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ASSESSING BIOPHYSICAL CHARACTERISTICS OF GRASSLAND FROM SPECTRAL MEASUREMENTS

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ABSTRACT

Remote sensing offers a potential alternative to tedious hand sampling as a means of monitoring vegetation condition and estimating productivity over large areas of grasslands.

Spectral reflectance measurements were made on a tallgrass prairie (Konza Prairie) near Manhattan, Kansas during 1983 with a multiband radiometer (Barnes MMR). Measurements were made on a weekly basis depending on the weather. Two treatments were examined: one prairie treatment was burned in the spring and the other was left unburned with the previous year's senescent grasses covering the soil. Green leaf area indices and dry matter accumulations (green and senesced above ground phytomass) were measured on the area monitored by the radiometer. The indices of near-infrared to red ratio, greenness, and normalized difference were computed from spectral reflectance data. The relationships between these spectral reflectance indices and grass biophysical parameters (LAI and phytomass) were assessed for the entire growing season.

I. INTRODUCTION

Grasslands are an important forage resource for beef production and wildlife habitat. Michieli (1979) states that 37% of United States land area is rangeland and provides 40% of the forage needed for the national beef herd. Range and wildlife managers could use a reliable technique to estimate grassland productivity over large areas of grassland.

The long-term objective of this study is to find spectral reflectance indices from which accurate estimates of productivity in a diverse grassland system can be made. The goal of this preliminary study is to assess the relationship between grassland biophysical parameters and three widely accepted reflectance indices.

II. MATERIALS AND METHODS

A. SITE DESCRIPTION

Spectral and growth analysis data were obtained during 1983 at the Konza Prairie Research Natural Area (KPRNA) located 8 kilometers south of Manhattan, Kansas (latitude 39° 9'N, longitude 96° 40'W). Soil at this site is a silty clay loam classified as a udic ustoll (Bidwell and McBee, 1973) typical of the Flint Hills uplands. The area of study is unplowed native bluestem prairie. Big bluestem (Andropogon gerardi vitman), little bluestem (Andropogon scoparius Michx.), and indian grass (Sorghastrum nutans (L.) Nash) are the dominant species. Thirty-six other species were observed in a vegetation composition study performed on 23 August 1983 by L.C. Hulbert (KPRNA director). The large number of species provide canopy diversity in leaf area, leaf angle, leaf shape, and leaf color. In addition, plant biomass density and spatial distribution are more variable than in monoculture crops.

Climate of the prairie uplands is humid subtropical with temperature ranges from -35°C to 47°C annually. Average precipitation is 800 mm per year with variable seasonal distribution resulting in many wet-dry cycles in a normal growing season of 176 days.

B. DATA ACQUISITION

Spectral reflectance measurements were initiated on 15 April 1983 along two 300 m transects of prairie that were covered with senescent grasses was burned resulting in two different surfaces referred to as the burned and unburned treatments. Spectral measurements were continued through the growing season on days with clear sky conditions using a truck mounted Barnes modular multispectral radiometer (MMR) oriented in the nadir viewing position. The instrument measures spectral reflectance in seven discrete wavebands from 0.45 μm to 2.35 μm, each with a 15° field of view.

Spectral reflectance measurements were collected from three sampling sites established each day of reflectance data acquisition on each treatment transect. Four plant samples were taken within three days of spectral measurements from each of the sampling sites, by hand pulling the vegetation at the ground level from within a 0.1 m^2 sampling frame. These sites were then marked to avoid accidental repitition of sampling of plants or reflectance measurements later in the season. In the laboratory, the plant material was separated into green grass leaves, green grass stems, green nongrass leaves, green nongrass stems, standing dead, and litter components. Total green leaf area of both grass and nongrass species was determined using a Li-Cor model 3100 optical area meter. Components of plant samples were oven dried at 65°C for 72 hours. Green leaf area index (LAI) and phytomass per unit area were computed as the ratio of total green leaf area and phytomass dry weight to total sampled soil surface area, respectively.

