REMOTE SENSING OF CONIFEROUS FOREST STRUCTURE IN GRAND TETON NATIONAL PARK

CLAYTON BLODGETT ✦ DEPARTMENT OF GEOGRAPHY
KANSAS APPLIED REMOTE SENSING PROGRAM
UNIVERSITY OF KANSAS ✦ LAWRENCE
AND
MARK JAKUBAUSKAS ✦ DEPARTMENT OF GEOGRAPHY
GEOGRAPHY REMOTE SENSING LABORATORY
UNIVERSITY OF OKLAHOMA ✦ NORMAN

✦ INTRODUCTION

Satellite remotely sensed multispectral data provides a systematic, synoptic means for broad-area spatially-explicit estimation of biophysically important variables. By using ground measurements of biotic properties to calibrate remotely sensed multispectral data, vegetation properties measured at sample points can be extrapolated across a large geographic region (Graetz, 1990). Biophysical variables derived by this empirical method may include the successional state of the vegetation, or an intrinsic property of the vegetation, such as biomass, leaf area index, cover, or moisture content (Jensen, 1983; Waring et al., 1986; Spanner et al., 1984; Graetz, 1990). Spatially-explicit estimation of forest biophysical factors at landscape to regional scales has applications in forest management and ecology, including insect infestation susceptability, forest fire behavior, and estimating plant and animal species habitat and diversity.

Our previous research examined relationships between forest structure, successional state, and spectral reflectance characteristics. Results indicated that decreases in visible and middle-infrared spectral reflectance are related to the age and development of a coniferous forest stand. Spectral reflectance changes are rapid during the initial stages of stand regeneration, but the rate of change slows as the stand progresses into later successional stages (Blodgett and Jakubauskas, 1996; Jakubauskas, 1996).

Our ongoing objectives are to develop methods for estimation of forest biophysical parameters from satellite remotely sensed data and to compare Yellowstone and Teton coniferous forests in terms of forest structure and successional pattern. Forest stands sampled in 1995 in Grand Teton National Park are 500 - 1000 meters lower in elevation than the Yellowstone sites (sampled 1992-1994), and subject to different temperature and precipitation regimes. Sampling in 1995 was directed at increasing our database of lodgepole-dominated forest stands in the Greater Yellowstone Area.

STUDY AREA

Grand Teton National Park contains several temperate coniferous forest habitat types, with lodgepole pine *(Pinus contorta var latifolia)* comprising a significant portion of the total forested area. Other coniferous forest species found in GTNP include Douglas-fir *(Pseudosuga menzesii)*, subalpine fir *(Abies lasiocarpa)*, Engelmann spruce *(Picea engelmannii)* and whitebark pine *(Pinus albicaulis)*. The ecology and successional history of coniferous forests in the Yellowstone Ecosystem have been well documented by researchers (Taylor 1969; Despain 1973, 1990; Romme 1982; Romme and Despain 1989a, 1989b).

✦ METHODS

Forest stands were located in the field using a combination of National Aerial Photography Program (NAPP) 1:40,000 color-infrared photography and topographic maps. Environmental measurements for each stand were taken within a 20x25 m plot, except in young, dense stands where a 10m x10m plot was used. Particular care was taken in the field to ensure that sites were located in the center of a homogeneous stand to avoid edge effects. Diameter at breast height (DBH) was tallied in 5 cm size classes by species for trees greater than 2.5 m in height. Counts were also performed for standing dead trees in the same size classes. Trees less than 2.5 m high were tallied as seedlings by species. Height of the dominant overstory was calculated for each sample plot using a clinometer, averaging values for five dominant trees. Twenty 0.5 m x 0.5 m understory quadrats were placed at equal intervals along four transects within each plot, and understory vegetation was recorded by species as percent cover within each quadrat using the Daubenmire technique (Daubenmire, 1959). Ground cover not occupied by herbaceous or low woody plants was classified by percent cover into moss/lichen, litter, persistent litter (deadfall and sticks larger than 1 cm diameter), rock, and soil.

