Operational Monitoring of Alteration in Regional Forest Cover Using Multitemporal Remote Sensing Data (2000-2003)

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General Objectives of the Study

- This research will apply remote sensing techniques to map changes in forest cover in California to examine LCLUC over several 5-year time periods

- The scope of this research will be the testing and improvement of an operational FS-CDF forest change monitoring program

Specific Objectives of the Study

Research Objective 1

Establish an operational forest cover change monitoring program based on the following project efficiency indicators:

- **Change-map accuracy assessment**
- **Flexibility of implementation**
- **Interpretability of methods and results**
- **Consistency across phenologically diverse areas**

Specific Objectives of the Study

Research Objective 1: Related research questions

1. **Which change detection techniques produce the most accurate, interpretable maps of forest cover change?**

2. **How do the existing FS-CDF program methods compare to those generated by state-of-the-art techniques?**

3. **How do results differ between southwest and northeast California study sites?**

Specific Objectives of the Study

Research Objective 2

Implement the forest monitoring program established in Objective 1 to analyze the extant data sets (spanning 1985-2000)

Specific Objectives of the Study

Research Objective 2: Related research questions for the following time periods- 1985-1990, 1990-1995, 1995-2000

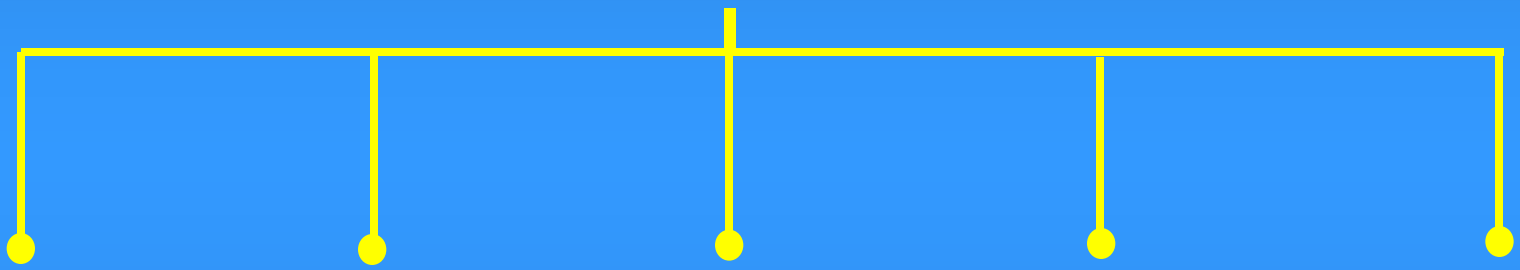
1. **How is forest cover change manifested in terms of a) geographical extent, b) cause, c) rate?**

2. **How does forest cover change affect landscape spatial patterns (e.g., habitat fragmentation)?**

3. **How are changes in forest cover associated with mapped lifeform and species categories in the region?**

