NASA Affiliated Research Center (ARC)
San Diego State University (SDSU)

Landscaped Vegetation Assessment in Urban Environments

Project conducted by:

AgriCast
Escondido, CA 92033

AgriCast Participant

Alan Walters, President

SDSU Faculty Participants

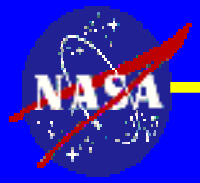
Allen Hope and Douglas Stow (*Geography*), Project Scientists

SDSU Staff Participant

Pete Coulter *(Geography)*, ARC Technical Manager
John Kaiser *(Geography),* ARC Coordinator

SDSU Graduate Student Participants

Dawn Service, Martin Lowenfish, Katrina Schutte, Scott Redlin *(Geography)*, Research Assistants

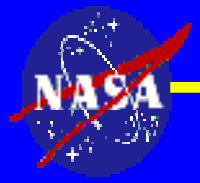


Project Objectives

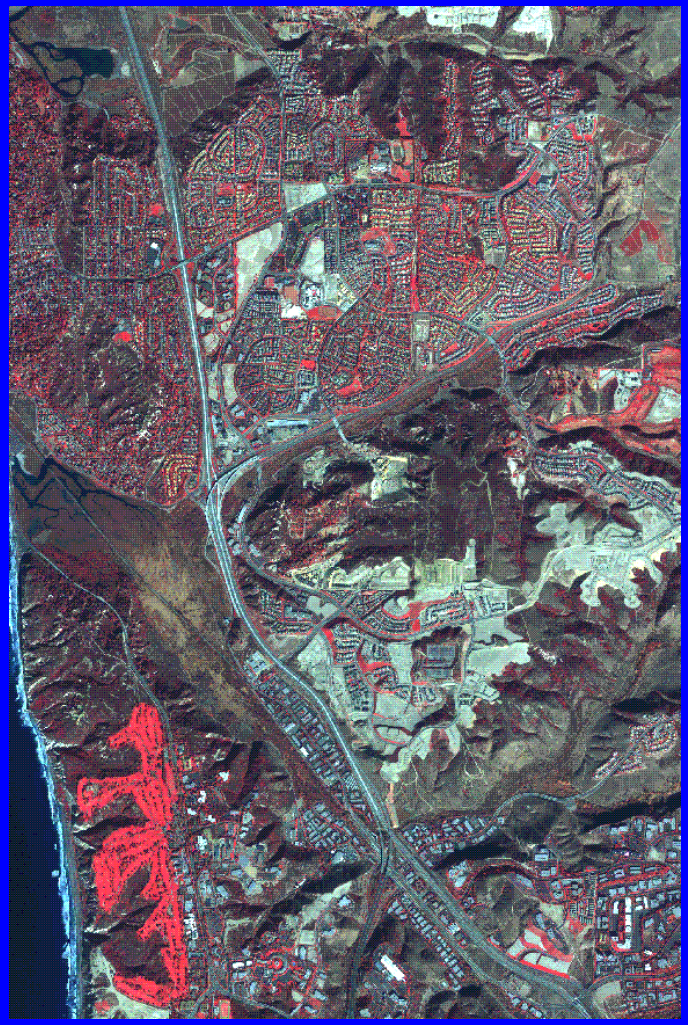
1) Explore multiple techniques for mapping and quantifying urban landscaped vegetation with 4 m IKONOS satellite imagery

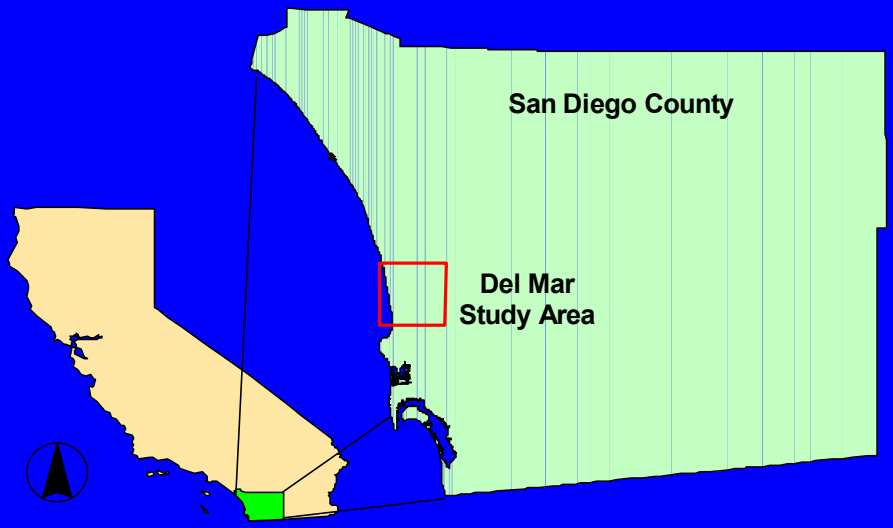
2) Assess the accuracy of IKONOS-derived maps of urban landscaped vegetation

3) Assess the accuracy of IKONOS-derived maps of impervious, tree/shrub, and grass cover



Del Mar Study Area

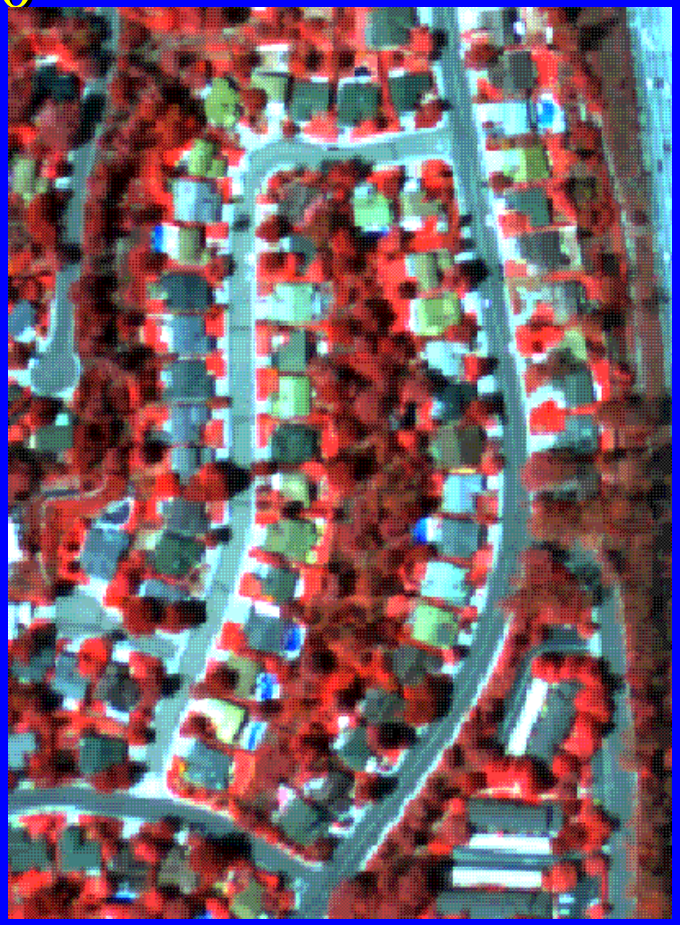




NASA AgriCast SDSU

Multispectral Imagery from IKONOS and ADAR 5500

IKONOS (4 m Satellite)



ADAR 5500 (1 m Airborne)

NASA

AgriCast

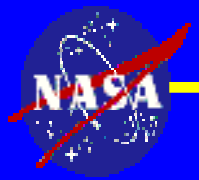
SDSU

Calibration/Validation Techniques

Ground Data at SFR and MFR sites

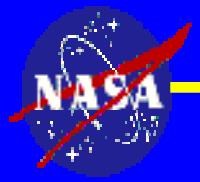
ADAR 5500 Reference Map

IKONOS Validation at 89 sites

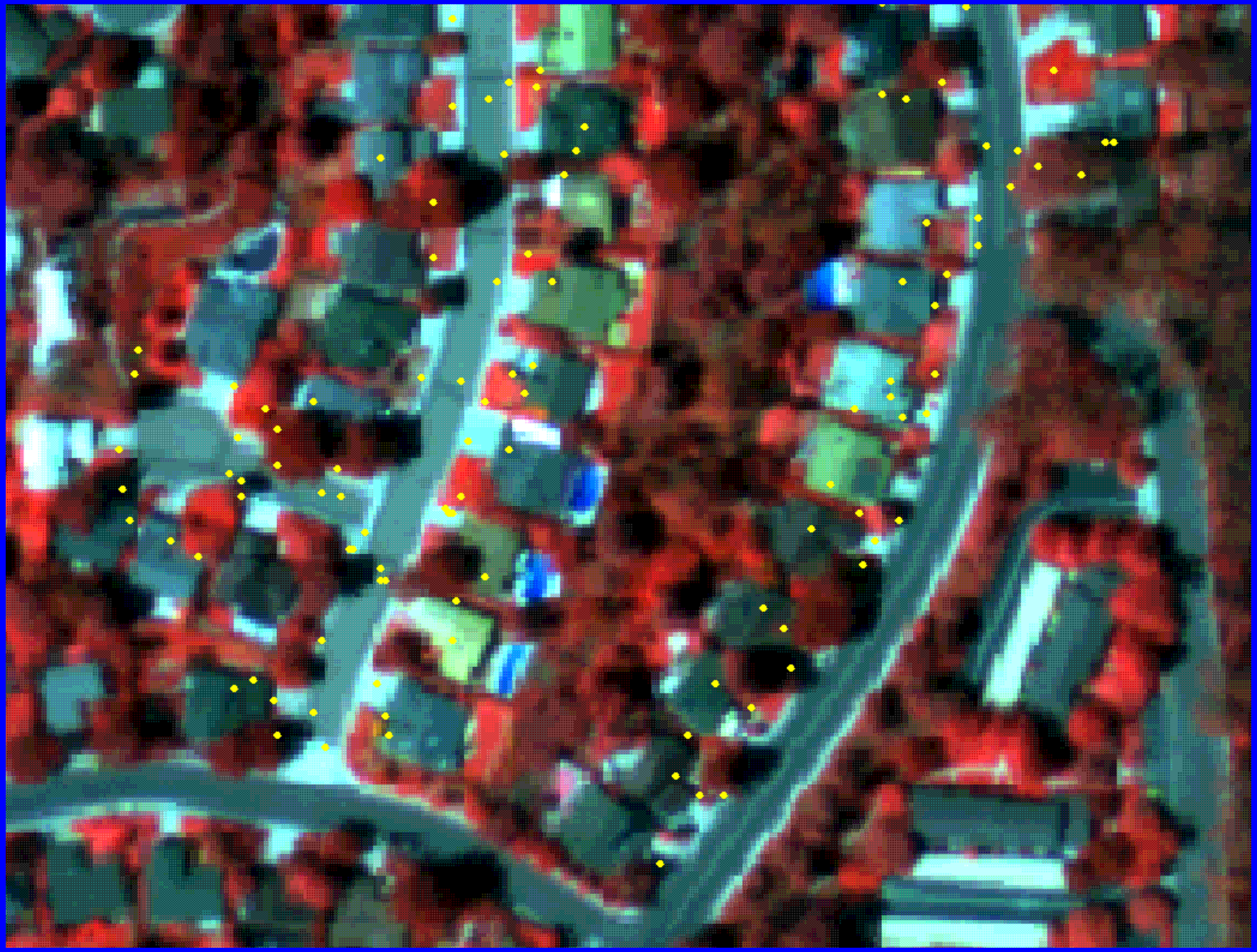


Ground Data at SFR and MFR Sites

- 200 random points at SFR and 200 at MFR
- Cover sampled for 1 m ground unit at each point
  - Impervious
  - Tree/shrub
  - Grass/ground-cover



Ground Data at SFR and MFR Sites



NASA Affiliated Research Center (ARC)
San Diego State University (SDSU)





