The Variable Plot Method for Estimating Shrub Density

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Reliable measurements of shrub density on range lands can be made without the use of time-consuming line transect or plot methods. A quick, one-man system of counting shrubs can be used to estimate the percentage of an area covered by woody plants. This procedure has been employed successfully to estimate densities of shrubs and half-shrubs ranging from 6 inches to 30 feet in crown diameter.

Usually called the variable-plot method, the system was developed

in Austria. It was first proposed by Bitterlich (1948), who used it to make timber volume estimates without the necessity of establishing sample plot boundaries. Bitterlich's method was introduced to American foresters by Grosenbaugh (1952). A simple modification of the original technique permits it to be used to estimate shrub cover directly in percent.

The variable-plot method requires no actual measurements in the field. No plots or lines are laid out on the ground, and it is unnecessary to measure the dimensions of any plant. The usual measured plots or lines are replaced by a series of sampling points distributed at random throughout the area to be surveyed. At each sampling point, the observer views through the eyepiece of a hand-held angle gauge every shrub visible from that point. The angle gauge is illustrated in Figure 1. Those shrubs are counted whose horizontal crown spread appears larger than the crossarm of the angle gauge. Shrubs whose crown spread appears less than the length of the crossarm are ignored. Figure 2 is a schematic diagram showing a shrub that would be counted and one that would not. The distance at which a shrub is
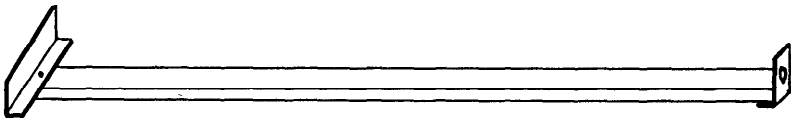

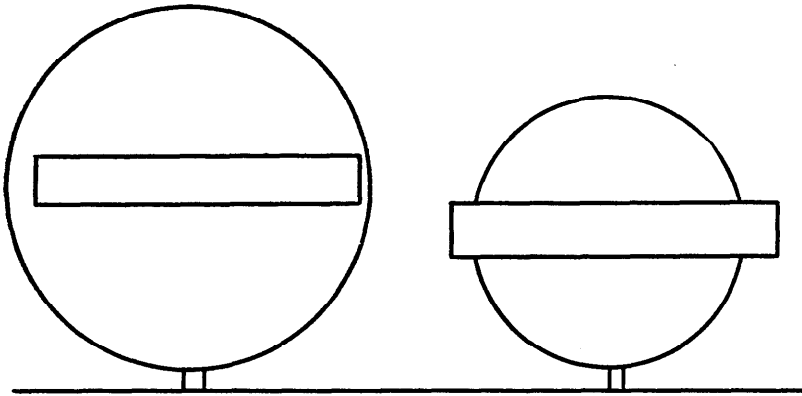FIGURE 1. The angle gauge. Crossarm is at the left, eyepiece at the right.

FIGURE 2. Schematic diagram of two shrubs viewed with the angle gauge. The shrub on the left would be counted; the one on the right would not.

counted depends upon its size. Large shrubs are counted at a greater distance from the observer than small ones.

To determine shrub crown density in percent, it is necessary only to divide the average shrub count for all the sampling points by a predetermined constant. This constant is determined by the dimensions of the angle gauge. The number of sampling points required on any area depends on the desired intensity of the survey.

Principle of the Method

The plots from which the method takes its name are entirely theoretical—they are not laid out on the ground. Each sampling point is the center of several theoretical circular plots of varying radii (Husch, 1956). At each sampling point, there are many overlapping plots with a common center, each plot corresponding to one of the shrubs counted with the angle gauge.

Let us assume that an angle gauge has an overall length of 30 inches, with a crossarm six inches long. When held to the eye, this gauge intercepts a horizontal angle of 9°25'. This angle just includes a circle at five times its diameter from the observer. A circle that intercepts a larger angle than 9°25' will appear larger than the instrument crossarm, and is closer to the eye than five times its diameter. One which intercepts a smaller

angle is farther away and will appear smaller than the cross arm. These relations follow from the fact that the overall length of the gauge is five times the length of its crossarm.

A small circle occupies one percent of the area of a large circle if the radius of the large circle is five times the diameter of the small one. For instance, a circle ten feet in diameter has an area of about 78.54 square feet. A large circle whose radius is five times the diameter of the small one, or fifty feet, has an area of 7,854 square feet. Thus, the small circle occupies one percent of the area of the large one.

Now let us consider a shrub stand as observed with the angle gauge from a single sampling point. Any shrub whose horizontal crown spread appears exactly equal to the length of the crossarm is five times its own diameter from the sampling point; if it appears to extend beyond the edges of the crossarm it is closer than this limit. These are the shrubs that are counted.

