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Residue Effects on Radiometric Reflectance Measurements of Northern Great Plains Rangelands*

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The diversity of rangeland ecosystems makes application of remote sensing data difficult. This study was conducted to determine the effects of plant surface residue on rangeland canopy radiometric measurements. Measurements were made on moderately and heavily grazed native rangeland pastures. Standing senesced plant residue was collected and spread in the autumn to establish treatments of 0%, 33%, 66%, and 100% ground cover. Canopy radiometric measurements were made weekly the following grazing season using the red (RED) (0.63–0.69 μm) and near infrared (NIR) (0.76–0.90 μm) wavebands of a Mark II radiometer. We examined relationships between wavebands, ratio vegetation index (R = NIR / RED), the normalized difference vegetation index [ND = (NIR − RED) / (NIR + RED)] and forage dry matter accumulation and surface plant residue. All wavebands and indices were significantly related to dry matter accumulation on both moderately and heavily grazed pastures. Separation of residue treatments by radiometric measurements was more evident on moderately grazed than on heavily grazed pastures. Red reflectance was most sensitive to surface residue treatments and separated residue from no residue plots until early June when green growth became dominant. Vegetation indices R and ND tended to be lower for the 100% surface residue treatment for both pastures and higher for the 0% treatment for the moderately grazed pasture. Results suggest that different amounts of surface residue would not greatly interfere with using radiometric measurements to predict dry matter accumulation on Northern Great Plains native rangeland.

INTRODUCTION

Use of remote sensing technology on semiarid rangelands to determine vegetative growth provides opportunities for better land resource management. However, rangelands include diverse ecosystems that vary in plant species, surface residue cover, soils, and landscape. Such an ecosystem makes it difficult to develop vegetation indices from radiometric data for prediction of green dry matter accumulation (Tueller, 1989).

Aase et al. (1987) determined that different relationships existed among vegetation indices developed for both leaf area and green dry matter for Northern Great Plains native mixed prairie that was overgrazed, moderately grazed, or reseeded to crested wheatgrass [*Agropyron desertorum* (Fisch. ex Link) Shult.]. Conversely, Tucker et al. (1983; 1985) reported a strong relationship between the normalized difference vegetation index [ND = (NIR − RED) / (NIR + RED)] and above ground green dry matter for a multispecies grassland.

Work on monocultures of grasses has provided satisfactory relationships between vegetation indices and green dry matter accumulation. Tucker (1977), Tucker et al. (1975), and Pearson et al. (1976) determined the red (RED) waveband (0.63–0.69 μm) to be more sensitive to changes for low levels of green dry matter accumulation of blue grama [*Bouteloua gracilis* (H.B.K.) Lag ex Griffiths], and the near infrared (NIR) waveband (0.74–1.00 μm) to be more sensitive to moderate and high levels. Asrar et al. (1986), working with taller big bluestem (*Andropogon gerardi* Vitman), found that a greenness transformation was superior to either the ratio

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vegetation index (R = NIR / RED) or ND in estimating canopy leaf area.

Standing senesced plant residue and surface litter remaining from prior years present a potential problem in the development of remotely sensed vegetation indices to determine green dry matter accumulation on rangelands (Huete and Jackson, 1987). On croplands, where residue cover to protect soil from erosion is a desirable condition, attempts to use radiometric measurements to determine residue quantities have not been satisfactory (Aase and Tanaka, 1991; Gausman et al., 1975).

The objectives of this study were to evaluate the relationships of vegetation indices and RED and NIR waveband reflectance to a mix of surface residue and green dry matter and to determine the effects of surface residue on development of vegetation indices for Northern Great Plains rangelands.

