SPECTRAL-ECOLOGICAL CHARACTERIZATION AND MAPPING OF FOREST HABITAT AND COVER TYPES WITHIN YELLOWSTONE NATIONAL PARK, WYOMING

MARK E. JAKUBAUSKAS ♦ KEVIN P. PRICE
KANSAS APPLIED REMOTE SENSING PROGRAM
UNIVERSITY OF KANSAS ♦ LAWRENCE

♦ INTRODUCTION

Remotely sensed multispectral data collected from satellites provide a systematic, synoptic ability to assess conditions over large areas on a regular basis. Early use of this satellite data for land cover mapping was based on spectral differences of cover types, with little integration of ancillary data such as soils or topographic information (Iverson et al. 1990). In recent years, concurrent with trends toward integrating remotely sensed and ancillary data for improved classification accuracy (Cibula and Nyquist 1987; Frank 1988), there has been increasing interest in utilizing remotely sensed data for extracting biophysically important variables, relating observed spectral reflectance to leaf area index, biomass, net primary productivity, and vegetation moisture content (Waring et al. 1986; Hobbs and Mooney 1990).

The concept of using remotely sensed spectral data to map and monitor the progress of succession within forests and other environments has not been extensively explored. However, the capability to map and predict successional stages of forest habitat types on a landscape to regional scale has important implications for animal habitat management, assessment of insect infestation susceptibility, prediction of fire behavior, and evaluation of plant and animal species diversity. Ecological models based on established successional change rates and trends permit the prediction of future environmental conditions, landscape patterns, and the propagation and effects of disturbances across these landscapes (Hall et al. 1988; Romme 1982). Despain (1990) provides two examples where information on habitat and cover types is important for park management purposes: the cumulative effects model for grizzly bears; and the prediction, assessment, and management of mountain pine beetle outbreaks in conifer forests. Accurate mapping of habitat and cover types can provide information on the distribution and pattern of specific plant communities important to animal species for food, cover, and breeding ground (Knight and Wallace 1989). The ability to map and predict successional stages of forest habitat types has implications for prediction of fire behavior and spread. Previous studies (Despain 1990; Romme and Despain 1989; Romme 1982; Taylor 1969) have noted the relationship between forest age and fire susceptibility. Older stands are comparatively more flammable than younger stands due to fuel accumulations on the ground and in the canopy, and have a higher propensity to propagate and sustain extensive crown fires. Spatial patterns of cover types may also be important, with a highly fragmented landscape mosaic providing natural firebreaks under typical weather conditions. Consequently, as Despain (1990) has noted, the ability to map forest habitat and cover types is of importance for estimation of fire intensity and spread.

The use of a single habitat type provides a logical unit for environmental stratification of the study site. Since a habitat type integrates vegetation, climate, topography, and soils (Pfister and Arno

1980), using a single habitat type forces a restriction to selective ranges in climate, topography, and soils types. These constrictions will minimize the effects of abiotic variation on the recorded spectral reflectance, allowing analysis of spectral variation to be concentrated on the changes in biotic factors associated with succession.

♦ OBJECTIVES

This research project has the following objectives:

1. Identification of spectral reflectance patterns characteristic of successional stages of selected Rocky Mountain forest habitat types and cover types.

2. Establishment of baseline environmental characteristics for the subsequent monitoring of forest successional stages.

3. Identification of the biotic factors (forest composition and structure) influencing spectral reflectance.

♦ STUDY AREA

Habitat types common to the Yellowstone area have been defined by Romme (1982) and Steele et al. (1983), while early postfire succession in the region has been extensively researched by Lyon and Stickney (1976) and Taylor (1969). Romme (1982) described two major habitat types within the Little Firehole River watershed in southwestern Yellowstone. On more xeric upland sites, the *Pinus contorta/Carex geyeri* habitat type dominates, while in more mesic uplands, the *Abies lasiocarpa/Vaccinium scoparium* habitat type is dominant. Within each habitat type, Romme identified six postfire successional stages. The specific locations of sample sites for this study within the northwest Central Plateau region were determined through the analysis of geographic and remotely sensed data.

♦ METHODS

A map of abiotically homogeneous units was created using overlay analysis on abiotic data layers (slope, aspect, elevation, and surficial geology) stored in a GIS database. This map was used to identify the spatial extent and distribution of habitat types and minimize abiotic effects upon vegetation (and consequently spectral reflectance values). Spectral data for a selected habitat type were extracted from a Landsat TM scene using the GIS habitat type layer to mask selected units. The multispectral data coincident with the selected units were subjected to an unsupervised classification algorithm to create a map of spectrally distinct vegetation cover types within the habitat type. Using this map as a guide for field operations, biotic characteristics were measured at sample sites within each cover type derived from the satellite data analysis.