The spectral reflectance data were used to derive a greenness function based on a constrained principal component analysis technique described in Miller et al. (1984):

$$\begin{aligned}\text{GREENNESS} = & -0.0440{*}\text{MMR1} - 0.0240{*}\text{MMR2} \\ & - 0.1747{*}\text{MMR3} + 0.7916{*}\text{MMR4} \\ & + 0.3875{*}\text{MMR5} - 0.2310{*}\text{MMR6} \\ & - 0.3700{*}\text{MMR7}.\end{aligned}$$

In addition, the near-infrared to red ratio (NIR/RD) and normalized difference (ND) were calculated as:

$$\text{NIR/RD} = \text{MMR4}/\text{MMR3}$$

$$\text{ND} = (\text{MMR4} - \text{MMR3})/(\text{MMR4} + \text{MMR3}).$$

III. RESULTS AND DISCUSSION

Figure 1 shows the general trend in development of green leaves for both the burned and unburned treatments through the season. The burned treatment had higher mean LAI values than the unburned treatment during the early part of the growing season. The burned treatment also reached a higher maximum LAI than the unburned; however, both treatments reached their maximum LAI on calendar day 182. During the senescence period very small differences were observed between the corresponding mean LAI of the two treatments.

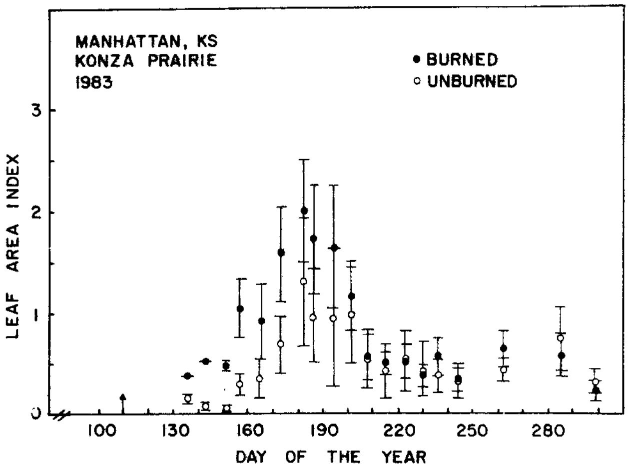

Figure 1. Temporal distribution of green leaf area index for the burned and unburned grass prairie treatments. Error bars represent ±1 standard deviation.

The temporal trend of NIR/RD showed a similar pattern to green leaf development (Fig. 2).

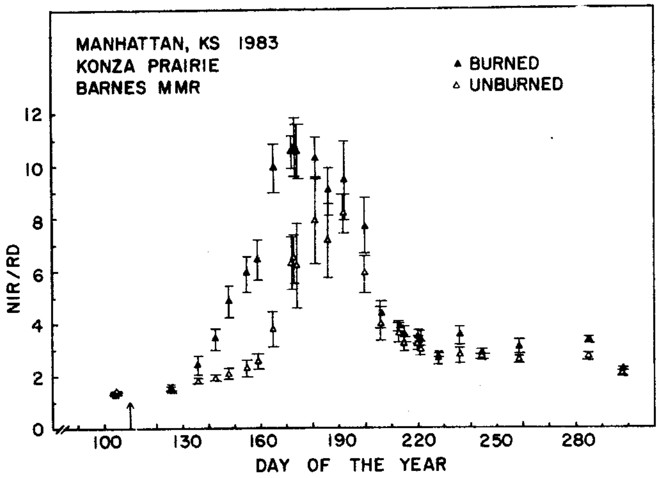

Figure 2. Temporal profiles of near-infrared to red ratio (NIR/RD) for the burned and unburned treatments of the grass prairie. Error bars represent ±1 standard deviation.

The NIR/RD for the burned treatment increased more rapidly than the unburned treatment early in the season and also reached a higher maximum value at an earlier date (day 173). This difference was primarily due to the dominant influence of senescent vegetation on quality of the reflected radiation in the unburned treatment early in the season. Small differences were observed between

NIR/RD of the two treatments during the period of senescence.

Figure 3 illustrates the change in greenness index for the two treatments through the growing season.

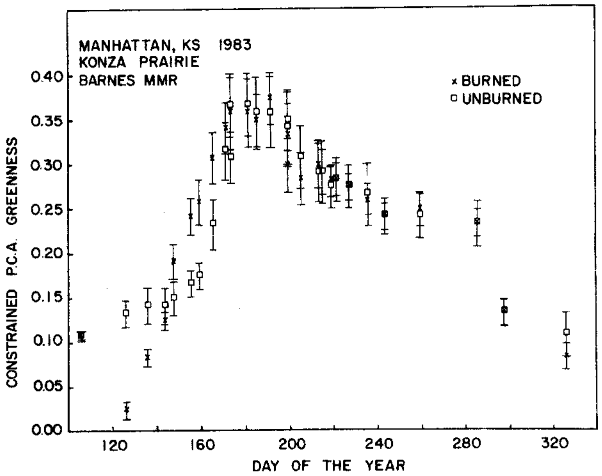

Figure 3. Temporal greenness profiles for the burned and unburned treatments of the grass prairie. Error bars represent ±1 standard deviation.

