Progress Report for NASA LCLUC Program

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

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Background

The forested ecosystems of California are undergoing accelerated anthropogenic disturbance, such as urban expansion, the invasion of non-native plants and fire suppression. These anthropogenic disturbances interact with natural disturbances, such as fire and post-fire succession, and pest infestation, to significantly alter forest cover. Remotely sensed imagery provides the most cost-effective and consistent means to monitor inter-annual structural changes in California forests given the rate of disturbance, large areal extent, and diversity of plant species.

In spite of the growing need for precise estimates of deforestation (and reforestation) to support both international policy, regional land management, and basic research, a fully operational program of measurement, monitoring and mapping has yet to be developed for the forests of California. However, in a novel attempt to address the growing threat to forest sustainability in California, the United States Department of Agriculture (USDA) Forest Service (FS) and the California Department of Forestry and Fire Protection (CDF) are collaborating in a statewide change detection program to identify land cover change across all land ownership categories within five-year time periods. The inter-agency collaboration developed in part due to FS interest in drought assessment and insect-caused canopy damage within coniferous forest, as well as state and other agencies (i.e., Bureau of Land Management and U.S. Bureau of Reclamation) concerns with the loss of oak woodlands to type-conversion, fuelwood harvest and urban development.

By establishing an experimental framework, this program has proved promising for regional mapping of forest cover changes in California. The effort has been hampered, however, by the lack of opportunity to examine the variety of remote sensing and other data analysis methods such as scene normalization, change feature extraction, field-data collection, classification, and accuracy assessment, in order to meet operational and standardization needs. Faced with this task, the FS-CDF change detection program welcomes a research component addressing these issues as a way to increase efficiency through technology by improving and automating change-monitoring procedures.

We hypothesize that the existing monitoring system can be improved upon through the quantitative comparison of innovative data processing techniques, and validated with accurate and timely in situ data. This research focuses on two regional study sites, an 88,000 km^2 area in southwestern California and a 54,600 km^2 area in northeastern California, which respectively typify Mediterranean and Mountain-Mediterranean-type forest-dominated ecosystems. By focusing on two dynamic, data-rich case studies in California the findings of this research will contribute to testing and improvement of forest change monitoring methods for global change research interests.

Key Words:

1) Research Fields: Change detection, Deforestation, Fire ecology.
2) Geographic Area/Biome: North America.
3) Remote Sensing: Atmospheric correction, IKONOS, LANDSAT, MODIS.
4) Methods/scales: GIS, In-situ data, Local scale, Mixture modeling, Regional scale.

Research Questions

- NASA ESE scientific questions being answered:
  What are the changes in land cover and/or land use (monitoring/mapping activities)?
  What are the causes of LCLUC?

- The proportion of social science used in the study is 0%

- Themes Covered in project:

Theme	% Of Project
Carbon	0
Water	0
Nutrients	0
GOFC (mapping/monitoring of forest cover change detection)	100
Other	0

Research goals

The schedule of tasks and milestones for this research is shown in Table 1. The current period of performance is shaded. Goal 1 is underway and near completion in this performance period.

Goal 1. This research applies remote sensing and spatial analysis techniques to map changes in forest cover in two study sites in California between 1996 and 2000. In the context of improving a current FS-CDF forest monitoring program and implementing a regional scale operational forest monitoring program, the research objective is to design an operational forest cover change-monitoring program based on the following project 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 produce the most accurate (i.e., error-free, to in situ validation data) maps of forest cover change?
b. For the most accurate change mapping technique which atmospheric and seasonal normalization techniques produce the most accurate maps of forest cover change?
c. How do forest cover change detection accuracies differ, if at all, between southwest and northeast California study sites?
d. If the alternative forest cover change detection techniques produce higher accuracy results than the FS 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 forest monitoring program established in research Objective 1 to analyze the following data sets (1990-2000, 1996-2000 and 1990-2000):

Related research questions:

a. How is forest 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

Following intensive discussions with our FS and CDF collaborators, we expanded our investigation of forest change detection procedures to include comparisons of image normalization approaches. In addition, the presence of wildfire smoke plumes in the image data led us to investigate haze-correction algorithms that would reduce spatially-varying haze for change detection purposes. The results of this work are presented in the next section.

