Total Ground-Cover Estimates from Corrected Scene Brightness Measurements

Eric M. Sanden, Carlton M. Britton, and James H. Everitt

Abstract

*Total ground-cover estimates from spectral reflectance data were studied using a scene brightness factor, corrected for variations in soil moisture content. Red and near-infrared radiometer readings were collected from ground level on a bermudagrass [*Cynodon dactylon *(L.) Pers.] rangeland in south Texas. A soil line was developed to obtain brightness factor and correction factor values that were correlated to total ground-cover measurements. Data were collected under two conditions: (1) when the soil was dry and vegetation senescent, and (2) under wet soil and green vegetation conditions. Although the correction factor did not improve the correlation between brightness measurements and total ground cover, overall correlations were high. The best correlation (*r *= 0.87) was obtained when vegetation was near peak greenness and the soil was saturated. This study suggests that under certain conditions scene brightness measurements can provide relatively accurate total ground-cover estimates.*

Introduction

Total ground cover, the proportion of surface area covered by vegetative canopy, is an important variable for assessing land quality and trend. In grassland ecosystems, total ground cover is an indicator of a site's carrying capacity and soil erosion susceptibility. Recently developed remote sensing techniques are replacing the destructive and time consuming practice of measuring this variable manually.

In addition to total ground cover, the spectral response of a grassland is influenced by senescent vegetation and soil moisture content (Williamson, 1990; Gausman *et al.*, 1975). Many remote sensing vegetation indices use a ratio of the red (0.6 to 0.7 μm) and near-infrared (NIR; 0.8 to 1.1 μm) spectral wavebands to normalize the data with respect to these nuisance variables, with varying degrees of success (Tucker *et al.*, 1983; Elvidge and Lyon, 1985; Heilman and Boyd, 1986).

The objective of this study was to develop a vegetation index, based on scene brightness, to measure total ground cover of a grassland site. This index is a derivation of the perpendicular vegetation index (Richardson and Wiegand, 1977) to increase its sensitivity to both green and senescent vegetation. A correction factor was developed to address variations in soil moisture content.

Study Area

The study site is 1 ha of common bermudagrass [*Cynodon dactylon* (L.) Pers.] rangeland about 85 km north of Brownsville, Texas. A humid subtropical climate typifies the region with an average annual precipitation of 58 cm. At the time of the study, however, drought conditions persisted. The site is comprised of a level, light-toned Delfina loamy fine sand soil (Whittle, personal communication). Thirty 1-m^2 sample plots were randomly located on the study area and excluded from grazing. These plots displayed wide ranges of ground cover and degree of senescence. Soil line data were collected from a 3-m^2 non-vegetated sample plot located on the study site.

Methodology

Variations in soil background characteristics were largely controlled by locating the sample plots on a single, homogeneous soil type. Data were collected on 16 November 1989, when the soil was dry and the vegetation senescent, and on 24 September 1990, under wet soil and green vegetation conditions. A Mark II hand-held radiometer was used to obtain reflectance measurements of the sample plots in the red (0.63 to 0.69 μm) and NIR (0.76 to 0.90 μm) wavebands from a height of about 1 m. The radiometer's effective field-of-view provided a sample area of approximately 1 m^2. Blackbody and white panel radiometer readings were obtained for instrument calibration and percent reflectance calculations. All measurements were collected near solar noon under clear skies.

A 35-mm color transparency was taken of each plot from a height of about 1.5 m, using a wide-angle lens. Total ground-cover measurements were obtained from these photographs.

A 250-g sample of the surface 2 cm of soil was collected from each plot and analyzed to determine soil moisture content. These measurements were used to compute scene brightness correction factors.