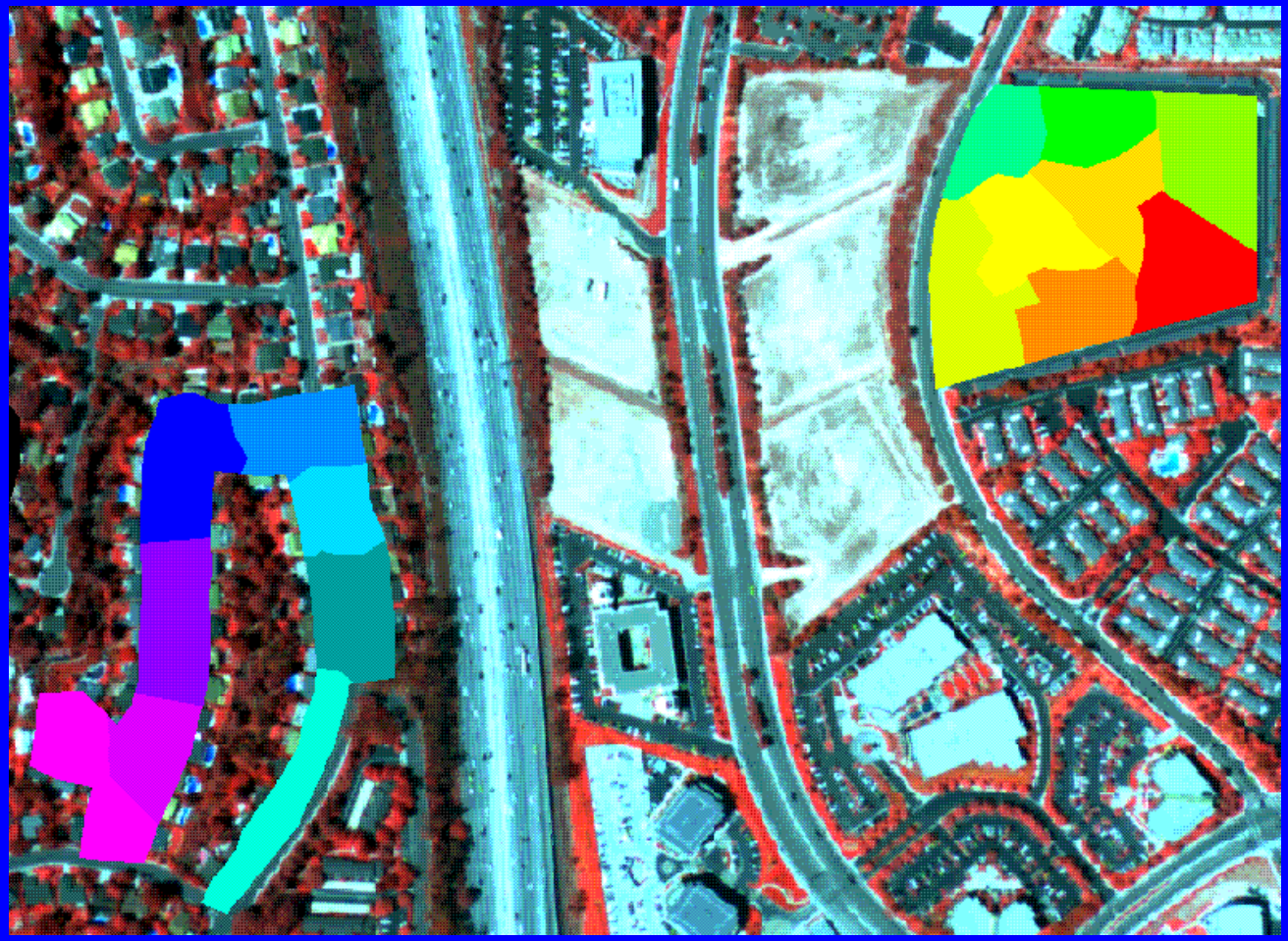


NASA

AgriCast

SDSU

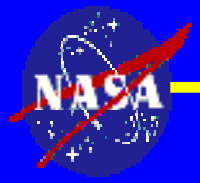
Validation of ADAR 5500 Reference Products with Ground Data



NASA AgriCast SDSU

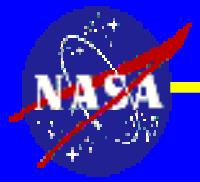
Landscaped Vegetation Cover from Ground Observations and 1 m NDVI Threshold Image

Spatial Unit	Ground Reference	1 m NDVI Threshold	Error
SFR1	33%	42%	8%
SFR2	12%	31%	19%
SFR3	36%	30%	-6%
SFR4	33%	34%	1%
SFR5	21%	25%	5%
SFR6	39%	31%	-8%
SFR7	48%	44%	-3%
SFR8	33%	28%	-5%
MFR1	56%	50%	-6%
MFR2	40%	32%	-8%
MFR3	36%	36%	0%
MFR4	42%	37%	-5%
MFR5	36%	50%	14%
MFR6	56%	55%	-1%
MFR7	40%	24%	-16%
MFR8	20%	28%	8%
SFR Aggregated	**32%**	**33%**	**1%**
MFR Aggregated	**41%**	**39%**	**-2%**

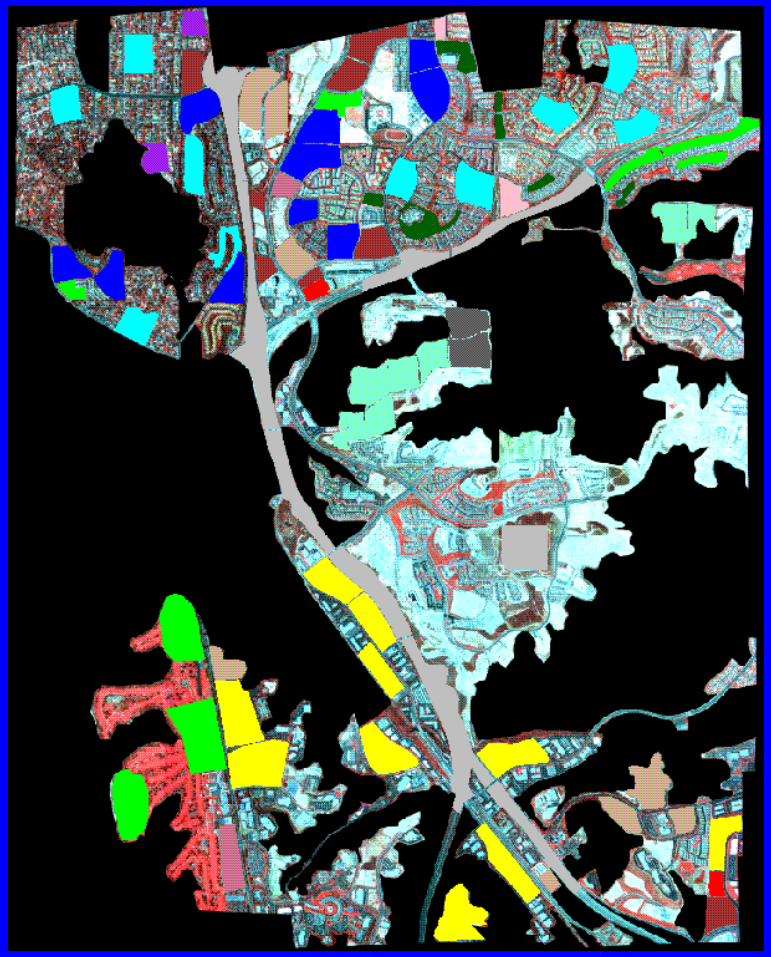


Classifying Urban Landscaped Vegetation

1) Unsupervised classification
2) Supervised classification
3) NDVI thresholding
4) Green vegetation, soil, shade fraction image products



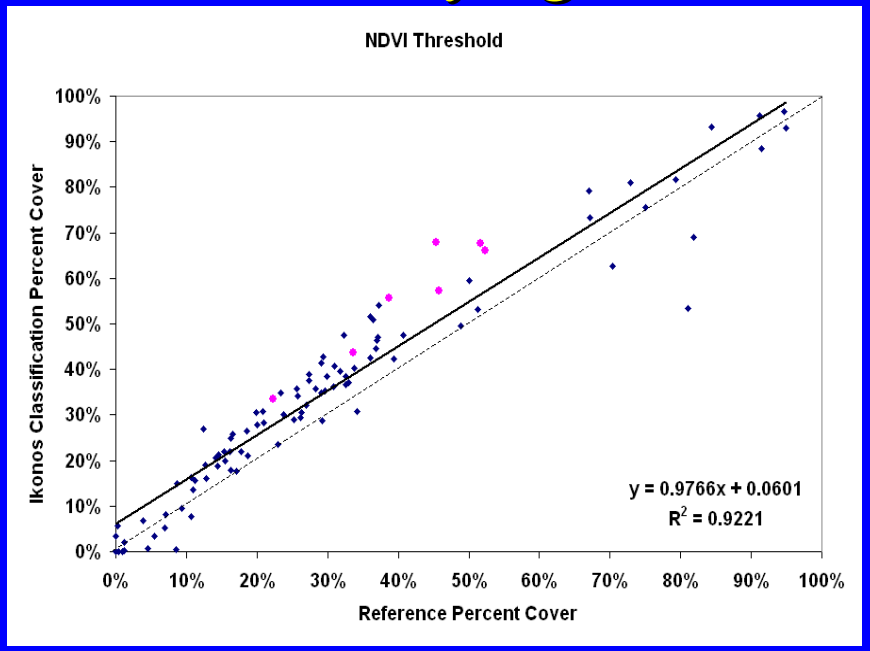
Validation of IKONOS Classification Products with ADAR 5500 Reference Data

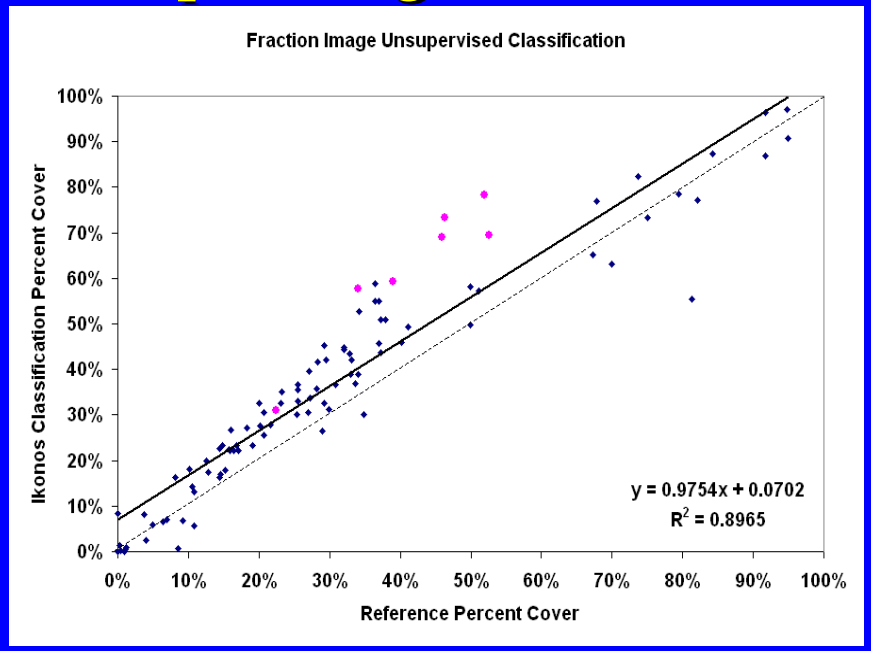


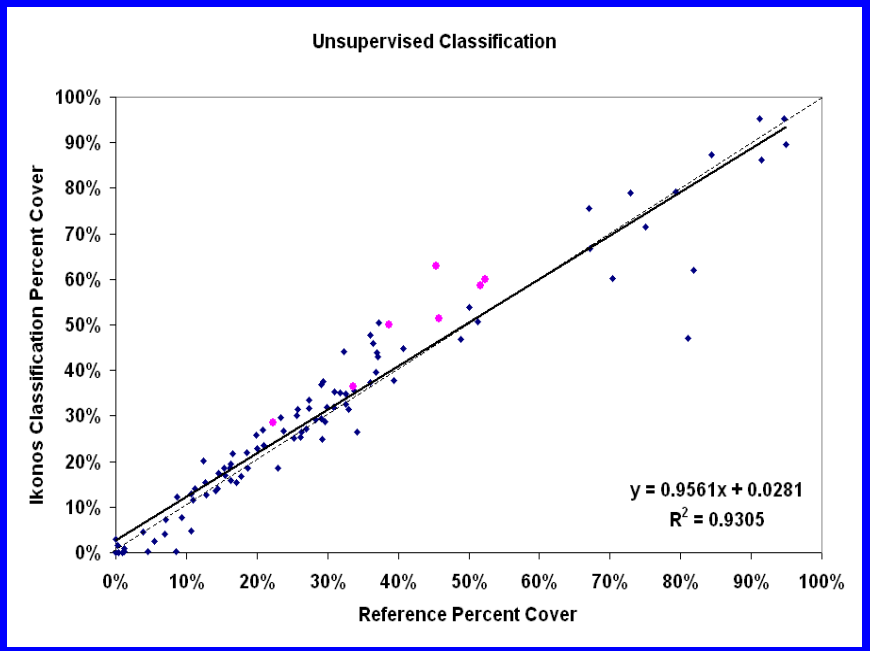
- Spaced Rural Residential
- Single Family Residential
- Multiple Family Residential
- Light Industry
- Transportation
- Commercial
- Office
- Commercial Recreation
- Parks
- Hotel / Motel
- Extractive Industry
- Public Services
- Hospital
- School

