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ESTIMATES OF HERBACEOUS STANDING CROP BY MICRODENSITOMETRY

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BIOGRAPHICAL SKETCH

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ABSTRACT

Green standing herbage of seeded big bluegrass *(Poa ampla)* and corresponding dry weight were each regressed as dependent variables (Y) on color infrared photo image density (X) obtained from two photoscales: 1:563 and 1:3855. Standing crop biomass expressed by the linear equation: $Y = a + b(X)$ was from the 1:563 photoscale. The coefficient of determination ($r^2 = 0.752$) between image density and harvested dry weight was highly significant ($P = 0.01$). The same regression using the smaller photoscale (1:3855), although significant ($P = 0.05$), was not as good ($r^2 = 0.639$). Mean image density of six simulated productivity levels was significantly different ($P = 0.05$) among most levels of production represented in both photo scales.

INTRODUCTION

There are nearly one billion acres of land in the United States classified as range. Approximately 337 million acres of land in the western United States are occupied by native and improved grasslands.

An additional 236 million acres have a low shrub cover and also support a significant amount of herbaceous vegetation. Estimates of herbaceous standing crop are frequently needed for management decisions. For example, wildlife depend entirely, and domestic animals depend in part, on the vegetation in these areas for sustenance. We need to know how much is available for use to avoid serious impacts on the resource. This information is also needed to evaluate and monitor energy balances of ecosystems since productivity is directly related to energy flow.

Herbaceous standing crop has been estimated periodically by ground sampling. The procedures are costly, time consuming, tedious, and often with considerable error. Estimates of herbaceous productivity obtained by ground sampling only are additionally confounded by time. Plant populations may change considerably during the long sampling period. Aerial photographs, coupled with ground techniques, provide the opportunity to avoid some of the many sampling problems.

Foresters have successfully used aerial photographs to estimate various tree and timber stand characteristics (Aldrich 1966, Aldred and Kippen 1967, Lyons 1967, Sayn-Wittgenstein and Aldred 1967). Work has been done on identification and cover measurements of shrubby and herbaceous species (Carneggie, Wilcox, and Hacker 1971, Driscoll and Francis 1970). However, little or no research has been done on estimating herbage production from aerial photographs.

An experiment was initiated during the 1969 field season to determine if amounts of herbaceous standing crop could be estimated from differences in optical image density of aerial photographs. The research was done at the Manitou Experimental Forest, 25 miles northwest of Colorado Springs, Colorado, on a seeded stand of big bluegrass *(Poa ampla* Merr.).

METHODS

Ground Sampling

Six levels of standing crop were created on 3 X 3 meter square plots. Each plot was cut to a uniform height level that corresponded to a 20 percent increment removal ranging from 0 to 100 percent. These increments were used to represent various levels of standing crop production. Each treatment was replicated four times. It was recognized that the cutting procedure disturbed the natural geometry of the grass stand and would not truly represent normal conditions. However, the incremental levels of herbage removal also represented levels of herbage utilization.

Herbage remaining on each plot after cutting was estimated by double sampling with a heterodyne meter, an electronic device that senses mass within an array of probes (Neal and Neal 1965). All harvested material was retained for dry weight determinations. All ground sampling was done between August 12-14, the time of maximum herbage production.

Aerial Photography

Aerial photographs were obtained at two resultant scales--1:563 and 1:3855--on August 17 at approximately 1100 hours. Photos were taken from a Forest Service Aero Commander 500-B using two 70 mm Maurer

KB-8A cameras equipped with 150 mm Schneider Xenotar lenses. 1/ Simultaneous photographs were taken with two film types at each scale: Ektachrome Infrared Aero, type 8443, with a Wratten 12 filter, and Anscochrome D-200, type 7230, with an HF-3 filter. Weather at the time of the mission was clear with 100-mile visibility.

Data Reduction and Analyses

Interpretation of both film types indicated that the color infrared positive transparencies provided more discriminatory evidence of differences among standing crop levels than the color positive transparencies. Therefore, the color infrared transparencies were used in conjunction with a GAF 650 microdensitometer to provide data about image density of the various treatments. The machine was programmed to scan with an effective aperture of $416\mu^2$ using a green filter (Wratten 93). Preliminary filter tests with this and other imagery identified the green filter as providing greater image density spread among photo images of vegetation (Reppert, Driscoll, and Heller 1972).

Since the specific study area was seeded grassland, all microdensitometer scan lines were oriented perpendicular to the drill rows. Thus, possible scan lines on vegetation only or spaces between drill rows of vegetation were avoided. Nine random starts per imaged plot were used for the 1:563 scale photos; five were used for the 1:3855 scale photos. The base data from the microdensitometer was in the form of an analog strip chart readout, which was digitized by an Auto-trol digitizer and analyzed by regression and correlation.

RESULTS AND DISCUSSION

Green standing herbage and corresponding harvested dry weight were each regressed as dependent variables (Y) on the photo image density (X).

If a correlation coefficient (r) of 0.80 is assumed to be acceptable, the image density derived from both photographic scales provided a reliable estimate of either green standing herbage or harvested dry weight (Table 1). In all cases, the correlation coefficient was high (≥ 0.80) and significant (P = 0.01), indicating a strong relationship between image density values and amount of herbaceous biomass. Data from the 1:563 photoscale gave the "best" estimate (r = 0.87) of harvested dry weight. Expressed in linear regression form, this becomes

$$Y = a + b(X), \text{ where}$$

Y = standing crop production (dry weight),

a = 151.72,

b = 62.61, and

X = photo image density.

1/ Trade names and commercial products are mentioned for the benefit of the reader and do not imply endorsement or preferential treatment by the U. S. Department of Agriculture.

