horizontal plane. This is virtually impossible in field application, since the observer must usually be above the bushes to be able to see and distinguish them. This difference in observer and plant height increases the measuring distance to the shrubs. For a given gauge angle, the greater the sighting distance, the greater the shrub diameter must be to be counted. Since this effect is most pronounced near the observer, proximate bushes could easily be ignored and not counted.

Therefore, subject to the interaction effects of plant height, it would appear that a crossarm of 4-15/64 inches will develop the greatest accuracy for the vegetation under study. Interestingly enough, this concept results from the fact that cover data by this length crossarm are significantly

Table 1. Means of percent cover of three shrub types as determined by three methods by three individuals.

	SHRUB TYPES								
	Nuttall Saltsage			Big Sagebrush			Greasewood		
Observer	Visual Estimate	Sq. Ft. Plot	Variable Plot[1]	Visual Estimate	Sq. Ft. Plot	Variable Plot	Visual Estimate	Sq. Ft. Plot	Variable Plot
A	15.0	7.9	12.98	30.0	5.2	22.18	15.0	3.5	14.38
B	15.0	.9	12.25	20.0	8.7	20.12	10.0	6.0	11.15
C	15.0	7.8	12.05	15.0	14.4	24.08	5.0	5.1	13.75
Average:	15.0	5.5	12.43	21.7	9.4	22.13	10.0	4.9	13.09

[1]Each figure is an average of cover estimates with four different angles as determined by four crossarm lengths.

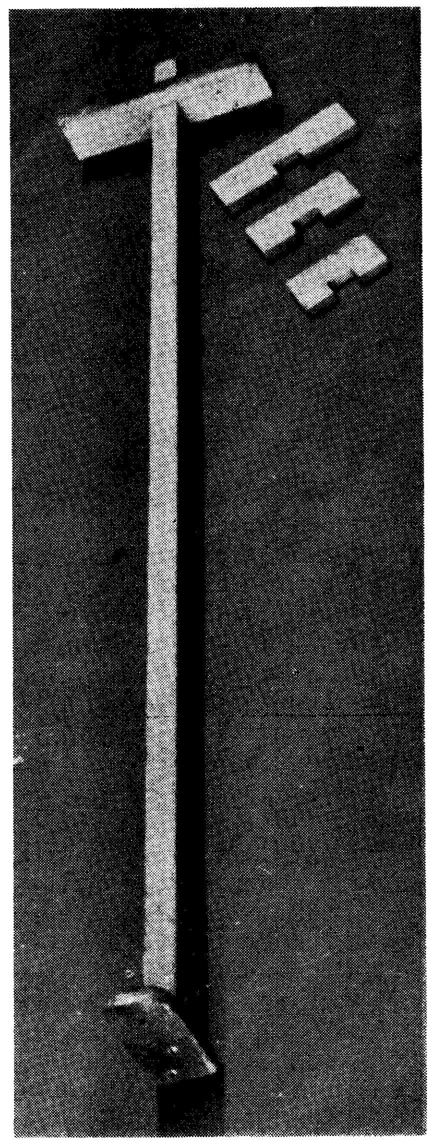

FIGURE 4. The Wooden angle gauge was prepared for rapid exchange of crossarms.

Table 2. Mean squares of crown cover estimate by variable plot procedures for relation of variance to shrub types, crossarm lengths, and observers.

Source of Variation	Degrees of Freedom	Mean Square
(S)hrub Type	2	352.28**
(C)rossarm Length	3	31.33**
(O)bserver	2	16.99*
S x C	6	8.96*
O x S	4	5.63
C x O	6	.96
Error (S xC x O)	12	2.80

*Significant at the 5-percent probability level.
**Significant at the 1-percent probability level.

different from the others. Also, the foregoing conclusions and the intuitive results of a summers' application of the variable plot technique are in accord.

The significance of the interaction between shrub types and crossarm lengths in the analysis of variance (Table 2) appears to be due to the differences in saltsage height and growth form from the other species. Crown cover estimates of sagebrush and greasewood increased from the shortest to the 4-15/64 inch crossarm length and decreased with the longest length. Saltsage estimates, however, were relatively uniform by the shorter lengths and decreased markedly with the the longest crossarm. The low estimate of saltsage by the longest crossarm length (Table 3) can be explained in light of the height differential between observers and plants. Further, the uniformity of estimate with the other three lengths follows with the low plant stature, wherein fewer countable plants would be missed than would be the case with the taller species.

The significant observer variation in the analysis of variance of Table 2 results from a very interesting sample bias situation. It will be noted in Table 1 that the average variable plot cover estimate of saltsage by observer "B" is intermediate between those of the other two observers. In the sagebrush and greasewood types, his estimate is noticeably lower than the other. The tendency of observer "B" to underestimate is also noted in Table 3. Least significant difference (L. S. D.) at the 5-percent probability level is less than the differences between observer "B" and the others.