NASA AgriCast SDSU

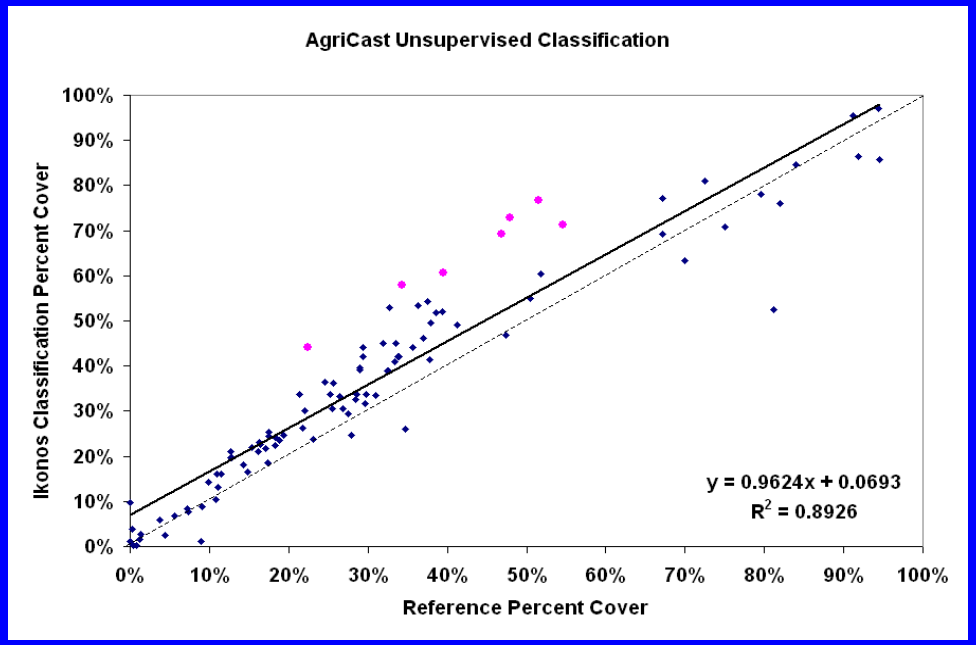
Classifying Urban Landscaped Vegetation

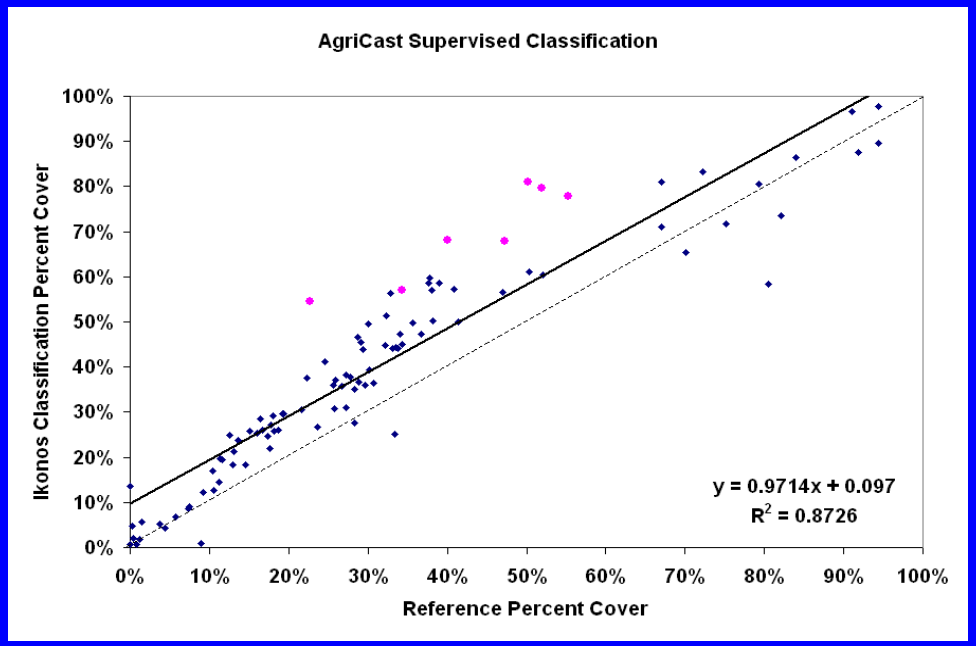




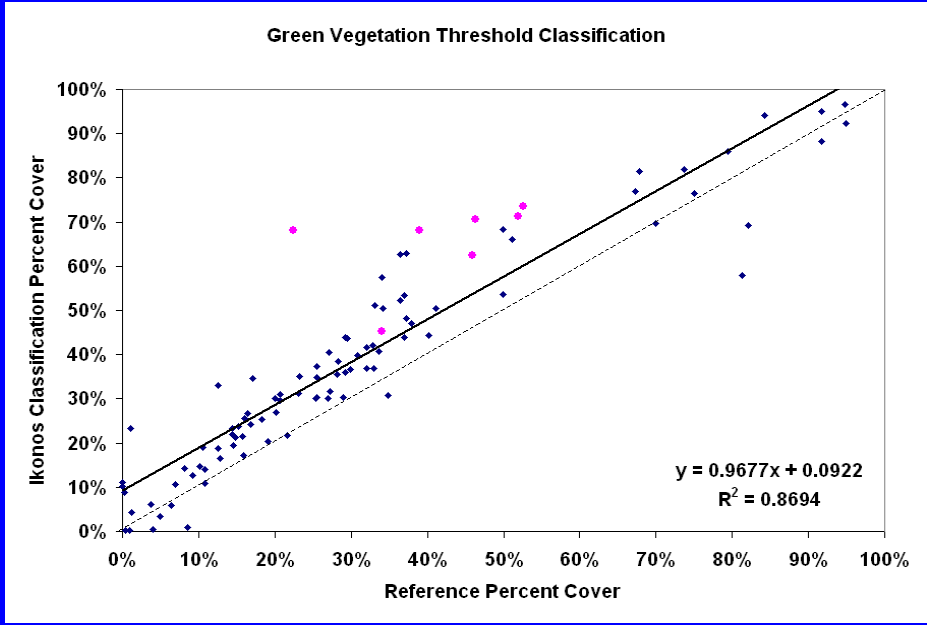


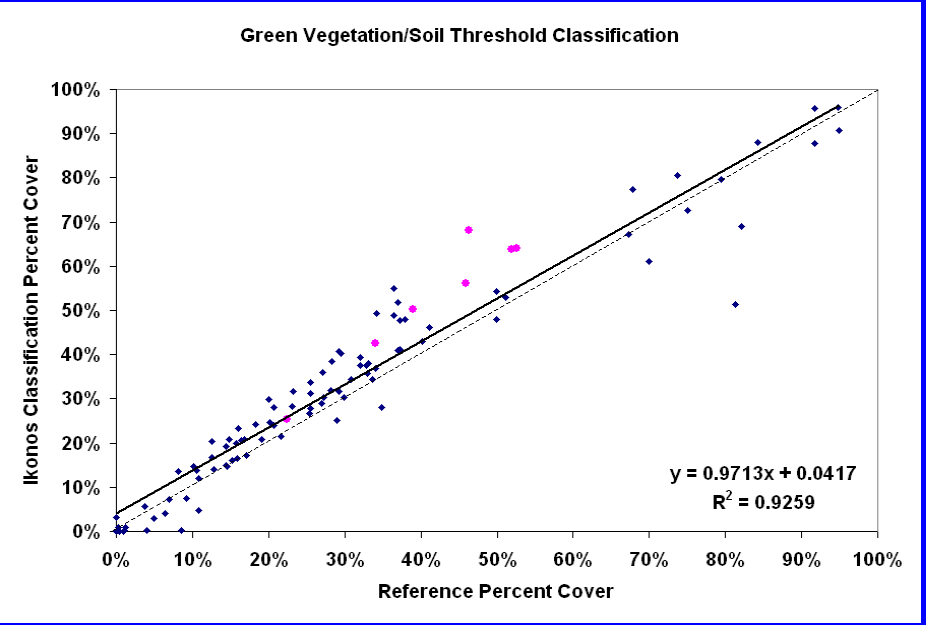
Classifying Urban Landscaped Vegetation

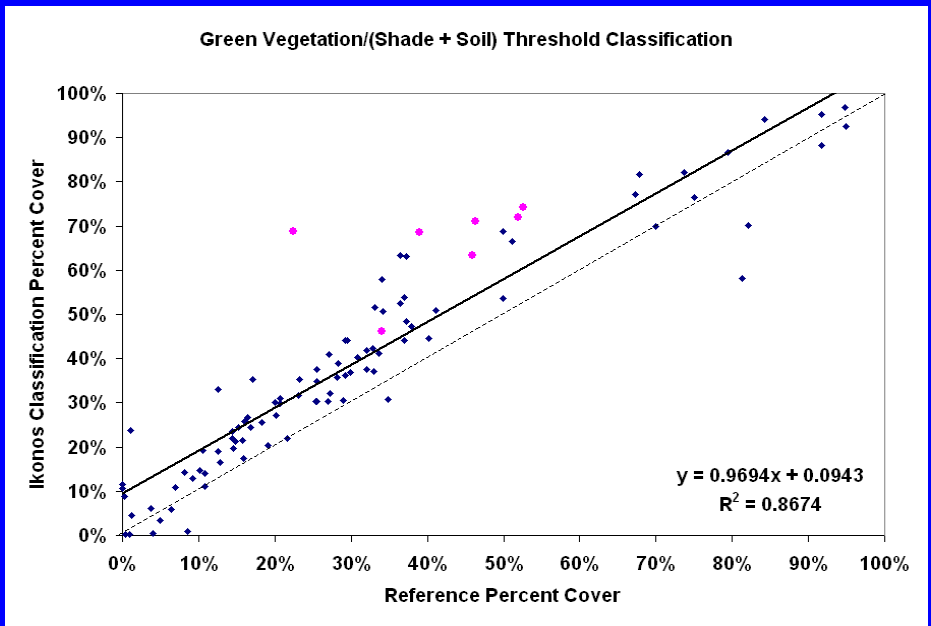


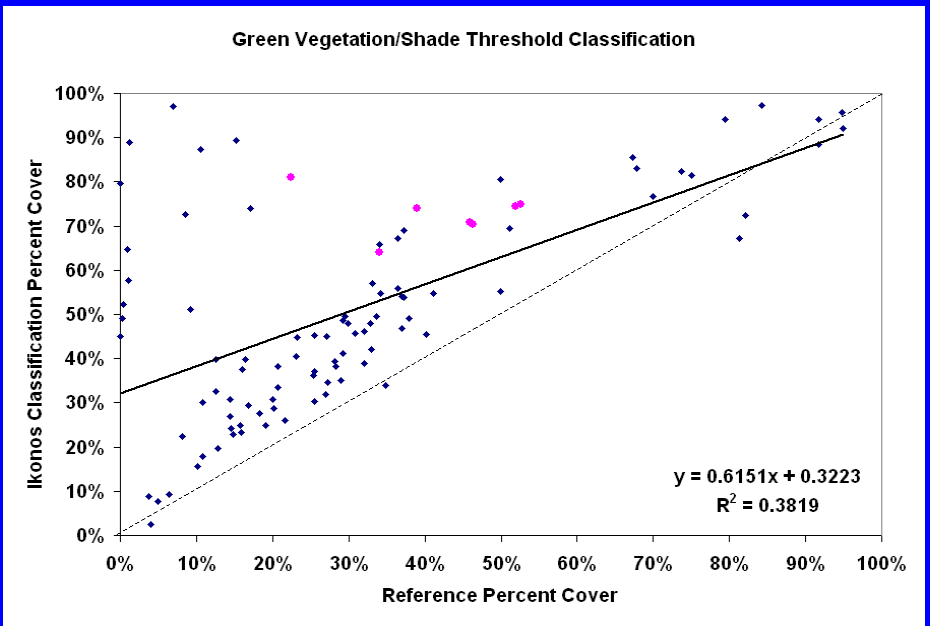


Classifying Urban Landscaped Vegetation



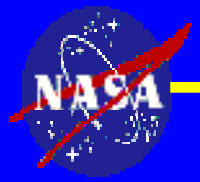






Relationship of Landscaped Vegetation Cover between IKONOS Classification and 1 m Reference

Classification Method	RMSE
NDVI Threshold	8.50%
Unsupervised Classification	6.40%
AgriCast Unsupervised Classification	9.70%
AgriCast Supervised Classification	12.40%
Fraction Image Unsupervised Classification	10.00%
Green Vegetation Threshold Classification	12.10%
Green Vegetation / Shade Threshold Classification	28.90%
Green Vegetation / Soil Threshold Classification	7.30%
Green Vegetation / (Shade + Soil) Threshold Classification	12.40%