Greenness for the unburned treatment lagged behind the burned treatment early in the season, but reached a similar maximum value for both treatments on day 180. The greenness for both treatments, however, declined less rapidly relative to LAI and NIR/RD during senescence.

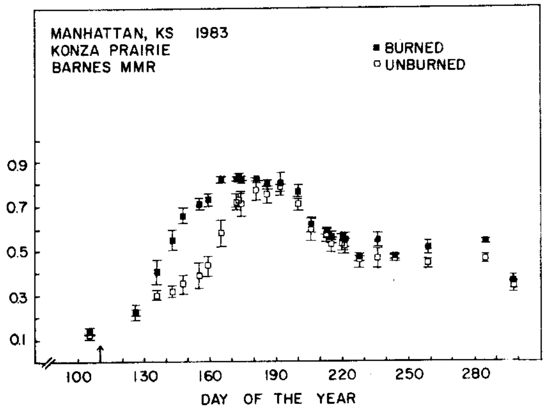

Figure 4. Temporal profiles of normalized difference (ND) for the burned and unburned treatments of the grass prairie. Error bars represent ±1 standard deviation.

The temporal trend of ND was similar to that of NIR/RD, but the early separation between the treatments was more pronounced. The maximum ND was less well defined, and at the end of the season, it did not decline to the values observed at the beginning of the season.

To further study the components of vegetation of the two treatments, temporal plots of total green and senescent phytomass were examined. The total phytomass for the unburned treatment were consistently greater than those of the burned treatment (Fig. 5).

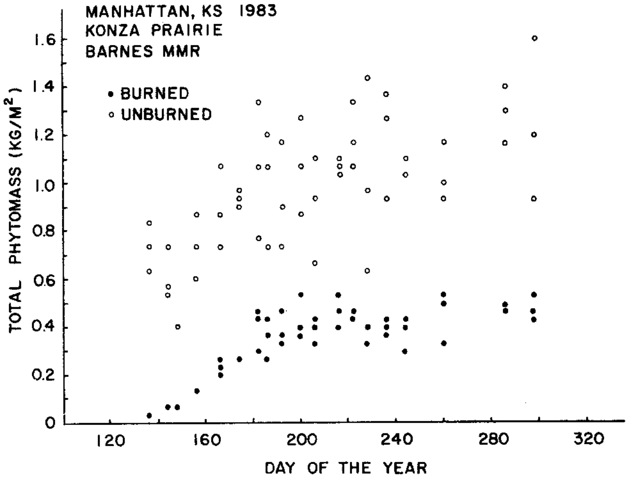

Figure 5. Total (green + scenescent) seasonal phytomass accumulation for the burned and unburned treatments of the grass prairie.

Total phytomass of both treatments increased until approximately day 200 and remained at that level thereafter. A direct estimate of total phytomass from the spectral reflectance indices discussed previously would seem impractical since the unburned treatment had higher phytomass than the burned treatment, whereas NIR/RD, greenness, and ND values for the burned treatment exceeded those of the unburned treatment throughout most of the season.

Green phytomass was closely related to greenness. The green phytomass for the burned treatment was slightly higher than that of the unburned treatment early in the season, but they both increased to a similar maximum near day 182 (Fig. 6). In examining the difference in brown phytomass of the two treatments (Fig. 7), it is evident that brown phytomass was the dominant feature in the unburned treatment through much of the season but was only a minor component in the burned treatment.

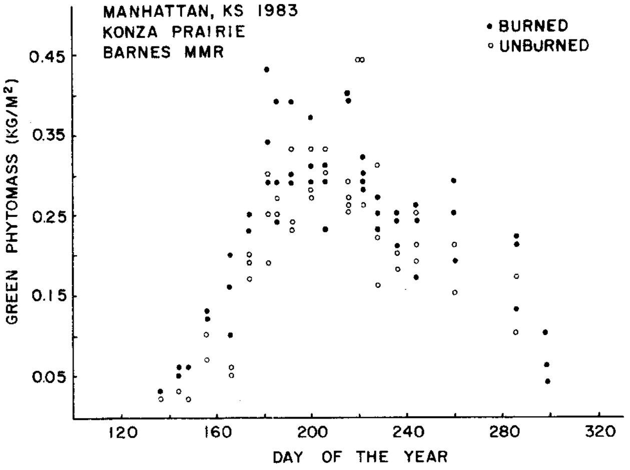

Figure 6. Seasonal production of green phytomass for the burned and unburned treatments of the grass prairie.