MATERIALS AND METHODS

Our work was conducted on both moderately and heavily grazed native rangeland pastures near Mandan, North Dakota (40°46'N, 100°55'W) that had been grazed at the same intensity for the previous 70 years. The soil was a Williams loam (fine-loamy mixed, Typic Argiboroll). The moderately grazed native pasture was typical of a Northern Great Plains mixed prairie site that was grazed with yearling steers at 1 steer / 3.2 ha. The 1985 grazing season was from 21 May to 8 October. Primary cover composition as determined at the end of August 1984 by first hits using the point frame technique (Levey and Madden, 1933) was 13% blue grama, 10% threadleaf sedge (*Carex filifolia* Nutt.), 9% yellow sedge (*Carex pennsylvanica* Lam.), 5% needleandthread (*Stipa comata* Trin. and Rupr.), 4% western wheatgrass (*Agropyron smithii* Rydb.), 4% prairie junegrass [*Koeleria pyramidata* (Lam.) Beauv.], 44% litter, and 11% other species. The heavily grazed native pasture was a mixed prairie site that had been purposely overgrazed at the intensity of 1 steer / 0.9 ha. The 1985 grazing season began on 21 May, but was terminated on 30 August due to lack of forage. Cover composition of the heavily grazed pasture was 34% blue grama, 35% litter, 22% bare ground, and 9% other species. In October 1985, after grazing was completed, an area from each pasture was fenced to exclude grazing in 1986. All data reported in this report were collected from within the fenced areas.

In October 1985, 16 1-m^2 plots from each pasture were clipped at the soil surface to establish a randomized block design with four replications. Plant residue for the ground cover treatments was collected in October 1985 by clipping standing senesced herbage at the soil surface. Clipped herbage was spread over one plot in each replication to give 100% (240 g / m^2) ground cover when viewed from a nadir position. Treatments of 33% and 66% ground cover were established based on weight of residue applied for the 100% ground cover. Plots with no residue were also established as were plots of bare soil, half of which were left dry, and the other half wetted for the reflectance measurements.

To determine dry matter accumulation, all herbage present (senesced and green) was clipped weekly at the soil surface from 0.25 m^2 areas from each pasture beginning on 22 April and ending on 7 September. Prior to clipping, reflectance measurements were taken over the sample areas in each pasture. The herbage samples were oven dried at 70°C, weighed, and total dry matter calculated on a g / m^2 basis.

Reflectance measurements from the residue and dry matter accumulation plots were made on clear days with an Ideas, Inc. Mark-II[1] three-band radiometer having a 24° field of view. Reflected radiation in the RED (0.63–0.69 μm) and NIR (0.76–0.90 μm) wavebands were obtained from the radiometer which was mounted on a portable mast to reach a height of 2 m above the soil surface. Five readings were taken from each plot and averaged. The readings were taken between 1200 and about 1240 h CST. The radiometer was calibrated prior to each set of readings in each pasture by measuring reflectance from a painted barium sulfate plate.

We calculated reflectance factors from the RED and NIR radiometric readings. The ratio vegetation index (R = NIR / RED) and the normalized difference vegetation index [ND = (NIR − RED) / (NIR + RED)] were calculated as described by Jackson (1983). The reflectance factors and vegetation indices were used in regression analyses to determine relationships between canopy reflectance characteristics and green dry matter accumulation and surface residue.

RESULTS AND DISCUSSION

Total dry matter production from both pastures increased from initial harvest to the 28 July harvest (Fig. 1). Initial harvest dry matter on 22 April is a measure of the standing senesced herbage remaining after completion of grazing in 1985 and prior to spring green-up in 1986. Green-up was visible about 1 May. The moderately grazed pasture produced consistently more dry matter than the heavily grazed pasture at all sample dates. Peak dry matter production was 195 g / m^2 on 28 July and 261 g / m^2 on 7 September for the heavily and moderately grazed pastures, respectively.

Regression analyses indicated that both vegetative indices and both waveband reflectances had statistically significant relationships to vegetative dry matter produc-

[1]Mention of trade names is for the benefit of the reader and does not constitute an endorsement by the U.S. Department of Agriculture over other products not mentioned.

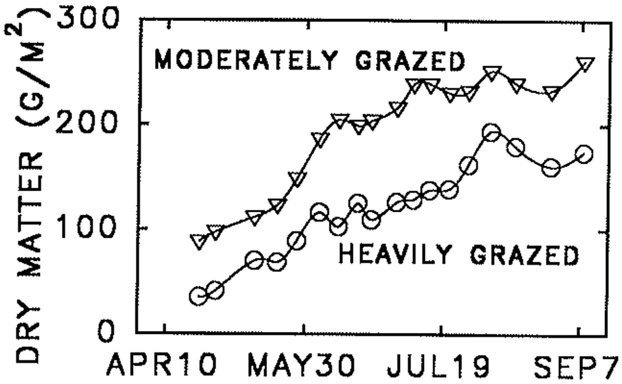


Figure 1. Dry matter accumulation over time for moderately and heavily grazed native pastures.

tion on both pastures (Table 1). NIR reflectance was significantly correlated to vegetative dry matter but had the smallest correlation coefficient for both moderately and heavily grazed pastures. Correlation coefficients for the relationship of dry matter production to vegetation indices and waveband reflectances were greater on the moderately grazed than on the heavily grazed pasture. Slopes of regression equations for dry matter production versus vegetative indices and reflectance factors were positive for NIR, *R*, and ND, but negative for RED.

