Operational Monitoring of Land Cover Change in California Using Multitemporal Remote Sensing Data

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Project Overview

To address the growing threat to forest and shrubland sustainability caused by rapid and widespread land cover change in California, the US Forest Service, California Department of Forestry and Fire Protection, and San Diego State University 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 land cover monitoring.

Changes in forest, shrub and grassland cover types are the primary focus of this program, but changes in urban-suburban areas are also mapped. Specifically, this involves the testing of techniques that minimize time-consuming human interpretation and maximize automated procedures for large area retrospective monitoring of land cover change.

Project Objectives

Research Objective 1

Establish an operational land cover monitoring program based on the following efficiency indicators:
- Map accuracy assessment
- Flexibility of implementation
- Interpretability of methods and results
- Consistency across phenologically diverse areas

Related Research Questions

- Which change detection methods produce the most accurate, interpretable maps of land cover change?
- How can methods be improved for operational needs?
- How do these results compare between southwest and northeast California?

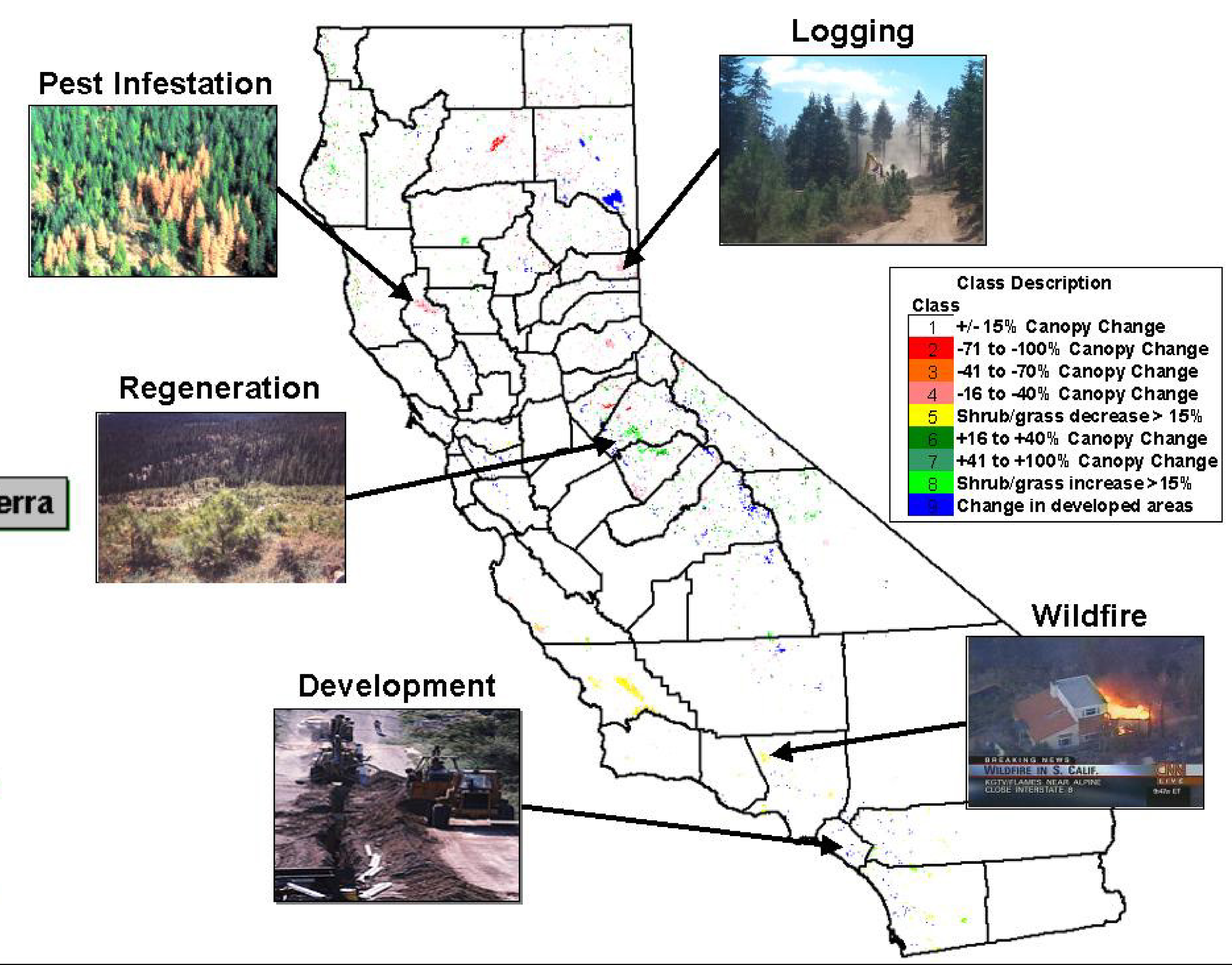
Research Objective 2

Implement the monitoring program established in Objective 1 to analyze the extant data sets (1985-1990, 1990-1996, and 1996-2000).