Each shrub counted with the angle gauge occupies one percent of the area of a hypothetical plot whose radius is five times the diameter of the shrub. When a shrub is observed with the angle gauge, a theoretical plot of this radius is automatically set up. The limits of this plot are established by the fact that if a shrub is outside the plot, it appears smaller than the

instrument crossarm and is not counted. Each shrub counted therefore represents one percent shrub cover, and the total number counted is the percent of shrub cover at that sampling point.

A numerical example may help make this clear. A shrub, exactly ten feet in diameter, is located 25 feet from a sampling point. When this plant is observed through the angle gauge, a theoretical plot fifty feet in radius is automatically set up, and the shrub is observed to lie within this plot. Since the area of the shrub is 78.54 square feet, and that of the plot is 7,854 square feet, the shrub occupies one percent of the theoretical plot. At first glance, it might appear that since this shrub is less than fifty feet from the plot center, it represents more than one percent ground cover. A little thought will show that this is not so. The angle gauge sets up a maximum limit beyond which shrubs are not counted, and any shrub within this limit represents one percent of the area of the hypothetical plot.

A second shrub ten feet in diameter forty feet from the observer is still within the fifty foot limit, and it also occupies one percent of the area of the plot. If these two are the only shrubs which lie within five times their own diameter from the plot center, the shrub density at that sampling point is two percent, no matter how many plants there may be on the area that are more than five times their diameter away. If, however, a shrub twenty feet in diameter is sixty feet from the observer, it also is less than five times its diameter away. Its theoretical plot has a radius of 100 feet, and the shrub occupies one percent of the plot. These three plants taken together then indicate a three percent ground cover at that sampling point.

In other words, any shrub which is not more than five times its own diameter from the sampling point represents one percent of shrub cover at that point. The total number of shrubs that lie within

this limit represents the percent of ground cover at that point. Many other shrubs will be visible from each sampling point, but only those that lie within the specified limit contribute to the estimate of ground cover. The variable-plot method is nothing more than a means of counting all the shrubs that lie within this limit.

The instrument just described is unwieldy and hard to use in the field. Better results are obtained if the crossarm is made smaller, thus intercepting a smaller angle. A smaller crossarm means that shrubs will be counted at a greater distance from the eye, and that more than one shrub will be needed to equal one percent ground cover. Therefore, with a smaller crossarm the shrub count must be divided by a constant to determine the percent of shrub density.

To determine the relation between this constant and the dimensions of the instrument, it is necessary to consider the mathematics of the method. Percentage of ground cover may be written

$$P = \frac{n\,S^2}{(2R)^2} \times 100 \qquad (1)$$

where P is percentage, n is number of shrubs on the plot, S is shrub diameter in feet, and R is plot radius in feet. The angle gauge is so constructed that

$$\frac{W}{L} = \frac{S}{R} \qquad (2)$$

when W is the length of the crossarm and L is the overall length of the instrument (more precisely, the distance of the crossarm from the eye). Substituting in (1),

$$P = n \times \frac{W^2}{(2L)^2} \times 100 \qquad (3)$$

This can be expressed in the form

$$W = \frac{L}{5\sqrt{\dfrac{n}{P}}} \qquad (4)$$

If r is the constant by which the shrub count at any point must be divided to find the percentage of ground cover, then

Table 1. Convenient division factors and crossarm lengths.

Division Factor	Ratio of crossarm length to distance of crossarm from the eye	Length of crossarm for instrument length of 30 inches	Width of calibration target at 100 feet from the eye.
		Inches	Feet
1	1:5	6.0	20.00
2	1:7.07	4 15/64	14.14
3	1:8.66	3 15/32	11.54
4	1:10	3.0	10.00
5	1:11.18	2 11/16	8.94
6	1:12.27	2 29/64	8.15

$$P = \frac{n}{r} \text{ and } r = \frac{n}{P} \qquad (5)$$

Substituting (5) in equation (4), the final form becomes

$$W = \frac{L}{5\sqrt{r}} \qquad (6)$$

It should be pointed out that this formula is mathematically not strictly accurate. A correction should be made for the fact that the line of sight intercepts a chord closer to the observer than the true crown diameter. The error due to omission of this correction is so small as to be almost undetectable in variable-plot sampling.

From equation (6) it can be seen that if an instrument is 30 inches long and has a division constant of 2, its crossarm must be 4.24 inches long. The ratio of crossarm length to the distance of the crossarm from the eye is 1:7.07. Table 1 lists several other convenient division constants, with their accompanying ratios and crossarm lengths.