Table 1. Coefficients of Correlation (r) and Determination (r^2) for Image Density Values and Green and Corresponding Harvested Dry Weight; Color Infrared Photoscales 1:563 and 1:3855

	Photo Scale	
	1:563	1:3855
Green Weight		
r	0.85**	0.81**
r^2	0.72	0.66
Dry Weight		
r	0.87**	0.80**
r^2	0.75	0.64

** Highly significant (P = 0.01)

Since operational application of this technique may not allow dry weight determinations, however, the relationship between green standing crop and image density might be more practical. In this case, an estimate of green herbaceous standing crop, using the 1:563 photoscale, can be expressed by the linear regression equation,

$Y = a + b(X)$, where

Y = standing crop production (green weight),

a = 281.31,

b = 115.64, and

X = image density.

Additional analyses were made to compare image density differences among the six levels of standing crop. Image densities at the smaller photographic scale (1:3855) showed significant ($P = 0.05$) differences among all treatment levels except the 60 and 80 percent standing crop herbage treatments (Table 2). For the 1:563 photo scale, the mean image densities between the 0 and 20 percent levels of standing crop herbage were not significantly different ($P = 0.05$).

The reason for non-significance between the two treatments at each photo scale may be due primarily to the way the treatments were applied. Herbage height increments were used to simulate the various productivity levels rather than actual weight. Height and weight are not linearly related for herbaceous species; the relationship is exponential. Consequently, image density differences, which have been shown to be related to mass on the ground, may not be expected to differentiate equal height classes.

The 70 mm photographic system used for this research must be considered a sampling mechanism. The camera system was developed primarily to take photographs from a low-flying aircraft. Due to the relatively small film format (70 mm X 70 mm) and the narrow lens view angle, a single frame does not provide the synoptic view of the landscape otherwise recorded with conventional aerial camera systems. Consequently, the 70 mm system should be used to sample strips of landscape photographed simultaneously on film of conventional format.

CONCLUSIONS

We have defined a way in which green standing herbage, or corresponding dry weight mass, can be estimated from large-scale color infrared aerial photographs.

Many thousands of acres of land, especially in the West, have been seeded to monospecific grass stands. The technique developed here can be applied to these stands to obtain reliable estimates of herbage production. Such estimates are difficult to obtain by ground procedures only due to large areas and attendant inadequate sampling. We need to test the technique with native herbaceous plant communities, however. The plant species composition of such ranges is much more heterogeneous, and may yield more complex image density patterns on color infrared photos.

Table 2. Mean Optical Image Density of Standing Crop Levels by Color Infrared Photo Scales

	Photo Scale	
Standing Crop Levels	1:3855	1:563
	--- mean image density ---	
100	3.2067	3.0459
80	3.1016 1/	2.9534
60	3.0961 1/	2.8787
40	3.0191	2.7749
20	2.8937	2.5524 1/
0	2.8084	2.5383 1/

1/ Bracketed means represent homogeneous subsets (no significant difference). (Duncan 1955)

The technique should be applicable to native communities. Sampling techniques can then be used to estimate herbaceous productivity of large areas of land whereby the large scale photos are used to subsample smaller scale photos. This information could then be used in conjunction with imagery from space to quantify productivity of herbaceous communities without the problem of extended sampling periods.

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LITERATURE CITED

Aldred, A. H., and Kippen, F. W. 1967. Plot volumes from large-scale 70 mm air photographs. Forest Sci. 13:419-426.

Aldrich, R. C. 1966. Forestry application of 70 mm color. Photogramm. Eng. 32:802-810.

Carneggie, D. M., Wilcox, D. G., and Hacker, R. B. 1971. The use of large-scale aerial photographs in the evaluation of western Australian rangelands. Dep. of Agri. of West. Aust. Tech. Bull. No. 10.

Driscoll, R. S., and Francis, R. E. 1970. Multistage, multiband, and sequential imagery to identify and quantify non-forest vegetation resources. Annual Progress Report for Earth Resources Survey Program, OSSA/NASA. Sci. and Tech. Aerosp. Reps., NASA, Washington, D.C.

Duncan, D. B. 1955. Multiple range and multiple F tests. Biometrics 11:1-42.

Lyons, E. H. 1967. Forest sampling with 70 mm fixed airbase photography. Photogramm. Eng. 22:213-231.

Neal, D. L., and Neal, R. L. 1965. A new electronic meter for measuring herbage yield. U. S. Forest Serv. Res. Note PSW-56, 4 p. Pac. Southwest Forest and Range Exp. Sta., Berkeley, Calif.

Reppert, J. N., Driscoll, R. S., and Heller, R. C. 1972. Microdensitometry to identify plant communities and components on 70 mm color infrared aerial photographs. Manuscript to be submitted for publication in the J. Range Manage.

Sayn-Wittgenstein, L., and Aldred, Alan H. 1967. Tree volume from large-scale photos. Photogramm. Eng. 67:69-73.

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FISHEYE LENS IN FOREST SAMPLING

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BIOGRAPHICAL SKETCH

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He is the author of several publications, amongst them the manual "Photographic Interpretation of Tree Species in Ontario."

Victor is a member of the Association of Professional Engineers of Ontario, the Ontario Professional Foresters Association, the American Society of Photogrammetry and the Society of Photographic Scientists and Engineers. He is also a member of the Editorial Board of the "Photogrammetria" of the International Society for Photogrammetry.

ABSTRACT

Aerial forest sampling is generally achieved with large-scale photographs. Forest cover on a close-up photo shows no landmarks for the identification of exact location. This paper demonstrates a simple and economical idea to overcome this problem by the combination of a fisheye lens with the sampling lens of two synchronized 35mm cameras.