Progress Report for NASA LCLUC Program

Operational Monitoring of Alteration in Regional Forest Cover Using Multitemporal Remote Sensing Data

http://typhoon.sdsu.edu/nasa_lcluc/

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Principal Investigator:

Dr. Janet Franklin
Tel: 619-594-5491
janet@typhoon.sdsu.edu

Co-Principal Investigator

Dr. Douglas Stow
Tel: 619-594-5498
stow@mail.sdsu.edu

Project Manager

John Rogan
rogan@rohan.sdsu.edu

Department of Geography and
Center of Earth Systems Analysis and Research
San Diego State University
5500 Campanile Drive
San Diego, CA 92182-4493

Fax: 619-594-4934

Collaborators

Lisa Levien, USDA Forest Service, Sacramento, CA

Chris Fischer, California Department of Forestry and Fire Protection, Sacramento, CA

Dr. Curtis Woodcock, Department of Geography, Boston University, Boston, MA

Consultants

Dr. Xueqiao Huang
Information Specialist, ACS Government Solutions Group, Inc., River Ridge, Louisiana

Background

Growing international concern over the status of both 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 yet challenging research theme for many of the programs recently initiated by these agencies (e.g., Land Cover Land Use Change [LCLUC]; Global Observation of Forest Cover [GOFC]). A key element in addressing this theme is involving of regional management authorities, (e.g., USGS and USDA Forest Service [FS]), in providing the necessary link between local/ municipal and national/ international land cover monitoring projects. These projects are increasingly using complex 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 growing threat to forest and shrubland sustainability, caused by rapid and widespread land cover change in California, the FS and the California Department of Forestry and Fire Protection (CDF) are collaborating in a statewide land cover change monitoring program to improve monitoring data quality, data capability and minimize large area monitoring costs. Changes in forest, shrub and grassland cover types are the primary focus this approach, but changes in urban/suburban areas are also mapped. These change maps are required for regional interagency land management planning, fire and timber management, species habitat assessment and existing land cover map updating.

This program requires an examination and comparison of the variety of remote sensing methods available, such as scene normalization, change feature extraction, classification, and accuracy assessment, in order to meet operational and standardization needs. Faced with this task, the monitoring program welcomed a research and experimentation component with San Diego State University (SDSU), as a way to increase efficiency through technology, by improving and automating change monitoring procedures. Specifically, this involves testing techniques that minimize time-consuming human interpretation and maximize automated procedures for large area mapping of land cover change. The long-term objective of this project is the application of its statewide *proof of concept* to the ongoing land cover mapping and monitoring program.

Key Words:
1) Research Fields: Land cover change, deforestation, fire ecology.
2) Geographic Area/Biome: North America
3) Remote Sensing: Atmospheric correction, IKONOS, LANDSAT
4) Methods/scales: GIS, in-situ data.

Research questions

NASA ESE scientific questions being answered:

1. What are the changes in land cover and/or land use (monitoring/mapping activities)?
2. What are the causes of LCLUC?

Research goals

Goal 1. This research applies remote sensing and spatial analysis techniques to map changes in land cover in two study sites in California between 1996 and 2000. In the context of improving a current FS-CDF land cover monitoring program and implementing a regional scale operational monitoring program, the research objective is to design an operational land cover change monitoring program based on the following efficiency indicators: accuracy of forest change maps, flexibility of implementation, and consistency of methods in phenologically diverse study areas.

Related research questions

a. Which forest cover change detection techniques produces the most accurate (i.e., error-free) maps of land cover change?
b. For the most accurate change mapping technique, which atmospheric and seasonal normalization techniques produce the most accurate maps of land cover change?
c. How do land cover change detection accuracies differ, if at all, between southwest and northeast California study sites?
d. If the alternative land cover change detection techniques produce higher accuracy results than the existing FS-CDF methods, are they operational (i.e., ready for, or in condition to undertake a required function according to FS-CDF needs), flexible (i.e., characterized by a ready capability to adapt to different and changing requirements) and consistent (i.e., having comparable map accuracy over large, heterogeneous areas)?

Goal 2. Implement the land cover monitoring program established in research objective 1 to analyze the following data sets (1985-1990, 1990-1996 and 1996-2000).

Related research questions:

a. How is land cover change manifested (net loss or gain) in terms of: i) geographical extent and pattern, and ii) cause, for the two study areas?
b. How do the changes in forest cover affect different vegetation types in each region, in terms of frequency of disturbance, and vegetation species and lifeform?