Research Relevance

LCLUC Disturbance Monitoring



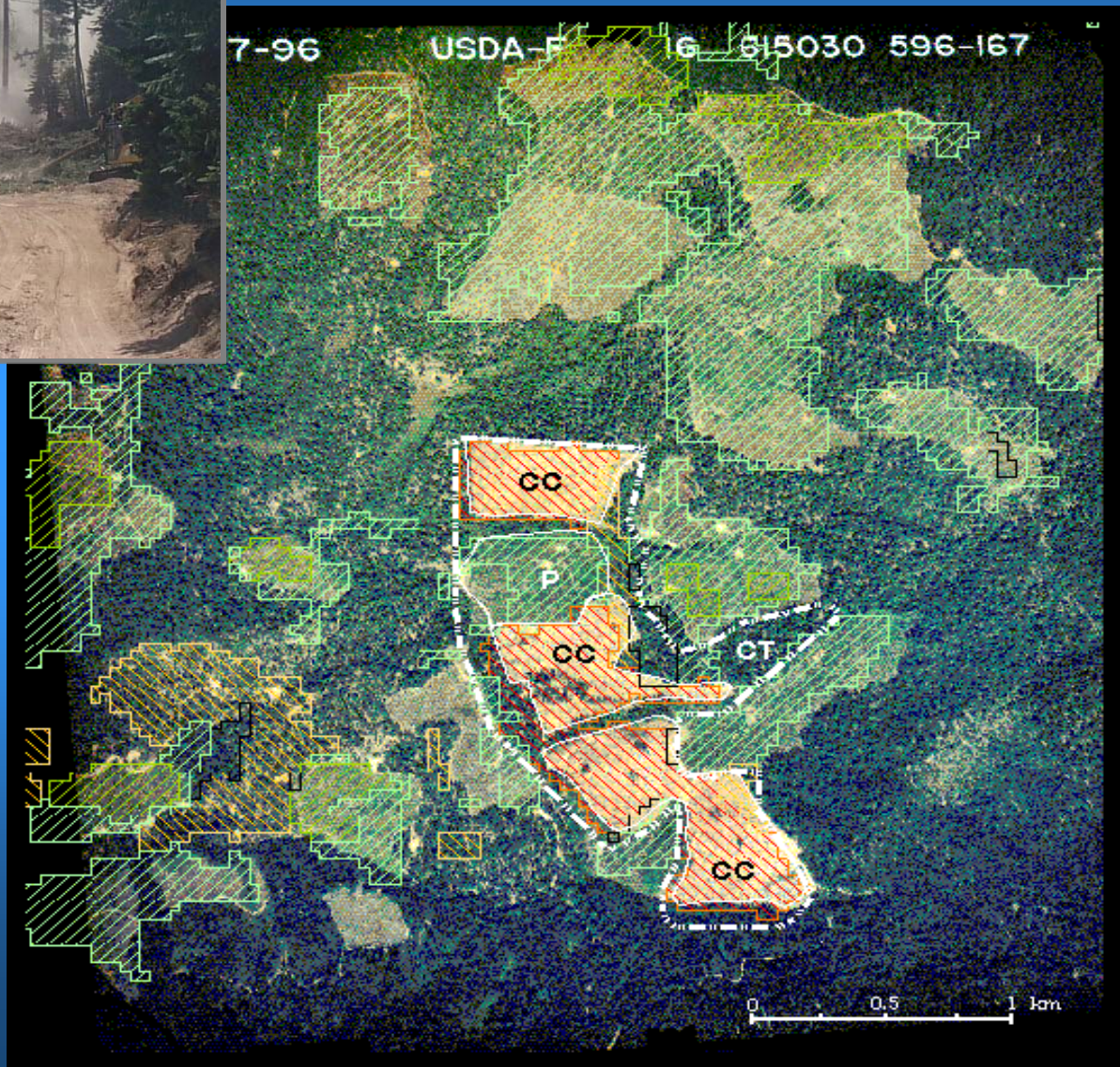
Logging
* Selective
* Clearcut

Fire
* Wildfire
* Prescribed

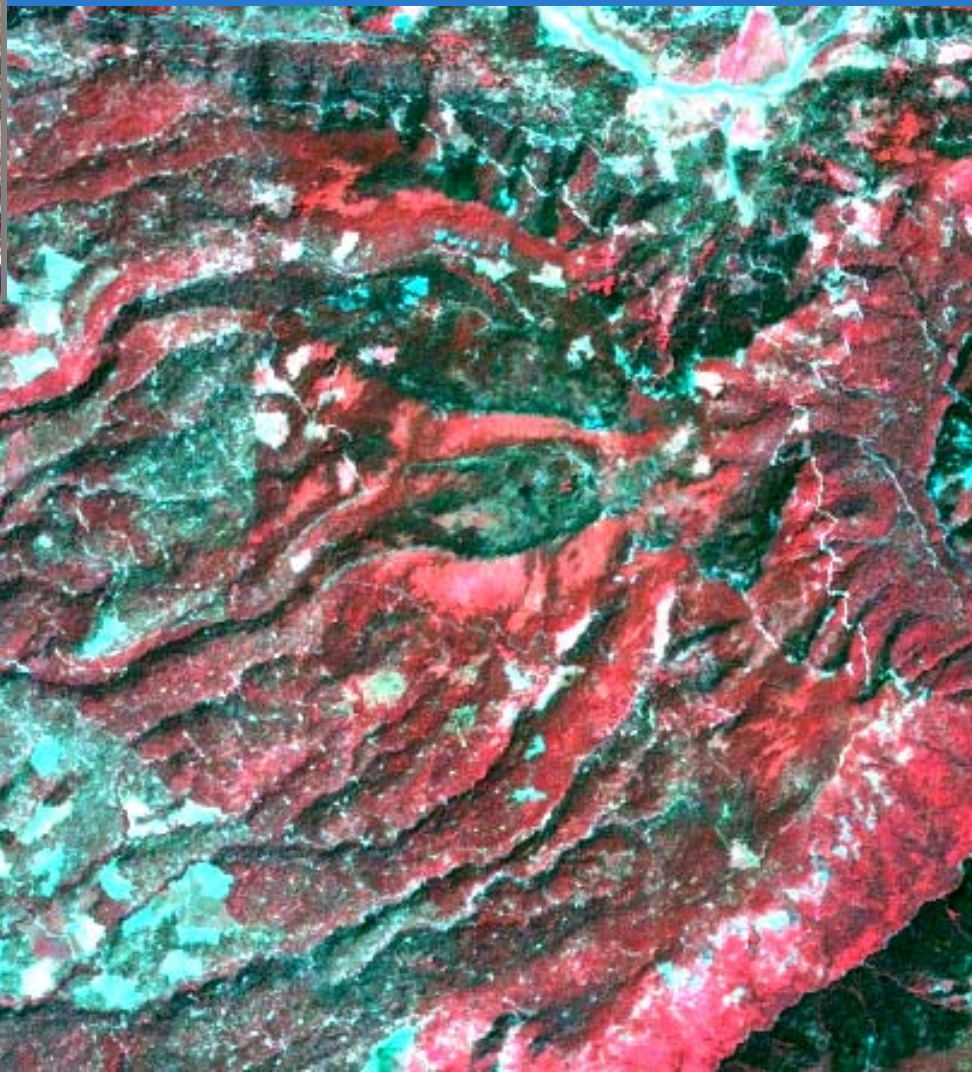
Pest Infestation

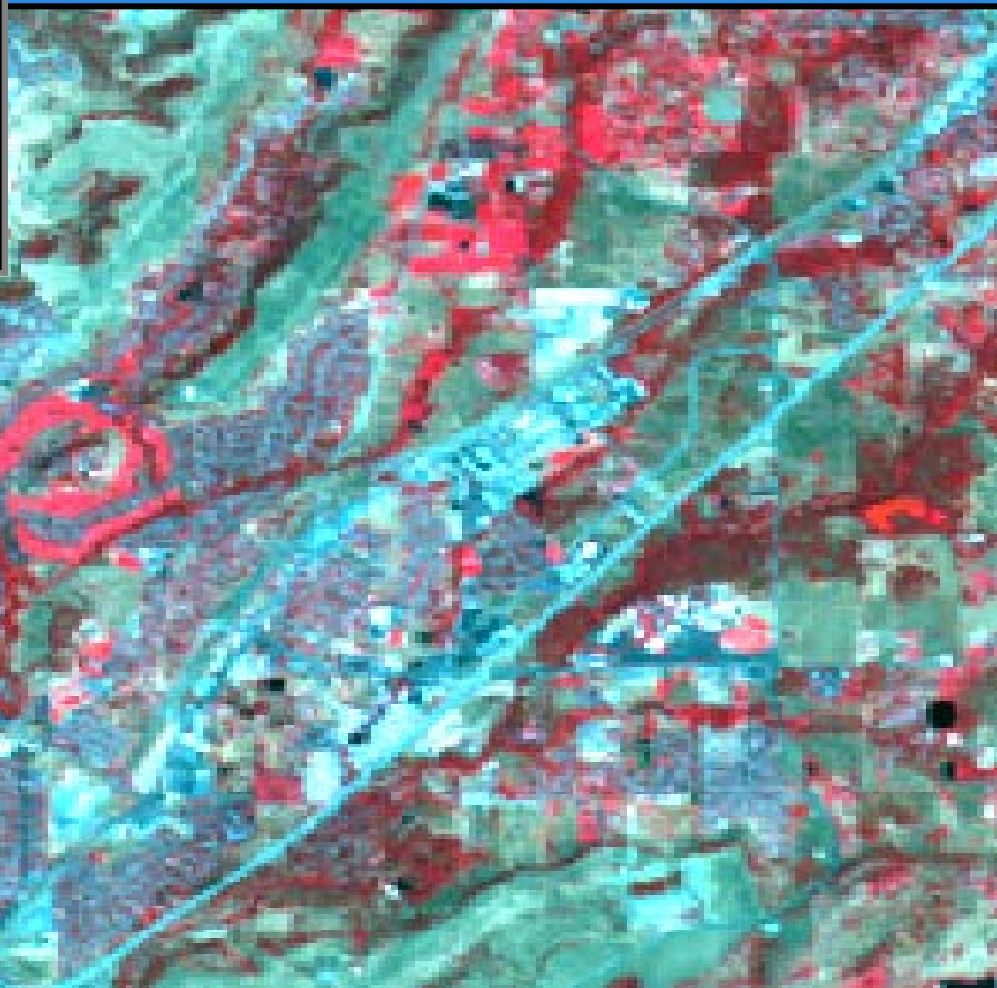
Regrowth
* Natural
* Replanting

Urban Growth


7-96
USDA-F
16 615030 596-167
CC
P
CC
CT
CC
0
0.5
1 km

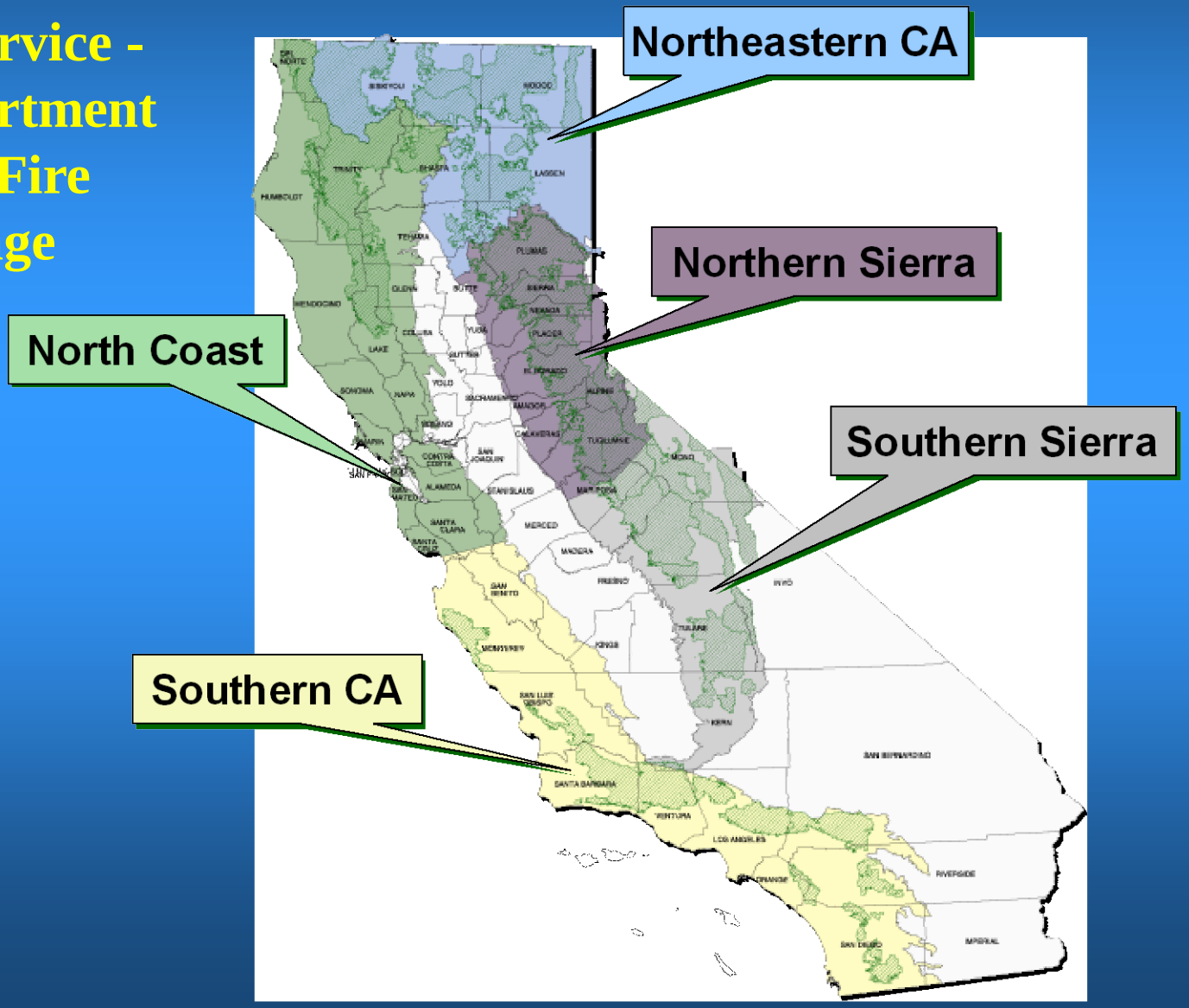

BREAKING NEWS
WILDFIRE IN S. CALIF.
KGTV/FLAMES NEAR ALPINE
CLOSE INTERSTATE 8
CNN
LIVE
9:47a ET





Existing FS-CDF Program Methods

