A Two-step Sampling Technique for Estimating Standing Crop of Herbaceous Vegetation

D.M. ANDERSON AND M.M. KOTHMANN

Abstract

Standing crop of vegetation may be estimated by sampling foliar cover per unit area and then determining mass per unit of cover. Multiplying foliar cover per unit area by mass per unit of cover gives mass per unit area (standing crop). By this method standing crop is estimated rapidly with low variance while minimizing the amount of actual harvesting required. Standing crop of both major and minor species can be estimated adequately without over sampling major species and under-sampling minor species. The technique is most easily applied to herbaceous plant communities of low stature.

Technicians and scientists are frequently required to estimate standing crop of vegetation on large areas that have high diversity levels. Harvesting by species is slow which limits the number of plots that can be sampled. A large number of plots are usually required to obtain an adequate sample, especially where precision in sampling species of secondary importance to the standing crop is required. Therefore a technique more efficient than actual harvest for estimating standing crop by species would be useful.

The objective of this paper is to outline an efficient technique of estimating standing crop by a two-stage procedure which utilized ocular estimation of cover by species, and clipping to determine weight per unit of cover.

Authors are research scientist, U.S. Dep. Agri., Agri. Res. Serv., Jornada Experimental Range, Box 3JER, NMSU Las Cruces, N.M. 88003; and professor, Department of Range Science, Texas A&M Univ., College Station 77843.

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Armstrong (1907) used a plot frame with a permanently attached grid, and Goebel et al. (1958) used a plot frame with a sliding crosspiece to measure the relative proportion of ground surface occupied by different plant species. Stewart and Hutchings (1936) used circular plots without a grid to estimate ground cover by species. The geometrical shape of the plot may affect the accuracy of the estimate. The rectangular plot is generally superior in heterogenous vegetation; however, there are practical limitations in its placement, and on the amount of periphery if the plot is lengthened excessively (Daubenmire 1959).

Cook et al. (1948) combined clipping with estimating cover by units to estimate the weight per unit area of each plant species. A plant unit was defined as an easily recognizable portion of an individual plant; however, the unit size varied among species. The weight of each species per unit of land area was determined by multiplying the weight per unit of cover by the number of units of cover per unit of land area for that species.

Edlefsen et al. (1960) incorporated the concept of a unit with constant area into a plot frame which had legs that could be adjusted for varying heights of vegetation. The plot size was 1.52×1.52 m divided into units of 58 cm^2. The concept of a constant area unit was perpetuated by Kothmann (1968); however, the frame size was reduced to 0.30×0.61 m and the legs were removed. Durham and Kothmann (1977) increased the area of the frame to 0.5×0.5 m with units of 100 cm^2 and added legs 46 cm long.

Methods

Plot Frame

The size and shape of the plot may vary depending upon the density, homogeneity, and growth form of the vegetation. The plot

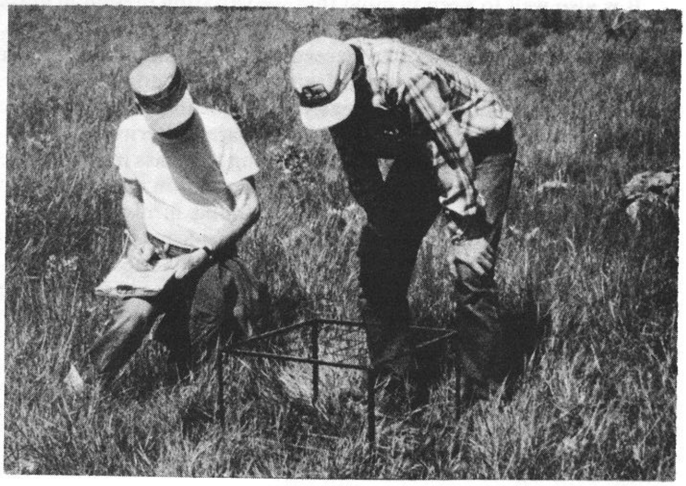

Fig. 1. *Reading units of foliar cover with a 0.25-m² plot frame.*

frame used for this study is 0.5 m on a side with a grid of wires welded on 10-cm centers. It is supported by permanently attached legs 46 cm long. Both the frame and legs are constructed from 1.27-cm angle iron.