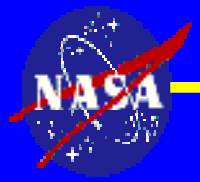


Classifying Tree/Shrub and Grass/Ground-Cover Vegetation

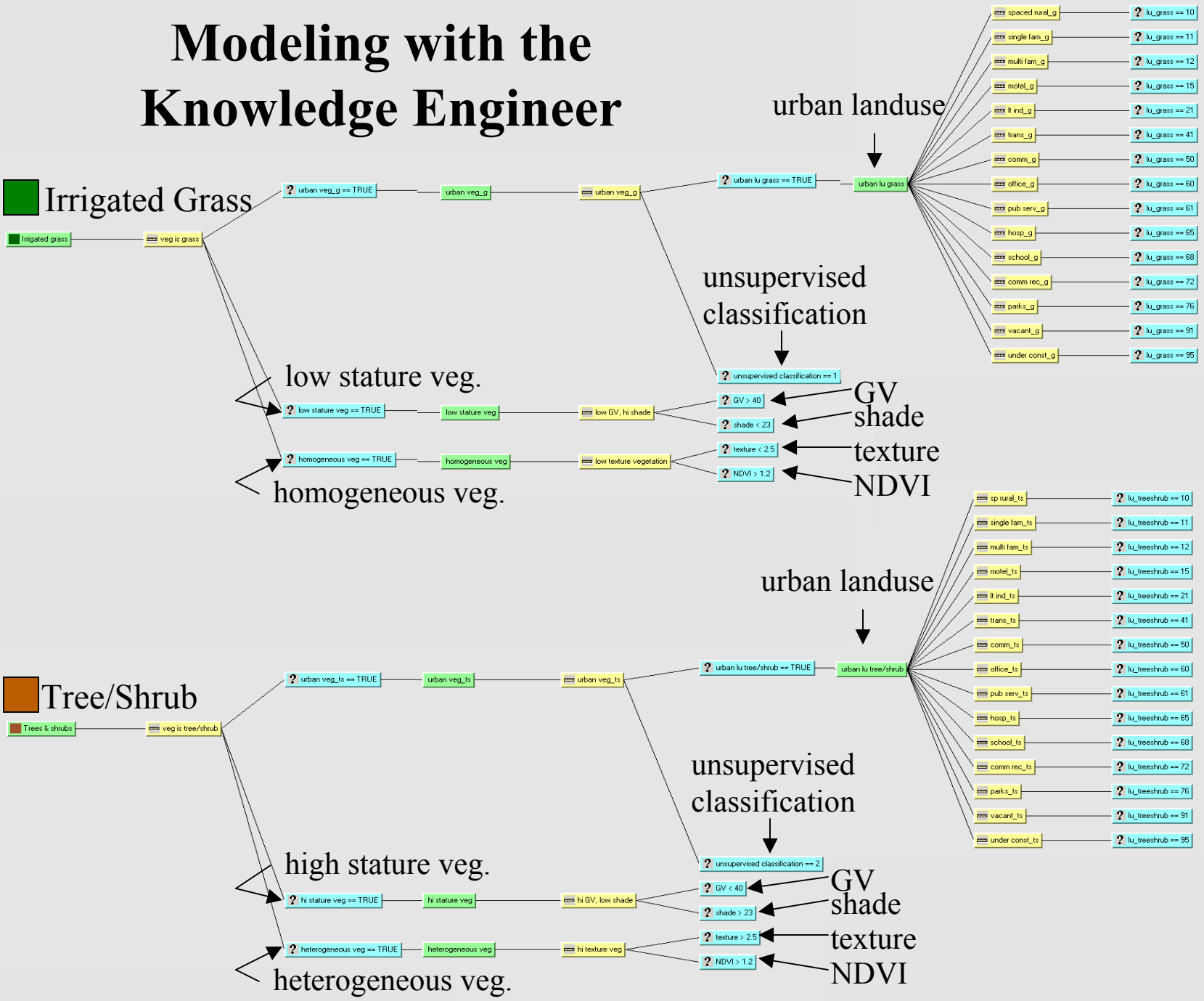
1) Unsupervised classification

2) Supervised classification

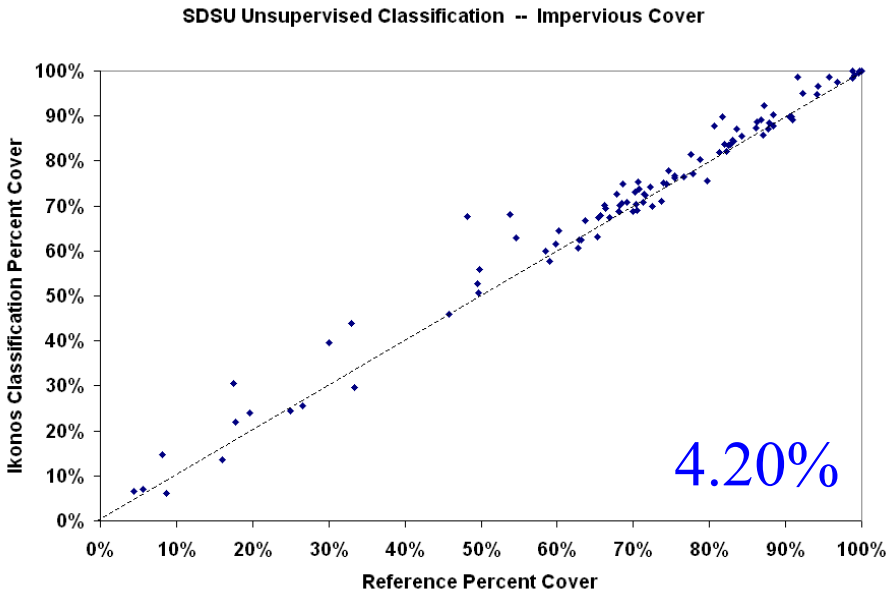
3) Combining image and ancillary data using the ERDAS Knowledge Classifier

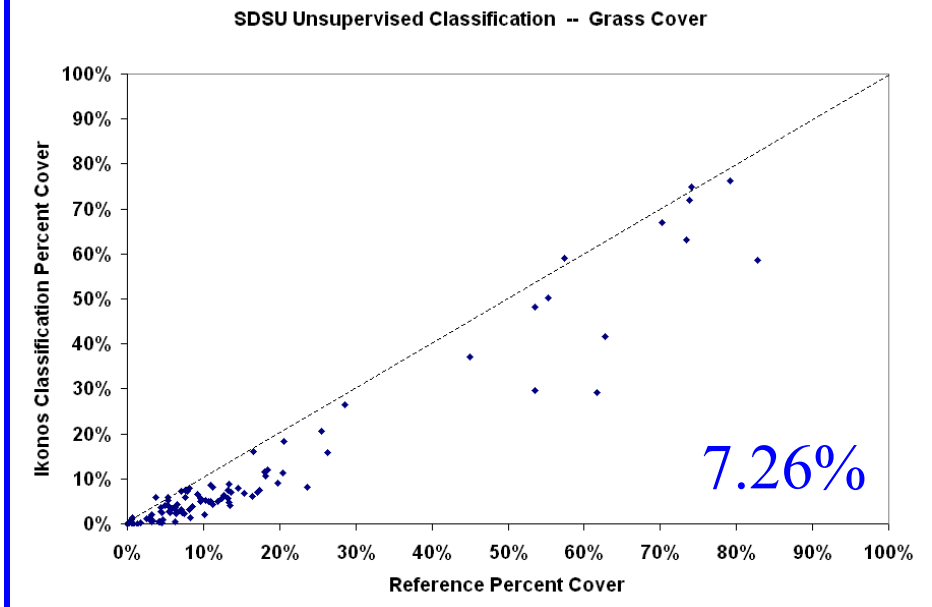


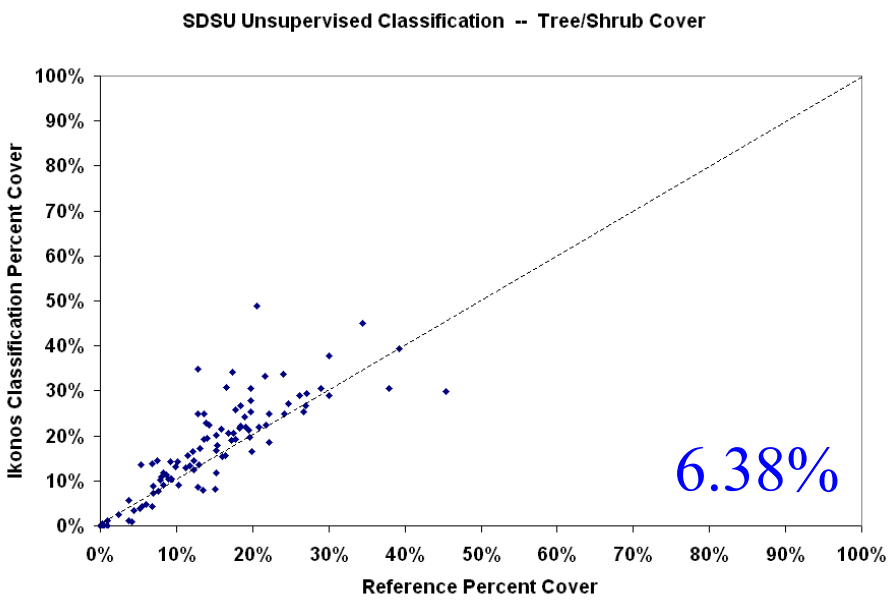
Modeling with the Knowledge Engineer



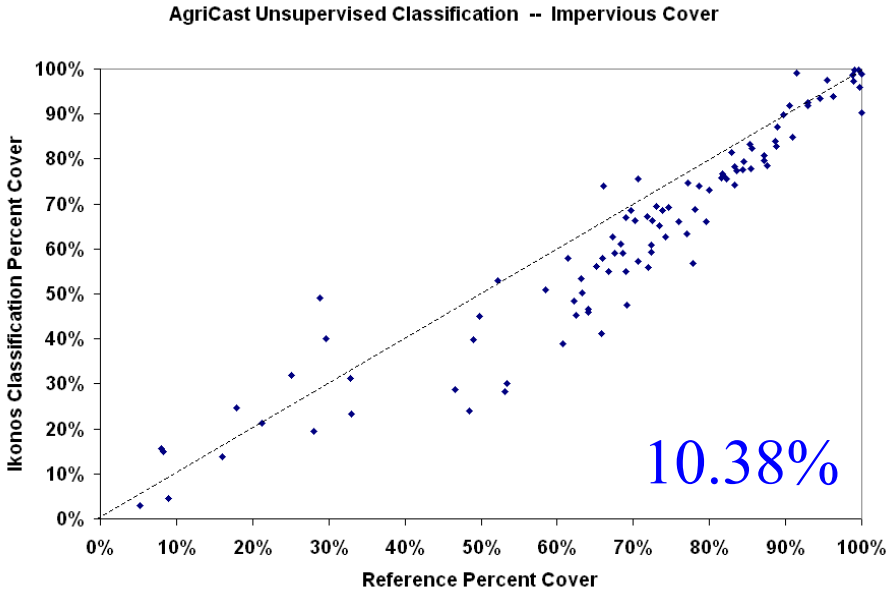
Classifying Impervious, Tree/Shrub, and Grass

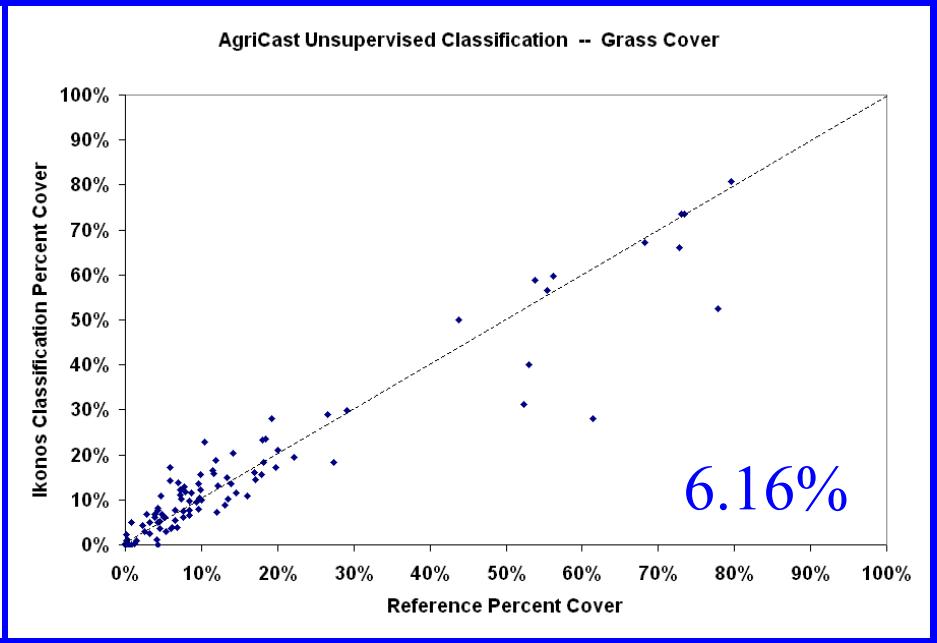


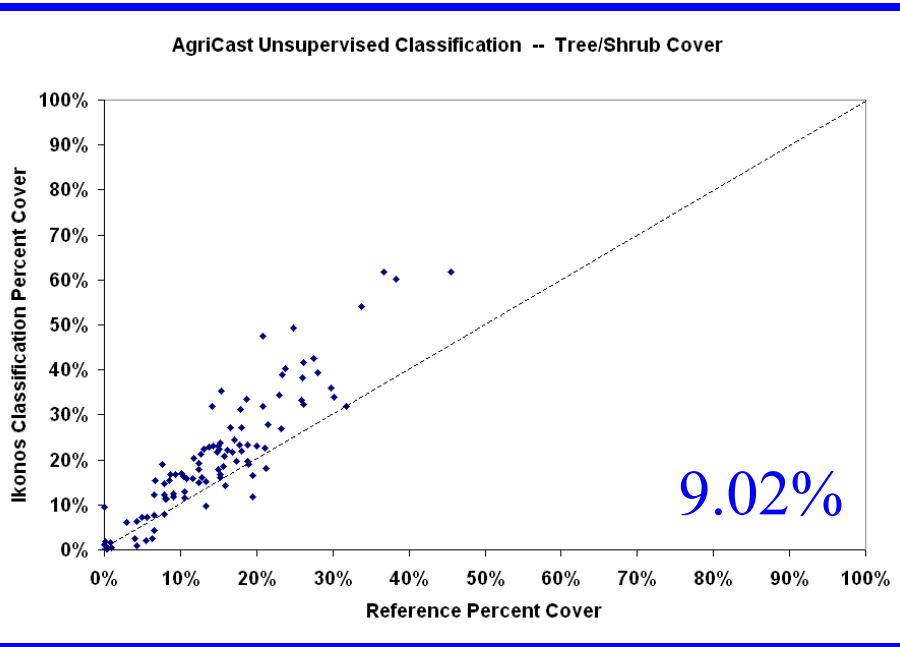




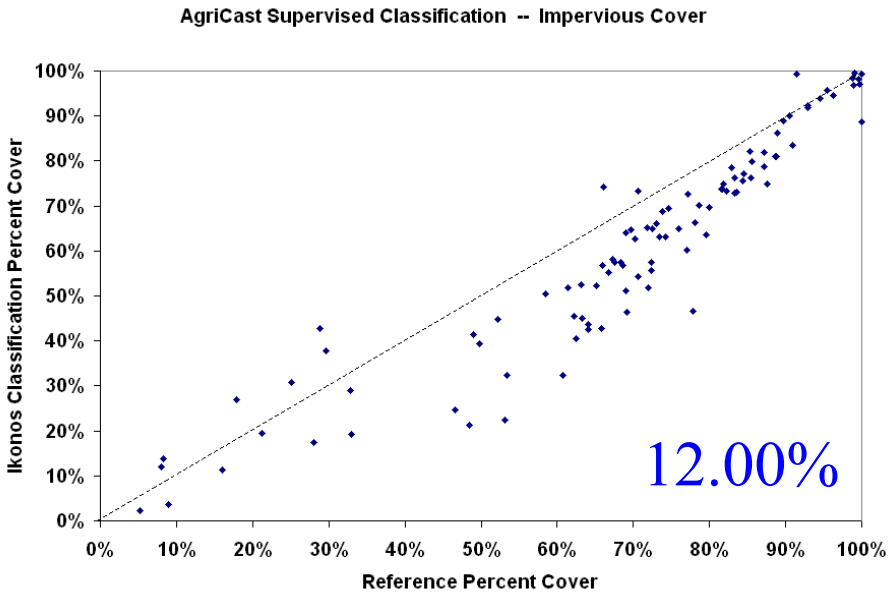
Classifying Impervious, Tree/Shrub, and Grass