*USDA Forest Service - California Department of Forestry and Fire Protection Change Monitoring Program



Existing FS-CDF Program Methods

Change Data
with accuracy assessment

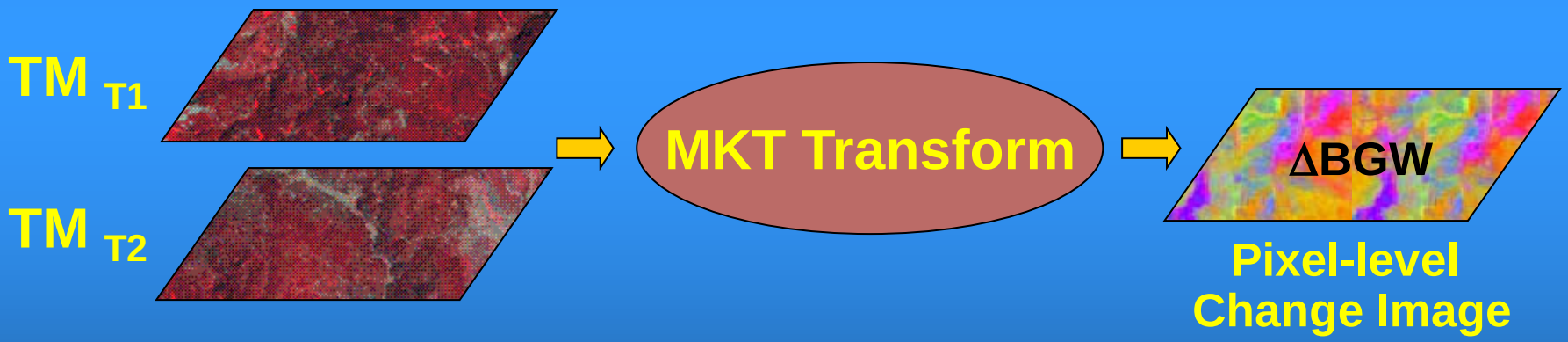
- - 70 to - 100% CC
- - 41 to - 70% CC
- - 16 to - 40% CC
- + 15 to - 15% CC
- + 16 to + 40% CC
- + 41 to + 100% CC
- Shrub/Grass Decrease > 15%
- Shrub/Grass Increase > 15%
- Change w/in Existing Urban Area
- Cloud or Cloud Shadow

Cause Database

- Mortality
- Wildfire
- Harvest
- Regeneration
- Fuel Break
- Thinning
- Development
- Conversion
- Other
- Unknown