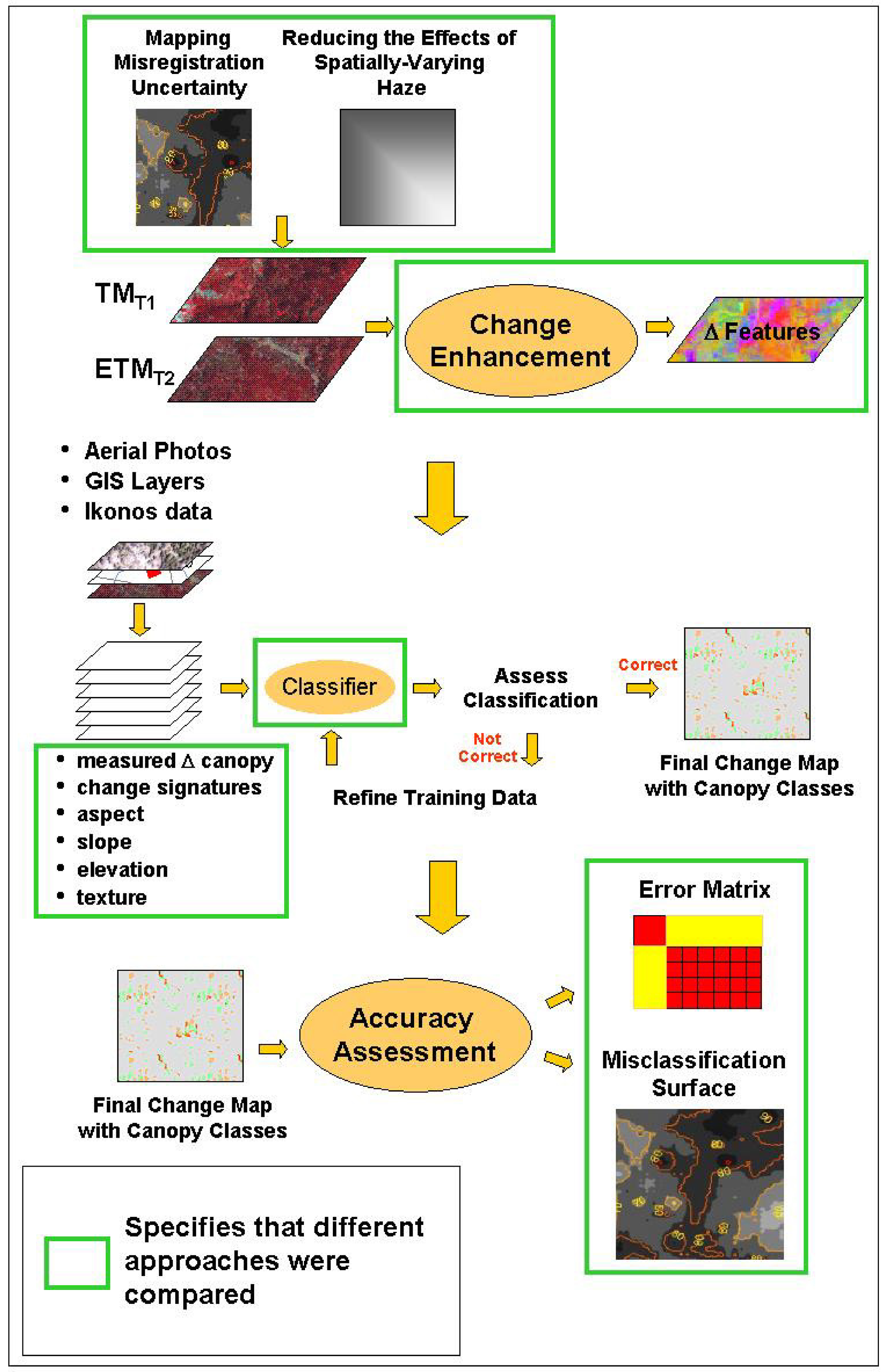
Related Research Questions

- How is land cover change manifested in terms of geographical extent, cause, and rate?
- How does land cover change affect landscape spatial patterns (e.g., habitat fragmentation)
- How are changes in land cover associated with vegetation lifeform and land ownership in the state?