Soil line data, obtained during the first sample period, included radiometer measurements and soil samples collected from the non-vegetated plot at different moisture levels. Data were first collected under dry soil conditions. Approximately 40 ml of water were then applied to the plot and another soil sample and reflectance measurement was taken. This process was repeated until soil saturation occurred, as evidenced by pooling on the surface, providing 12 sets of data. Soil samples were analyzed to determine the

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E.M. Sanden and C.M. Britton are with the Department of Range and Wildlife Management, Texas Tech University, Lubbock, TX 79409.

J.H. Everitt is with the USDA-Agricultural Research Service, Remote Sensing Research Unit, 2413 E. Hwy. 83, Weslaco, TX 78596.

E.M. Sanden is presently with the Department of Plant and Earth Sciences, University of Wisconsin-River Falls, River Falls, WI 54022.

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specific moisture content associated with each set of radiometer readings. The soil line was developed through simple regression of red and NIR soil reflectance values at the various stages of saturation (Richardson and Wiegand, 1977). The 12 reflectance data points were then orthogonally projected onto the soil line.

A reflectance graph was created for each sample period with the soil line and the sample plot data points. The 30 data points were then orthogonally projected onto the soil line. The brightness factor value of each point was calculated as the simple Euclidean distance, along the soil line, between the projected dry soil reflectance point and the projected reflectance point of the vegetated plot. Because the dry soil plot represented maximum scene brightness, highly reflective plots exhibited small brightness factor values.

Soil moisture is a nuisance variable inversely related to scene brightness. A sample plot with a high soil moisture content will display an artificially low reflectance (large brightness factor value). A correction factor representing the influence of soil moisture on scene brightness was designed to compensate for this effect.

The simple Euclidean distances between the projected dry soil point and the 11 projected wet soil points were measured along the soil line. A regression model was developed with soil moisture and distance from the dry soil point as independent and dependent variables, respectively. The correction factor for a specific plot was determined by substituting the corresponding moisture content value into the model equation. This value, representing the decrease in scene brightness due to soil moisture, was subtracted from the plot's raw brightness factor value.

The total ground-cover estimates of the plots were obtained using a point intercept procedure (Bonham, 1989). Five hundred sample points were randomly located on the projected image of a plot photograph, and the percent total ground cover was defined as the proportion of sample points occurring on green or senescent vegetation. Senescent vegetation included both litter and standing dead plant biomass.

Two simple linear regression models were developed for each sample period. One model used uncorrected brightness factor values and total ground-cover estimates as the independent and dependent variables, respectively, while the second model incorporated the corrected brightness factor values as the independent variable.

Diagnostic analyses were used to test model assumptions. Heteroscadasticity was evaluated using Hartley's test of constant variance and by observing residual scatterplots (Winer, 1971; Neter *et al.*, 1989). The normal distribution of the error terms and the absence of significant outlier influence was assessed using residual scatterplots and normality plots (Looney and Gulledge, 1985; Neter *et al.*, 1989). A cross-validating procedure, with data-splitting, was used to validate each model (Neter *et al.*, 1989). Simultaneous confidence interval bands (α=0.05) were constructed for each regression curve.

Results

Reflectance graphs of both sample periods are given in Figure 1. The reflectance data points and the soil line (r = 0.993) are shown. These graphs were used to obtain brightness factor and correction factor values. The scatterplot displayed a strong linear distribution along the "brightness axis" during the first sample period, when senescent vegetation dominated the site. A greater variance along the perpendicular "greenness axis" was evident during the second sample period, dominated by live, green vegetation (Kauth *et al.*, 1979).

Figure 2 shows the total ground-cover prediction models for both sample periods using uncorrected brightness factors.