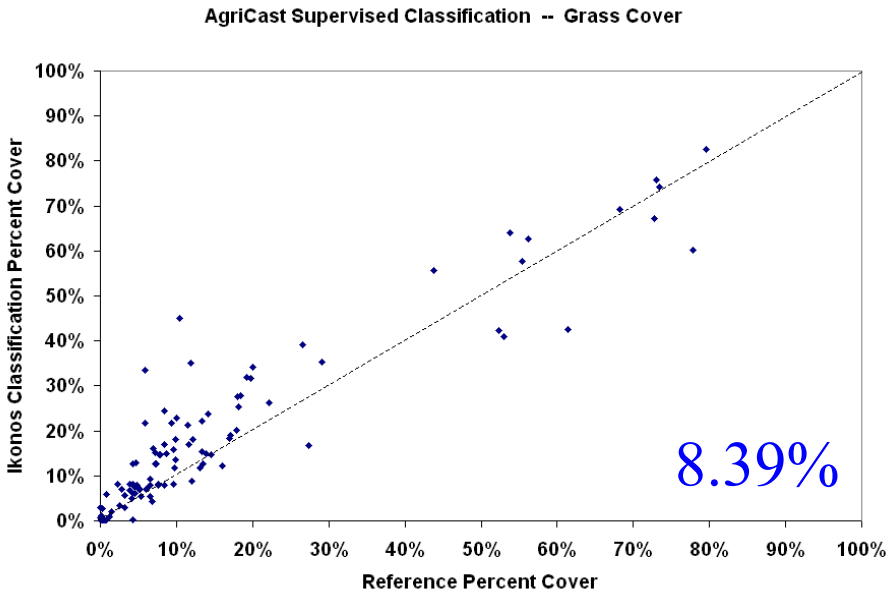


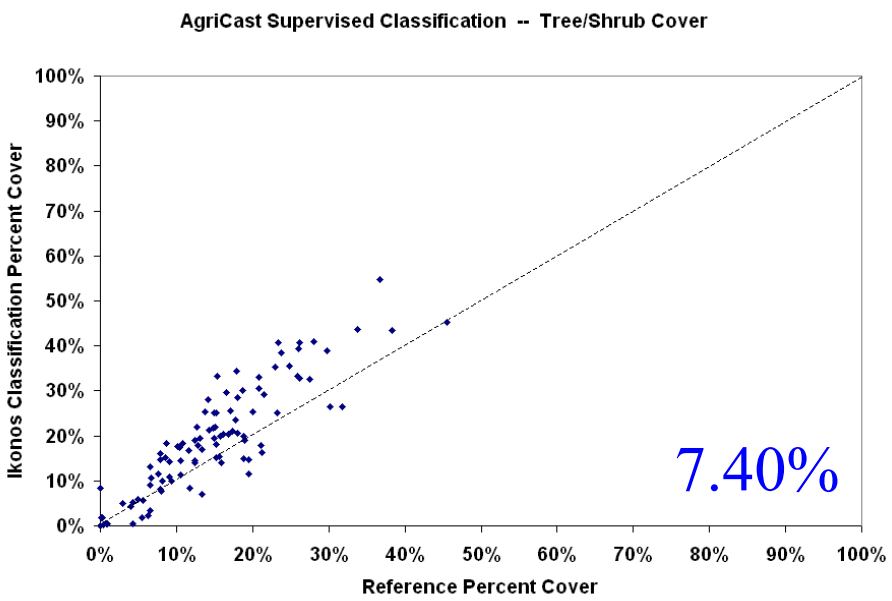




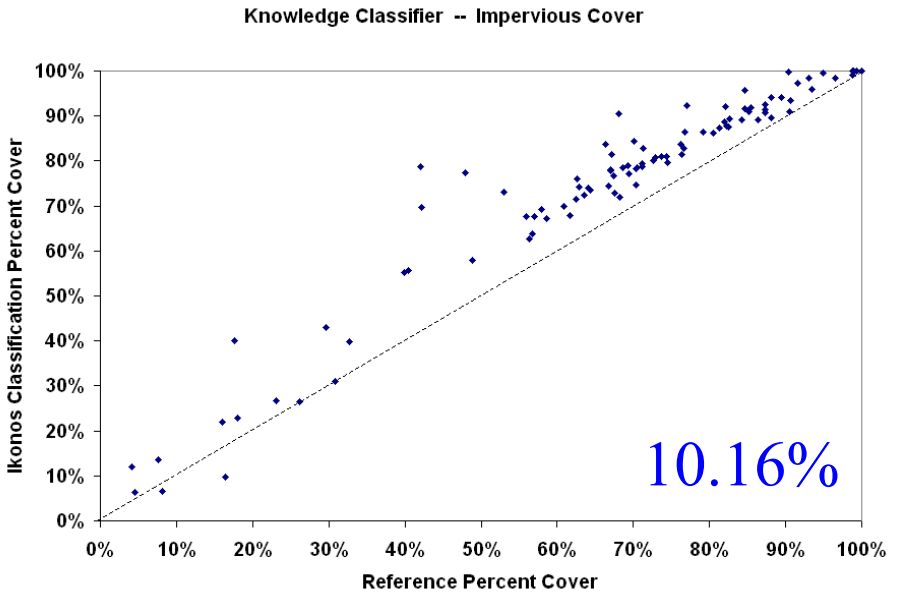
Classifying Impervious, Tree/Shrub, and Grass

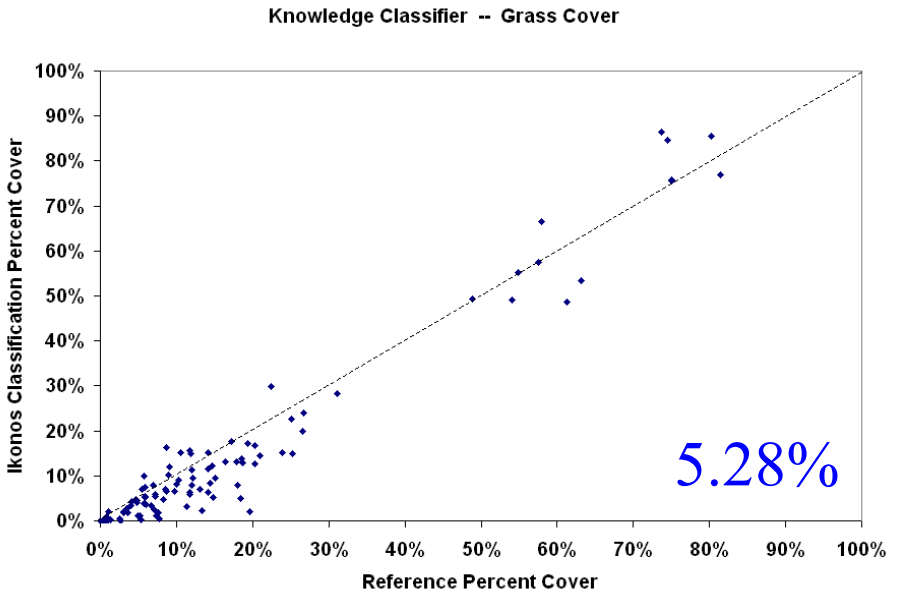


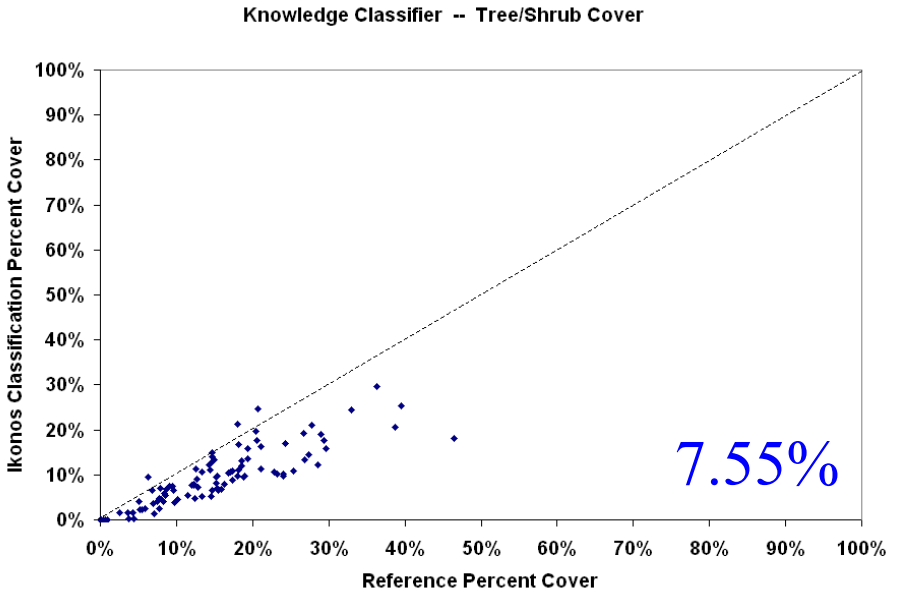




Classifying Impervious, Tree/Shrub, and Grass

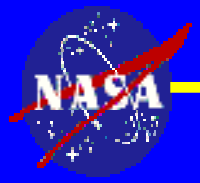






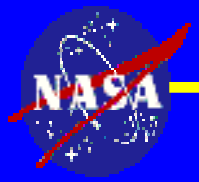
Impervious, Tree/Shrub, Grass RMSE Values

Classification Method	Impervious	Tree/Shrub	Grass
SDSU Unsupervised	4.20%	6.38%	7.26%
AgriCast Unsupervised	10.38%	9.02%	6.16%
AgriCast Supervised	12.00%	7.40%	8.39%
Knowledge Classifier	10.16%	7.55%	5.28%



Conclusions

- Simple and complex techniques achieve similar results when classifying IKONOS 4 m imagery
- Estimates of landscaped vegetation fraction within 5% to 12% of reference at scale of ~15 acres (small neighborhood)
- Overestimation of landscaped vegetation consistently obtained when compared to 1 m reference data
- High resolution imagery is useful for calibration/validation, with added cost
- Visual interpretation effective for masking natural (non-landscaped) vegetation



NASA Food and Fiber Applications of Remote Sensing (FFARS)
San Diego State University (SDSU)

Regional Change Monitoring of Habitat Reserve Systems Using Very High Resolution Remotely Sensed Data

August 1, 1999 - July 31, 2002

Principal Investigator: *Douglas Stow*

Co-Investigators: *Janet Franklin, Allen Hope, John O'Leary*
Project Manager: *Lloyd Coulter*
Graduate Assistants: *Aaron Johnson, Pauline Longmire, Scott Redlin, John Rogan, Alys Wall, Elizabeth Witztum, Aaron Petersen, Debbie Fugate, Rasmus Larsen*
Department of Geography, San Diego State University

Project Consultant: Edward Almanza

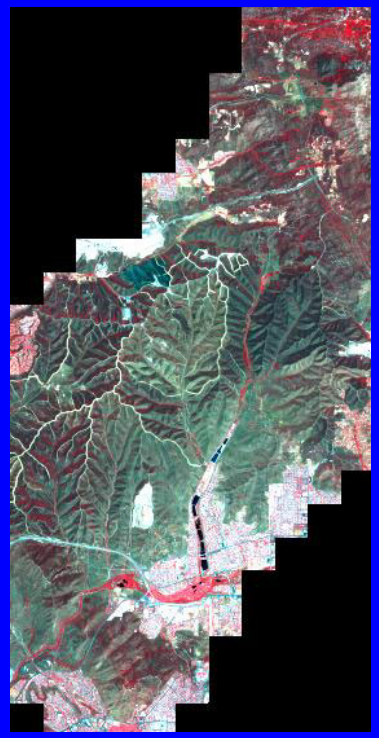
NASA Food and Fiber Applications of Remote Sensing (FFARS)
San Diego State University (SDSU)

Precision Master Data Sets

2000 Poway East
(West Portion)

June 29
11:19 AM PDT
(18:19 GMT)

Order #: 64476
Sun Az: 109
Sun Elev: 67



2000 Poway East
(Mid Portion)

June 7
11:16 AM PDT
(18:16 GMT)

Order #: 64475
Sun Az: 110
Sun Elev: 68

2001 Poway East
(West Portion)

May 30
11:36 AM PDT
(18:36 GMT)

Order #: 75007_001$_{0000}$
Sun Az: 121
Sun Elev: 71

2001 Poway East
(Mid Portion)

June 10
11:38 AM PDT
(18:38 GMT)

Order #: 75007_002$_{0000}$
Sun Az: 118
Sun Elev: 72

2001 Poway East
(Mid *East Only* Portion)

May 8
11:34 AM PDT
(18:34 GMT)

Order #: 75007_000$_{0000}$
Sun Az: 130
Sun Elev: 68

NASA Food and Fiber Applications of Remote Sensing (FFARS)
San Diego State University (SDSU)

Southern California Shrubland Habitat

Potential Land Surface Changes of Interest

- Invasion of non-native plants
- Fire and post-fire succession of vegetation
- Removal of vegetation for urban and agricultural development
- Reduction of vegetation cover and stature from recreation and transportation related impacts
- Reduction of vegetation cover and stature from climatic variation
- Vegetation community type change