Overstory density and seedling density were computed from size-class data collected for each stand (4 tree species x 16 diameter classes). All data were normalized to a one-hectare standard unit. Size diversity was calculated by counting the number of size classes in which trees were tallied in a plot, and dividing the total by 16 (16 = maximum possible number of size classes). Basal area for living and dead stems was computed using the mean diameter value for each size class (e.g., 2.5 cm for the 0-5 cm size class). Total percent living cover, and percent cover by life form (e.g., shrubs, grasses, and forbs) was computed for each plot.

Indian IRS-1B LISS-II multispectral satellite imagery was acquired for October 2, 1994, June 29, 1995, and August 12, 1995 (Figure 1). The LISS-II acquires data in three visible bands (blue, green, red) and one near-infrared band, with a spatial resolution of 36.5 meters and a radiometric resolution of 128 brightness levels. Data were georeferenced to a Universal Transverse Mercator (UTM) coordinate system. Brightness values were extracted from each scene for each spectral band on each date of image data. A normalized difference vegetation index (NDVI) was computed from the red and near-infrared bands of the IRS data (NDVI=(NIR-Red)/(NIR+Red)). Temporal trends in spectral reflectance for each stand in each spectral band were assessed, and statistical analysis of spectral:structural relationships is ongoing.

✦ RESULTS

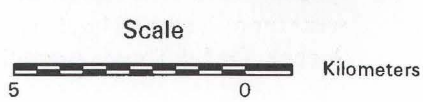
Forest stands show distinct seasonal trends in spectral reflectance as expressed in a normalized difference vegetation index (Figure 2). NDVI trends are described below for four stands (Sites 1, 2, 24, and 34) that represent the different overstory and understory stand structures encountered in field sampling in GTNP. Site 24 represents relatively young stands (lodgepole regenerating in a recent burn), sites 2 and 34 are intermediate (lodgepole overstory, subalpine fir beginning to establish in understory and overstory), and site 1 contains a significant subalpine fir cohort in the lodgepole pine overstory.

Single-date trends of spectral reflectance across the four sites are consistent with successionally-associated changes in spectral response observed for lodgepole pine forest in the GYA (Jakubauskas, 1994; Jakubauskas, 1996). Young stands show low NDVI values, and NDVI values progressively increase with age and development of a stand.

Site 24 is located in the Mystic Isle Fire scar, immediately west of Spaulding Bay and south of Deadman Point. Overstory density and seedling counts are high in this plot (5100 and 22,400 stems/ha, respectively), but due to the small diameter of the young trees, live basal area is low (2.5 m^2/ha). Because the canopy structure is relatively "thin" as viewed by the sensor, and the volume of plant material is low, the overall NDVI in all dates is lower than the NDVI values for more mature stands (1, 2, and 34). Understory cover by grasses and forbs is also low, producing lower-magnitude seasonally-associated (June-August) changes in NDVI than are associated with stands with a higher understory herbaceous cover.

Intermediate stands (representative sites 2 and 34) show similar NDVI values and changes in NDVI during the growing season. Site 2 is located on the Sargents Bay peninsula, originating from fires in the latter 19th century. Cores from this stand indicate that the mean age of the dominant lodgepole pine cohort is 110 years b.p. Stand structure data indicate that subalpine fir is only beginning to establish on this site

Figure 1. Indian IRS-1B LISS-II Multispecral Satellite Imagery.



(seedlings < 3.0 cm only), and the canopy structure is relatively even-aged and even height. Site 34, located on the west slope of Mt. Reid, is even more advanced in terms of establishment of subalpine fir, with individual subalpine fir stems up to 20 cm DBH. No lodgepole pine seedlings occurred on this site.