Modifications and adjustments

(i) Atmospheric Issues

a. A quantitative comparison of multi-date image normalization techniques for land cover change detection. This addition was made following discussion with our FS and CDF collaborators

b. An examination of the utility of a space-varying haze-correction algorithm for removing the effects of wildfire smoke plumes in TM and ETM^+ imagery. This modification was needed due to the presence of large smoke plumes in our acquired imagery for several time periods (i.e., June 1985 and July 2000).

(ii) Conceptual Issue

a. As per the suggestion made by NASA-LCLUC committee, changes in land cover between 1985 and 1990 will be investigated. The addition of this time period will provide a greater understanding of land cover change dynamics in California and will provide the FS-CDF land cover mapping and monitoring program (LCMMP) with baseline data for change trajectory analyses.

(iii) Accuracy Issue

a. Research by the SDSU-Geography LCLUC team highlights the need for increased information to be provided to map users. In addition to the typical confusion-matrix approach to map accuracy information, we recognize the need to provide spatial accuracy information. We are exploring kriging and simulation approaches to spatial error representation in maps (see example in Figure 1).

Progress during this reporting period

To date, the collaborative research study has resulted in:
(i) Products
a. Land cover change maps (1990-1996 and 1996-2000) in California. These maps are available at the following web address http://frap.cdf.ca.gov/.
b. Spatially-varying haze-corrected Landsat 7-ETM$^+$ imagery for areas in northern and southern California.
c. Geometrically rectified and radiometrically normalized TM and ETM$^+$ imagery for northern and southern California for the following dates: 1985, 1990, 1996, 2000.
(ii) Research
a. Normalization: Comparison of several dark object subtraction (DOS)-related atmospheric correction algorithms to pseudo-invariant feature (PIF) and the Atmospheric & Topographic Correction (ATCOR) models is nearing completion. Preliminary results reveal that the 'simple' DOS approaches are sufficient for atmospheric normalization in change detection, when compared to the more time-consuming PIF approach. A full comparison using the ATCOR models will complete this process.
b. Spatially-Varying Haze Correction: The Carlotto (1999) spatially-varying haze removal approach was implemented on scenes affected by wildfire smoke plumes to reduce the effects of scattering and allow accurate detection of canopy depletion. A statistical comparison between a pre and post-correction data showed that the algorithm removes the effects of smoke plumes without significantly altering the pixel values of areas unaffected by haze. In addition, areas that underwent canopy depletion over time were readily detected and mapped with high accuracy (i.e., > 85%). We recommend this approach for use in multitemporal remote sensing studies where imagery is affected by smoke plumes.
c. Image Classification: We compared three different machine-learning methods of classifying land cover change in California-decision trees implemented using Splus software, the machine learning classifier (MLC) (Huang and Jensen 1997), and an artificial neural network classifier (Fuzzy ARTMAP). Examining simple *change* vs. *no-change*, all three classifiers produced very high overall accuracies of ~96% when evaluated with test data. Examining five change classes (i.e., vegetation increase and decrease classes), all three classifiers produced overall accuracies of ~90%. Finally, examining all of our nine land cover change classes, Fuzzy-ARTMAP resulted in 81% classification accuracy (~10%) higher than S-Plus and MLC.
d. Fire scar burn severity mapping: In order to increase the accuracy of fire perimeter information and provide ancillary data for change products, we examined various approaches to mapping vegetation burn severity using IKONOS and ETM data. To date, spectral mixture analysis (SMA) and MKT (Multitemporal Kauth Thomas) techniques produce higher supervised classification accuracies (i.e., 8-10%) than a new burn approach-Normalized Burn Ratio (NBR).

Next steps
1. Complete the comparison between atmospheric normalization approaches and make recommendations for land cover change studies.
2. Complete land cover change classification comparison (described in ii-c, above) for northern California and for the 1985-1990 data sets.
3. Following the completion of our land cover change data sets for southern and northern California (September 2000), address conceptual research question as outlined in Goal 2 of the research proposal.

Most significant results:
a. The spatially-varying haze correction algorithm has proven useful in removing the effects of wildfire smoke plumes in Landsat imagery and has been adopted into the FS-CDF land cover change mapping and monitoring program
b. At this early stage, Fuzzy ARTMAP artificial neural network classifier appears promising for mapping land cover change over large areas.

New findings
a. Our need to provide additional forms of map accuracy assessment have led us to explore the visualization of map spatial accuracy/errors (see Figure 1).