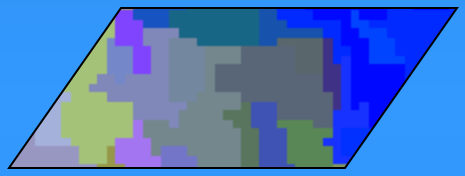
Existing FS-CDF Program Methods

Expert Program Methods - Phase I
Image Processing



Existing FS-CDF Program Methods

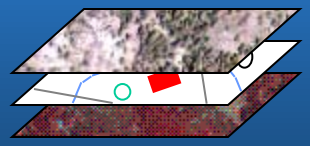
Expert Program Methods - Phase II
Classify and Label Change

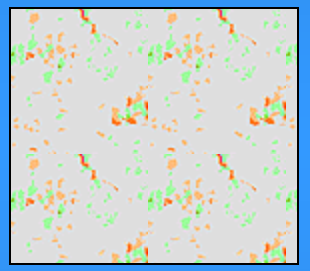


Unsupervised Classification

Label Change

- Aerial Photos
- GIS Layers
- Other Imagery





Canopy Cover Change Map

Study Sites


Lassen National Forest
Plumas National Forest
Sacramento
Angeles National Forest
San Bernardino
National Forest
Cleveland National Forest

Current Methods

The research proposed presents a comprehensive, multitemporal, multistage forest cover change monitoring strategy

1. Data sets:

- **Landsat 5 and 7, Aerial Photos, ADAR, IKONOS**
- **Fire Perimeters, Pest Records, Logging Records**
- **Canopy cover measurements (densitometer and high spatial resolution resolution multispectral data)**

Canopy Cover Measurements

IKONOS Data (4 meter)

Current Methods

2. Radiometric Normalization
3. Image Enhancement Techniques
   - Spectral Mixture Analysis
   - Change Vector Analysis
   - Spatial Indices (Texture-Context)
4. Classification
   - Classification Tree
   - ANN-Fuzzy ARTMAP
5. Evaluation
   - Error Matrix, Fuzzy Accuracy, Spatial Accuracy

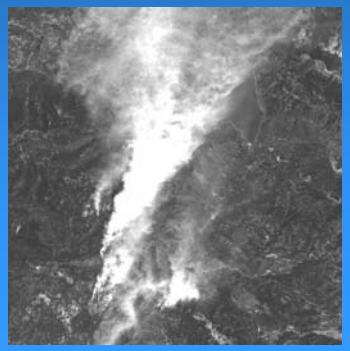
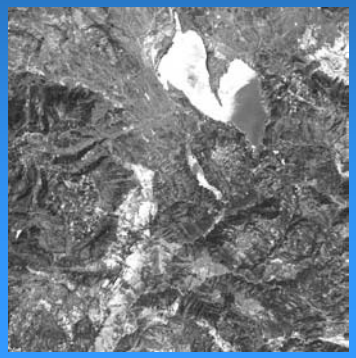
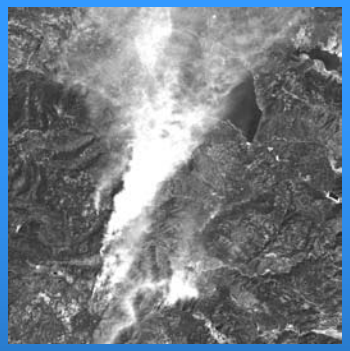
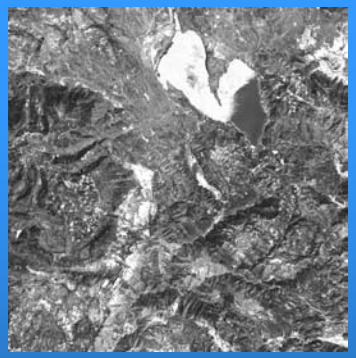
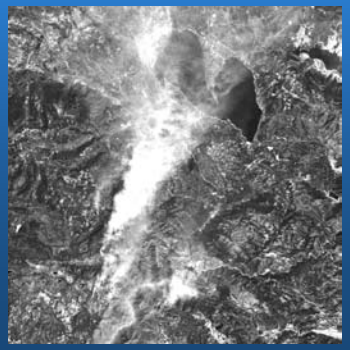
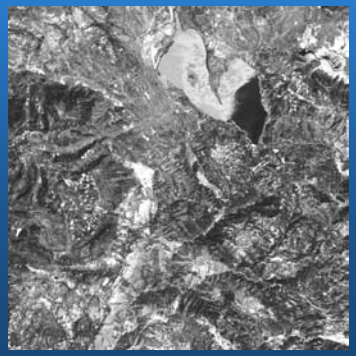
Scientific Results

- Atmospheric Correction /Normalization
- Image Change Enhancement
- Image Classification
- Accuracy Assessment

Atmospheric Correction/ Normalization

- Space-varying haze correction (Carlotto, 1999)
- Spectral measurement space consists of two subspaces
  - Subspace 1 = bands affected by scattering (visible)
  - Subspace 2 = bands less affected by scattering (infrared)
- Correspondence between the two subspaces used to predict Subspace 1 as a function of Subspace 2 on a per-pixel basis

Spatially Varying Haze Correction

	Uncorrected	Corrected
Landsat 7 ETM Band 1		
Landsat 7 ETM Band 2		
Landsat 7 ETM Band 3		

Atmospheric Correction/ Normalization

- **Results (ANOVA between pre vs. post correction)**
  - **The algorithm removes the effects of smoke plumes without altering the pixel values of areas unaffected by haze**
  - **Areas that *have* changed between dates are readily detected, post-normalization**
  - **Reliable and easily implemented across varying topography and landcover types**

Image Enhancement Comparisons

- Study attempted to
  - Examine the potential of Multitemporal Spectral Mixture Analysis (MSMA) to map changes in forest cover over large areas
  - Compare the MSMA approach to that of MKT
  - Evaluation based on
    - Classification accuracy
    - Ease of use, flexibility of implementation, operational issues etc.

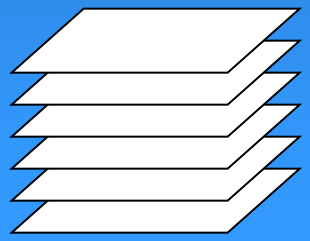
Image Enhancement Comparisons

- **Results**
  - **MSMA produces four change fractions (i.e., Δ shade, Δ green veg., Δ non-photosynthetic veg., and Δ soil) using reference endmembers**
  - **MSMA Δ fractions are biophysically robust and interpretable**
  - **MSMA Δ classification using approach was repeatedly 5-10% more accurate than MKT in all investigations**
  - **However, MKT produces equally reliable Δ features and is more easily implemented**

Image Classification Comparisons I

- Study attempted to
  - Examine the potential of a C4.5-based classification tree Machine Learning Classifier (MLC)
  - Compare the utility of the MLC approach to S-plus
  - Evaluation of MLC vs. S-plus based on
    - Classification accuracy
    - Ease of use, flexibility of implementation, operational issues etc.