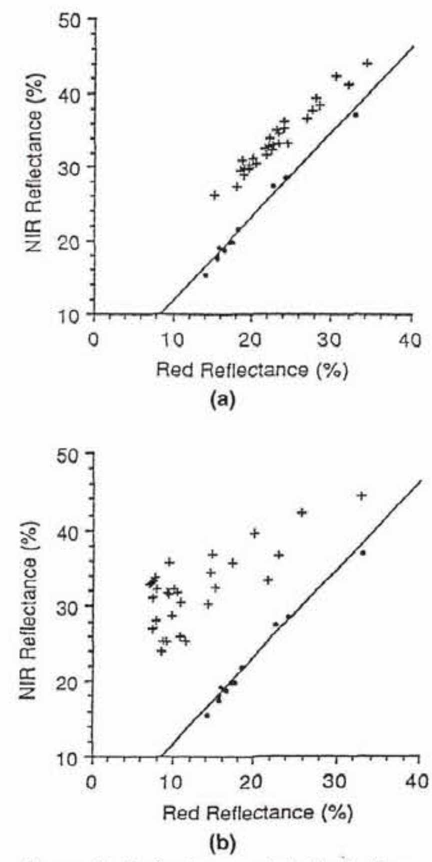

Figure 1. Reflectance plots including the soil line (dots) and the sample plot's spectral data points (crosses). (a) Sample period 1 (November). (b) Sample period 2 (September).

The total ground-cover prediction models incorporating the correction factors are given in Figure 3. The simultaneous confidence bands (α = 0.05) are included to provide a range of cover estimates for specific scene brightness values. Descriptive statistics for these models are presented in Table 1. The second-order polynomial correction factor model (r = 0.995) is given in Figure 4. Scene brightness correction factors were obtained from this model.

An F-test for equality of models was used to compare the total ground-cover prediction models on the basis of slope and intercept at an α = 0.05 level of significance (Steel and Torrie, 1980). Comparisons between corrected and uncorrected brightness factor models suggested equivalence for the first sample period (F = 0.83), and inequality for the second sample period (F = 13.71). Comparisons between the uncorrected brightness factor models of each sample period suggested equivalence (F = 0.06), while the corrected models of both sample periods were unequal (F = 23.00).

Discussion

Total ground-cover estimates using scene brightness appear satisfactory for many applications. Estimates within 10 to 20 percent of the true value appear feasible at a 95 percent confidence level.

The model correlation coefficients from this procedure are comparable to those obtained in other studies. Using a variety of vegetation indices, Wiegand *et al.* (1979) reported typical r-values from 0.70 to 0.95 for models used to predict

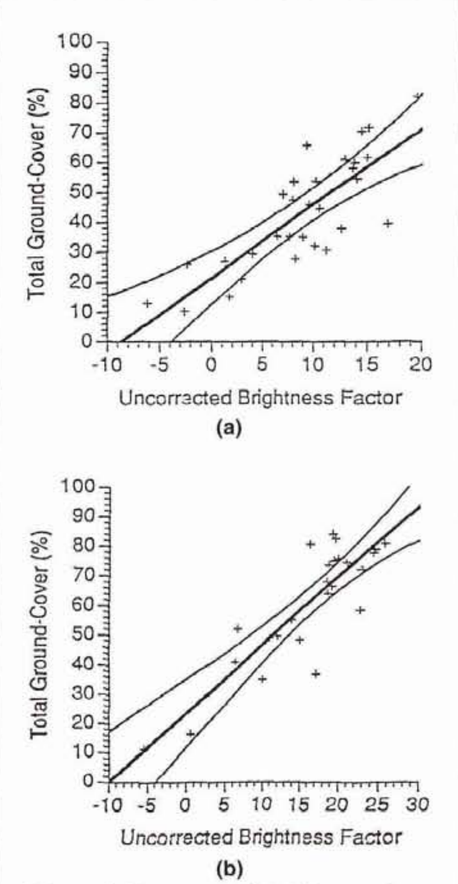

Figure 2. Uncorrected total ground-cover prediction models with simultaneous confidence bands (α = 0.05). (a) Sample period 1 (November). (b) Sample period 2 (September).