Construction and Use of the Instrument

The angle gauge can easily be made from a strip of hardwood and some scrap metal. Extruded aluminum angles of the "do-it-yourself" variety sold by hardware stores make excellent material for the eyepiece and crossarm. The angles should be about 1¼ inches on a side. The eyepiece should have a viewing hole about ⅜ inch in diameter. An instrument length of about 30 inches is convenient. If it is much shorter, difficulty will be experienced in keeping both

the crossarm and the more distant shrubs in focus at the same time.

To illustrate the procedure followed in using the variable plot method, Table 2 lists the actual counts from a field trial made in an open stand of creosote bush (*Larrea tridentata*) and palo verde (*Cercidium microphyllum*). The angle gauge was calibrated to require a division constant of 2. Twelve sampling points were located at arbitrary intervals of four chains, on two lines through the area. From each sampling point, those shrubs were counted whose diameters appeared larger than the crossarm. The counts were totaled and divided by 12 to find the average. This average was then divided by 2, the division constant of the instrument, to estimate the percentage of the area covered by shrubs. In this case, the total

Table 2. Sample variable-plot tally in a creosote bush type.

| Sampling Point | Shrubs Counted | |
	Creosote Bush	Palo Verde
1	22	4
2	21	9
3	27	11
4	49	8
5	27	7
6	23	10
7	29	7
8	40	7
9	38	14
10	29	16
11	40	9
12	29	2
Total	374	104
Average	31.17	8.67
Density	15.58%	4.33%

crown density of creosote bush was
estimated at 15.6 percent; that of
palo verde at 4.3 percent.

The principal difficulty in the
use of the variable-plot method is
that distant shrubs which should
be counted tend to be obscured by
those nearby. This difficulty is
minimized by using a crossarm
length which permits a division
factor of 2. Shorter crossarms,
with larger division constants, are
occasionally useful in very sparse
and open shrub stands. A longer
crossarm, with a division constant
of unity, becomes completely un-
manageable, and introduces seri-
ous errors.

In dense shrub stands, many dis-
tant shrubs are obscured and ac-
curacy falls off rapidly. The meth-
od is not very reliable where den-
sities exceed about 35 percent. For
this reason, it is best suited to
sparse desert-shrub types, to areas
of shrub invasion in grasslands,
and to other open types. If the
plants are small, it is necessary to
crouch down in order to keep the
line of sight nearly horizontal.

Steep slopes require a correction
of shrub counts to increase accur-
acy. The count at any point is
multiplied by the secant of the
angle of slope perpendicular to
the contour. An average slope
correction can be used if shrub
density does not change markedly
with changes in slope.

Another possible source of trou-
ble lies in the distance of the cross-
arm from the eye. It is this dis-
tance which determines the char-
acteristics of the angle gauge,
rather than the actual overall
length of the instrument itself. It
is best to use the following cali-
bration procedure in adjusting the
final position of the crossarm. Sup-
port the instrument firmly and
measure a distance of 100 feet
from the eyepiece. At this distance,
lay out a target at right angles to
the line of sight. If the angle has
a division constant of 2, the target
should be 14.14 feet across. Sizes
of target for other constants are
listed in Table 1. With the eye-
piece held firmly against the bones

Table 3. Results of tests of variable-plot method in various shrub types.

Species	Estimated percentage of shrub cover				
	Variable Plot		Line Transect		100% Tally
	Number of plots	Percent of cover	Number of lines	Percent of cover	Percent of cover
Creosote bush	12	15.58	10	15.25	
Palo verde	12	4.33	10	3.10	
Mesquite	15	12.07			12.64
Burroweed	36	10.43	24	9.78	

surrounding the eye, move the
crossarm backward and forward
on the wooden base until the target
is exactly covered. Fasten the
crossarm securely at this point. A
slotted bolthole on the crossarm fa-
cilitates calibration. If eyeglasses
are worn, the instrument can be
made shorter so that the eyepiece
rests against the glasses.

The data obtained from vari-
able-plot samples are subject to the
usual statistical analyses. Com-
monly used formulas can be used
to compute standard deviation,
standard error of the mean, and
other useful statistics. Further-
more, variable-plot data lend them-
selves readily to the calculation of
an index of dispersion. This index
is a measure of the spatial distribu-
tion of individual plants, indicat-
ing whether they are more or less
uniformly distributed than would
be expected as a result of pure
chance. Rice and Penfound (1955)
describe in detail the method of
calculating this index, which is of
value in many ecological studies.

Bitterlich's method was first
used to measure basal area of tree
stems in square feet per acre. For
this purpose, a crossarm length to
eye distance ratio of 1:33 has com-
monly been used, rather than the
1:7.07 recommended for shrubs.
Estimates using this small cross-
arm have been found quite reliable
in forest stands (Rice and Pen-
found, 1955; Shanks, 1954). Husch
(1955) found that he obtained
more accurate estimates of basal
area by using a 1:16.5 ratio. All of
these investigators found that the
variable-plot method took much
less time than the conventional
methods with which it was com-
pared.

