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ESTIMATING VEGETATIVE BIOMASS FROM LANDSAT-1 IMAGERY FOR RANGE MANAGEMENT.

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ABSTRACT

Evaluation of LANDSAT-1, band 5 data for use in estimation of vegetative biomass for range management decisions was carried out for five selected range sites in the Sandhills region of Nebraska. Analysis of sets of optical density-vegetative biomass data indicated that comparisons of biomass estimation could be made within one frame but not between frames without correction factors. There was high correlation among sites within sets of radiance value-vegetative biomass data and also between sets, indicating comparisons of biomass could be made within and between frames. Landsat-1 data are shown to be a viable alternative to currently used methods of determining vegetative biomass production and stocking rate recommendations for Sandhills rangeland.

INTRODUCTION

Estimates of vegetative biomass from reflectance data acquired by aircraft and satellites have been evaluated by a number of investigators. In general, these studies indicate that estimates of vegetation density based on reflectance data are complicated by factors associated with the vegetation itself, and with the underlying soil when vegetation does not cover the soil surface completely.

Reflectance is influenced by the kind as well as the density of vegetation. Thus, differences in reflectance were used by Laver and Krumpe (1) to distinguish stands of woody species and herbaceous species, and by Tueller, et al., (2) to distinguish the various vegetation types in Nevada. We have observed that pure stands of different grass species may be differentiated on high-altitude color-infrared photography. Wiegand (3) demonstrated relationships between reflectance measured in multispectral scanner (MSS) bands of LANDSAT-1 and vegetation density in given stands of known crops. In the case of mixed rangeland vegetation, however, estimates of vegetative biomass may be complicated by differences in plant species as well as vegetation density.

A further complexity in estimating vegetative biomass involves the multiple layers of vegetation described by Pearson and Miller (4). The masking of a short-grass layer by a mid- or tall-grass layer is a possibility in mixed-species rangeland. In addition, the presence of continuous vegetative cover can make layering a more critical factor than in areas where vegetation is less dense.

In areas where vegetation cover is discontinuous, however, reflectance characteristics of the soil surface may be a complicating factor in estimating vegetative biomass. For example, it has been shown repeatedly that reflectance from a soil surface is influenced by the moisture content of the surface. Moreover, Mathews et al. (5) found that the reflectance from surface soil is also influenced by the amount of clay, silt and organic matter in the soil.

The purpose of this paper is to discuss the use of MSS data acquired by LANDSAT-1 in estimating vegetative biomass in the Sandhills rangeland of Nebraska, and to show the relationship of these estimates to range management decisions.

Study Area

The Sandhills region of Nebraska encompasses about 52,000 square kilometers (20,000 square miles) of rangeland. Certain characteristics of the region tend to minimize potential complexities in estimating vegetative biomass from reflectance data acquired by Landsat-1.

The region is dominated by dunes and intervening valleys composed of eolian sand and stabilized by grasses and grass-like plants. Soils formed in the wind-sorted sands are relatively uniform and contain more than 85 percent sand over approximately 85 percent of the region. Locally, soils containing 50 to 85 percent sand occur in valleys and are often characterized by near-surface water tables and continuous vegetation in response to subirrigation.

Because of the rapid infiltration and permeability of the sandy soils, the soil surface is normally dry in a matter of hours following rain showers, even in subirrigated valleys where the water table is within the lower portion of the soil profile. Thus, the possibility of wet surface soil as a factor influencing reflectance is minimized.

Very few plant species are unique to specific soils or range sites within the Sandhills region, except in wetland areas where relatively pure stands of water-tolerant species occur. Although the native vegetation consists of a mixture of species including short- and midgrasses, the distribution and density of rangeland plants is such that reflectance is not generally influenced by multiple layers of vegetation.

Vegetation surveys indicate a relatively high constancy (percentage of sites on which a given species is found) for the major forage-producing species. Woody plants are relatively insignificant within the native vegetation. Consequently, the relative non-segregation of species minimizes the influence of species differences on reflectance values.

Methods

Five selected range sites were sampled during the fall of 1972 and from May through October of 1973 and 1974. Vegetation within a quadrat one square meter in size at each site was clipped within three days of selected overpasses of LANDSAT-1. Dry weights of the samples as well as field observations related to range condition were obtained for each site.

