A PRELIMINARY ASSESSMENT OF FOREST CANOPY STRUCTURE IN GRAND TETON NATIONAL PARK

CLAYTON F. BLODGETT ✦ DEPARTENT OF GEOGRAPHY
KANSAS BIOLOGICAL SURVEY ✦ UNIVERSITY OF KANSAS
LAWRENCE

MARK E. JAKUBAUSKAS ✦ DEPARTMENT OF GEOGRAPHY
UNIVERSITY OF OKLAHOMA ✦ NORMAN

✦ INTRODUCTION

The potential impact of environmental change on human welfare has renewed interest in understanding the patterns and processes associated with global climate change. Goals of the Committee on Earth Sciences (1989) regarding the U.S. Global Climate Change Program concentrated on the development of sound scientific strategies for monitoring and predicting environmental change. The scaling of ecological characteristics from local to regional and global scales were identified by the Committee as key priorities.

The scaling of ecological information is not simply done by integrating or aggregating information from local scale investigations to regional and global scales (Caldwell et al., 1993). The complexity of the effects of scale variations rules out the use of simple generalizations (Foody and Curran, 1994). Information that is significant at local scales may be trivial when evaluated at regional or global scales. Biological interactions with the environment occur over many scales, suggesting a role for multiscale analysis in the description of these interactions (Schneider, 1994). Methods must be developed to better understand and evaluate ecological processes operating at multiple scales.

Forest structure attributes have been measured using remotely sensed data. Leaf area index (LAI), for example, has been related to the infrared/red ratio (Running et al., 1986; Peterson et al., 1987), the normalized difference vegetation index (NDVI) (Leblon et al., 1993), and gap fractions (Nel and Wessman, 1993). These methods generate values for each pixel in a satellite scene based on the relationship between one or more spectral and/or ancillary data channels and the attribute of interest. The spatial autocorrelation or spatial dependence present in surface phenomena and satellite data are usually not exploited during attribute assignment because of difficulty in quantifying the spatial patterns present (Woodcock et al., 1988). Geostatistics provides a statistically based technique to quantify spatial pattern.

Geostatistical techniques, in particular cokriging, can serve as an efficient means of modeling forest canopy structure at a variety of spatial scales to serve as inputs to global change models. The key issue will be to determine the factors that influence remotely sensed spectral reflectance and relating them to the ecological model across scales (Ustin et al., 1993).

The geostatistical techniques considered in this research include the following: the semivariogram, which allows the user to compare values of a random variable at two points separated by a given lag distance (Milne, 1991); kriging which uses the information on spatial dependence present in the semivariogram to estimate values at unsampled locations based on scattered sample data (Isaaks and Srivastava, 1989); and cokriging, the multivariate extension of kriging, which is appropriate when two or more variables are spatially interdependent and the variable of interest is undersampled (McBratney and Webster, 1983; Leenaers et al., 1989).

Geostatistical techniques have been successfully applied to remotely sensed data. Variograms have been used to determine components of coniferous canopy structure (Cohen et al., 1990), and to determine the spatial autocorrelation structure of Landsat Thematic Mapper (TM) imagery and intercepted photosynthetically active radiation (IPAR) (Lathrop and Pierce, 1991). Atkinson et al. (1992) used cokriging of ground-based radiometer data to estimate LAI, dry biomass and percent cover. Satellite imagery is an excellent candidate for inclusion as an explanatory variable in the cokriging process because it is an exhaustive sample of a given area.

✦ OBJECTIVES

This research project has the following objectives:

1. To develop models of forest structure (LAI, canopy biomass, surface roughness (average tree height), and basal area) using cokriging of field survey data with Landsat TM, MSS and NOAA AVHRR satellite data.

2. To determine if forest structure can be adequately represented at a variety of spatial scales using the forest structure models.

3. To determine the biotic and abiotic variables that define spectral variance and forest structure attributes across multiple spatial scales.

STUDY AREA

The research is being conducted in the Greater Yellowstone Ecosystem (GYE). This area is home to Yellowstone and Grand Teton National Parks, seven National Forests (Bridger-Teton, Shoshone, Custer, Gallatin, Beaverhead, Targhee and Caribou), an elk refuge and two wildlife refuges. Marston and Anderson (1991) define the GYE as the Yellowstone Plateau and surrounding mountain ranges above the 2130m contour. Major vegetation communities include foothill grassland/shrub steppe, riparian, mountain shrub, low-elevation forest, middle-elevation forest, subalpine forest and alpine tundra. The low-elevation forest is dominated by Douglas fir *Pseudotsuga menziesii*, the middle-elevation forests by lodgepole pine *Pinus contorta* var. *latifolia* and the subalpine forest by Engleman spruce *Picea engelmannii*, subalpine fir *Abies lasiocarpa* and whitebark pine *Pinus albicaulis* (Marston and Anderson, 1991). In the middle-elevation forest, lodgepole pine is a persistent dominant and extends from the Absaroka Range in eastern Yellowstone National Park, across the Bridger-Teton National Forest to the south flank of the Teton Range (Clark, 1981).