Classification Approach

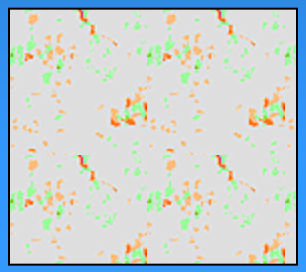


- measured Δ canopy
- BGW signatures
- covertype
- fire mask
- elevation
- aspect
- slope

Classifier

Assess Classification

Correct

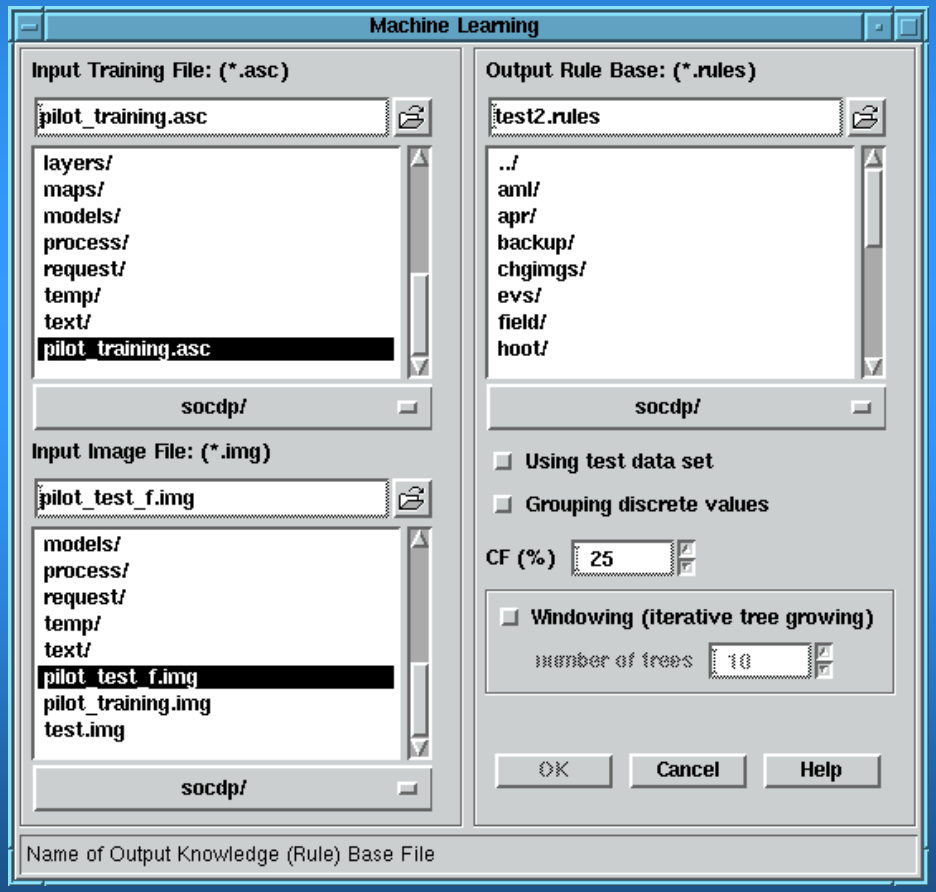


Final Change Map with Canopy Classes

Not Correct

Refine Training Data

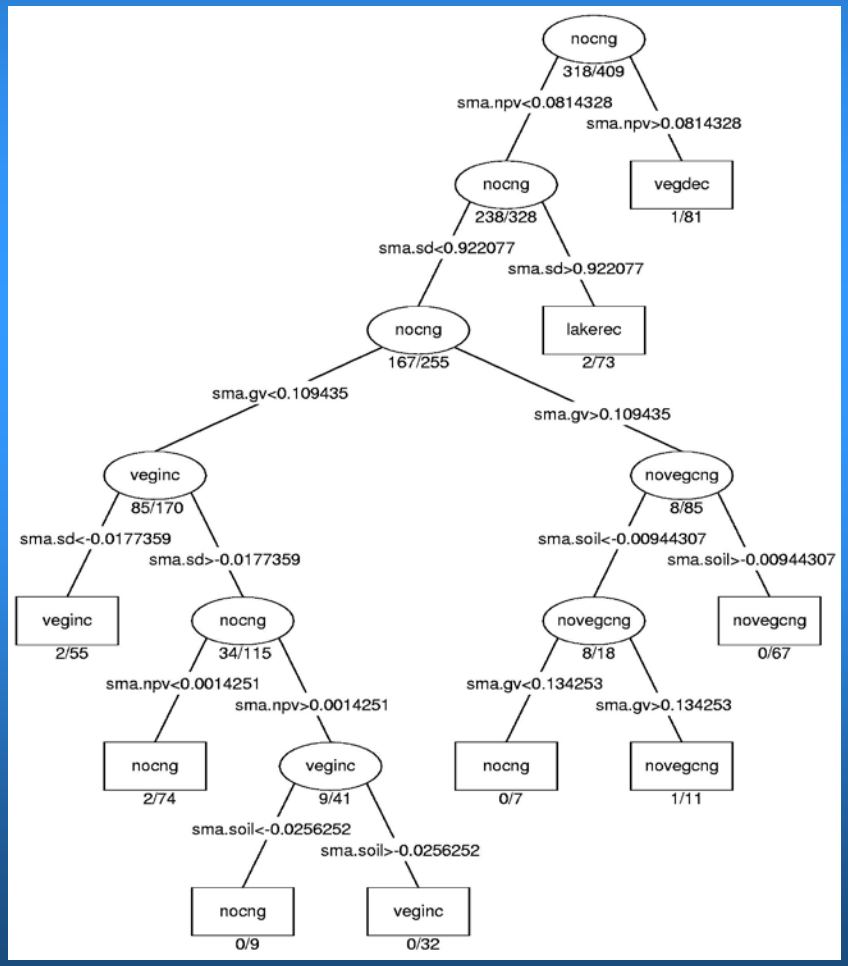
Machine Learning Classifier



- Useful interface with Erdas
- Rules easily classified
- Deals with categorical data well
- Iterative tree growing negates the need for pruning

- Tendency to create large trees
- Rules determine that unclassified pixels receive value of largest category in the map
- Thematic output has been unreliable

S-plus Classification Tree Approach



- No existing interface with Erdas
- Rules easily classified
- Difficulty with categorical data with layers having more than 31 classes

- Trees are manageable, through pruning, providing more control
- Thematic output is generally reliable

S-Plus classification accuracy (Southern California)