The soil line plot of NIR versus RED reflectance values, as defined by Richardson and Wiegand (1977), showed that residue amounts had little effect on reflectance after green-up started (Fig. 2). All reflectance values were above the soil line except for the pre-green-up values from radiometric measurements on 7, 21, and 27 April (data within rectangle in Fig. 2). This suggests that reflectance from residue before green-up in these native pastures is similar to the soil reflectance. Aase and Tanaka (1984) also could not easily separate bare soil from wheat straw using reflectance parameters.

The data show that radiometric reflectance measurements were sensitive to appearance of green vegetation at an early growth period. As vegetative growth progressed, RED reflectance values decreased to about

Table 1. Linear Regression of Red (RED), Near-Infrared (NIR), Normalized Difference Vegetation Index (ND), and Ratio Vegetation Index (*R*) with Total Dry Matter of Moderately and Heavily Grazed Native Pastures

Pasture	*Reflectance and Vegetative Index*	*Intercept*	*Slope*	*Correlation Coefficient*
Moderately	RED	428.28	−20.91	0.94**
	NIR	−278.75	15.13	0.58*
	ND	−34.29	488.10	0.92**
	R	−57.65	89.09	0.93**
Heavily	RED	328.14	−19.48	0.91**
	NIR	−117.10	7.16	0.37*
	ND	−102.03	450.53	0.87**
	R	−92.98	71.70	0.88**

*,** Significant at 0.05 and 0.01 levels, respectively.

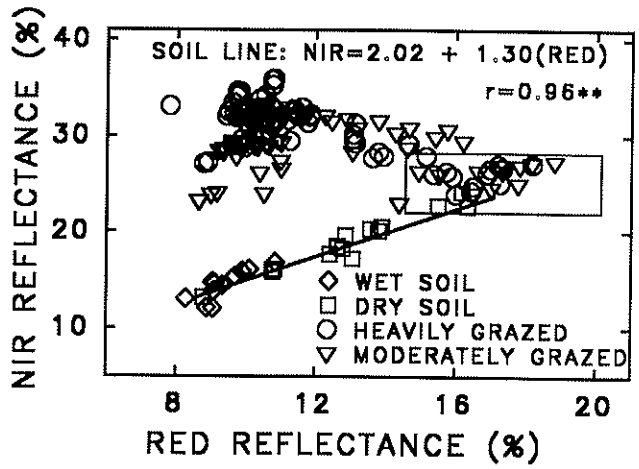
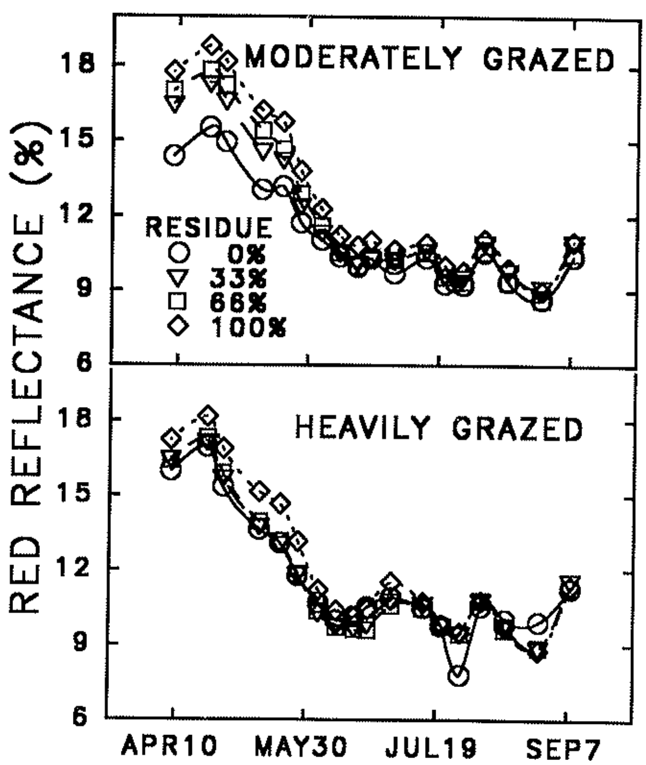