Progress to date

To date, the collaborative research has acquired the image, GIS and ground validation data for this project. As per our timeline, we have geometrically processed our image pairs and examined the effects of image normalization on the ability to discriminate multi-date changes in forest cover. The effects of wildfire-caused haze on the ability to discriminate forest cover change were also examined for a region in northern California. The utility of image enhancement (Multitemporal Spectral Mixture Analysis) and decision tree classification techniques were evaluated in a rapidly-changing region in southern California.

Next steps: 1) comparing the effects of a variety of radiometric normalization algorithms in the two study areas, 2) examining the utility of a spatially-varying image scattering normalization algorithm over fire-prone regions, 3) collecting ground validation data for forest cover change mapping in southern California, and 4) evaluating the use of decision tree versus artificial neural network classifiers to discriminate and map forest cover change

Most significant results:

- **We compared the ability of two linear change enhancement techniques, the Multitemporal Kauth Thomas and Multitemporal Spectral Mixture Analysis, and two classification techniques, maximum-likelihood and decision-tree, to accurately identify changes in vegetation cover in a southern California study area between 1990 and 1996. Supervised classification accuracy results were high (> 70% correct classification for four vegetation change classes and one no-change class) and showed that, 1) the decision tree classification approach outperformed the maximum likelihood classification approach, by ~10%, regardless of the enhancement technique used, and 2) using decision tree classification, multitemporal spectral mixture analysis-change fractions (i.e., green vegetation, non-photosynthetic vegetation, shade and soil) outperformed multitemporal Kauth Thomas change-features (i.e., change in brightness, greenness and wetness) by ~5%.**

- **We compared the ability of three radiometric normalization procedures, two dark object subtraction (DOS) and a pseudo-invariant feature approach, to improve the discriminabilty of regions of forest cover change across two Landsat (E)TM scenes (1996-2000). The two DOS approaches resulted in higher Jeffries-Matusita (JM) statistical separability for simple-difference imagery, than the pseudo-invariant feature approach. Prior to normalization, smoke-obscured images were subjected to a spatially-varying haze normalization procedure (Carlotto, 1999), which significantly reduced the scattering effects of haze on the visible ETM bands (i.e., bands 1-3) (Figure 1).**

New Findings:
The Carlotto (1999) approach appears to be very useful in areas affected by spatially-varying smoke and haze.

Carlotto, M.J., 1999. Reducing the effects of space-varying, wavelength-dependent scattering in multispectral imagery. International Journal of Remote Sensing, 20(17): 3333-3344.

New Potential: “-“
New Products: “-“

Conclusions

To date, our research has kept in line with our goals for the time period, and has adjusted to FS-CDF consultant needs in regard to image processing procedures. At the present time, we are investigating normalization procedures for both study areas, and will continue with the schedule of tasks as shown in Table 1.

Publications

Rogan, J., Franklin, J., and Roberts, D. A. (in review), A quantitative comparison of methods for monitoring multitemporal vegetation change using Thematic Mapper imagery. *Remote Sensing of Environment*, submitted February 2001.

Rogan, J., and Franklin, J. (accepted), Mapping burn severity in southern California using spectral mixture analysis. *Proceedings of IGARSS 2001* Sydney, Australia 9-13 July.

Rogan, J., Franklin, J., Stow, D., Levien, L., and Fischer, C. (accepted), Toward operational monitoring of forest cover change in California using multitemporal remote sensing data. Proceedings of *IGARSS 2001* Sydney, Australia 9-13 July.

Presentations

Rogan, J., and Franklin, J. (2001), Mapping fire severity in southern California using spectral mixture analysis techniques. Presented at the Annual Meeting of the Association of American Geographers, New York, New York, February 28th-March 2nd.