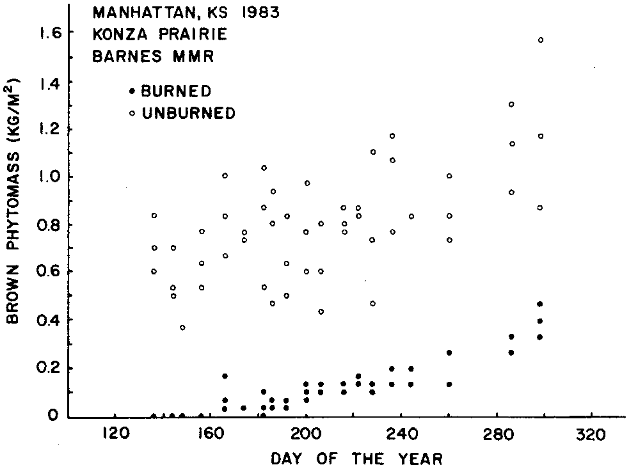

Figure 7. Seasonal accumulation of brown phytomass for the burned and unburned treatments of the grass prairie.

To estimate total phytomass (green + brown) in the unburned treatment, a spectral index is needed that could account for the amount of brown phytomass present. If reflectance is indeed a surface characteristic, this index may be nonexistent. Figure 8 shows the spectral reflectance of the two treatments with 470 g/m^2 and 1240 g/m^2 brown phytomass present on the burned and unburned surfaces, respectively. The differences in reflectance were perhaps not great enough to account for the different brown phytomass quantities in each treatment; however, the potential may exist at higher spectral resolution or in the middle infrared wavelengths.

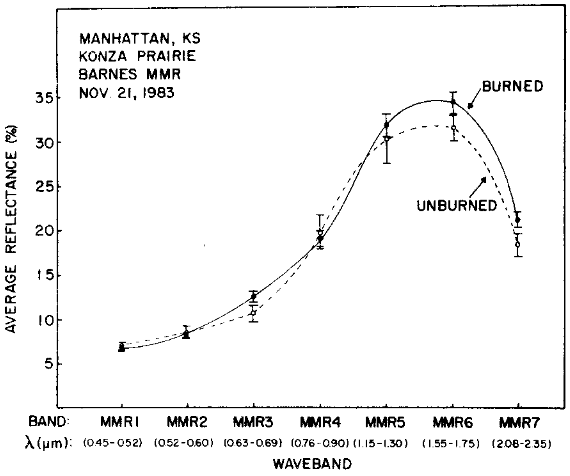

Figure 8. Final average reflectance of the burned and unburned treatments as a function of the wavebands of the Barnes MMR. The major difference between the two treatments was the quantity of senescent phytomass, 470 gm^{-2} and 1240 gm^{-2} for the burned and unburned treatments, respectively.

IV. CONCLUSIONS

The biophysical characteristics of a mixed grassland prairie system present a new challenge in productivity estimation from spectral reflectance measurements. In particular, in the unburned treatment there were three major components (soil, green vegetation, and brown vegetation) that contributed to a combined scene reflectance. To estimate LAI, a means of distinguishing the reflected radiation of green vegetation from that of soil and senescent vegetaion is needed.

To predict total phytomass (sum of dry green and brown above ground phytomass per unit area), similar problems were encountered. In natural grasslands a "bank" of brown phytomass in various stages of decomposition accumulates over the years. If spectral reflectance is considered mainly as a surface characteristic, the depth or mass of this "bank" cannot be directly related to its spectral characteristics. This could be primarily a limitation of the visible wavelengths. The near and middle infrared may offer a potential for estimating total phytomass. If live green phytomass is the parameter of interest and brown phytomass is considered a component of the reflectance background along with soil, the problem of a mixed signal will arise. In this case, a reflectance index that is insensitive to background senescent vegetation and soil is desireable.

V. ACKNOWLEDGMENT

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