Estimation of Foliar Cover

An appropriate sampling scheme should be used to determine the number and location of plots required to sample foliar cover adequately on the study area. Foliar cover of each plant species is estimated and recorded to the nearest one-fourth unit (25 mc²) with 1 unit being 100 cm². Units are defined by the wire grid. Foliar cover of a plant is defined by the perimeter of the normal spread of foliage (Daubenmire 1959), not complete ground cover or leaf area index. Cover units should be estimated from a vertical position (Fig. 1). To insure consistency in estimating units of foliar cover, the observers must practice reading units of foliar cover for all species encountered before sampling begins. Cover data are recorded as units of cover per plot for each specis.

Determination of Mass per Unit

Immediately following the estimation of foliar cover, mass per unit of cover is obtained. The objective is to collect a representative random sample of units of cover for each species. It is necessary to clip several samples for each species containing a combined total of about 50 units of cover to calculate a variance for the mass per unit. These samples may each contain equal numbers of units, such as 5 bags of 10 units each, or they may contain varying numbers of units.

The mass per unit may be calculated by 3 different techniques, mean per unit, ratio, or regression estimates. Only the regression estimate is considered in this paper since it gives a more precise mean per unit estimate (Cochran 1953).

Calculations

The first step in calculating standing crop from foliar cover is to sum units of cover per plot by species. Plots in which a species does not appear should be given a value of zero. The sum of units recorded for all species in a single plot may be greater than 25 because of a layered vegetation canopy. However, the total will usually be less than 25 units because mulch, bare ground, rocks, dung heaps, and other items are not considered during sampling. Total units of cover and the variance are calculated.

The second step is to calculate the mean mass per unit of cover by regression. A linear regression ($Y=bx$) is fitted with the line forced through the origin. The variance for b should also be calculated.

Standing crop for a single species can now be calculated using the following procedure:

$$SC = (\bar{x})(W)(CF) \tag{1}$$

where:
SC = standing crop (kg/ha) of a species
CF = correction factor (40) to change units from g/0.25m² to kg/ha
W = b (g/unit)
$\bar{x}$ = mean units of cover per plot

The variance for standing crop is obtained using Goodman's (1960) formula for the variance of a product. The assumptions are that the two variables, cover and weight per unit of cover, are independent and normally distributed.

$$Var(SC) = [CF]^2\,[(W)^2(S_{\bar{x}}^2)+(x)^2(VW)+(Sx^2)(VW)] \tag{2}$$

$S_{\bar{x}}^2$ = variance for mean units of cover per plot
VW = variance for b

Total standing crop can be obtained by summing standing crop values obtained for individual species (Equation 1). The variances associated with these sums are likewise obtained by summing the appropriate values obtained from equation (2).

Species composition of standing crop based on weight can be obtained as follows:

$$C_i = \frac{Z_i}{\sum_{i=1}^{k} Z_i} = \frac{a}{b} \tag{3}$$

where:
c_i = composition of the ith species
Z_i = standing crop (kg/ha) for the ith species
k = total number of species
$\sum_{i=1}^{k} Z_i$ = total standing crop.