NASA Food and Fiber Applications of Remote Sensing (FFARS)
San Diego State University (SDSU)

Change Vector Classification Process

- Common area mask
- Urban mask
  - removes potential high magnitude urban changes
- Radiometrically normalize imagery
  - custom histogram matching algorithm. Matches mean and variance per-waveband.
- Difference red, near-infrared and NDVI layers

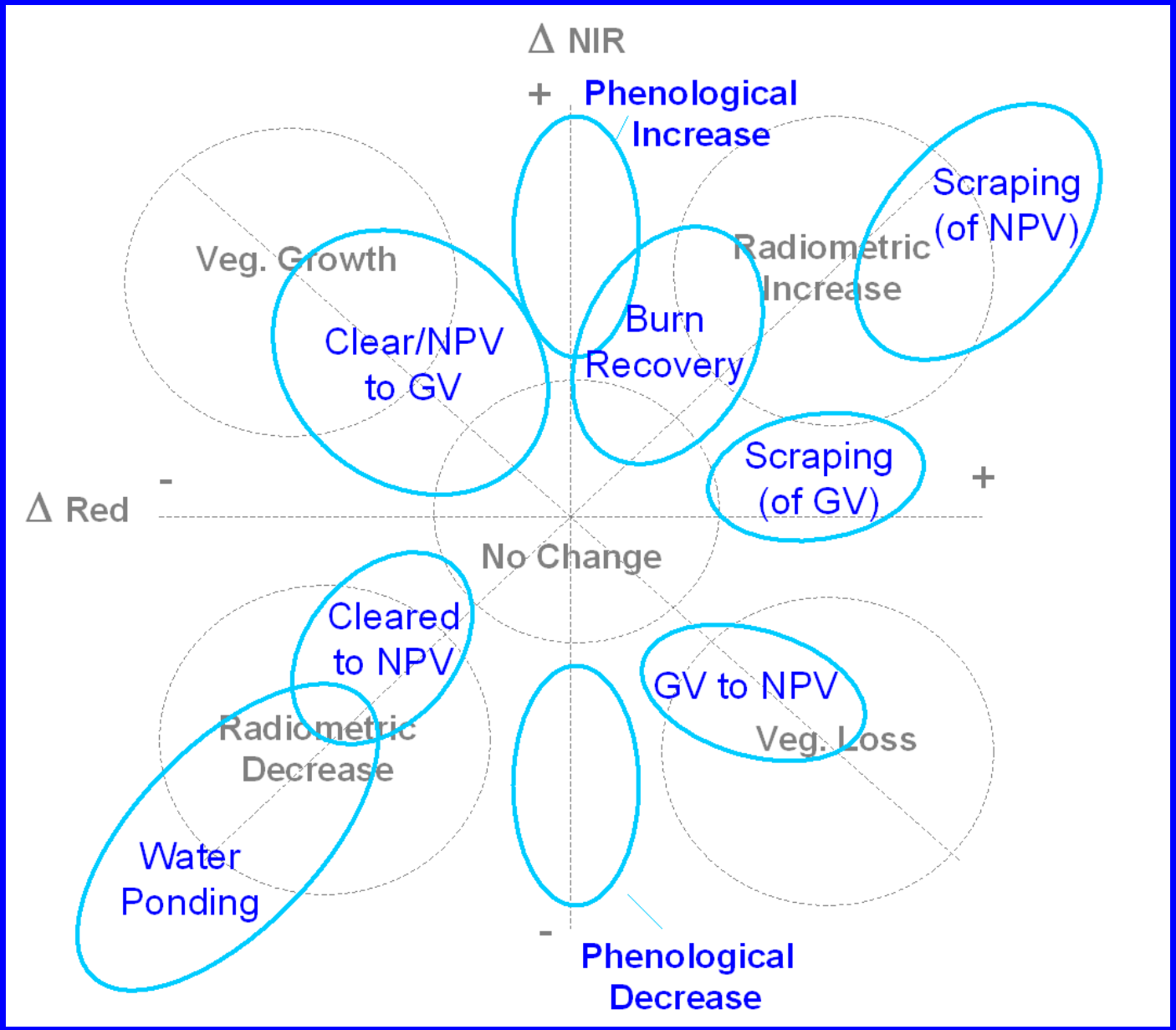
* Mask non-change areas

- Classify remaining portions of 3-layer difference image
- Post-classification smoothing (3x3 majority filter)

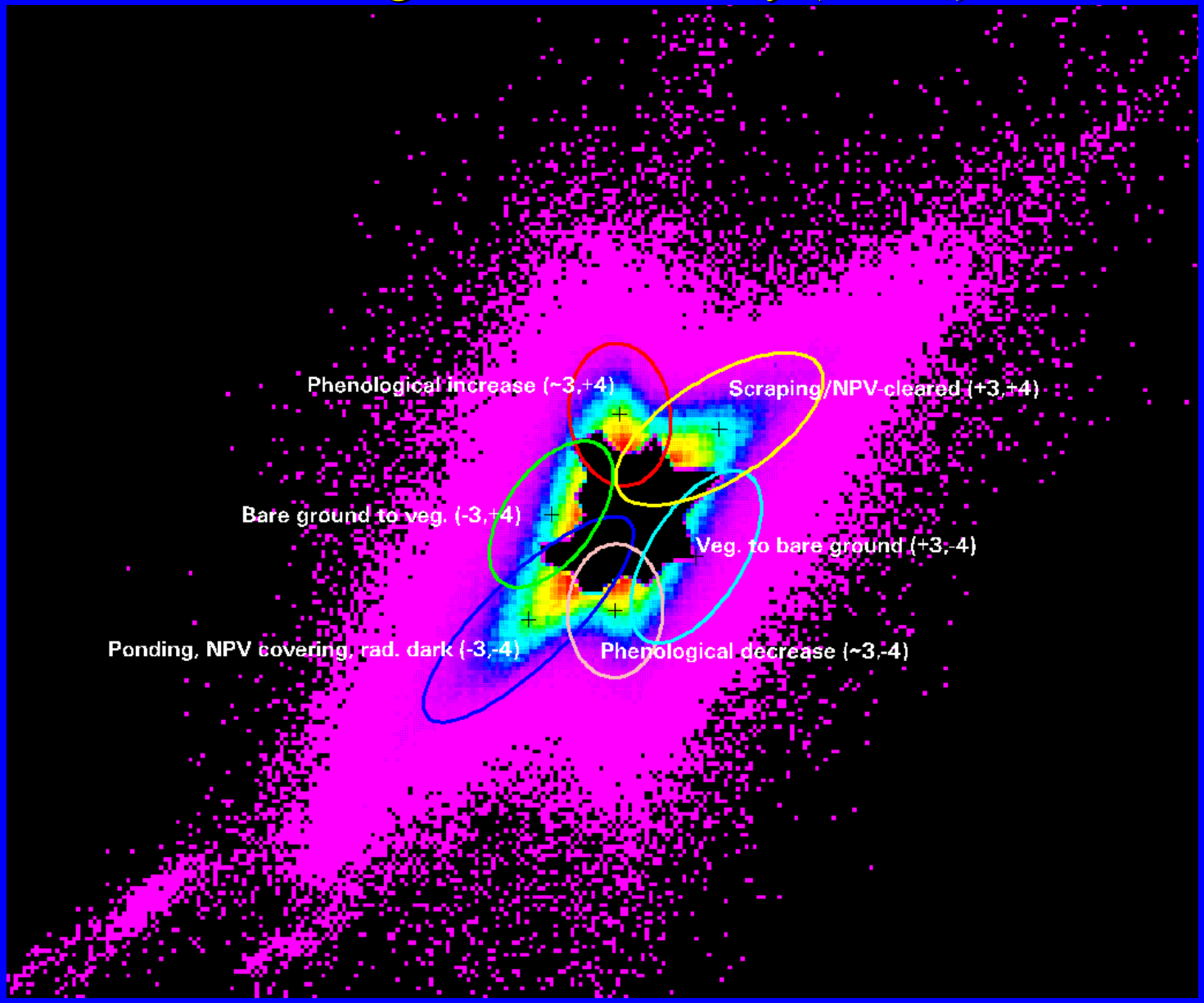
Mask Non-Change Areas

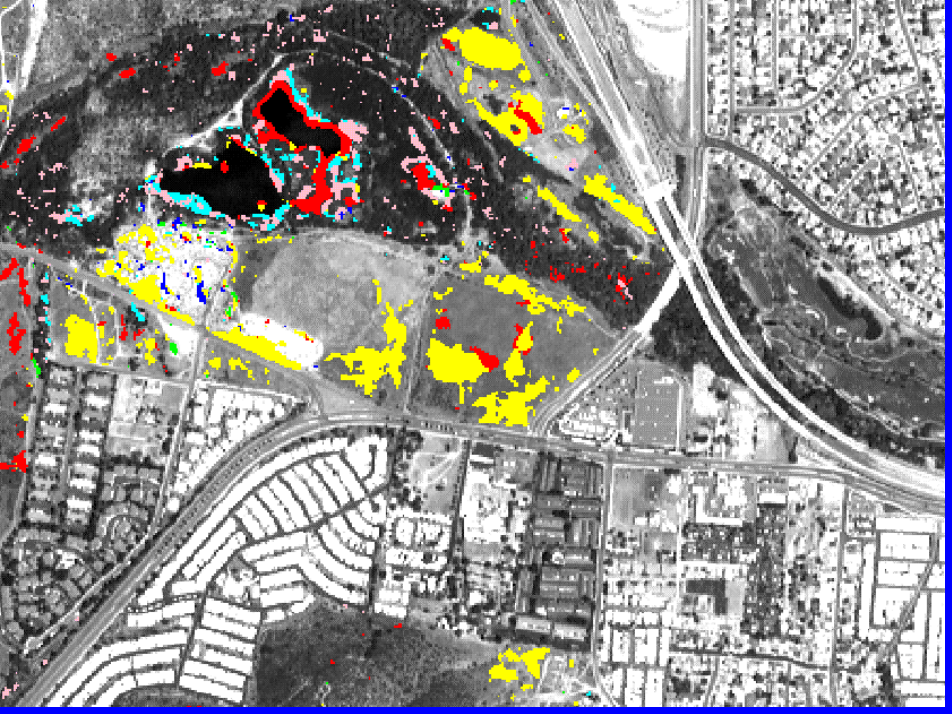
- ~50 spectral classes generated from 3-layer difference image
- Non-change classes interactively determined using feature-space plots and image viewing
- Areas classified as non-change are masked from the continuous difference image
- The remaining “change” pixels are then classified

NASA Food and Fiber Applications of Remote Sensing (FFARS)
San Diego State University (SDSU)



NASA Food and Fiber Applications of Remote Sensing (FFARS)
San Diego State University (SDSU)

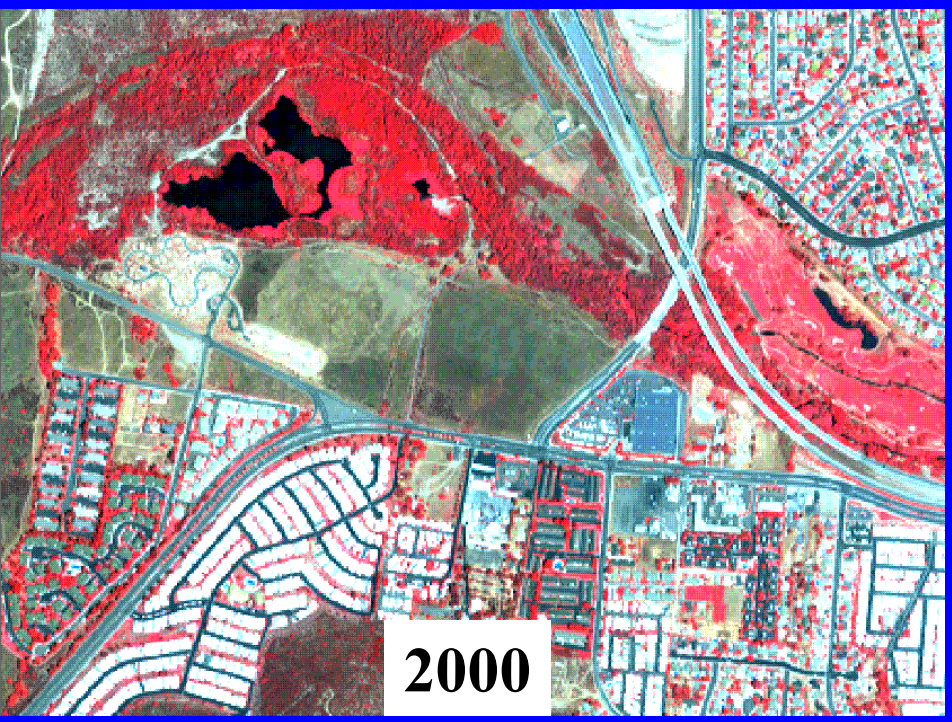


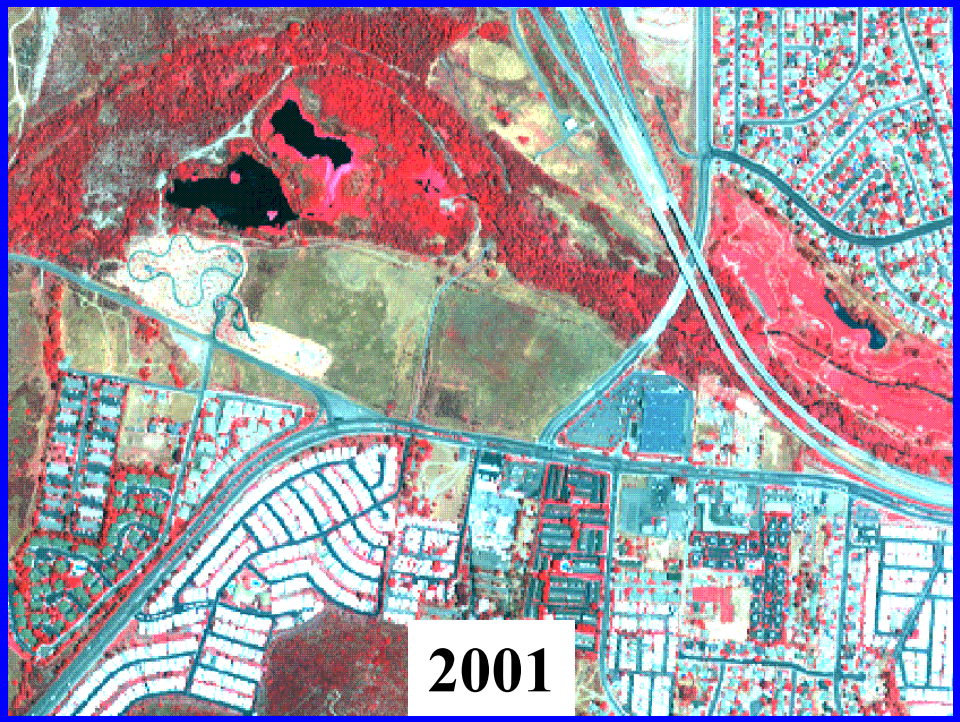


Change Vector Classes

- NPV to Clear, Rad. Increase
- Ponding, Rad. Decrease
- NPV/Bare to Green Veg.
- Green Veg. to Bare/NPV
- Phenological Increase
- Phenological Decrease