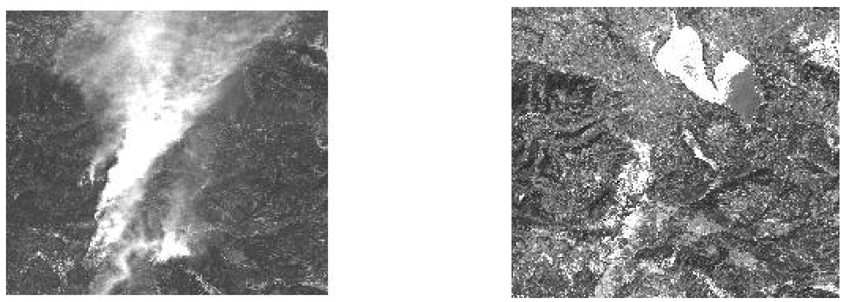
Table 1: Schedule of Tasks and Milestones for Deliverables

TASKS AND DELIVERABLES	PROJECT YEAR 1- 2000/ 2001				PROJECT YEAR 2- 2001/ 2002				PROJECT YEAR 3-2002/ 2003			
	J A S	O N D	J F M	A M J	J A S	O N D	J F M	A M J	J A S	O N D	J F M	A M J
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
These general task categories apply to Phases I and II	**Program Prototyping and Testing -------------------→ For 1990-1996 Data**						**Program Implementation ---------------------------→ For 1996-2000 and 1990-2000 Data**					
1. Acquisition of Image Data	-----											
2. Radiometric Image Processing	----	---				--			--			
3. Geometric Image Processing	--	------					--			--		
4. Image Enhancement		---	-----				--	-		--		
5. Change Feature Extraction												
6. Field Data Collection	-------				--------	----	--		--------			
7. Image Classification			--	-----				---		--		
8. Classification Evaluation				-------				---	----		---	
9. California Team Meeting	•				•				•			
10. NASA Team Meeting/Reporting				---•				---•				---•
11. Data Product Transfer/ Outreach	--		--		--------	---	--	--		--	------	--------
12. Journal Presentations and Conference Presentations				•	•			•	•			••

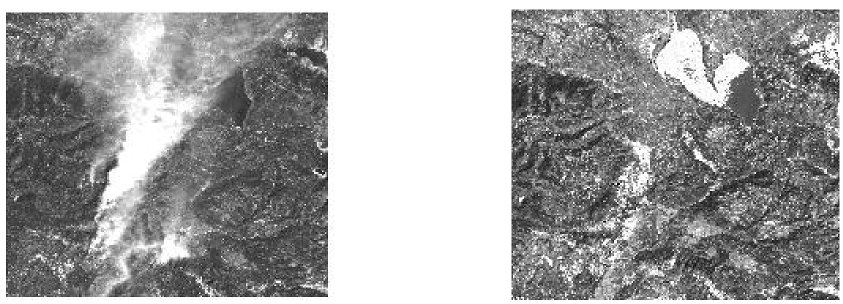
----------- = TASK ACTIVITY

• = REPORTS AND PRESENTATIONS

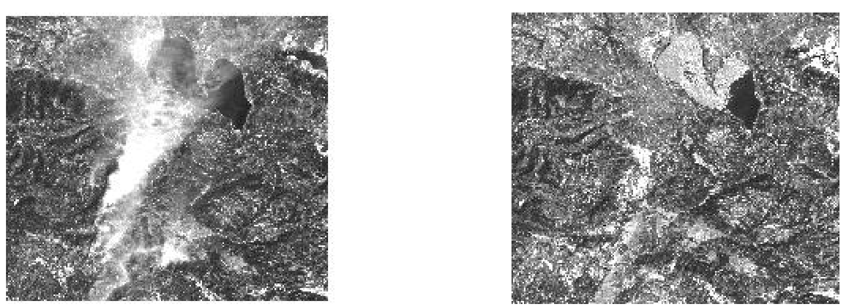
Figure 1: Haze equalization results for a haze-affected area of Plumas National Forest, August 2000. Original images are on the left and corrected images are on the right.



ETM Band 1 original (left) and corrected (right)



ETM Band 2 original (left) and corrected (right)



ETM Band 3 original (left) and corrected (right)