Comparisons with Other Sampling Methods

Several tests were made to com-
pare the variable-plot procedure
with standard estimating methods
in diverse shrub types in southern
Arizona. Results of these compari-
sons are summarized in Table 3.

Data were available on the per-
centage of crown cover in a 6-acre
stand of mesquite (*Prosopsis juli-
flora*). The crown area of each tree
had previously been measured, and
the percent of ground cover de-
termined. The complete tally
showed a cover density of 12.64
percent, while the variable-plot
samples estimated density to be
12.07 percent.

The variable-plot method was
next compared with the line tran-
sect method (Canfield, 1941) in
common use by range technicians.
As the line transect method is gen-
erally considered to give fairly re-
liable estimates of plant density, a
comparison of the two methods
will presumably give an index to
the accuracy of the variable-plot
technique.

The 12 variable-plot samples in
the creosote bush stand previously
described were compared with ten
200-foot line transects run through
the same area. The variable-plot
samples gave a creosote bush den-
sity estimate of 15.58 percent,
while the line transect estimate
was 15.25 percent. There was a
greater difference in the palo verde
estimates, which were 4.3 percent
and 3.1 percent, respectively. How-
ever, the palo verdes were so wide-
ly scattered that neither sample
was adequate.

In order to test the effect of a
smaller crossarm, a second set of

variable-plot samples was taken from the same sample points as in the first survey, using an instrument with a division constant of 4. Collection of the data for this second set of samples took longer than the first because of the greater number of shrubs that had to be counted, and to the greater effort required to avoid missing some. In spite of all precautions, a few were evidently missed, because the 4X angle gauge yielded a density estimate of only 14.3 percent for the creosote bush, compared with the previous estimate of 15.6 percent. The palo verde estimate was almost the same for the two instruments, because of the large size and small number of these trees, which were easily visible even at a distance.

A final comparison was made in a stand of burroweed (*Happlopappus tenuisectus*), a desert half-shrub averaging about one foot in diameter. Thirty-six variable-plot samples were compared with 24 line transects, each 100 feet long. The variable-plot density estimate was 10.43 percent, while that by line transects was 9.7 percent. The difference between these two results was less than the expected sampling error calculated for either method.

Since these tests compared one sampling method with another, it was not possible to calculate the statistical significance of the difference between them. However, it has generally been considered that any sampling method is satisfactory that yields an estimate within 10 percent of the true cover density. The agreement between the variable-plot estimates and those made by other methods strongly suggests that density estimates made by the variable-plot method will fall well within these limits.

The variable-plot technique is most applicable where nearly circular objects are sampled. If shrub crowns are extremely irregular, considerable bias will be introduced. For this reason, the method is most useful in reconnaisance and extensive surveys. In forestry work, the angle prism suggested by Bruce (1955) has been widely adopted instead of a stick. This idea could be tried for estimating shrub cover, but the angle prism appears to have fewer advantages in counting shrubs than it does in counting small tree trunks.

Summary

The variable-plot method can be used to estimate shrub density in percent without measurement of distance or area. This method is faster and easier to apply than any of the standard shrub-estimating procedures now in common use. In tests in three different vegetation types, it closely approximated the estimates obtained by other sampling methods. It is most reliable in open shrub stands with a density of less than 35 percent; beyond that point accuracy falls off rapidly. Variable-plot data are subject to statistical analysis, and are particularly useful in calculating an index of dispersion. The variable-plot method appears to be a practical means of reducing the labor required in collecting field data on shrub density.

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Report On Argentina

WALTER DUTTON, back from his F.A.O. range assignment in Argentina, is enthusiastic about the future possibilities for increased livestock production in that country. Breeding standards are high. A favorable climate over much of the area allows exceptionally long growing periods. Grazing capacities on both natural grasslands and artificial pastures are outstanding—in many places 2 to 5 acres per head per cow for one year. Currently, however, the outlook is not encouraging. General failure during the growing period to convert surplus forage to hay and silage for use in winter is the main stumbling block to increased production. All too common are low calving and lambing percentages, long periods for steers to reach maturity, and heavy incidence of foot-and-mouth disease, stemming directly from lack of adequate feed during critical periods. On the other hand, and indicative of what can be done, a few outfits are marketing 18 month old steers, weighing 1100 to 1200 pounds, from alfalfa-rye grass-bromegrass pastures without any supplemental feeding. In Patagonia, about 70 percent of the land is owned by the Federal Government but is entirely without any provision for management or protection such as that given Bureau of Land Management and National Forest lands in the States. Consequently, as a result of many years of abusive use, much of the land in this province is in a serious stage of depletion.