✦ METHODOLOGY

Preliminary field surveys were conducted during the summer of 1994 to gather initial data on stand structure and dynamics in the Grand Teton forests. Field surveys consisted of systematic sampling of stand parameters within a 20 x 25 m plot. All trees within the plot were tallied in 5 centimeter diameter classes by species. Seedlings were tallied in four height classes: 0.5-1.0 m, 1.0-1.5 m, 1.5-2.0 m, and 2.0-2.5 m, by species. Increment cores were extracted from dominant trees that appeared to represent the pioneer cohort of each plot to estimate the year of stand origin. Average height of the overstory was calculated using a clinometer. Visual estimates of cover by understory vegetation were recorded by species within twenty 0.5 m x 0.5 m quadrats established at equal intervals along four transects (five quadrats/transect). Ground cover not occupied by herbaceous or low woody plants was classified by percent cover into moss/lichen, litter, persistent litter, rock, or soil.

Following field work, overstory density, seedling density, total density, number of seedlings by species, dead density, basal area, and biomass were computed from size-class data collected for each stand (4 tree species and standing dead x 16 diameter classes), normalizing data to a one hectare standard unit. Basal area was for living and dead trees was computed using the mean diameter value for each size class (e.g., 2.5 cm for the 0.0 cm - 5.0 cm size class). Biomass for living overstory species was computed using the allometric equations from Gholz et al. (1979). Leaf area index (LAI) was computed for each stand using the basal area equations of Kaufman et al. (1982). Total percent understory living cover, and percent cover by life form (e.g., shrubs, grasses, and forbs) was computed for each plot.

Table 1. Stand Structure by Plot

Plot #	Age of Origin	Density (Overstory)	Seedlings	Basal Area	Biomass	LAI
1	93.5	2,420	8,880	48.94	10,890.94	10.56
2	110.8	2,260	2,540	46.42	9,950.46	8.08
3	89.6	1,360	2,260	28.71	6,094.44	5.05
4	102.4	1,820	360	33.88	7,281.12	5.9
5	104.2	1,600	3,480	30.63	6,768.13	5.8
6	132	1,300	5,800	30.09	8,297.87	10.6
7	82.75	1,180	1,200	27.83	5,899.97	5
8	102	900	1,020	30.91	6,308.18	5.39
9	102.6	1,840	80	24.7	5,421.65	4.3
10	103.4	720	720	20.85	4,369.04	3.97
11	116	1,300	4,100	42.11	9,192.06	8.91
12	115.5	940	4,220	16.4	3,698.58	3.64
13	89.8	800	1,380	28.04	6,294.69	6.77
14	79	880	400	26.11	5,246.09	4.55
15	108.6	1,480	3,820	29.55	6,279.39	5.31

✦ RESULTS

A total of fifteen sites were sampled during the 1994 field season. A total of 88 trees were cored, of which 67 were *Pinus contorta* var. *latifolia*, 18 were *Abies lasiocarpa* and 3 were *Picea engelmannii*. The average age of origin for the plots sampled was approximately 102 before present, with a standard deviation of approximately 13 years. Only three plots fell outside plus or minus one standard deviation from the mean age of origin, even though structurally, the stands are quite different (Table 1.) Additional analyses will be performed, including detrended correspondence analysis and cluster analysis, after incorporating additional data from the 1995 field season.

✦ CONCLUSION

This research will develop new methodologies for generating forest canopy structure variables from satellite data. A key shortcoming of existing methods for determining forest structure from remotely sensed data (Running et al., 1986; Peterson et al., 1987; Leblon et al., 1993; Nel and Wessman, 1993) is the lack of accuracy or error assessment associated with each measure (Asrar, 1989). Cokriging provides the error variance as part of the output from the algorithm and examination of the error variance indicates if the results of the technique are acceptable. Model comparison will determine if local forest structure information can be adequately represented as the spatial resolution of the satellite data becomes coarser. This will indicate the potential of scaling forest structure variables to regional and global levels using satellite data in conjunction with geostatistical techniques.

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