Project Study Area and Statewide Land Cover Change Map 1990-1996



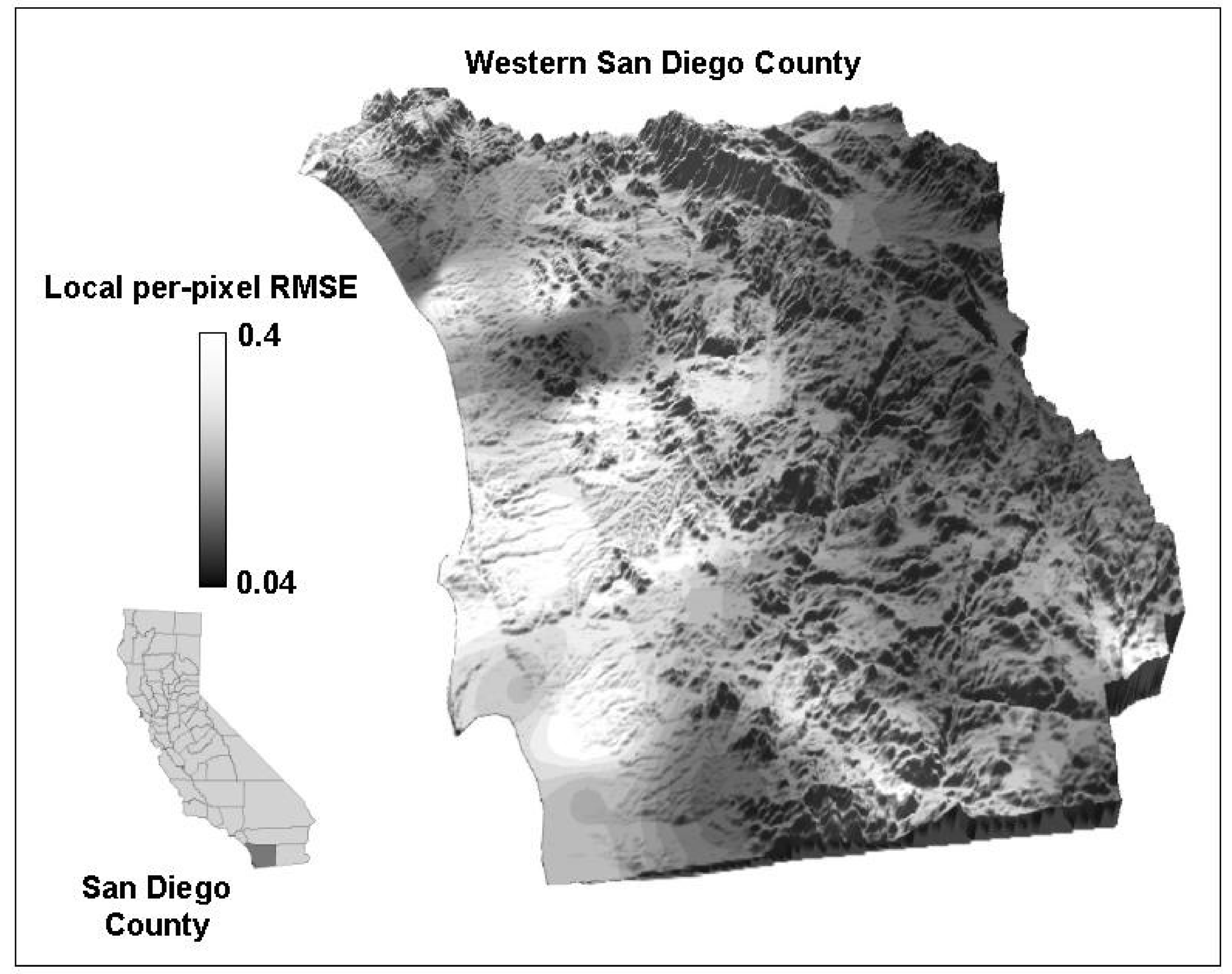
Data Processing Methodology



Assessing and Mapping Geometric Misregistration Uncertainty

- Knowledge of the spatial variability of geometric misregistration error is important for assessing and understanding the potential and limitations of maps representing land cover change across vast areas.
- Spatial variation in geometric root mean square error was generated for a sub-area in southern California, via kriging of local ground control point error.
- In this example misregistration errors are associated spatially with urban areas and the edges of lakes and reservoirs