		Reference class									
		1	2	3	4	5	6	7	8	9	Sites
	1	97	9	2				1			**109**
	2	4	47	1	1	1					**54**
Classified as	3	2		58		1					**61**
	4	9	4	9	74	4		8	10		**118**
	5				1	75			1	4	**81**
	6						25		2		**27**
	7	2	1	1				69			**73**
	8					2	1		65		**68**
	9									71	**71**
Sites		**114**	**61**	**71**	**76**	**83**	**26**	**78**	**78**	**75**	**662**

Overall Accuracy = 88%

Class	Class Description
1	-71 to -100% CC
2	-41 to -70% CC
3	-16 to -40% CC
4	+15 to -15% CC
5	+16 to +40% CC
6	+41 to +100% CC
7	Shrub/grass decrease > 15%
8	Shrub/grass increase >15%
9	Change within existing developed areas

Producer's Accuracy	
Class	%
1	85
2	77
3	82
4	97
5	90
6	96
7	88
8	83
9	95

User's Accuracy	
Class	%
1	89
2	87
3	95
4	63
5	93
6	93
7	95
8	96
9	100

MLC classification accuracy (Southern California)

		Reference class									
		1	2	3	4	5	6	7	8	9	Sites
	1	89	6	2							**97**
	2	2	37	2				1			**42**
Classified as	3	17	10	70	3	8	1	5	4	1	**119**
	4			1	70	1		2	3	1	**78**
	5	1			2	55			1		**59**
	6					2	21				**23**
	7	4		7	2			70			**83**
	8				1	4			74		**79**
	9		1							81	**82**
Sites		**113**	**54**	**82**	**78**	**70**	**22**	**78**	**82**	**83**	**662**

Overall Accuracy = 86%

Class	Class Description
1	-71 to -100% CC
2	-41 to -70% CC
3	-16 to -40% CC
4	+15 to -15% CC
5	+16 to +40% CC
6	+41 to +100% CC
7	Shrub/grass decrease > 15%
8	Shrub/grass increase >15%
9	Change within existing developed areas

Producer's Accuracy	
Class	%
1	79
2	69
3	85
4	90
5	79
6	95
7	90
8	90
9	98

User's Accuracy	
Class	%
1	92
2	88
3	59
4	90
5	93
6	91
7	84
8	94
9	99

Order of variables used at each split: S = S-plus, M = MLC

Variables	*1*	*2-3*	*4-6*	*7-9*	*10-12*
Fire			S	M	
Aspect				M	
Slope				M	
Elevation		S M			
Vegetation		S M			
MKT_1			S M		
MKT_2	S M				
MKT_3			S		M
MKT_4			M		
MKT_5			M		
MKT_6				S	M

Image Classification Comparisons I

- **Results**
  - **Both approaches produce canopy cover change maps of high classification accuracy (i.e., overall accuracy and individual class accuracies)**
  - **Due to large trees produced by C4.5, rules can tend to be less *generalizable* to larger areas**
  - **In general, S-plus classifies better at the pixel level and at the site level**
  - **S-plus can be easily implemented**

Image Classification Comparisons II

- Study attempted to
  - Examine the potential of Fuzzy ARTMAP
  - Compare the utility of the ARTMAP approach to S-plus
  - Evaluation of ARTMAP vs. S-plus based on
    - Classification accuracy
    - Ease of use, flexibility of implementation, operational issues etc.

ARTMAP classification accuracy (Southern California) (test site)

		Reference class									
		1	2	3	4	5	6	7	8	9	Sites
	1	17									17
	2		29	1							30
Classified as	3			23							23
	4				11						11
	5					27	1				28
	6						1				1
	7							10			10
	8								24		24
	9									15	15
Sites		17	29	24	11	27	2	10	24	15	159

Overall Accuracy = 98.7%

Class	Class Description
1	-71 to -100% CC
2	-41 to -70% CC
3	-16 to -40% CC
4	+15 to -15% CC
5	+16 to +40% CC
6	+41 to +100% CC
7	Shrub/grass decrease > 15%
8	Shrub/grass increase >15%
9	Change within existing developed areas

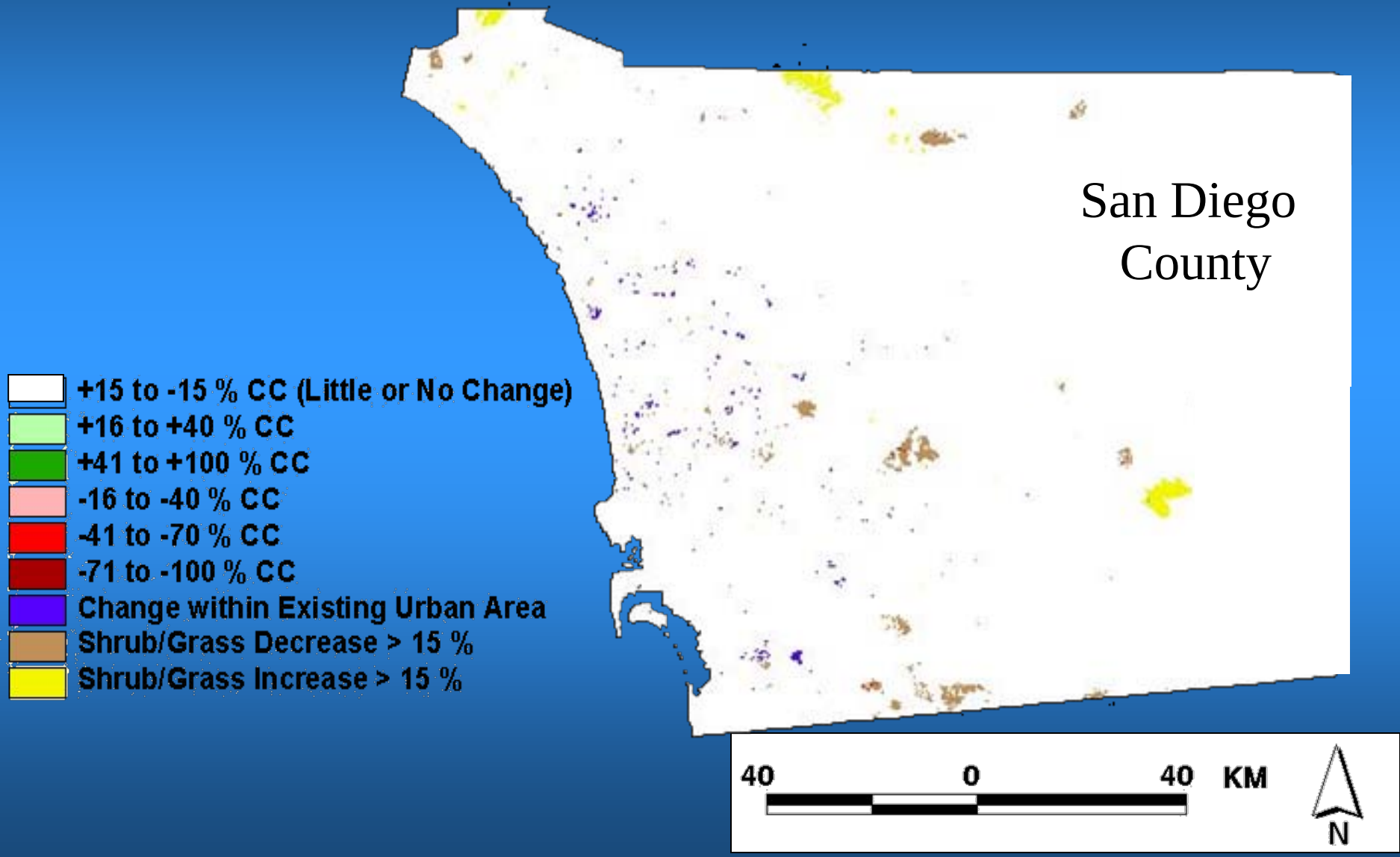
Producer's Accuracy	
Class	%
1	100
2	100
3	96
4	100
5	100
6	50
7	100
8	100
9	100