Biotic measurements for each selected site were taken within a 20 x 25 m square plot, except in young, dense stands where a 10 x 10 m plot was employed. Diameter at breast height (DBH) was measured in 5 cm size classes by species for trees greater than 2.5 m in height, using a Biltmore stick. Trees smaller than 2.5 m high were counted in four seedling classes: 0.5-1.0 m, 1.0-1.5 m, 1.5-2.0 m, and 2.0-2.5 m, by species. In plots where the dense cover of seedlings precluded seedling counts for the entire plot, two subplots of 10 x 10 m were established in opposite corners of the plot, and seedlings were tallied in the four height classes. Density (number of stems/hectare) and basal area/hectare were calculated for all plots using DBH tallied by species. Mean height of the dominant overstory was estimated for each sample plot. Tree cores were extracted from a representative sample (5-10 individuals) of each plot to calculate approximate age and assess the disturbance history of the dominant overstory.

Within each stand plot, twenty 0.5 x 0.5 m understory plots were established at equal intervals along four transects through each plot. Understory vegetation (grasses, forbs, and shrubs) were recorded by species as percent cover within each subplot using the Daubenmire technique (Daubenmire 1959). Ground cover not occupied by herbaceous or low woody plants were classified into five classes: moss/lichen, litter, persistent litter, rock, and bare soil. Slope, aspect, and elevation were assessed for each plot.

Statistical analysis of the biotic field data will be performed to determine whether ecological differences among successional stages are correlated with the satellite spectral data. A multiple analysis of variance (MANOVA) will be used to test for significant differences among the groups (Davis 1983). If two preliminary spectral successional stages are determined to be essentially identical biotically and spectrally, the two classes will be merged and new statistics calculated for the new class. From this analysis, a final set of biotically and spectrally unique successional stages will be produced.

The second phase of satellite data analysis will define the relationships between spectral response patterns and biotic variables. Spectral values will be extracted from the Landsat image and used as dependent variables, while the biotic data will be used as the independent variables in multiple regression analysis. Multiple regression analysis will also be used to determine the relationship of selected biotic variables to the calculated age (time since origin/establishment) of the stand.

♦ LITERATURE CITED

Cibula, W. G., and M. O. Nyquist. 1987. Use of topographic and climatological models in a geographical database to improve Landsat MSS classification for Olympic National Park. Photogrammetric Engineering and Remote Sensing 53:67-75.

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. Northwest Science 33:43-66.

Davis, J. C. 1983. Statistics and Data Analysis in Geology (2nd Edition). John Wiley and Sons.

Despain, D. G. 1990. Yellowstone Vegetation: Consequences of Environment and History in a Natural Setting. Roberts Rinehart, Boulder, CO.

Frank, T. D. 1988. Mapping dominant vegetation communities in the Colorado Rocky Mountain Front Range with Landsat Thematic Mapper and digital terrain data. Photogrammetric Engineering and Remote Sensing 54:1727-1734.

Hall, F. G., D. E. Strebel, and P. J. Sellars. 1988. Linking knowledge among spatial and temporal scales: Vegetation, atmosphere, climate, and remote sensing. Landscape Ecology 2:3-22.

Hobbs, R. J., and H. A. Mooney. 1990. Remote sensing of biosphere functioning: Concluding remarks. Chapter 15 in Remote Sensing of Biosphere Functioning. R. J. Hobbs and H. A. Mooney, eds. Ecological Studies 79, Springer-Verlag, NY.

Iverson, L. R. R. L. Graham, and E. A. Cook. 1990. Applications of satellite data to forested ecosystems. Landscape Ecology 3:131-143.

Knight, D. H., and L. L. Wallace. 1989. The Yellowstone Fires: Issues in landscape ecology. BioScience 39:700-706.

Lyon, L. J., and P. F. Stickney. 1976. Early vegetal succession following large Northern Rocky Mountain wildfires. Proceedings of the Tall Timbers Fire Ecology Conference, Missoula, MT. pp. 355-373.

Pfister, R. D., and S. F. Arno. 1980. Classifying forest habitat types based on potential climax vegetation. Forest Science 26:52-70.

Romme, W. H. 1982. Fire and landscape diversity in subalpine forests of Yellowstone National Park. Ecological Monographs 52:199-221.

Romme, W. H., and D. G. Despain. 1989. Historical Perspectives on the Yellowstone Fires of 1988. BioScience 39:695-699.

Steele, R., S. V. Cooper, D. M. Ondov, D. W. Roberts, and R. D. Pfister. 1983. Forest

Habitat Types of Eastern Idaho-Western Wyoming. U.S.D.A. Forest Service General Technical Report INT-144.

Taylor, D. L. 1969. Biotic Succession in Lodgepole Forests of Fire Origin in Yellowstone National Park. Ph.D. Dissertation, University of Wyoming, Laramie, WY.

Waring, R. H., J. D. Aber, J. M. Melillo, and B. Moore. 1986. Precursors of Change in Terrestrial Ecosystems. BioScience 36:433-438.