Figure 2. The soil line and vegetative points for moderately and heavily grazed native pastures. Data points within inserted box are from pre-green-up vegetation measurements.

mid-June for all residue treatments for both pastures, after which the values remained essentially constant for both pastures (Fig. 3). However, until early June, RED reflectance values were higher from plots where surface residue had been applied. Separation among residue treatments was greater for the moderately grazed than the heavily grazed pasture.

Figure 3. Relationship between red waveband (RED) reflectance and measurement date for moderately and heavily grazed native pastures covered with different amounts of surface residue.



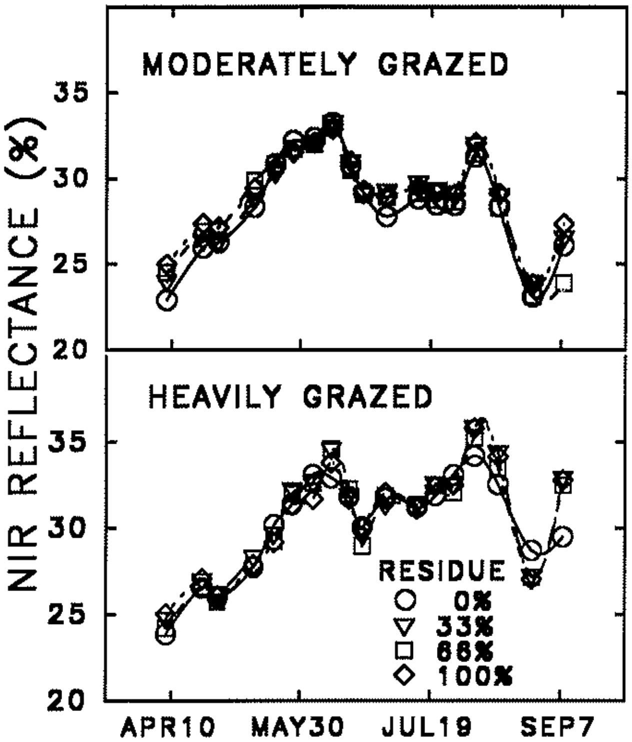


Figure 4. Relationship between near infrared waveband (NIR) reflectance and measurement date for moderately and heavily grazed native pastures covered with different amounts of surface residue.

The NIR reflectance values for all residue treatments increased during early green-up to early June, and then trended lower as vegetation senesced (Fig. 4). NIR reflectance values were similar for both pastures and all residue treatments.

The pattern of seasonal change in the ND and *R* vegetation indices was similar for both pastures. Both indices increased most rapidly during green-up to early June followed by a slight decrease, as vegetation senesced, through early September (Figs. 5 and 6). During green-up the 100% residue treatment, as compared with the other treatments, had slightly lower vegetation indices for both pastures. Vegetation indices for the 0%, 33%, and 66% residue treatments were similar on the heavily grazed pasture. For the moderately grazed pasture, the 0% residue treatment had slightly higher vegetation indices than the 33% and 66% residue treatments.

Results of this study showed that residue quantities of 80 g / m^2 and 160 g / m^2 (33% and 66% residue) produced similar reflectance values and vegetation indices for both moderately and heavily grazed pastures. The 240 g / m^2 (100% residue) surface residue lowered vegetation indices and increased RED reflectance values for both pastures. The seasonal pattern of vegetation indices and reflectance values showed that vegetation green-up was detectable even at surface residue quantities of 240 g / m^2. Overall, differences among reflectance values and vegetation indices for the four surface residue treatments were considered small, suggesting that different amounts of surface residue would not greatly conflict with using radiometric data to predict dry matter accumulation on Northern Great Plains rangelands. In other rangeland studies, Huete and Jackson (1987) found that spectral vegetation indices were unreliable for detecting standing green grass in a taller canopy of senesced grass.