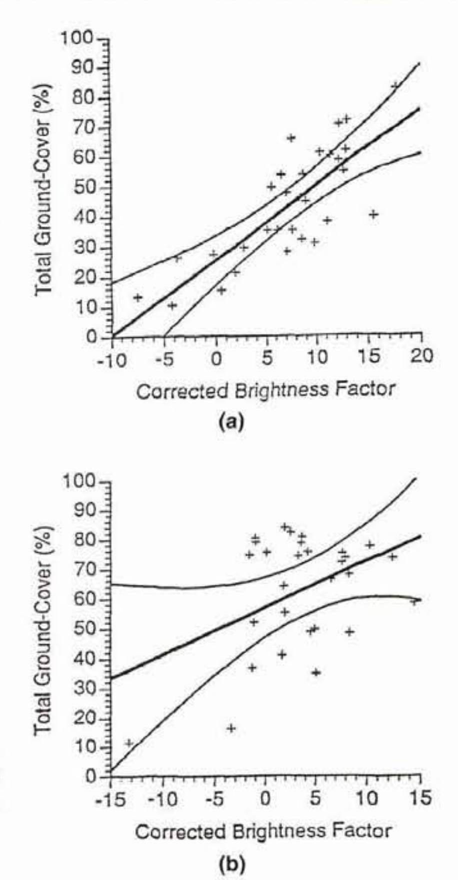

Figure 3. Corrected total ground-cover prediction models with simultaneous confidence bands (α = 0.05). (a) Sample period 1 (November). (b) Sample period 2 (September).

leaf area index (LAI) values of wheat fields with Landsat data. Weiser *et al.* (1986), studying several common vegetation indices, obtained correlation coefficients between 0.80 and 0.97 for tallgrass prairie LAI prediction models using hand-held radiometer data.

The correlation between ground cover and scene brightness was highest during sample period 2, when green vegetation and high soil moisture conditions prevailed. The first sample period was characterized by dry soil and senescent

Table 1. Descriptive Statistics for Total Ground-Cover Prediction Models.

Model	r	RMSE*	Intercept	Regression Coefficient
Sample Period 1-Uncorrected Brightness Factor	0.81	10.98	21.57	2.47
Sample Period 1-Corrected Brightness Factor	0.80	11.36	25.21	2.49
Sample Period 2-Uncorrected Brightness Factor	0.87	9.64	23.37	2.33
Sample Period 2-Corrected Brightness Factor	0.43	17.82	57.00	1.57

*positive square root of the mean square error

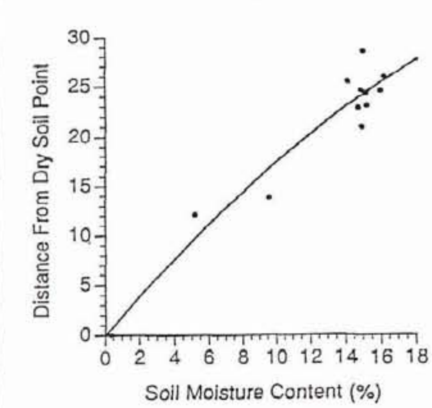

Figure 4. Second-order polynomial regression model used to determine correction factors. Plot-specific correction factors were obtained using the appropriate soil moisture value as the independent variable.

vegetation. Scene brightness measurements, therefore, may represent a soil response index, with wet soil being more distinguishable from green vegetation than dry soil is from senescent vegetation. This conclusion is consistent with results obtained by Huete *et al.* (1984), who determined that the chlorophyll and internal leaf structure of green vegetation decreases a scene's red reflectance and increases the NIR reflectance. A lower spectral contrast between senescent vegetation and dry, highly reflective soil was evident during the first sample period.

The scene brightness correction factors did not enhance the cover prediction models during either sample period. A greater soil moisture variation between plots within a sampling period may have increased the utility of this correction factor.

Conclusions

The results of this study suggest that scene brightness measurements can be used to develop accurate models for total ground-cover measurement. Scene brightness, unlike many remote sensing vegetation indices, appears sensitive to both green and senescent vegetative ground cover.

