Thematic Mapper Analysis of Blue Oak (*Quercus douglasii*) in Central California[1]

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Abstract: Digital Thematic Mapper (TM) satellite data from September 1986 and December 1985 were analyzed to determine seasonal reflectance properties of blue oak rangeland in the La Panza mountains of San Luis Obispo County. Linear regression analysis was conducted to examine relationships between TM reflectance and oak canopy cover, basal area, and site topographic variables. September reflectance in TM3 was strongly negatively correlated with oak canopy cover (r^2=0.62), less strongly related to oak basal area or density (r^2=0.2-0.4). December reflectance was not as strongly correlated as September reflectance. These results indicate that late summer TM data can be used effectively to monitor oak cover in California's rangelands, even in rugged environments.

California Blue Oak (*Quercus douglasii* H. & A.) is the dominant overstory species over a large portion of rangelands in California. In recent years, the long-term viability of this species under modern land use regimes has been called into question. Regeneration of blue oaks appears to be impeded by a combination of factors (Borchert and others, 1989), and management of the rangeland where blue oak is most common is being reviewed. A detailed inventory of the current status of the species is necessary for future management planning, as well as to provide a baseline for monitoring.

Digital satellite imagery is the most economical and objective source of data currently available for mapping and monitoring oak woodland over large areas. There are presently four satellite-borne sensors providing synoptic coverage of California. These are the NOAA Advanced Very High Resolution Radiometer (AVHRR), the French satellite SPOT, and the Landsat Multi-Spectral Scanner (MSS) and Thematic Mapper (TM). The data provided by AVHRR is not of sufficient spatial resolution (1.1 Km) for detailed analysis of the highly variable landscapes typical of blue oak habitats. Landsat MSS provides coverage at 80 m. resolution with four spectral bands, and SPOT HRV provides coverage at 20 m. resolution in three multispectral bands, as well as a panchromatic channel with 10 m. resolution. Landsat thematic Mapper data has been used successfully to map blue oak woodlands (Brockhaus and Pillsbury, 1987). The 30m spatial resolution of TM is well suited for mapping complex vegetation mosaics and its high spectral dimensionality, including three visible, one near-infrared, and two mid-infrared channels, allows good discrimination of natural vegetation types. Although the use of TM data for mapping blue oak stand types has been demonstrated, the sensor also has the potential to provide quantitative information on stand characteristics such as basal area and crown closure. Much work is needed to test and calibrate TM data for this purpose. In this paper we evaluate the potential of TM data for estimating basal area and crown closure over rugged terrain.

STUDY AREA

The study area is located in the La Panza Range of southern San Luis Obispo County, California, and covers two diagonally adjacent 7.5 minute USGS quadrangles, Pozo Summit and Los Machos Hills (figure 1). Over 90 percent of the study region lies within Los Padres National Forest. The climate is Mediterranean, with warm, dry summers and mild, wet winters. Average annual precipitation at Pozo, on the western edge of the study region, is 527 mm, most of which falls between November and March. Temperatures range from 0 to 25 degrees Celsius. Elevations range from 300 - 1175 m, with the lower elevations characterized by long rows of steep, rolling hills incised by lower-order intermittent streams and drainage gullies. Study plots were selected to include the entire range of slopes and aspects present in the region. Regional vegetation is a mosaic of mixed chaparral, chamise chaparral, coastal sage scrub, grassland, valley oak savanna, blue oak woodland and blue oak/ digger pine woodland and forest.

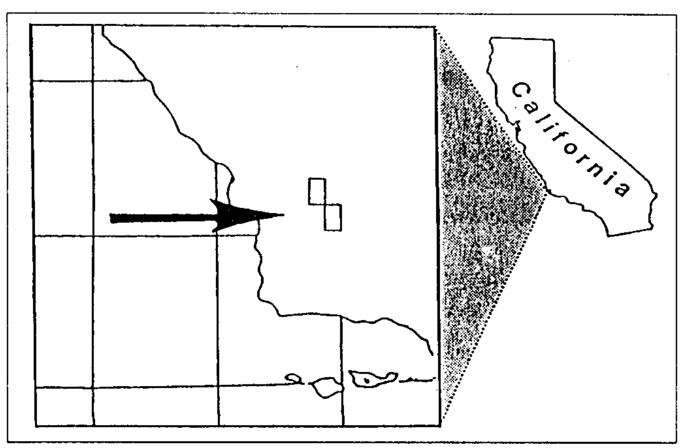

Figure 1—Location of Study Area.

