

Monitoring Land Cover Change in California Using Multitemporal Remote Sensing Data¹

John Rogan,² Doug Stow,² Janet Franklin,² Jennifer Miller,²
Lisa Levien,³ and Chris Fischer⁴

Introduction

Growing concern over the status of global and regional forest resources has led to the implementation of numerous multi-agency projects to establish long term operational systems for land cover monitoring. Land cover change (i.e., location, extent and cause) is identified as the most important and challenging research theme for many of the programs recently initiated by monitoring agencies. A key element in successfully addressing this theme is the involvement of regional and state-level management authorities to provide the necessary link between local/municipal and national/international land cover monitoring projects. Increasingly, these projects are using complex mapping procedures that require the integration of remotely sensed data, state-of-the-art image processing approaches, collateral spatial data, and georeferenced (GPS) field validation data within a Geographic Information System (GIS).

To address the challenge of forest and shrubland sustainability in the midst of rapid and widespread land cover change in California, the USDA Forest Service (USFS) and the California Department of Forestry and Fire Protection (CDF) are collaborating in the statewide Land Cover Mapping and Monitoring Program (LCMMP) to improve the quality and capability of monitoring data, and to minimize costs for statewide monitoring. Changes in forest, shrub, and grassland cover types are the primary focus in this program, but changes in urban/suburban areas are also mapped. Land cover change maps are required for regional interagency land management planning, fire and timber management, and species habitat assessment

An examination and comparison of the variety of remote sensing methods available, such as scene normalization, change feature extraction, classification, and accuracy assessment is warranted, in order to meet operational and standardization needs of the LCMMP. Faced with this task, the USFS and CDF staff associated with the LCMMP welcomed a research alliance with San Diego State University (SDSU) as a way to improve and automate change monitoring procedures. Specifically, techniques that minimize time-consuming human interpretation and maximize automated procedures for large area mapping of land cover change are being evaluated. The long-term objective of this study is statewide application of its *proof of concept* to the ongoing LCMMP.

¹A poster version of this paper was presented at the 2002 Fire Conference: Managing Fire and Fuels in the Remaining Wildlands and Open Spaces of the Southwestern United States, December 2–5, 2002, San Diego, California.

²Assistant professor, professor, professor, professor, respectively. Department of Geography, San Diego State University, 5500 Campanile Drive, San Diego, CA 92182.

³Remote sensing specialist, US Forest Service, 1920 20th Street, Sacramento, CA 95814.

⁴GIS specialist, California Department of Forestry and Fire Protection, 1920 20th Street, Sacramento, CA 95814.

Data and Pre-Processing

Landsat TM and ETM images captures four to five years apart are geometrically registered to the UTM WGS84 projection with GCP points located at major road intersections, dispersed throughout the entire scene with less than 0.45 pixel RMSE. A nearest neighbor algorithm is used to resample the images to a 30 m output grid. These data are acquired within a three-month acquisition window (June-August) to provide operational flexibility (i.e., to minimize atmospheric contamination from cloud cover or wildfire smoke plumes), and to assure that they occur before the onset of foliage change in hardwood vegetation. These image data are then independently normalized for atmospherical illumination differences and converted to reflectance values using a dark object subtraction (DOS) approach.

The Landsat TM Multitemporal Kauth Thomas (MKT) linear transformation is used to spectrally enhance the data prior to supervised classification. MKT produces six features of interest; three features that represent change in brightness, ΔB (MKT1), change in greenness, ΔG (MKT2), and change in wetness, ΔW (MKT3), and three features that represent mean, or stable brightness (MKT4), stable greenness (MKT5) and stable wetness (MKT6) between dates. Further, ancillary data layers such as elevation, slope and aspect are included in the classification process.

Land Cover Change Classes

The land cover change classification scheme (*table 1*) describes three discrete categories of forest canopy cover decrease and two classes of canopy increase. Further, a shrub cover increase and shrub decrease class is used, along with change in developed (urban) areas and no-change (+15 to -15 percent canopy change) categories. The -15 to 15 percent change class was designed to reduce the confusion between phenological related increase and post-disturbance recovery classes. This classification scheme was developed and is currently in statewide use by the LCMMP. In situ reference data were collected for classification training and testing phases, based on a stratified random sampling scheme and was acquired using both aerial photographs and field visits.

Table 1—*Land cover change categories for the study.*

Land Cover Change Classes
+15 to -15 pct canopy change
-71 to -100 pct canopy change
-41 to -70 pct canopy change
-16 to 40 pct canopy change
Shrub/grass decrease >15 pct
+16 to +40 pct canopy change
+41 to 100 pct canopy change
Shrub/grass increase >15 pct
Change in existing developed areas

Change Mapping Approach

A univariate classification tree algorithm are used to produce tree-structured rules that recursively divide the data into increasingly homogenous subsets based on splitting criteria. At each split, the values of each explanatory variable are examined and the particular threshold value of a single variable that produces the largest reduction in a deviance measure (e.g., increase in subset homogeneity) is chosen to partition the data. Explanatory variables that have already been used in the model may be reexamined and potentially reintroduced into the tree structure. As a result, hierarchical, non-linear relationships within the data are revealed (*fig. 1*).

Spectral and ancillary variables are readily integrated and their contribution to map accuracy revealed in the hierarchical structure of the classification trees, and in the increase in accuracy when ancillary data were included in the classification. The methods used in this study were successful for mapping discrete categories of land cover change at overall accuracy levels of 72 to 92 percent. *Figure 2* shows a portion of a land cover change map of southern California from 1990 to 1996.

Conclusions

To address the concern about the amount and health of forest and shrubland ecosystems in California from accelerating land cover change, several agencies are collaborating in a land cover mapping and monitoring program. We monitored land cover change in San Diego County (1990 to 1996) using multi-temporal Landsat TM data. Change vectors of Kauth Thomas features were combined with stable Kauth Thomas features and a suite of ancillary variables within a decision tree classification. A combination of aerial photo interpretation and field measurements yielded training and validation data. Overall accuracies of the land cover change maps were high. The Kauth Thomas (brightness, greenness and wetness) and ancillary variables were important in mapping land cover change.