Radiometer measurements were collected from ground level; however, this procedure should be applicable to other remote sensing data types. Further studies are needed to determine the effect of lower spatial resolution on these prediction models. A sensitivity to spatial resolution may limit this procedure to certain sensor data types.

The soil-moisture correction factor did not improve the total ground-cover prediction models. Studies are needed to more accurately quantify scene brightness reductions caused by the spectral contributions of green vegetation, soil moisture content, and shadow. Partial correlation and multivariable regression analyses may help account for the influences of these variables. Once an effective correction factor is developed, thermal infrared or SLAR radar may be used to obtain soil moisture measurements.

To assess land quality, all major vegetation components must be represented. The insensitivity of ratio-based vegetation indices to senescent vegetation often limits their effectiveness in natural resources management situations where diverse and dynamic conditions are typical. Vegetation indices based on scene brightness measurements to model complex ecosystem variables, such as total ground cover, merit further study.

References

Bonham, C.D., 1989. *Measurements of Terrestrial Vegetation*, John Wiley and Sons, Inc., New York, 338 p.

Elvidge, C.D., and R.J.P. Lyon, 1985. Influence of rock-soil spectral variation on the assessment of green biomass, *Remote Sens. of Env.*, 17:265-279.

Gausman, H.W., A.H. Gerbermann, C.L. Wiegand, R.W. Leamer, R.R. Rodriguez, and J.R. Noriega, 1975. Reflectance differences between crop residues and bare soils, *Proc. of Soil Sci. Soc. Amer.*, 39:752-755.

Heilman, J.L., and W.E. Boyd, 1986. Soil background effects on the spectral response of a three-component rangeland scene, *Remote Sens. of Env.*, 19:127-137.

Huete, A.R., D.F. Post, and R.D. Jackson, 1984. Soil spectral effects on 4-space vegetation discrimination, *Remote Sens. of Env.*, 13: 409-421.

Kauth, R.J., P.F. Lambeck, W. Richardson, G.S. Thomas, and A.P. Pentland, 1979. Feature extraction applied to agricultural crops as seen by Landsat, *Proc. LACIE Symp.*, Johnson Space Center, Houston, Texas, pp. 705-721.

Looney, S.W., and T.R. Gulledge, Jr., 1985. Use of the correlation coefficient with normal probability plots, *Am. Statis.*, 39:75-79.

Neter, J., W. Wasserman, and M.H. Kutner, 1989. *Applied Linear Regression Models, 2nd ed.*, R.D. Irwin, Inc., Burr Ridge, Illinois, 688 p.

Richardson, A.J., and C.L. Wiegand, 1977. Distinguishing vegetation from soil background information, *Photogrammetric Engineering & Remote Sensing*, 43(12):1541-1552.

Steel, R.G.D., and J.H. Torrie, 1980. *Principles and Procedures of Statistics*, McGraw-Hill Book Co., N.Y., 656 p.

Tucker, C.J., C. Vanpraet, E. Boerwinkel, and A. Gaston, 1983. Satellite remote sensing of total dry matter production in the Senegalese sahel, *Remote Sens. of Env.*, 13:461-474.

Weiser, R.L., G. Asrar, G.P. Miller, and E.T. Kanemasu, 1986. Assessing grassland biophysical characteristics from spectral measurements, *Remote Sens. of Env.*, 20:141-152.

Wiegand, C.L., A.J. Richardson, and E.T. Kanemasu, 1979. Leaf area index estimates for wheat from LANDSAT and their implications for evapotranspiration and crop modeling, *Agronomy J.*, 71:336-342.

Williamson, H.D., 1990. Estimating biomass of an improved pasture using SPOT HRV data, *Grass and Forage Sci.*, 45:235-241.

Winer, B.J., 1971. *Statistical Principles in Experimental Design, 2nd ed.*, McGraw-Hill Co., N.Y., 672 p.

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