0 Kilometers 1.5

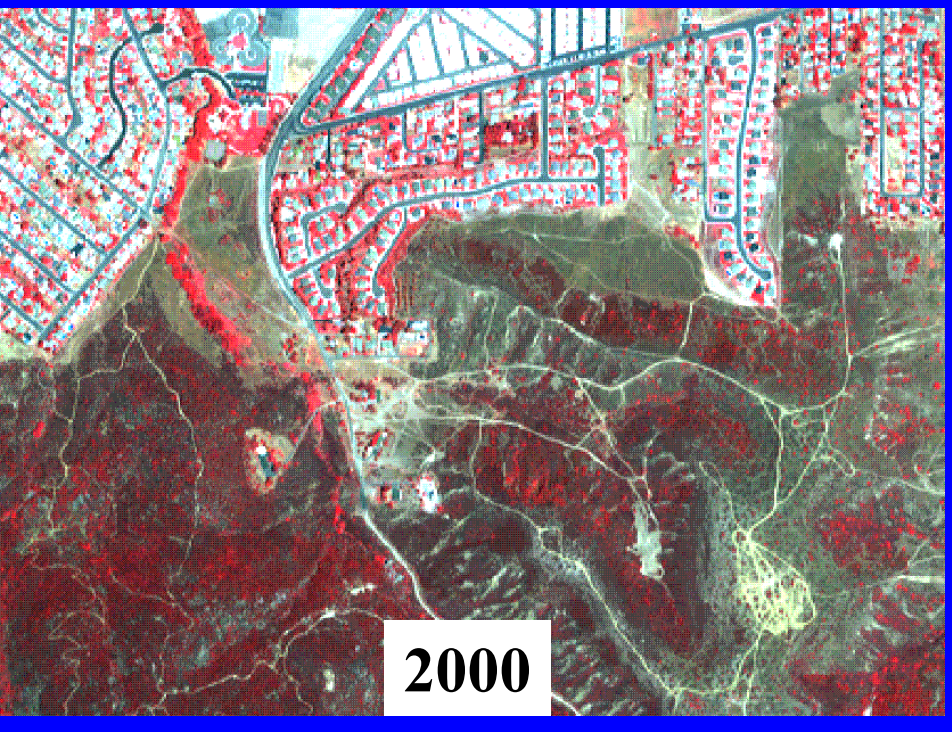


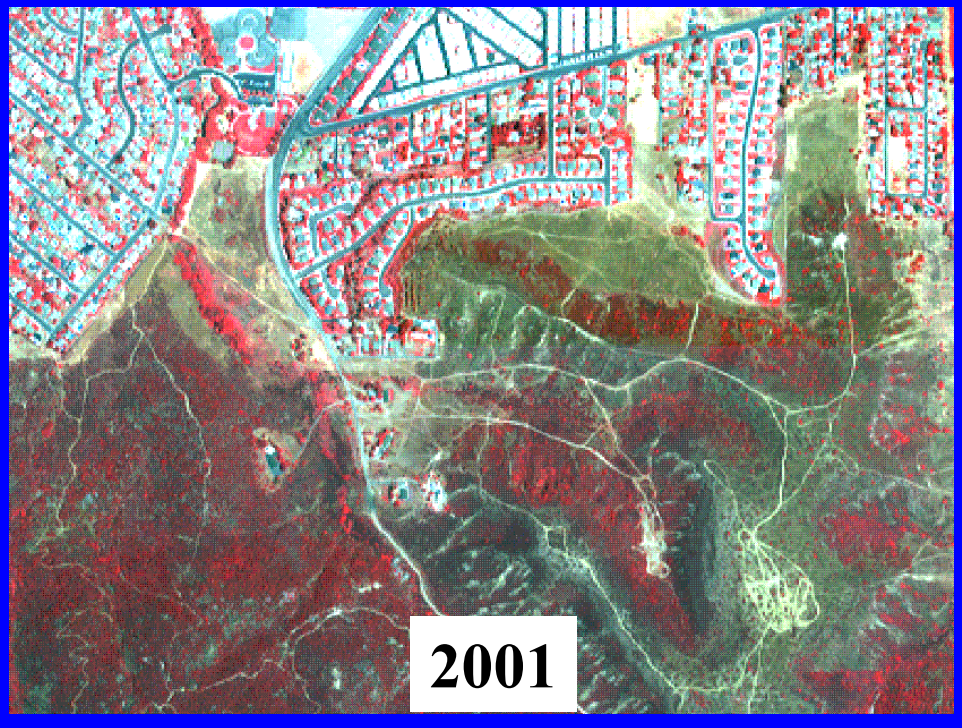


Change Vector Classes

- NPV to Clear, Rad. Increase
- Ponding, Rad. Decrease
- NPV/Bare to Green Veg.
- Green Veg. to Bare/NPV
- Phenological Increase
- Phenological Decrease

0 Kilometers 1.5

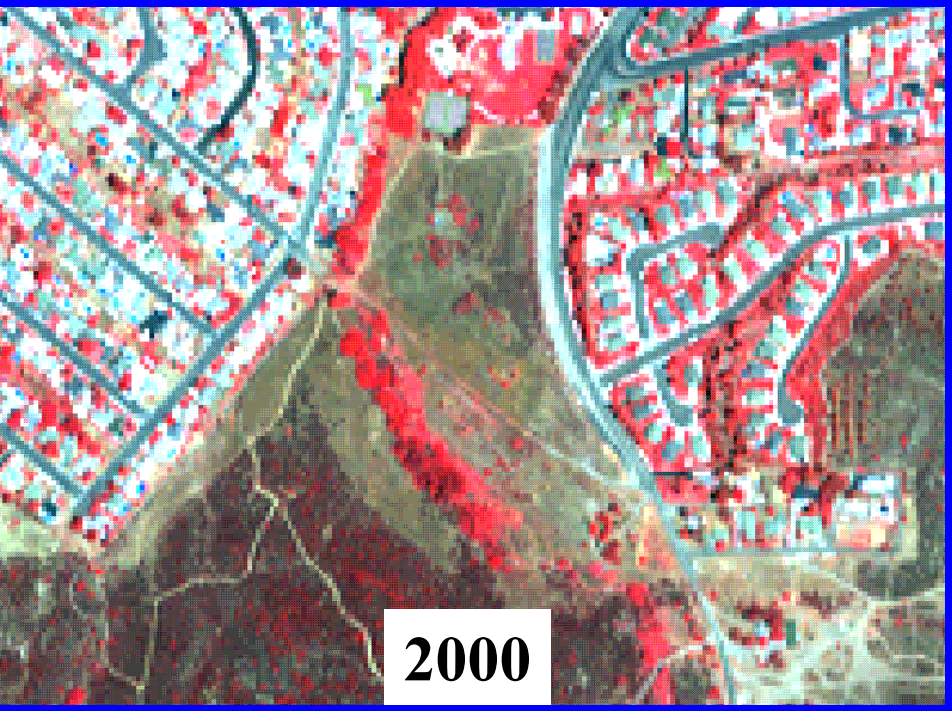


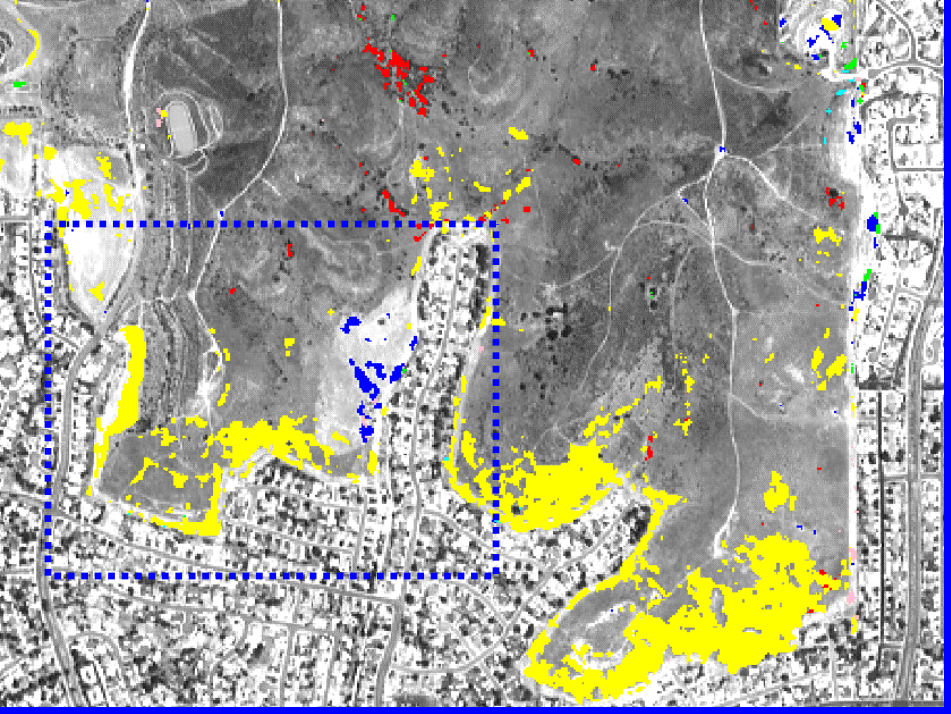


Change Vector Classes

- NPV to Clear, Rad. Increase
- Ponding, Rad. Decrease
- NPV/Bare to Green Veg.
- Green Veg. to Bare/NPV
- Phenological Increase
- Phenological Decrease

0 — Kilometers — 0.75

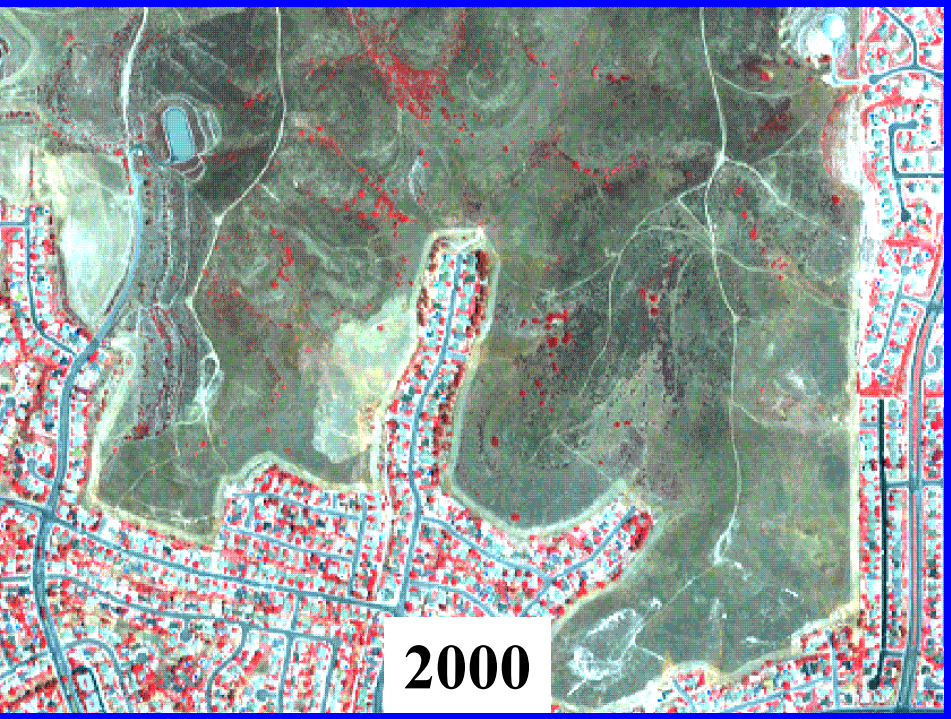


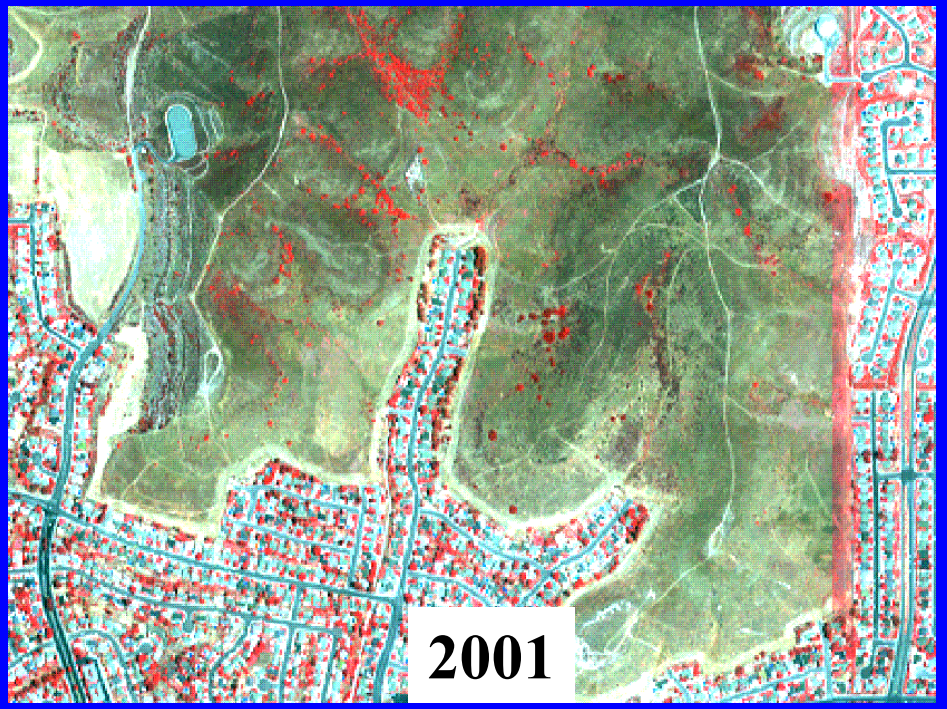


Change Vector Classes

- NPV to Clear, Rad. Increase
- Ponding, Rad. Decrease
- NPV/Bare to Green Veg.
- Green Veg. to Bare/NPV
- Phenological Increase
- Phenological Decrease