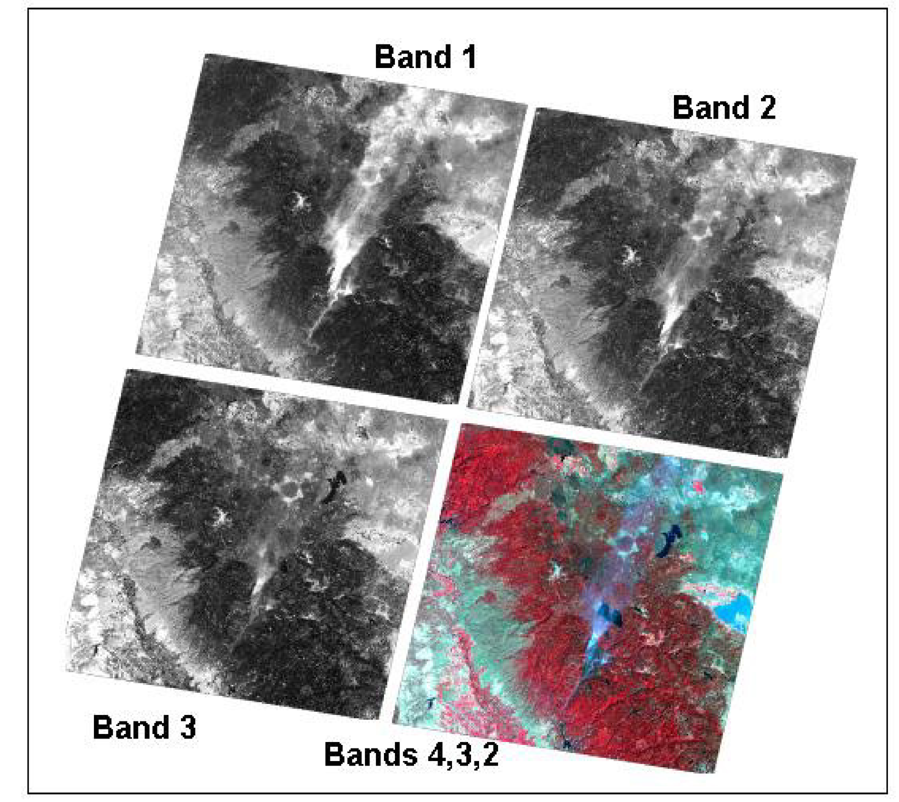
Geometric Misregistration Error Surface



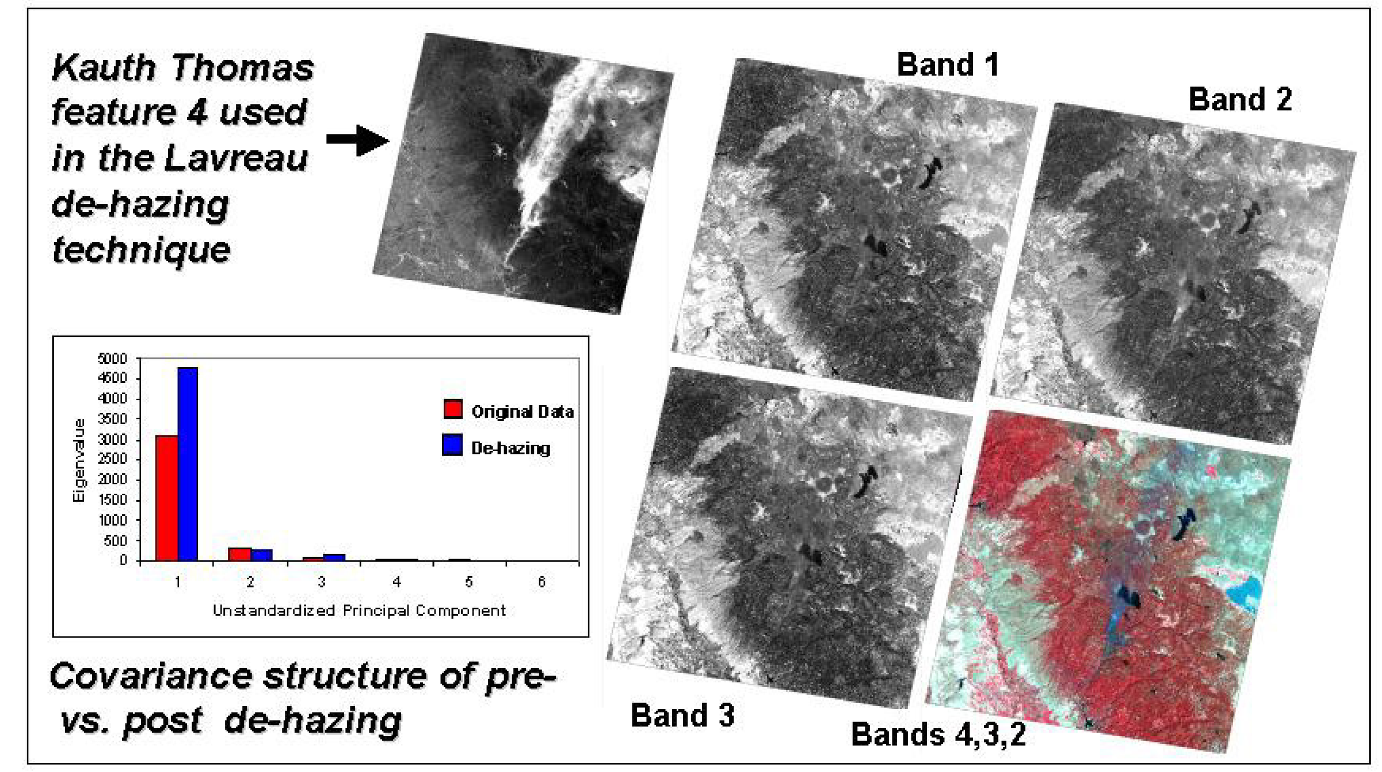
Correcting for Spatially-Varying Haze

- An algorithm developed by Carlotto (1999) to correct the effects of spatially-varying haze was modified for reducing the effects of smoke plumes on TM and ETM data
- We compared the Carlotto approach to that of Lavreau (1991) (based on Kauth-Thomas transformation) and found the former to be much more effective at removing haze, while preserving the covariance of the original data

Original Smoke-obscured Landsat ETM Image

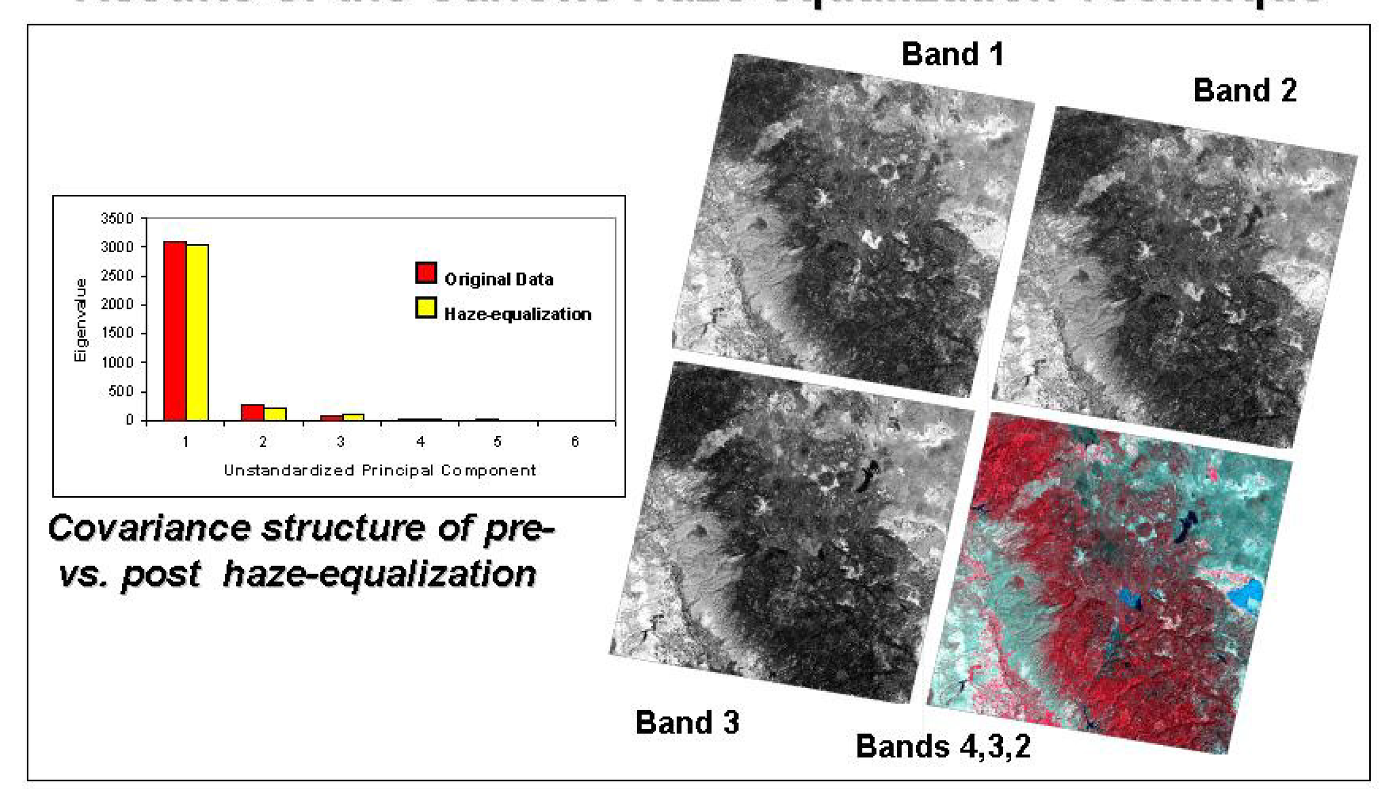


Results of the Lavreau De-hazing Technique



Covariance structure of pre- vs. post de-hazing

Results of the Carlotto Haze-equalization Technique



Covariance structure of pre- vs. post haze-equalization

Change Enhancement Approaches

A variety of pre-classification change enhancement approaches were tested an compared for their ability to produce biophysically meaningful change features, while at the same time, generate change-maps of high accuracy. The change enhancement approaches investigated were:

- Multitemporal Kauth Thomas (MKT) transformation
- Multitemporal Spectral Mixture Analysis (MSMA)

- Results for several study areas demonstrated that the MSMA approach produced significantly higher classification accuracies than MKT (ranging from 5-10%).

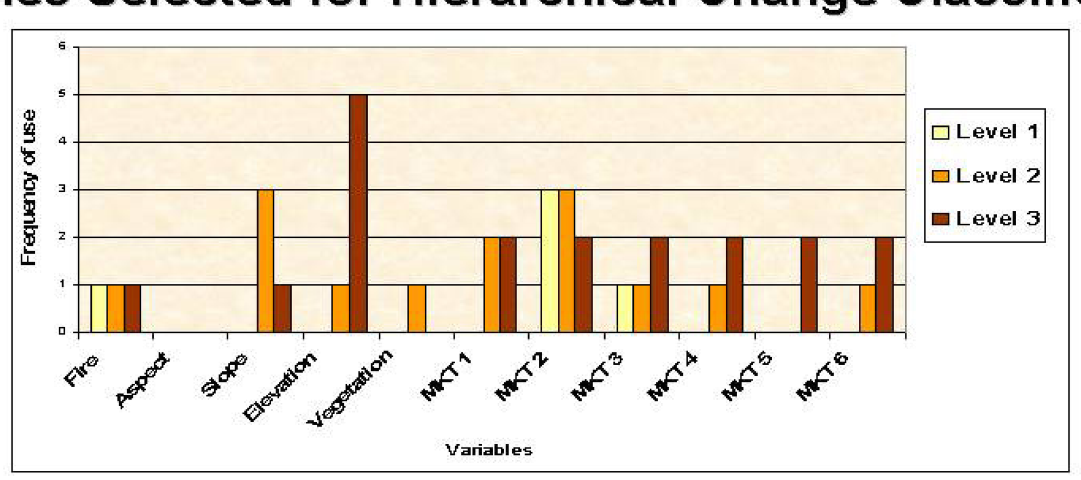
Variable Selection For Classification

- We assembled a wide variety of spectral and ancillary variables for input to three machine learning classifiers. The S-Plus and Machine Learning Classifier (MLC) (Huang and Jensen 1997) classification tree algorithms were used for variable selection for land cover change classification.
- Spectral variables included Kauth Thomas *stable* and *change* features. Ancillary variables included, elevation, slope, aspect, a fire-occurrence mask and several texture measures.

Hierarchical Land Cover Change Classification Scheme

Level 1	Level 2	Level 3
No change	No change *(nochange)*	+/-15% canopy change
Change	Decrease in vegetation *(decrease)*	-71 to –100% canopy change -41 to –70% canopy change -16 to 40% canopy change Shrub/grass decrease > 15%
	Increase in vegetation *(increase)*	+16 to +40% canopy change +41 to 100% canopy change Shrub/grass increase > 15%
	Change in developed area *(changedev)*	Change in developed areas

Variables Selected for Hierarchical Change Classification



Comparison of Machine Learning Classification Algorithms

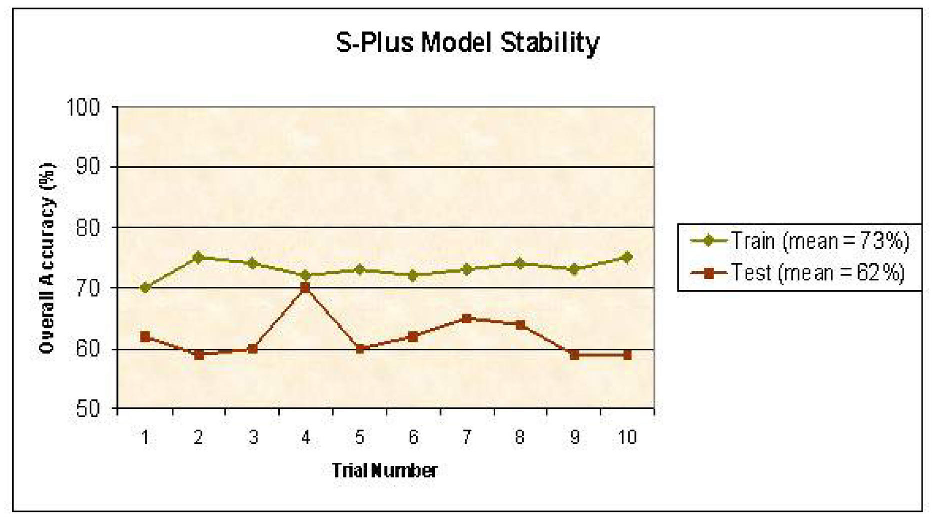
We compared the performance of three machine learning algorithms for mapping land cover change:

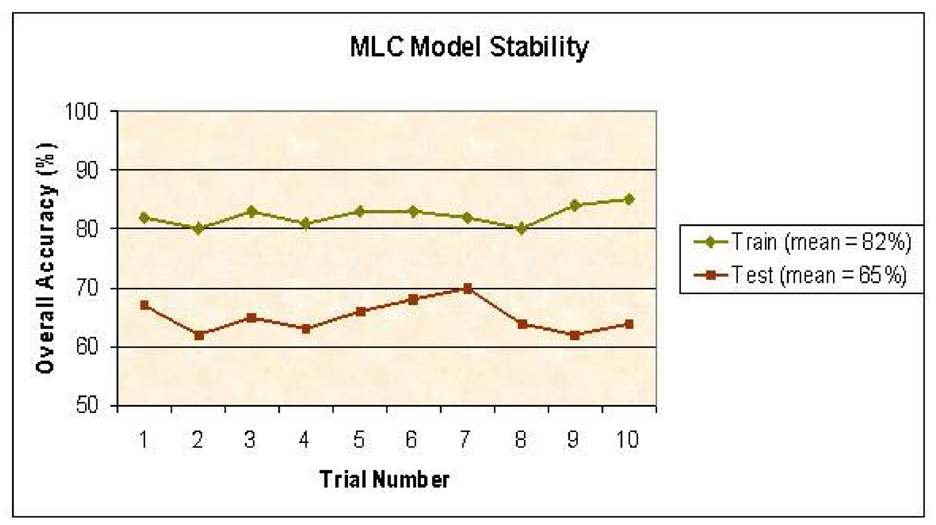
- S-Plus Classification Tree
- Machine Learning Classifier (C4.5)
- ARTMAP

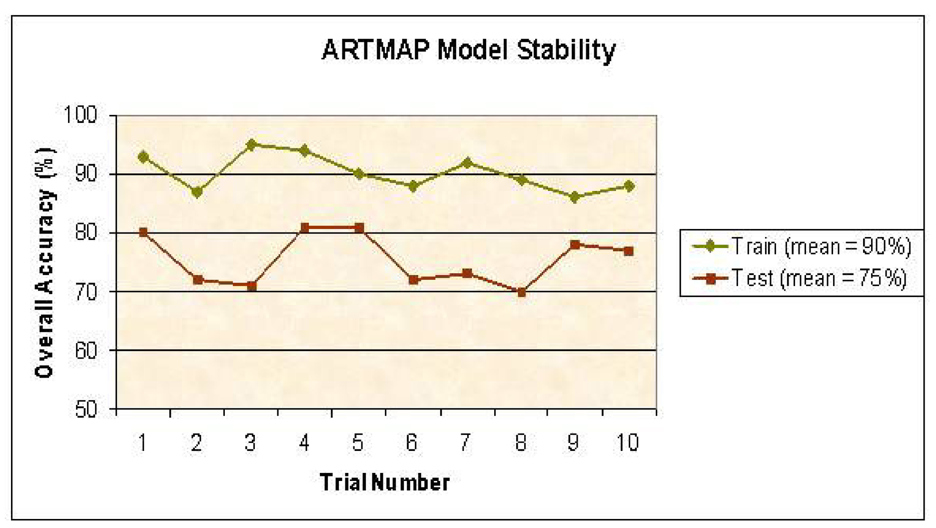
Comparisons were based on the following criteria:

- Mean class accuracy assessment
- Model stability
- Robustness to noise in the training data