The foregoing would be difficult to explain except that observer "B" was only four feet nine inches tall and observers "A" and "C" were six feet tall. On the saltsage site, the 15-inch differential in observer height evidently did not influence the overall estimate. However, on the big sagebrush and greasewood sites, lower estimation of cover by the shorter man evidently resulted from his inability to see and distinguish the individual plants as far from the observation point as the taller workers. Further inference from these data would indicate that any difference in observer height could result in variation of cover estimates, depending upon the height and growth form of the plants.

Summary and Conclusions

Range survey methods of shrub crown cover measurements must be rapid, accurate, and consistent among individuals. Studies were conducted to compare percent crown cover estimates from three methods of evaluation on three shrub types by three observers.

Cover values obtained by the visual estimation technique were variable. However, data indicated that relatively accurate determinations could be obtained with intensive training and repeated checks.

Transects of square foot plots appeared to be of little value as a shrub cover estimation technique. Observer differences were great and crown cover values were markedly lower than those obtained by the other methods.

Variable plot studies were conducted with four gauge angles as determined by different crossarm lengths. Evaluation of the data by analysis of variance indicated significant differences in shrub types, crossarm lengths, observers, and the shrub type X crossarm length interaction.

Variation due to crossarm length appeared to be due to characteristics of plant height and growth form and to differences in effective sampling radius as reflected by the different

Table 3. Means of percent cover by variable plot estimation of crossarm lengths and observers among shrub types and crossarm lengths and shrub types among observers.

	Crossarm Length (inches)				
Observer	2-29/64	3.0	4-15/64	6.0	Average[1]
A	15.03	16.17	18.83	16.00	16.51
B	12.77	14.77	17.17	13.33	14.51
C	15.57	15.43	19.83	15.67	16.62
Average[2]	14.46	15.46	18.61	15.00	
Shrub Type					
Saltsage	13.13	13.07	13.83	9.67	12.42
Sagebrush	19.07	21.77	25.67	22.00	22.13
Greasewood	11.17	11.53	16.33	13.33	13.09

[1]L. S. D. of 1.49 at 5-percent probability level.
[2]L. S. D. of 1.72 at 5-percent probability level.

gauge angles. The smaller the crossarm length, the greater the sampling radius, and when this distance becomes greater, the probability increases that the observer will underestimate the number of countable shrubs. On sagebrush and greasewood the two shorter crossarm lengths consistently underestimated cover, but on saltsage they did not. The estimates from the longest crossarm appeared to underestimate cover because of the differential in observer and plant heights. The next to the longest crossarm (4-15/64 in.) appeared to provide the best estimate of cover subject to the shrub type interaction, which tended to modify the results.

As observer height above the bushes increases, fewer countable bushes will be overlooked. Observer "B" was 15 inches shorter than the others, and consistently estimated less cover on sagebrush and greasewood. However, his estimates on saltsage were intermediate between the others.

Field studies should be conducted to determine the most accurate gauge angle subject to shrub height and density before range survey use of the variable plot technique. In addition, inherent variations in data due to different observer heights must be evaluated. With a minimum of procedural control the variable plot method of shrub crown cover estimation appears to be a highly satisfactory tool for range surveys.

LITERATURE CITED

ARMSTRONG, S. F. 1907. The botanical and chemical composition of the herbage of pastures and meadows. Jour Agric. Sci. 2:283-304.

BITTERLICH, W. 1948. Die Winkelzahlprobe. Allgemeine Forst-und-Holzwirtschaftliche Zeitung 59(1/2):4-5.

BROWN, D. 1954. Methods of surveying and measuring vegetation. Commonwealth Bur. Past. and Field Crops. Hurley, Berks, England: Bul. 42. 223 pp.

COOPER, C. F. 1957. The variable plot method for estimating shrub density. Jour. Range. Mangt. 10:111-115.

GREIG-SMITH, P. 1957. Quantitative plant ecology. Academic Press Inc., New York: 198 pp.

GROSENBAUGH, L. R. 1952. Plotless timber estimates—new, fast, easy. Jour. For. 50:32-37.

HYDER, D. N., AND F. A. SNEVA. 1960. Bitterlich's plotless method for sampling basal ground cover of bunchgrasses. Jour. Range Mangt. 13:6-9.

KINSINGER, F. E., R. E. ECKERT, AND P. O. CURRIE. 1960. A comparison of the line-interception, variable-plot and loop methods as used to measure shrub-crown cover. Jour. Range Mangt. 13:17-21.

OSTLE, B. 1956. Statistics in research. Iowa State Coll. Press. 487 pp.

PICKFORD, G. D. 1940. Range survey methods in western United States. Herb. Rev. 8:1-12.

SMITH, A. D. 1944. A study of the reliability of range vegetation estimates. Ecol. 25:441-448.