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Oak woodlands and grasslands, which occupy approximately 40 percent of the area, have been grazed by cattle to varying degrees throughout most of this century. Most private and public lands are still grazed, and grazing intensity is highly variable spatially and from year to year. Management of the area is oriented toward rangeland production, wildlife habitat protection, and watershed protection.

FIELD METHODS

Field measurements of slope angle, slope aspect, and tree basal area were collected during spring and summer, 1987 in 84 plots 60 by 60 m scattered throughout the project area. Forty-six plots were sampled by U.S. Forest Service ecologists for a related project, and 36 additional plots were collected for this study. Plots were located to sample the range of stand densities (including non-wooded grassland) and terrain conditions in the study area, and were centered in stands of relatively homogeneous physical and vegetational characteristics. Shrub cover did not exceed 10 percent in any of the sample plots.

Diameter at breast height was measured for all trees that occurred within a 0.1 acre (407 m^2) circular subplot centered in the 60 by 60 m plot. Estimates of overstory crown cover were obtained from 1:24,000 color stereo air photos acquired September, 1983. Crown cover within each plot was measured by magnifying the air photos to 1:8,000 and estimating total tree canopy cover (5 percent cover classes) by dot count of a 10 m grid.

Image Processing

Satellite data available for use in the study were from Landsat 5 Thematic Mapper path 42, row 36, for two dates: one scene from December 14, 1984, and the other from September 15, 1986. Both scenes were of good quality; however the September 1986 scene had some cloud cover, with approximately 10 percent cloud cover within the study area. Two subimages were extracted from each date of imagery corresponding to the Los Machos Hills and Pozo Summit topographic quadrangles. Twelve ground control points were used to register the subimages to each of the two 7.5 minute topographic maps using a first-order linear transformation. Radiance data were corrected for atmospheric effects by dark pixel subtraction (Moik 1980) based on near-IR reflectance from a nearby reservoir. We used this somewhat crude correction method because our analyses were concerned chiefly with relative pixel radiances in single bands rather than absolute radiance or reflectance values. Median radiances in all bands except the thermal band (TM 6) were extracted for a 2 by 2 window centered on each field plot.

DATA ANALYSIS

Correlation analysis and stepwise multiple regression were used to measure the association between oak canopy cover or basal area and the following variables: DN values for TM bands (excluding TM 6) in September and December, the first four principal components of the original spectral data for each data (based on the correlation matrix for sampled pixels), the Normalized Difference Vegetation Index (NDVI, (TM4 - TM3)/(TM4 + TM3)), and plot slope orientation. Slope orientation was expressed as (sin(slope angle))x(cos(slope aspect)), with aspect measured in degrees from north. This index ranges from -1 for a vertical south-facing slope to 1 for a vertical north-facing slope.

RESULTS

In September all TM bands and the first principal component of the bands were negatively correlated with oak canopy cover, with r-values ranging from -0.76 to -0.82. Correlations were slightly lower but still highly significant between tree cover and December spectral data (table 1). NDVI was positively correlated with oak canopy cover in September when oaks were in leaf and the understory was senescent, and weakly negatively correlated with oak cover in December when oaks were leafless and the understory was greening up.

Table 1— ***Correlations (r) of spectral data and oak canopy cover and basal area for September and December TM imagery. All correlations are significant at p<0.01.***

Spectral Band	Oak Canopy Cover	Oak Basal Area	Northness
September			
TM1	-0.79	-0.52	-0.46
TM2	-0.81	-0.53	-0.45
TM3	-0.83	-0.55	-0.44
TM4	-0.76	-0.46	-0.41
TM5	-0.82	-0.47	-0.45
TM7	-0.79	-0.46	-0.44
NDVI	0.73	0.47	0.42
PC1	-0.82	-0.41	-0.46
December			
TM1	-0.77	-0.41	-0.65
TM2	-0.72	-0.40	-0.68
TM3	-0.73	-0.38	-0.67
TM4	-0.67	-0.37	-0.67
TM5	-0.73	-0.37	-0.67
TM7	-0.74	-0.39	-0.65
NDVI	-0.28	0.13	0.17
PC1	-0.72	-0.40	-0.68