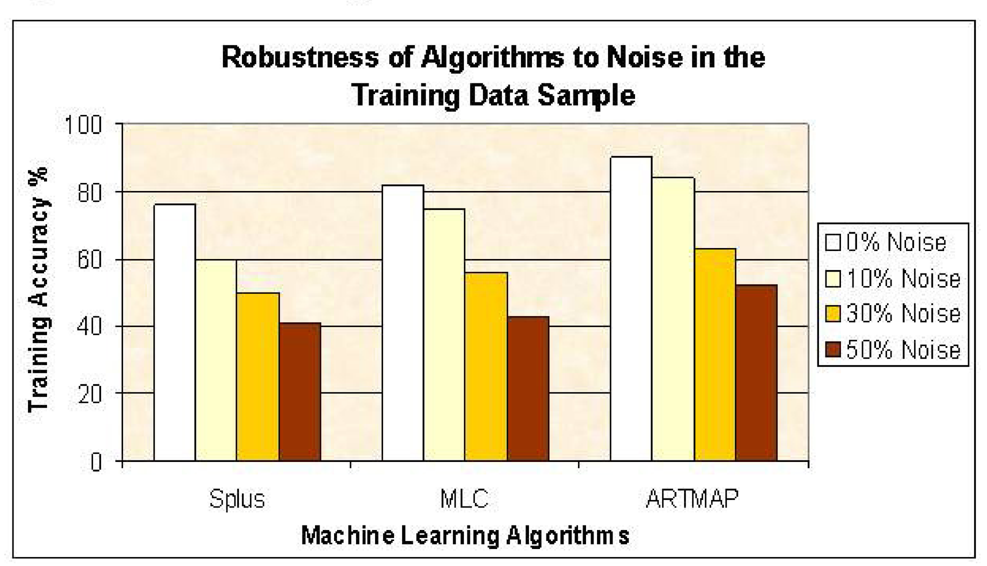
Comparison of Algorithm Stability



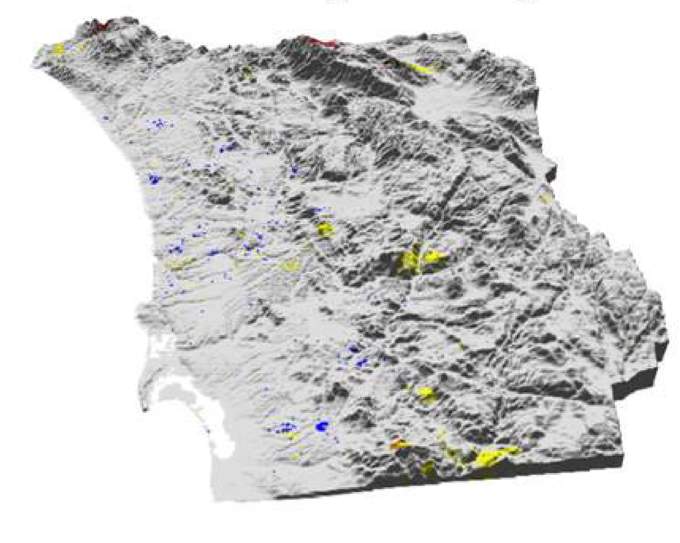




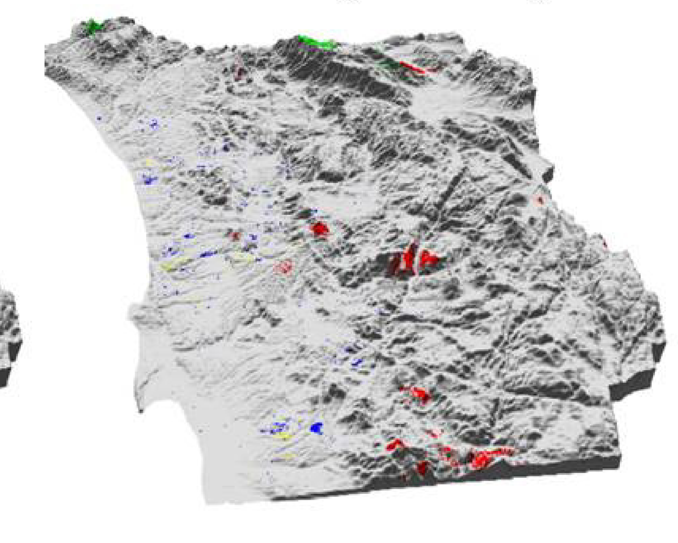
Comparison of Algorithm Robustness to Noise



1990-1996 Land Cover Change San Diego County



1990-1996 Cause of Change San Diego County

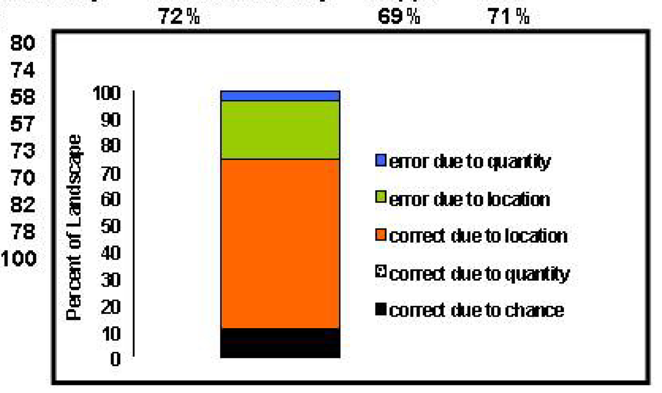


1990-1996 Error Matrix and Statistics

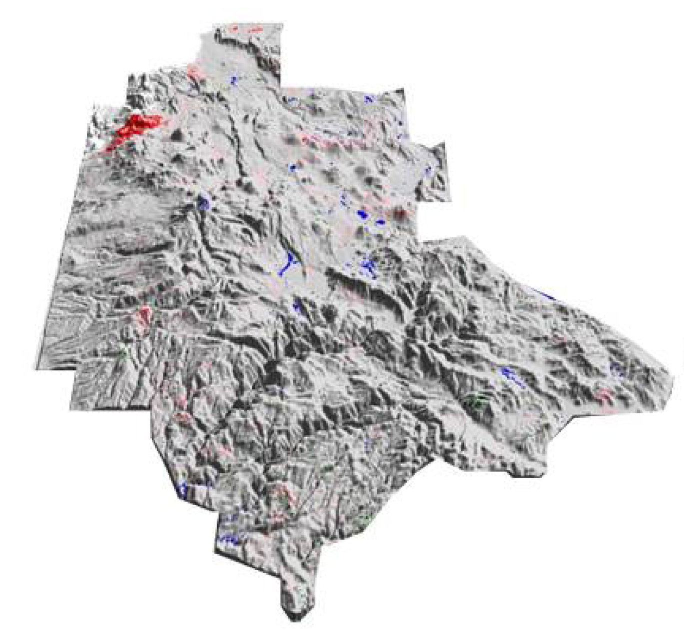
	Reference Class 1	2	3	4	5	6	7	8	9	Sites
1	35					2	1	6		44
2		28	7	2	1					38
3		6	25	9	3					43
4		4	5	24	9					42
5		2	3	5	27					37
6	1					30	8	2	2	43
7	1					5	28			34
8	3					3	3	32		41
9									38	38
Sites	40	40	40	40	40	40	40	40	40	360

Class	Producer's Accuracy %	User's Accuracy %
1	88	80
2	70	74
3	63	58
4	60	57
5	68	73
6	75	70
7	70	82
8	80	78
9	95	100

Overall Accuracy 72% Kappa 69% Kno 71%



1990-1996 Land Cover Change Plumas and Lassen National Forests



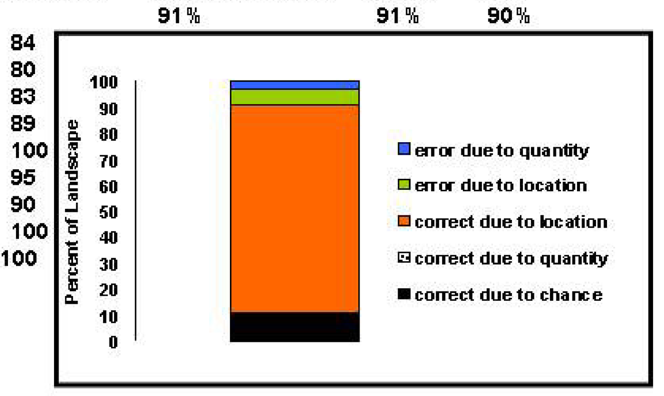
1990-1996 Cause of Change Plumas and Lassen National Forests

