Remote Sensing of Vegetation Recovery in Grasslands After the 1988 Yellowstone Fires in Yellowstone National Park

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Traditional methods for measurement of vegetative biomass can be time-consuming and labor-intensive, especially across large areas. Yet such estimates are necessary to investigate the effects of large scale disturbances on ecosystem components and processes. One alternative to traditional methods for monitoring rangeland vegetation is to use satellite imagery. Because foliage of plants differentially absorbs and reflects energy within the electromagnetic spectrum, remote sensing of spectral data can be used to quantify the amount of green vegetative biomass present in an area (Tucker and Sellers 1986).

In 1987 we found that Landsat Multispectral Scanner (MSS) imagery could be used to quantify green herbaceous phytomass (GHP) on ungulate summer range in the northeastern portion of Yellowstone National Park. Estimates of GHP in the study area were well within values reported for the habitat types sampled (Mueggler and Steward 1980). Annual variation in GHP was related to winter snow accumulation probably due to the timing of snow melt (Merrill et. al. 1988). Additionally, we found that GHP explained a significant amount of the variation in the per capita growth rate of elk and bison populations from 1972 to 1987 (Merrill et. al. 1988; Merrill and Boyce 1991).

The extensive fires that occurred in the Park during summer 1988 provided an opportunity to determine whether remote sensing could be used to monitor grassland vegetation recovery in the Park and to explore the effects of the 1988 fires on ungulate populations using models we developed in 1987. Previous studies have used Landsat imagery to monitor succession of seral stages after fire in pine (Jakubauskas et. al. 1990), but no studies to our knowledge have used this approach to quantify herbaceous recovery in grasslands.
The objectives during this study period were:

1. to develop a model for predicting GHP in sagebrush-grassland communities using 1989 Landsat TM spectral information and field data on GHP

2. to validate the 1989 model by comparing predictions made from it using 1990 Landsat data to actual field data collected in 1990.

Once we have validated our model, our objectives are to compare vegetation recovery in burned areas relative to unburned areas, and to apply the results of this analysis to the ungulate summer range model developed in 1987 to predict the effects of the fires on ungulate populations.

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✦ Study Area

The study was conducted in the northeast portion of Yellowstone National Park with major focus on the upper Lamar, Cache and Calfee River drainages and the Mirror Plateau. General descriptions of physiogamy and soils are given by Despain (1973). Elevations range from 1,5000 to 3,300 m. Climate of the Park is characterized by long, cold winters and short dry summers. Climatic patterns within the Park is 67.0 cm (26.8 in) and mean daily temperature in January and July is -10.3 C (13.5 F) and 13.9 C (57.1 F), respectively.

Descriptions of vegetation communities in the park have been given by Despain (1973). Our work focused on the non-forested plant communities within the study area. These included sagebrush *(Artemisia tridentata)* communities which have an understory of bluebunch wheatgrass *(Agropyron spicatum)* in dry areas and Idaho fescue *(Festuca idahoensis)* on the more mesic sites. Silver sagebrush *(Artemisia cana)* with an Idaho fescue co-dominant is found on areas associated with high water table such as streambanks and seeps. High elevation grasslands are dominated by Idaho fescue/tufted hairgrass *(Deschampsia cespitosa)* and tufted hairgrass/sedge (*Carex* spp.). At intermediate elevations, Idaho fescue/wheatgrass *(Agropyron spicatum* and *A. caninum)* communities are encountered with the latter dominating in the more mesic sites.

Elk *(Cervus elaphus)*, mule deer *(Odocoileus hemionus)*, bison *(Bison bison)*, moose *(Alces alces)*, bighorn sheep *(Ovis canadensis)*, and pronghorn *(Antilocapra americana)* are the major ungulates in this area (Houston 1982).

✦ Methods and Results

Vegetation Data Collection and Analysis

Vegetation data were collected from July 25-August 10 in 1989 and July 30-August 11 in 1990 at 40 sites across two elk summer ranges (Norris/Cache/Calfee Ridge complex and Mirror Plateau). Each site encompassed at least 0.81 hectares (2 acres or approximately 9 landsat pixels) of homogeneous vegetation. At each site physiographic characteristics were recorded using topographic 1:24,000 maps. Grassland habitat types followed Yellowstone National Park habitat mapping (Despain 1973).

Vegetation was sampled and analyzed using a double sampling approach (Merrill et. al. 1988). At each site, percent cover of graminoids, forbs, bare ground, rock, moss, lichens and wood were estimated. Average heights of plants within forage classes were also measured and an index to plant volume was calculated as canopy cover x average plant height. Shrub cover was measured using line intercept method.

Ten of the 30 microplots at each site were clipped to ground level. Vegetation was separated into green graminoids, green forbs and standing dead. A criterion of >= 25% "green" was used to differentiate green from senesced (standing dead) plants. Biomass samples were dried at 70° for 48 hours and weighed to the nearest 0.1 gm. All weights are reported as oven-dry weights. The relationship between plant volume and biomass was determined using a least squares multiple regression analysis. Plant volume explained between 54-67% of the variation in green forb biomass and 69-75% of the variation in grass biomass.

Landsat Data Acquisition and Analysis

Landsat Thematic Mapper (TM) imagery for August 2, 1989 and August 13, 1990 of the study area were acquired from EOSAT by the National Park Service. Due to mechanical problems with the receiving stations, EOSAT was unable to provide us with data from our projected August 6, 1990 overpass.

The closest date for which there was available data was August 13, 1990. Data from this overpass are less than ideal because the date is outside our sampling window and there are considerable clouds in the scene. Nonetheless, it is the most accessible data for comparing our field sampling information between years.

Digital Landsat data were transferred from 9-track computer tape to the Micro-computer Image Processing System (MIPS) for data processing. At each of the 40 sites the spectral values of 9 contiguous pixels were averaged for each of the 6 TM bands. Linear combinations of TM spectral values as well as published vegetation indices are being developed. The soil brightness index (SBI), the perpendicular vegetation index (PVI), and the green vegetation index (GVI) are derived using the Graham-Schmidt orthogonalization process (Frieberger 1960 in Jackson 1983). Jackson (1983) showed that these indices minimize soil background variations while improving green vegetation signals. Relationships between the averaged TM band spectral values and their various vegetation indices and phytomass estimates were determined using linear and nonlinear least squares multiple regression analysis.

✦ Ongoing Work

Currently we re reanalyzing our spectral models due to several errors found in the vegetation analysis. Once these data are corrected, we will select 1-4 spectral models based on the 1989 data which meet the following criteria. First, a spectral model must have a significant F value ($P < 0.05$). Second, a model must account for >=50% of the variance in the field data collected in 1989; predictive ability of the model will be assessed based on the standard error of the estimate. Finally, models which meet these criteria will be evaluated by comparing their predictions based on 1990 Landsat data to our 1990 field data.

To make this comparison, Landsat data from 1990 must first be corrected for differences related to changes in instrument sensitivity, electronic gain and bias (Markham and Barker 1986). Environmental conditions, such as sun angle and haze, that differ among satellites overpasses are corrected by regressing spectral signatures of 5 reference sites with no vegetation (e.g. bare rock or scree slopes, lakes, and hot springs) against values for the same areas in 1989. At lake sites, which absorb nearly all radiation, we took the average of the 3 lowest pixel values for each band. For hot springs, which reflected most radiation, we took the average of the 3 highest pixel values. For rock/scree slopes, we took the average of 9 adjacent pixel values. Additionally, from our preliminary assessments, we will be unable to use ground-truth data from 3 plots sampled in 1990 due to cloud cover. We expect to complete these analyses by our 1991 Annual Report.

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