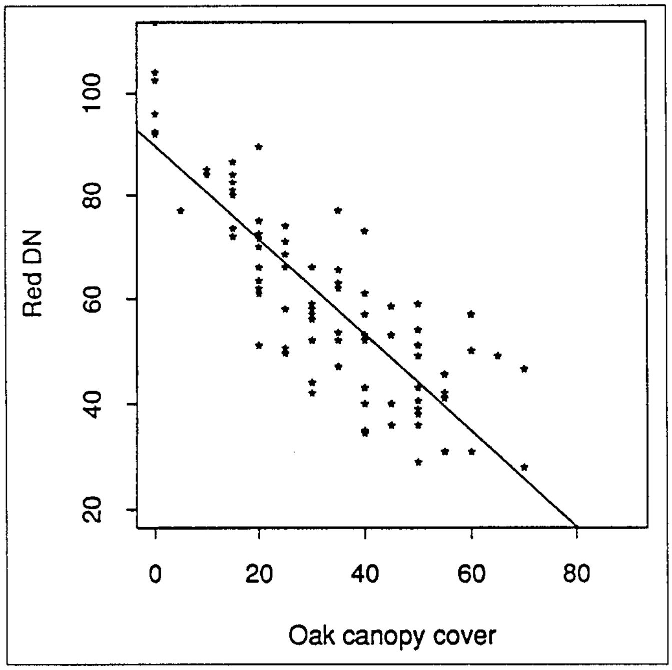

Figure 2—Regression of September TM3 radiances against photointerpreted oak canopy cover.

Spectral data were not as highly correlated with plot basal area as with tree canopy cover (table 1). This is due to the relatively weak relationship between tree canopy cover and basal area ($r = 0.62$, $p<0.01$).

Tree cover was significantly positively associated with slope orientation ($r=0.52$, $p<0.01$), with highest cover on steep north-facing slopes. TM DN values were negatively correlated with slope orientation, especially in the December scene, when topographic variation in illumination was relatively high (solar zenith angle = 66 degrees, solar azimuth = 146 degrees at the time of scene acquisition). Thus the strong negative correlations between TM data and oak cover could be partly due to the association of oak cover and topography.

Multiple regression analysis indicated that there was little predictive skill added by using more than one spectral band to predict oak canopy cover or basal area. This was mainly due to the high intercorrelation among the spectral channels (e.g., the first principal component accounted for 89.2 percent of the total variance in the September TM data). Thus, a simple regression of September TM 3 (red) versus cover proved to be the best model for predicting crown cover from the spectral data (Figure 2). No improvement was obtained through the use of multi-data imagery. The results were also not improved by transformations of the data.

DISCUSSION

Satellite monitoring of tree canopy cover in California's blue oak woodlands is feasible using simple correlative models, even in relatively homogeneous terrain with variable ground layer conditions. Tree cover is highly correlated with radiance in all TM bands in summer and winter imagery, without any compensation for varying illumination on sloping terrain. The high correlation can be attributed to a number of effects that vary depending on the season of image acquisition. In late summer, oak canopies are in leaf and the herb layer is dry and highly reflective. Canopy light absorptance and shadowing of the understory combine to create a strong negative relationship between pixel brightness and tree cover. The relationship is strengthened by the tendency for greater tree cover on north-facing slopes, where shadowing of the understory by tree canopies is greater.

In early winter, the leafless tree canopies are relatively dark against a background of thatch and emerging herbs. Light interception by the tree canopies is presumably much reduced, but tree shadowing of the understory is proportionally greater at the lower winter sun angles. Perhaps more important is the positive associations of tree cover with slopes receiving less sunlight at low winter sun angles.

A number of factors may have operated to reduce the correlation between tree cover and spectral data, most importantly: errors in registering imagery to field measurements, low precision and errors in estimating tree canopy cover in the air photos, spectral variation in the understory layer due to differences in composition, condition and illumination, and variations in tree canopy reflectance associated with leaf density and condition. Field reflectance measurements of the blue oak woodlands and grasslands are needed to isolate the relative importance of these sources of error.

In conclusion, our results are highly promising and indicate that both distribution and canopy structure of blue oak woodlands can be monitored with single-date TM data. Late summer imagery appears especially well-suited to meet these objectives.

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