Imagery from MSS band 5 acquired by Landsat-1 for the test sites was evaluated by optical density measurements of 1:1,000,000 positive transparencies using a McBeth densitometer. Readings represented average optical densities for ground areas of approximately 60 hectares (150 acres), well within the boundaries of the (600-1000 acre) 240-400 hectare management units studied. Correlation coefficients were then calculated for the resulting sets of optical density-vegetative biomass data.

In addition, printouts from computer compatible tapes of radiance values for MSS band 5 were used to obtain an average radiance value for an area 9 to 18 hectares (22 to 44 acres) in size at each test site. Averages of 20 to 40 picture elements were determined for each site. These average radiance values were then used to calculate correlation coefficients for the resulting sets of radiance value-vegetative biomass data.

Results

Vegation on the five sites consisted of mixtures of short- and mid-grasses, although the mid-grasses tended to increase as range condition improved. Several species were common to all sites: *Calomovilfa longifolia* (prairie sandreed), *Sporobolus cryptandrus* (sand dropseed), *Boutelova gracilis* (blue gramma), *Koeleria cristata* (prairie junegrass), and *Carex* species. *Poa compressa* (Canada bluegrass) was found on only two of the sites, while *Muhlenbergia pungens* (sandhills muhley) was found only on one site. Live vegetation constituted from 11 to 39 percent of the plant cover on the five sites.

The high correlation coefficients obtained for the sets of radiance value-vegetative biomass data from the five test sites indicated that reliable estimates of vegetative biomass can be made from MSS band 5 data obtained within the Sandhills region. However, greater variation existed among correlation coefficients for sets of optical density-vegetative biomass data than among corresponding sets of radiance value-vegetative biomass data.

Table 1 shows a relatively wide range of correlation coefficients from .20 to .94 for the sets of optical density-vegetative biomass data. A composite analysis of these 1973 data sets resulted in a low negative correlation coefficient (-.20),. In contrast, Table 2 shows relatively high correlation coefficients ranging from -.79 to -.93 for the sets of radiance value-vegetative biomass data. In addition, the correlation coefficient for a composite analysis of the 1972-1974 data was high (-.85).

Discussion

Statistically, the data in Table 2 indicate high reliability for remotely sensed estimates of vegetative biomass in the Sandhills region using radiance values in band 5 from computer compatible tapes. The close relationships obtained for the sets of radiance value-vegetative biomass data in comparison with the sets of optical density-vegetative biomass data probably result from the smaller and more uniform ground areas measured for radiance values as opposed to the larger and less uniform ground areas measured for optical density.

In addition, the relatively high correlation coefficient for the composite analysis of the sets of radiance value-vegetative biomass data (-.85) suggest that valid comparisons can be made of radiance values obtained on different dates by LANDSAT-1. Correlation coefficients for the sets of optical density-vegetative biomass data indicate that comparisons of optical densities within a LANDSAT frame are valid, but the low correlation coefficient for the composite analysis of these data suggests that valid comparisons of optical density on frames acquired on different dates cannot be made without application of correction factors.

Other investigators have utilized ratios of radiance values, usually between band 5 and band 6 or 7, to estimate vegetation density or biomass (3, 6). These ratios correlate with "green" biomass and are influenced by near-infrared reflectance in band 6 or 7 from vigorous, healthy, green plants as well as visible red reflectance in band 5. In the Sandhills rangeland, however, moisture stress may reduce near-infrared reflectance from the vegetation and thus indicate a decrease in vegetative biomass. Nevertheless, range plants under moisture stress are legitimate sources of forage, and vegetative biomass does not necessarily decrease during periods of moisture stress. Our results indicate that estimates of vegetative biomass in the Sandhills region using radiance values in band 5 alone involve a balance between the absorption of visible red light by live plant tissue and the reflectance of visible red light by exposed sandy soil.

Since range management involving animal stocking rates is based on the forage producing capability of individual management units, estimates of vegetative biomass within management units are important for management decisions. Two sites were selected from the five sites studied in the Sandhills region to illustrate management practices and to show management decisions based on traditional field estimates of forage production in comparison with satellite estimates of vegetative biomass.

One of these sites (Site A) was not grazed or mowed during the growing season of 1973. This permitted direct measurement of the maximum production of vegetative biomass. Clipping data obtained from Site A at intervals during the growing season showed a typical curve for forage production (Figure 1).