The larger separation among residue treatments for the moderately grazed pasture as compared with the heavily grazed pasture is due to more vegetation growth in the moderately grazed pasture. This further suggests that radiometric measurements are sensitive to small amounts of green plant material even in high surface residue environments. Thus remote sensing can have broad application to rangeland management. Quantifying the amount of green vegetation present on rangelands is useful to managers for determining cattle turnout dates, adjusting grazing pressure, and determining the amount of forage available for winter grazing. Sound management decisions require such information and contribute to good stewardship of our natural resources.

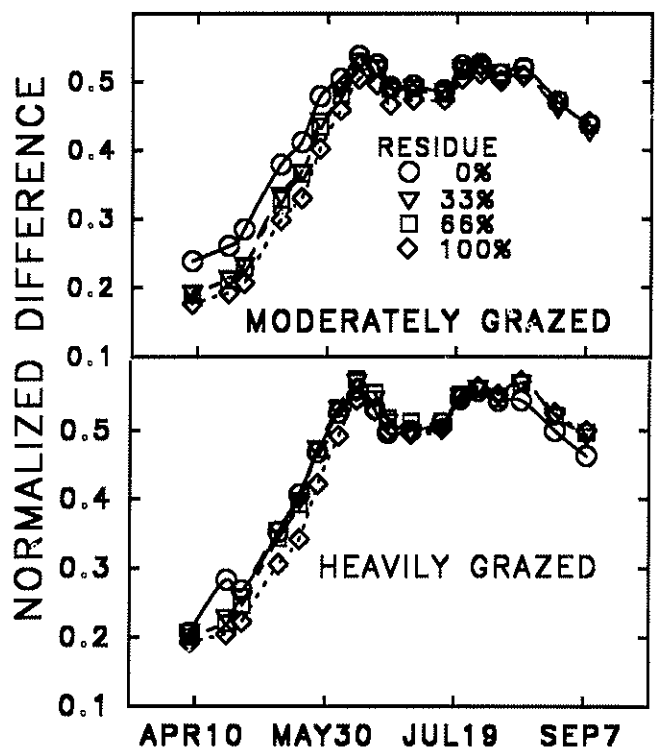


Figure 5. Relationship between normalized difference vegetative index and measurement date for moderately and heavily grazed native pastures covered with different amounts of surface residue.

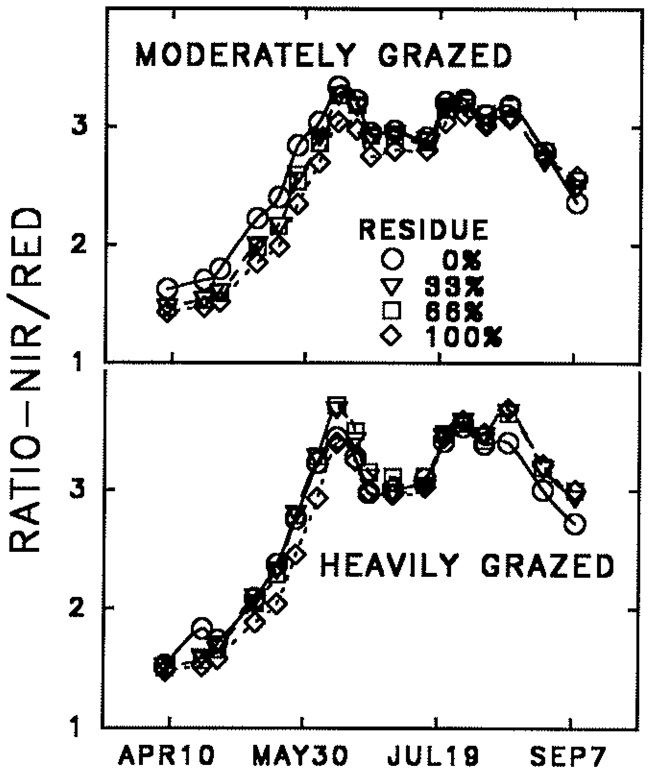


Figure 6. Relationship between ratio of near infrared / red (NIR / RED) waveband reflectance and measurement date for moderately and heavily grazed native pastures covered with different amounts of surface residue.

CONCLUSIONS

Our data show that remote sensing can be a useful tool for predicting forage production in diverse management systems on the Northern Great Plains. Surface residue may be quantifiable prior to spring green-up. Following green-up, residue amounts were masked by green plant material. Remote sensing can have application to rangeland management such as determining time of green-up and adjusting grazing intensity to maintain adequate forage, and plant and residue cover for soil protection.

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