New potential: "_"
New products: "_"

Conclusions
To date, our research has kept in line for the goals set for the time period and has adjusted to FS-CDF needs in regard to image processing procedures, and NASA-LCLUC suggestion that the time-scope of the research should be expanded to include a 1985 image.

Publications

Rogan, J., J. Miller, D. Stow, J. Franklin, L. Levien and C. Fischer, in preparation. Land cover change mapping in California Using multitemporal Landsat TM and Ancillary Data (*Photogrammetric Engineering and Remote Sensing*).

Franklin, J., S.R. Phinn, C. E. Woodcock and J. Rogan, in press. Multi-spectral and multi-temporal image processing approaches: Part 1. Image classification. In: *Methods and Applications for Remote Sensing of Forests: Concepts and Case Studies* (Eds. M. Wulder and S. E. Franklin), Kluwer Academic Publishers.

Rogan, J., J. Franklin and D. A. Roberts, 2002. A comparison of methods for monitoring multitemporal vegetation change using Thematic Mapper imagery, *Remote Sensing of Environment*, 80 (1), 143-156.

Rogan, J., J. Franklin, 2001. Mapping wildfire burn severity in southern California forests and shrublands using enhanced Thematic Mapper imagery, *Geocarto International*, 16(4), 89-99.

Presentations

2002, J. Rogan, J. Franklin and D. Stow, Mapping disturbances in forest and shrub cover in southern California using remote sensing data. Presented at Santa Margarita Ecological Reserve Station Spring Celebration Showcase, Santa Margarita Ecological Reserve, Riverside County, California, April 27th.

2002 J. Franklin, J. Rogan, D. Stow, L. Levien and C. Fischer, Operational detection of changes in forest and shrub cover in California using multitemporal Landsat data. Presented at the Ninth Biennial Remote Sensing Applications Conference, April 8th-April 12th.

2002 Rogan, J., J. Franklin, D. Stow, J. Miller, A comparison of classification techniques for mapping multitemporal change in forest cover using Thematic Mapper imagery. Presented at the Ninth Biennial Remote Sensing Applications Conference, April 8th-April 12th.

2002 Rogan, J., D. Stow, J. Franklin, L. Levien and C. Fischer, Evaluating the utility of a space-varying haze equalization algorithm in multitemporal remote sensing applications. Presented at the Ninth Biennial Remote Sensing Applications Conference, April 8th-April 12th.

2002 Lieberman, A., J. Rogan, D. Stow and J. Franklin, An Evaluation Of Kauth Thomas And Normalized Burn Ratio Enhancement Techniques For Delineating Burn Severity. Presented at the Ninth Biennial Remote Sensing Applications Conference, April 8th-April 12th.

2002 Rogan, J., and J. Franklin, A comparison of classification techniques for mapping multitemporal forest cover change using Thematic Mapper imagery. Presented at the Annual Meeting of the Association of American Geographers, Los Angeles, California, March 19th-March 23rd.

2001 Rogan, J, and J. Franklin, Operational monitoring of forest cover disturbance in California using multitemporal remote sensing data. Presented at the 64th Annual Meeting of the Association of Pacific Coast Geographers. University of California Santa Barbara, California, September 12-15, 2001.

2001 Rogan, J., Franklin, and Miller, J., Mapping fire severity in southern California forests and shrublands using spectral mixture analysis. Presented at the 21st Annual ESRI International User Conference, San Diego, California July 9-13.

2001 Rogan, J., and Franklin, J., Estimation, mapping and evaluation of thematic change-map classification accuracy using geostatistical methods. Presented at the University Consortium for Geographic Information Science Student Paper Competition, Summer Assembly, June 2001.

2001 Rogan, J., A Quantitative comparison of methods for monitoring multitemporal vegetation change using Thematic Mapper imagery, Presented at the California State University 15th Annual Student Research Competition (Hosted by San Jose State University, April 27-28, 2001).

Outreach

San Diego State University co-sponsored and organized RS002, the Ninth Biennial Remote Sensing Applications Conference April 8- April12, 2002 (Red Lion Hanalei Hotel, San Diego, CA) with the USDA Forest Service Pacific Southwest Region. This meeting attracted approximately 250 registrants and was highly successful in its goals to share information about remote sensing technology and applications for forest mapping and monitoring. Conference proceedings will be published on compact disk, with the sponsorship of ASPRS, in September 2002.

Figure 1: Example of forest and shrub cover change products being produced in this research project. The area shown is San Diego County, southern California. The change error map presents the spatial error of the classification process (i.e., S-Plus decision tree).