A second site (Site B) was subjected to grazing by livestock during the growing season so that a portion of the vegetative biomass was removed from the site. Thus, maximum production of forage could not be measured at Site B, but was judged on the basis of maximum potential production and an estimate of vegetative biomass removed by grazing animals. The decline in vegetative biomass at Site B after June 18, 1973, with the exception of small increases in response to periodic rain showers, showed the influence of grazing in removing vegetative biomass (Figure 1).

Data obtained at Sites A and B were compared with range management decisions based on field criteria developed by the Soil Conservation Service (SCS, USDA) through extensive experience within the Sandhills region. Site A showed good agreement between vegetative biomass measured by clipping and the recommended stocking rate. Clipping data from this site showed a maximum production of 1665 kilograms of vegetative biomass per hectare (1480 lb. per A). Recommended management for this site according to SCS criteria involved the utilization of one-fourth of the maximum production on one acre by one animal unit per month. Thus, 416 kilograms (370 lb.) of vegetative biomass would be utilized from Site A per month under good management.

Assuming that one animal unit requires 848 kilograms (750 lb.) of vegetative biomass per month, each acre of Site A would provide 0.5 animal units per month. This is the actual stocking rate recommended for Site A by the SCS on the basis of field criteria.

In the case of Site B, grazing was permitted on the site during most of the growing season. Thus, it was not possible to estimate actual maximum production either from clipping data or radiance values. Based on an SCS field estimate of "good" range condition class for Site B, however, maximum production should approximate 3390 kilograms per hectare (3000 lb. per A.). Radiance values from band 5 correlated with clipping data indicated approximately 1665 kilograms of vegetative biomass per hectare (1485 lb. per A.) at Site B during the period of peak production on June 18, 1973.

Application of SCS field criteria at Site B indicated "close" grazing on June 18, 1973, suggesting that more than the recommended amount of forage had been removed. Following the recommended management practice of utilizing one-fourth of the maximum production per month, approximately 1013 kilograms (2250 lb.) of vegetative biomass should have remained at Site B on June 18, 1975. Instead, the estimate of vegetative biomass from the radiance values as well as observations in the field indicated that "close" grazing had removed approximately one-half of the vegetative biomass.

Thus, estimates of vegetative biomass from LANDSAT-1 were correlated with clipping data and with SCS range management recommendations based on judgments in the field.

Conclusion

In the past, recommendations for stocking rates have been based on field estimates of species composition and the percent of vegetative cover, the best estimate of climatic conditions for the growing season, and experience. Normally, the agencies involved in recommending management plans do not have the manpower or resources necessary to collect sufficient data on vegetative biomass through clipping studies. Since radiance values acquired by LANDSAT-1 may be interpreted to give reliable estimates of vegetative biomass, these data provide an alternative for making recommendations for stocking rates over large areas. To be of maximum benefit, however, LANDSAT data must be available to decision makers within seven to ten days after acquisition.

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TABLE I. - COEFFICIENTS OF CORRELATION RELATING OPTICAL DENSITY VALUES OF POSITIVE TRANSPARENCIES FROM LANDSAT-1, BAND 5, TO VEGETATIVE BIOMASS ON FIVE TEST SITES.

Overpass Date 1973	Vegetative Biomass Range, kg/ha	Optical Density Range	Correlation Coefficient
May 14	134-684	.74-.84	.20
June 1*	540-1167	1.04-1.21	.78
July 26	371-1444	.49-.67	.94
August 17	297-1432	.29-.45	.74
September 22	355-1413	.71-.88	.82

* Four sites only.

TABLE II. - COEFFICIENTS OF CORRELATION RELATING RADIANCE VALUES FROM LANDSAT-1, BAND 5, TO VEGETATIVE BIOMASS ON FIVE TEST SITES.

Overpass Date	Vegetative Biomass Range, kg/ha	Radiance Value Range	Correlation Coefficients
Sept. 4, 1972	825-2396	23.38-36.77	-.93
May 14, 1973	380-684	36.33-45.53	-.92
Aug. 12, 1973	297-1432	26.57-38.83	-.83
July 5, 1974	876-1944	29.48-47.68	-.79

FIGURE I.-VEGETATIVE BIOMASS PRODUCTION ON TWO SITES SHOWING UNGRAZED (SITE A) AND GRAZED (SITE B) PRODUCTION CURVES.