User's Accuracy	
Class	%
1	100
2	97
3	100
4	100
5	96
6	100
7	100
8	100
9	100

Accuracy Assessment

- Approaches
  - Conventional error matrix (non-spatial)
  - Fuzzy accuracy (non-spatial)
  - Using misclassification probabilities (per class) to map spatial variation in error

Forest Canopy Cover Change Map



Change Map Error Matrix

Reference Class

Classified As	1	2	3	4	5	6	7	8	9	15	Sites
1	7										7
2		12									12
3			5	2							7
4			1	148	1		3	7	2		162
5					4						4
6						1					1
7				4			15		1		20
8				1	1			15			17
9				4					25		29
15										1	1
Sites	**7**	**12**	**6**	**159**	**6**	**1**	**18**	**22**	**28**	**1**	**260**

Class Description

Class	
1	-71 to -100% CC
2	-41 to -70% CC
3	-16 to -40% CC
4	+15 to -15% CC (Little or No Change)
5	+16 to +40% CC
6	+41 to +100% CC
7	Shrub/Grass Decrease > 15%
8	Shrub/Grass Increase > 15%
9	Change within Existing Developed Area
15	Cloud or Cloud Shadow

Producer's Accuracy

Class					
1	= 7 / 7	=	100%	Tree Decr	
2	= 12 / 12	=	100%	96%	
3	= 5 / 6	=	83%		
4	= 148 / 159	=	93%		
5	= 4 / 6	=	67%	Tree Incr	
6	= 1 / 1	=	100%	71%	
7	= 15 / 18	=	83%		
8	= 15 / 22	=	68%		
9	= 25 / 28	=	89%		
15	= 1 / 1	=	100%		

(inverse is error of omission)

User's Accuracy

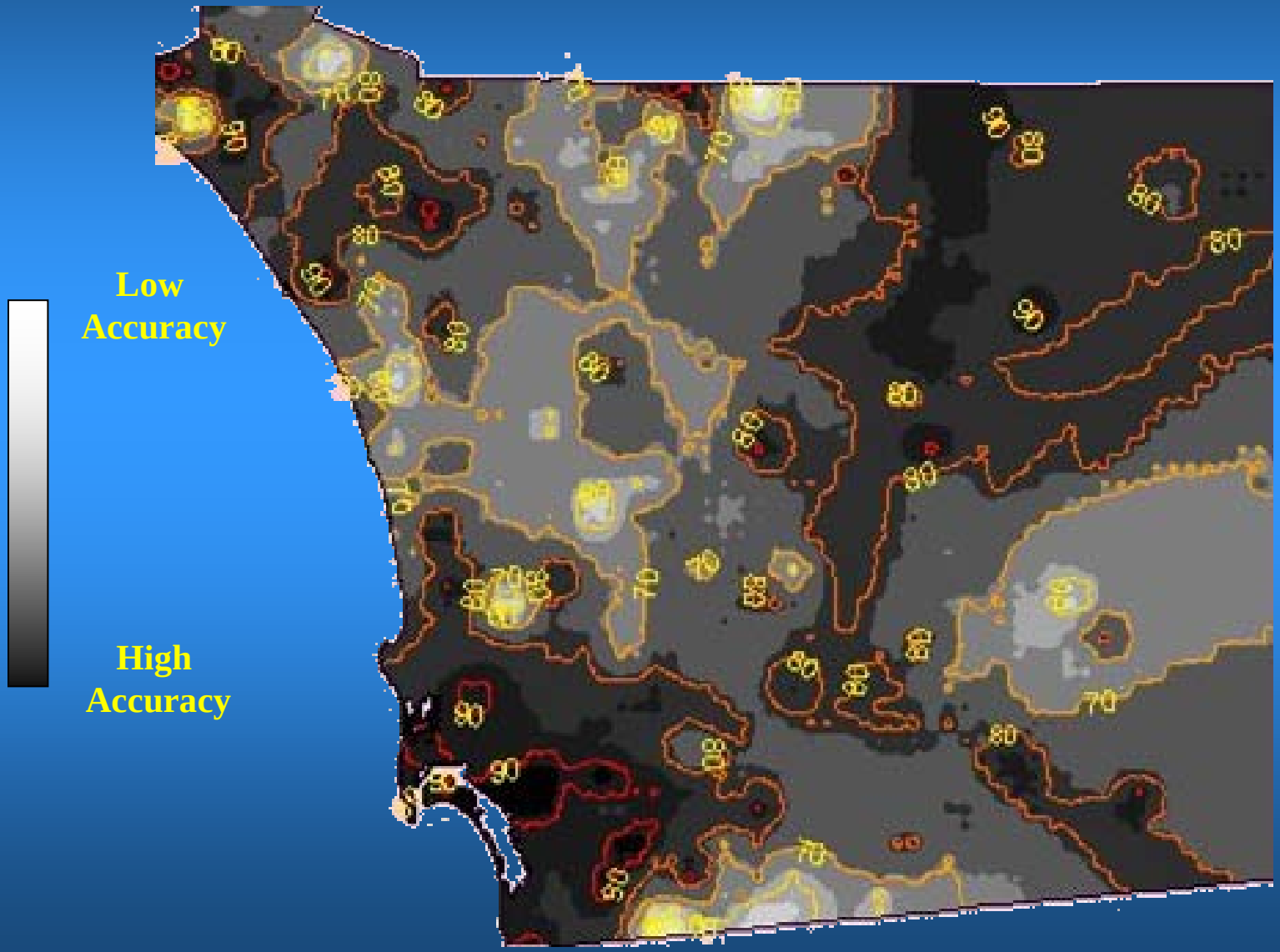
Class					
1	= 7 / 7	=	100%	Tree Decr	
2	= 12 / 12	=	100%	92%	
3	= 5 / 7	=	71%		
4	148 / 162	=	91%		
5	= 4 / 4	=	100%	Tree Incr	
6	= 1 / 1	=	100%	100%	
7	= 15 / 20	=	75%		
8	= 15 / 17	=	88%		
9	= 25 / 29	=	86%		
15	= 1 / 1	=	100%		