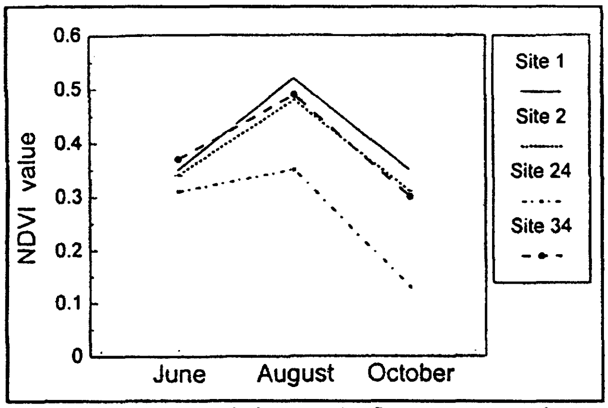


Figure 2. Seasonal trends in spectral reflectance expressed in a normalized difference begetation indes.

Site 1 is located on the east side of Spaulding Bay, and has a significant subalpine fir component in the dominant lodgepole pine overstory. Leaf area index (LAI) and biomass computed for this plot (10.56 and 10,890 kg/ha, respectively [Blodgett and Jakubauskas, 1996]) are at the high end of ranges in LAI and biomass found for lodgepole pine stands in the Yellowstone region (Jakubauskas, 1994). Live basal area computed for this site is the highest of any of the 39 stands sampled in 1994 and 1995 (Table 1). Spectrally, this stand type has the highest NDVI values of the four representative stands and shows a significant increase in NDVI during the summer, as understory herbaceous cover develops following snowmelt.

Analysis of relationships between forest structure and spectral reflectance is continuing, as well as new investigations exploring the temporal dependence of spectrally-derived biophysical parameters. Our preliminary results suggest a seasonal/phenological component to spectral response even for closed coniferous forest canopies, a condition that may exacerbate estimation of biophysical parameters from remotely sensed data. Field observations and data suggest that possibility that subalpine fir establishment in lodgepole pine stands of the Greater Yellowstone Ecosystem may occur at an earlier age postfire in Grand Teton National Park compared to the Central Plateau of Yellowstone, but additional sites are needed to substantiate this observation.

Table 1. Stand parameters derived from GTNP forest plots (1994-1995).

Plot	Overstory density	Size diversity	Live B.A.	Seedling total	Dead density	Dead B.A.	Percent dead
1	2420	0.44	48.94	8880	360	1.51	0.13
2	2260	0.31	46.42	2540	600	4.30	0.21
3	1360	0.44	28.71	2260	300	3.05	0.18
4	1820	0.31	33.88	360	420	1.86	0.19
5	1600	0.38	30.63	3480	500	4.41	0.24
6	1300	0.56	30.09	5800	160	2.28	0.11
7	1180	0.44	27.83	1200	400	4.59	0.25
8	900	0.44	30.91	1020	320	8.80	0.26
9	1840	0.31	24.70	80	440	1.71	0.19
10	720	0.44	20.85	720	180	4.57	0.20
11	1300	0.44	42.11	4100	380	7.57	0.23
12	940	0.38	16.40	4220	220	7.33	0.19
13	800	0.50	28.04	1380	160	2.75	0.17
14	880	0.44	26.11	400	160	11.70	0.15
15	1480	0.31	29.55	3820	500	8.81	0.25
16	1240	0.38	30.61	2180	140	2.58	0.10
17	1600	0.38	41.07	2420	400	4.67	0.20
18	1060	0.44	34.76	60	160	2.28	0.13
19	960	0.44	30.39	1600	460	4.70	0.32
20	1040	0.50	26.35	5100	240	4.44	0.19
21	1060	0.38	25.89	980	620	4.78	0.37
22	1360	0.31	31.69	120	560	2.32	0.29
23	920	0.31	28.33	60	340	5.51	0.27
24	5100	0.06	2.50	22400	0	0.00	0.00
25	2800	0.13	2.16	8000	0	0.00	0.00
26	2360	0.38	44.82	780	780	4.39	0.25
27	5400	0.13	3.04	13600	200	6.38	0.04
28	5500	0.06	2.70	18000	200	7.17	0.04
29	1600	0.44	38.56	1540	140	1.80	0.08
30	840	0.31	26.02	6640	0	0.00	0.00
31	1420	0.38	36.67	980	620	7.84	0.30
32	680	0.44	20.83	5920	320	11.39	0.32
33	1980	0.38	28.77	7500	1100	5.02	0.36
34	1380	0.44	32.41	1040	1000	12.11	0.42
35	620	0.50	20.65	1900	260	6.02	0.30
36	2460	0.31	38.28	100	1220	7.75	0.33
37	1740	0.31	44.05	1720	400	4.91	0.19
38	3160	0.25	48.20	180	1500	8.04	0.32
39	2040	0.44	52.13	1040	780	6.90	0.28