The variance associated with C is computed using the formula for variance of a ratio (Cochran 1953) as follows:

$$S_c^2 = \frac{a^2}{b^2}\left[\frac{Var(a)}{a^2} + \frac{Var(b)}{b^2} - \frac{2(Covar\ a,b)}{ab}\right] \tag{4}$$

where:
S_c^2 = variance for composition for a species
a = standing crop for the species
b = total standing crop

The covariance (a,b) is equal to the covariance (a, a+c) where b = a + c, assuming a and c are independent, then covariance (a,b) = variance (a) + 0. Thus, equation (4) is simplified to the following form:

$$S_c^2 = \frac{a^2}{b^2}\left[\frac{Var(b)}{b^2} + \frac{Var(a)(b - 2a)}{a^2 b}\right]$$

Example

Data collected for Texas wintergrass (*Stipa leucotricha* Trin. and Rupr.) will be used as an example of the 2-step method for estimating standing crop (Table 1). Mass per unit of cover is calculated by regression techniques with appropriate variances determined.

A total of 372.5 units of Texas wintergrass cover were recorded from a sample of 100 plots with Texas wintergrass occurring in 87 plots. The variance ($S_{\bar{x}}^2$) was 18.96.

Eight clipped samples containing different numbers of units were collected, dried and weighed (Table 1). Using the regression technique, mass per unit (b), and its variance (S_b^2) are calculated as follows:

$$b = \frac{2643}{702} = 3.76 \text{ g/unit.} \tag{5}$$

$$S_b^2 = \frac{[10{,}571 - (3.76)(2643)] \div 7}{702} = 0.13 \quad (6)$$

Calculations for standing crop are as follows:

$$SC = (3.725)(3.76)(40) = 560 \text{ kg/ha} \quad (7)$$

$$\text{Var (SC)} = [40]^2\, [(3.76)^2(18.96) + 3.725)^2(0.13) + (18.96)(0.13) = 435{,}708 \quad (8)$$

Confidence interval = 130.7 kg/ha ($P < .05$)

Discussion

Precision in ocular estimation of cover is imperative, so the same individual should estimate units of foliar cover for both steps of the sampling. Accuracy in determining standing crop with ocular estimation of foliar cover lies in reading and clipping the same volume of cover per unit consistently even though the volume of standing crop as seen within a unit may differ between individuals. Contrary to the clipping procedure proposed by Payne (1974), clipping of complete plots at regular intervals while sampling foliar cover on the area is not recommended, because this procedure will over-sample abundant species and under-sample minor species. Reading and clipping at the same time also reduces efficiency of this technique because the plot frame, recording forms, bags and clippers must all be carried at the same time. Two observers, one reading and one recording, can evaluate 100–200 plots in 8 hrs depending on vegetation density and the size and topography of the area sampled (Anderson 1977).

The technique is ideal for evaluating low-growing vegetation such as short and mid-grasses. Species should not be combined into miscellaneous grass and forb categories while recording cover in the field if frequency and total foliar cover data are desired as well as standing crop and species composition.

The regression technique used for estimating mass per unit of cover assumed a straight line through the origin. The ratio technique for such estimates is equally precise (Cochran 1953) but the ratio estimate is only a particular case of the linear regression estimate. Cochran (1953) states that the ratio estimate is unbiased, for any size of simple random sample, if the population is infinite and the relation between y and x is a straight line through the origin. These assumptions are reasonably valid for sampling herbaceous vegetation.

Table 1. Data used for example calculations of standing crop (kg/ha) and variance using a two-step sampling technique for cover and mass per unit of cover. Sample data are for Texas wintergrass on a continuously grazed paddock near Throckmorton, Texas, 23 September 1975.

Cover data:
n=*100 plots*
$\bar{x}$ = 372.5 units of cover
$S_{\bar{x}}^2$=18.96

Weight per unit of cover:

sample	units of cover	mass		
n′	x′	y	y²/x′	x′y
1	1	6.3	40	6
2	1	7.0	49	7
3	5	15.6	49	78
4	5	25.3	128	127
5	10	25.8	67	258
6	10	21.8	48	218
7	15	68.2	310	1023
8	15	61.7	254	926
Σ	62	231.7	945	2643

$\Sigma x'^2 = 702$ $\quad \Sigma y^2 = 10{,}571$ $\quad n' = 8$

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