(inverse is error of commission)

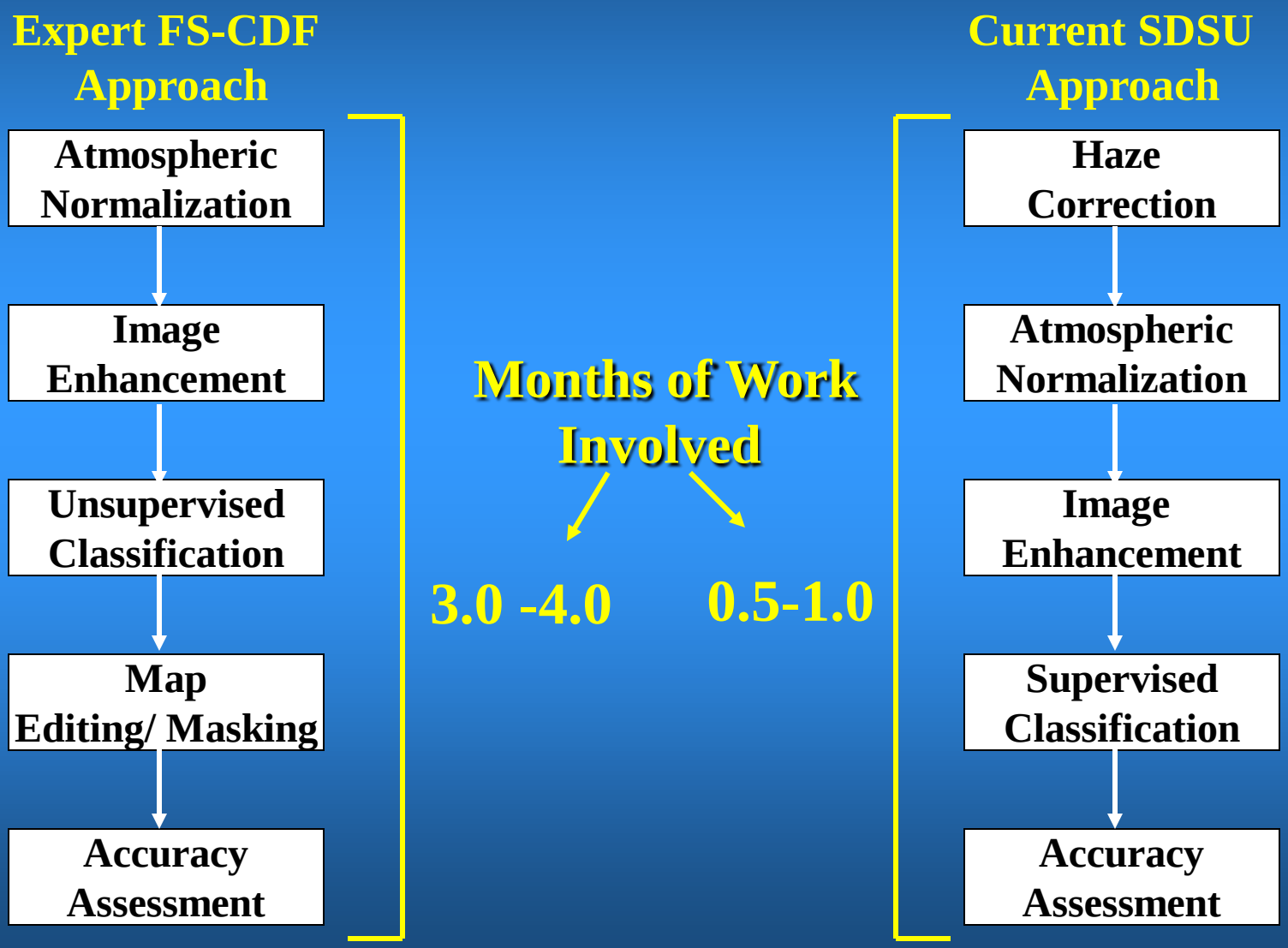
Training sites:	135	34%
AA sites:	260	66%
TOTAL sites:	395	

Overall Accuracy = 89.2%

Estimated Accuracy Map



Summary


Expert FS-CDF Approach
Atmospheric Normalization
Image Enhancement
Unsupervised Classification
Map Editing/ Masking
Accuracy Assessment
Months of Work Involved
3.0 -4.0
0.5-1.0
Current SDSU Approach
Haze Correction
Atmospheric Normalization
Image Enhancement
Supervised Classification
Accuracy Assessment

Future Steps

- Atmospheric Correction /Normalization
  - Compare DOS approaches with ATCOR3
- Image Change Enhancement
  - Examine the utility of Change Vector Analysis (CVA) vs. MKT (i.e, phenological increases)
- Image Classification
  - Compare S-plus Classification Tree approach to Fuzzy ARTMAP
- Accuracy Assessment (spatial)
  - Examine the use of ‘confidence’ images in conveying accuracy assessment

Most Significant Results/ Findings

- Spatially varying haze-correction algorithm should prove useful in fire-related studies
- Multitemporal Kauth Thomas is robust in enhancing change over large areas
- Classification Tree and or/ Fuzzy ARTMAP classifiers are better at mapping LCLUC because of their non-parametric nature, ability to incorporate non-image data and their generalizability
- Fuzzy approaches to mapping LCLUC and spatial accuracy mapping should be explored further

Work Schedule

TASKS AND DELIVERABLES	PROJECT YEAR 1- 2000/ 2001				PROJECT YEAR 2- 2001/ 2002				PROJECT YEAR 3-2002/ 2003			
	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 1996-2000 and 1990-1996 Data						Program Implementation ----------→ For all Data					
1. Acquire Image Data	--------	--------	--------	--------								
2. Acquire Collateral Data	--------	--------	--------	--------	--------	--------	--					
3. Image Preprocessing			--------	--------	--------							
4. Field Data Collection	-------				--------				--------			
5. Enhancement and Classification				--------	-------	--------	--------	----				
6. Meetings	--------		--------		--------		--------		--------	--------	--------	-------
7. Presentations	*			*			*			*	*	*

New Products

- Forest cover change maps of California ecoregions available (Time period 1990-1996) featuring the canopy cover change classes, described previously, at:
- http://www.frap.ca.gov