1990-1996 Error Matrix and Statistics

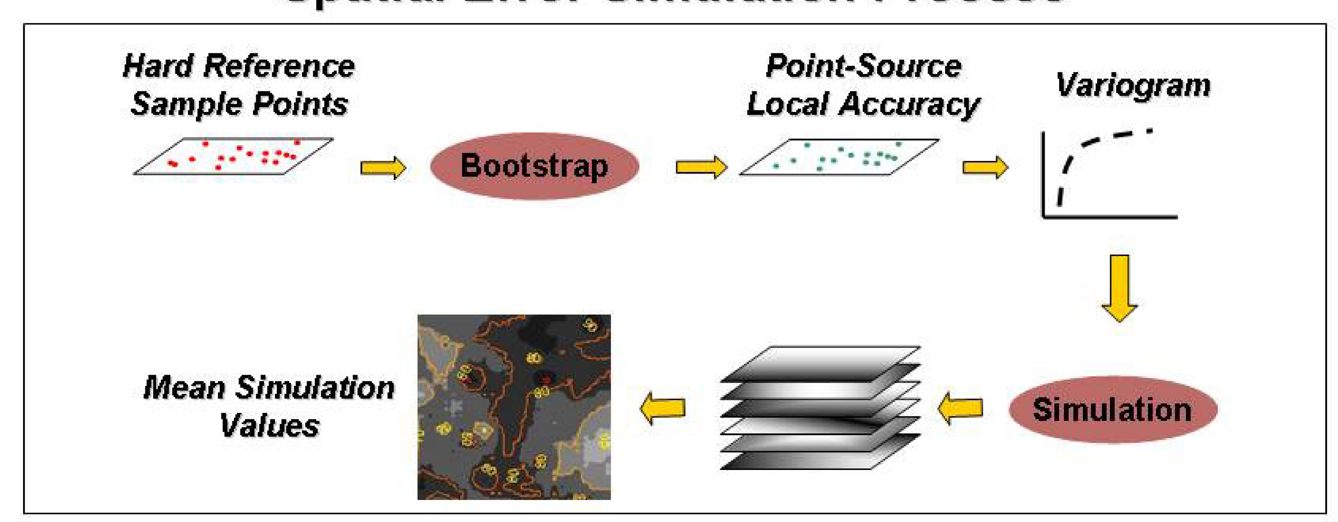
	Reference class 1	2	3	4	5	6	7	8	9	Sites
1	38	1	2	2		1	1			45
2	2	35	4	3						44
3		3	34	4						41
4		1		31	3					35
5					37					37
6						36	2			38
7						3	37	1		41
8								39		39
9									40	40
	40	40	40	40	40	40	40	40	40	360

Class	Producer's Accuracy	User's Accuracy
1	95	84
2	88	80
3	85	83
4	78	89
5	93	100
6	90	95
7	93	90
8	98	100
9	100	100

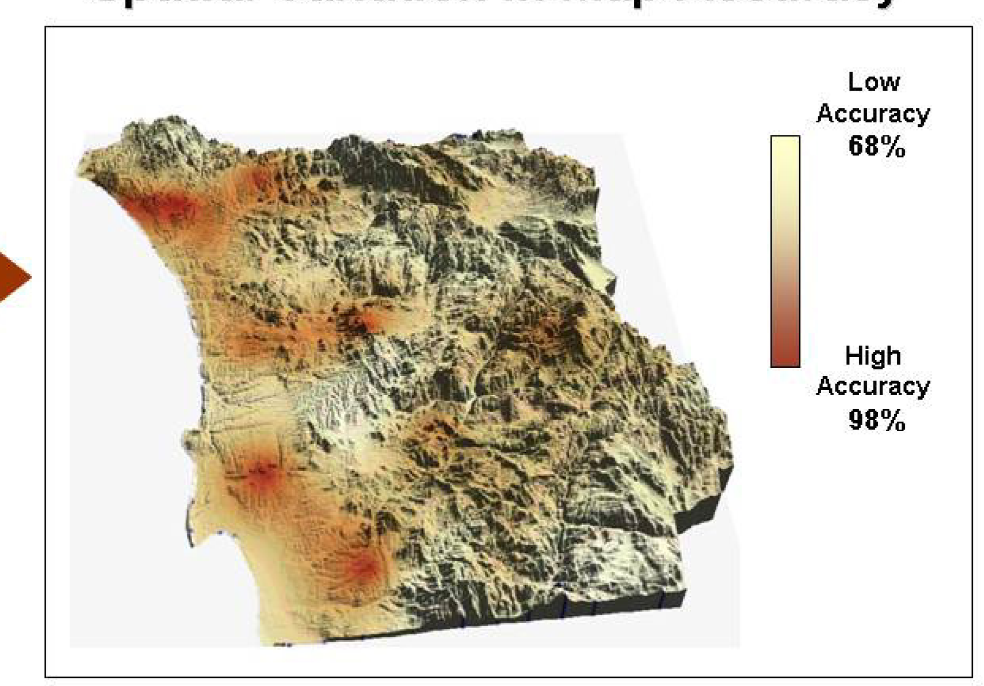
Overall Accuracy 91% Kappa 91% Kno 90%



Spatial Error Simulation Process



Spatial Variation in Map Accuracy



Summary of Classification Comparison

- ARTMAP produced consistently higher accuracies than S-Plus and MLC
- Model stability varied considerably between algorithms
- All models were sensitive to the presence of noise in the training data

Future Research Tasks

- Complete all land cover change mapping by January 2003
- Examine relationship between temporal change, disturbance regimes, and land ownership in the state