B.A. = Basal area (m^2/hectare). See text for description of other variables.

✦ ACKNOWLEDGEMENTS

We greatly appreciate the support and assistance provided by Dr. Hank Harlow and his staff at the UW/NPS Research Station. Portions of this research were conducted at the Kansas Applied Remote Sensing (KARS) Program (Edward A. Martinko, Director) at the University of Kansas. Funding was provided by a National Aeronautics and Space Administration Mission to Planet Earth Global Climate Change Fellowship (NGT-30062), the University of Wyoming/National Park Service (UW/NPS) Research Center, and a University of Oklahoma Junior Faculty Research Grant. Assistance with fieldwork was provided by Rodney Brown.

✦ LITERATURE CITED

Blodgett, C.F., and Jakubauskas, M.E. 1996. A preliminary assessment of forest canopy structure in Grand Teton National Park. University of Wyoming/National Park Service Research Center 18th Annual Report, University of Wyoming, Laramie, Wyoming. Pp. 37-41.

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

Despain, D.G. 1973. Major vegetation zones of Yellowstone National Park. Information Paper No. 19, Yellowstone National Park, National Park Service. 4 p.

Despain, D.G. 1990. Yellowstone Vegetation: Consequences of Environment and History in a Natural Setting. Roberts Rinehart, Boulder, Colorado. 239 p.

Graetz, R.D. 1990. Remote sensing of terrestrial ecosystem structure: An ecologist's pragmatic view, in Remote Sensing of Biosphere Functioning, R.J. Hobbs and H.A. Mooney, eds. Ecological Studies 79, Springer-Verlag, New York.

Jakubauskas, M.E. 1994. Modeling Coniferous Forest Succession in Yellowstone National Park Through Integration of Landsat Thematic Mapper and GIS Data. PhD Dissertation, University of Kansas, Lawrence, KS. 225 pp.

Jakubauskas, M.E. 1996. Thematic Mapper characterization of lodgepole pine seral stages in Yellowstone National Park, USA. Remote Sensing of Environment, 56:118-132.

Jensen, J.R. 1983. Biophysical remote sensing. Annals of the Association of American Geographers, 73(1):111-132.

Romme, W.H. 1982. Fire and landscape diversity in subalpine forests of Yellowstone National Park. Ecological Monographs, 52(2):199-221.

Romme, W.H., and Despain, D.G. 1989a. The Yellowstone Fires. Scientific American, 261(5):37-46.

Romme, W.H., and Despain, D.G. 1989b. The long history of fire in the Greater Yellowstone Ecosystem. Western Wildlands, 15(2):10-17.

Spanner, M.A., Acevedo, W., Peterson, D.L., Card, D.H., Teuber, K.W., Running, S.W., and Mouat, D.A. 1984. Remote sensing of the leaf area index of temperate coniferous forests. Proceedings of the Machine Processing of Remotely Sensed Data Symposium, West Lafayette, Indiana, p. 362-370.

Taylor, D.L. 1969. Biotic Succession in Lodgepole Forests of Fire Origin in Yellowstone National Park. PhD. Dissertation, University of Wyoming, Laramie, Wyoming. 320 p.

Waring, R.H., Aber, J.D., Melillo, J.M., and Moore, B. 1986. Precursors of change in terrestrial ecosystems. BioScience, 36(7):433-438.