0 Kilometers 1.5

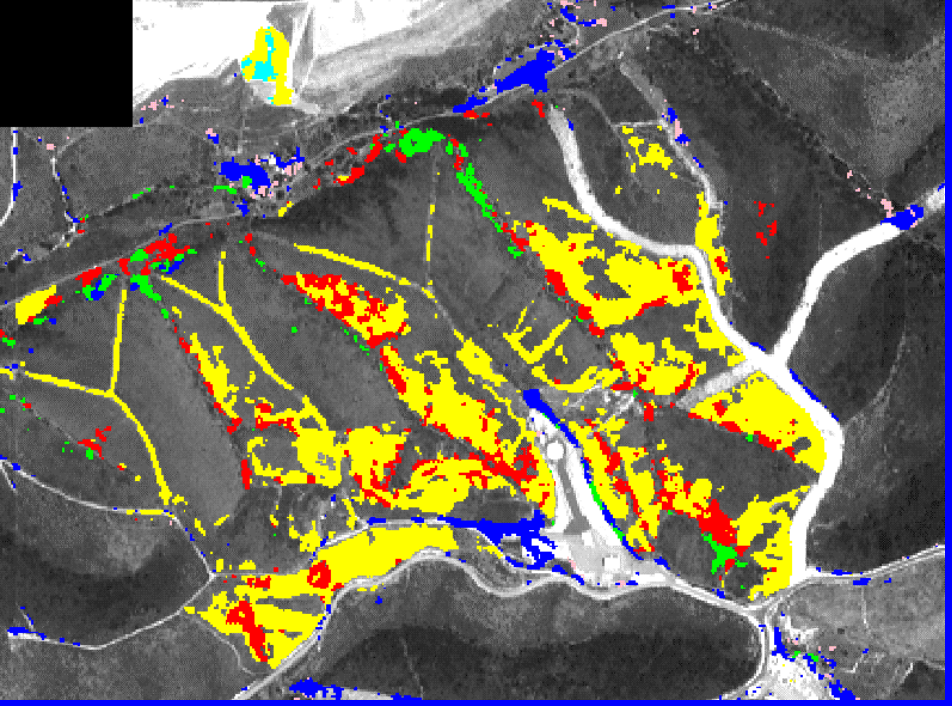




Change Vector Classes

- NPV to Clear, Rad. Increase
- Ponding, Rad. Decrease
- NPV/Bare to Green Veg.
- Green Veg. to Bare/NPV
- Phenological Increase
- Phenological Decrease

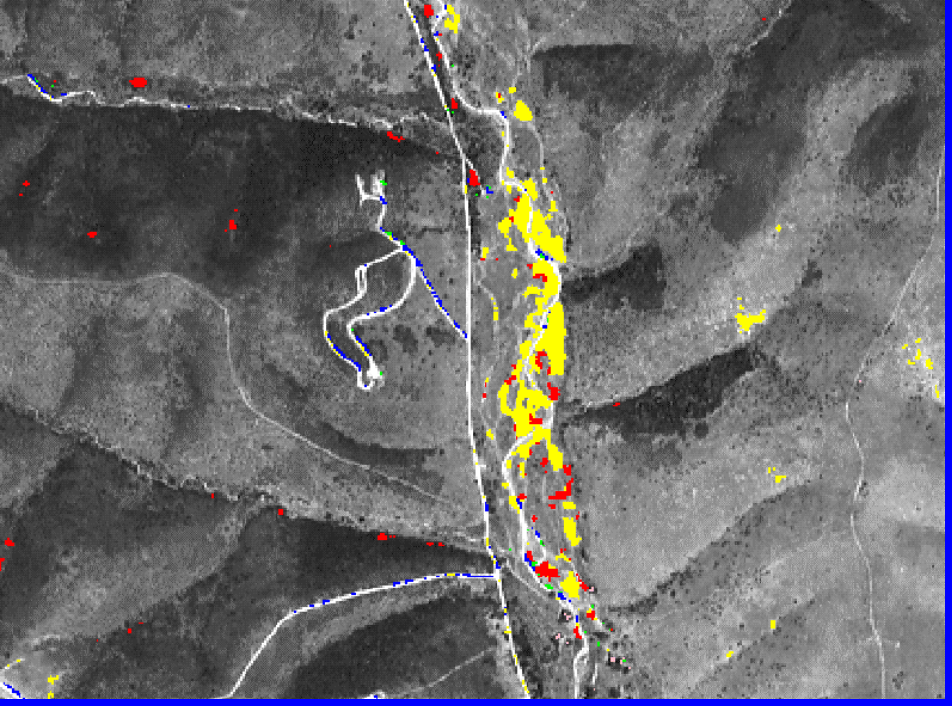
0 Kilometers 0.75



Change Vector Classes

- NPV to Clear, Rad. Increase
- Ponding, Rad. Decrease
- NPV/Bare to Green Veg.
- Green Veg. to Bare/NPV
- Phenological Increase
- Phenological Decrease

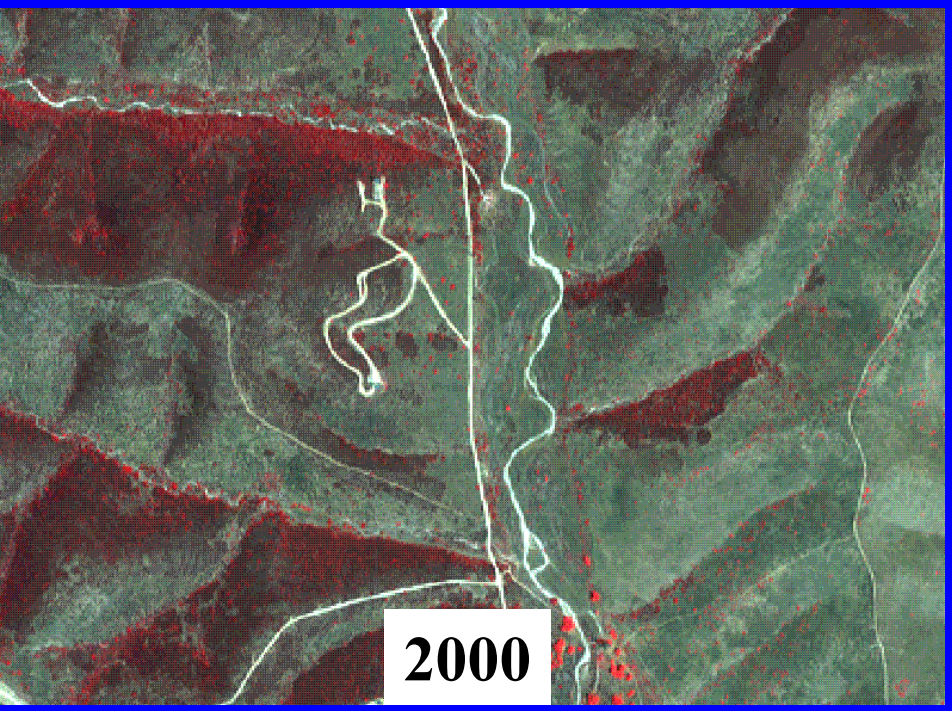
0 Kilometers 1.5

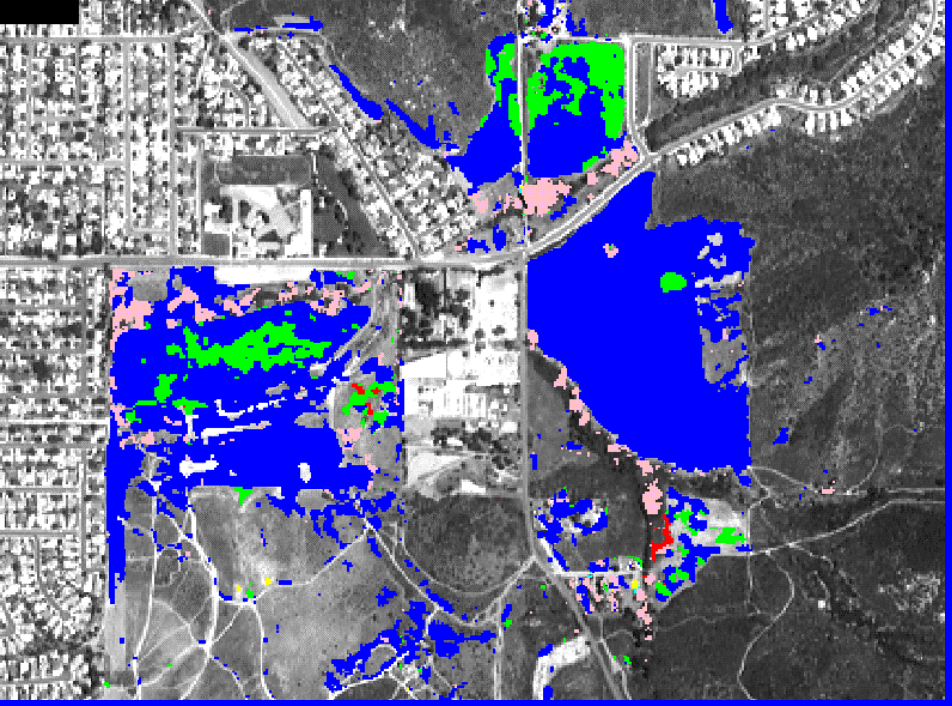


Change Vector Classes

- NPV to Clear, Rad. Increase
- Ponding, Rad. Decrease
- NPV/Bare to Green Veg.
- Green Veg. to Bare/NPV
- Phenological Increase
- Phenological Decrease

0 Kilometers 1.5

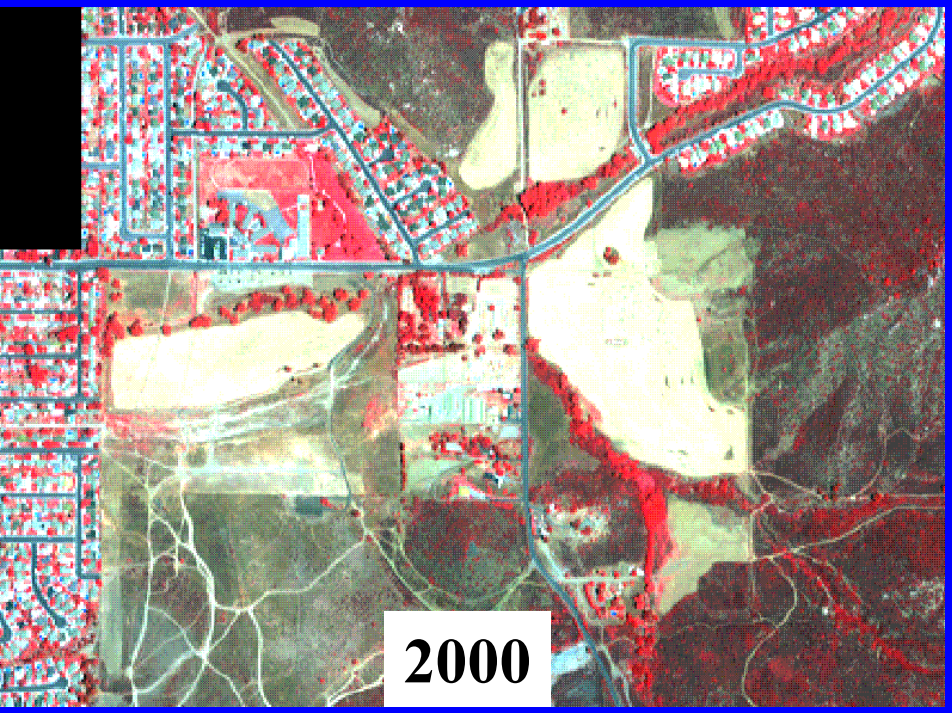


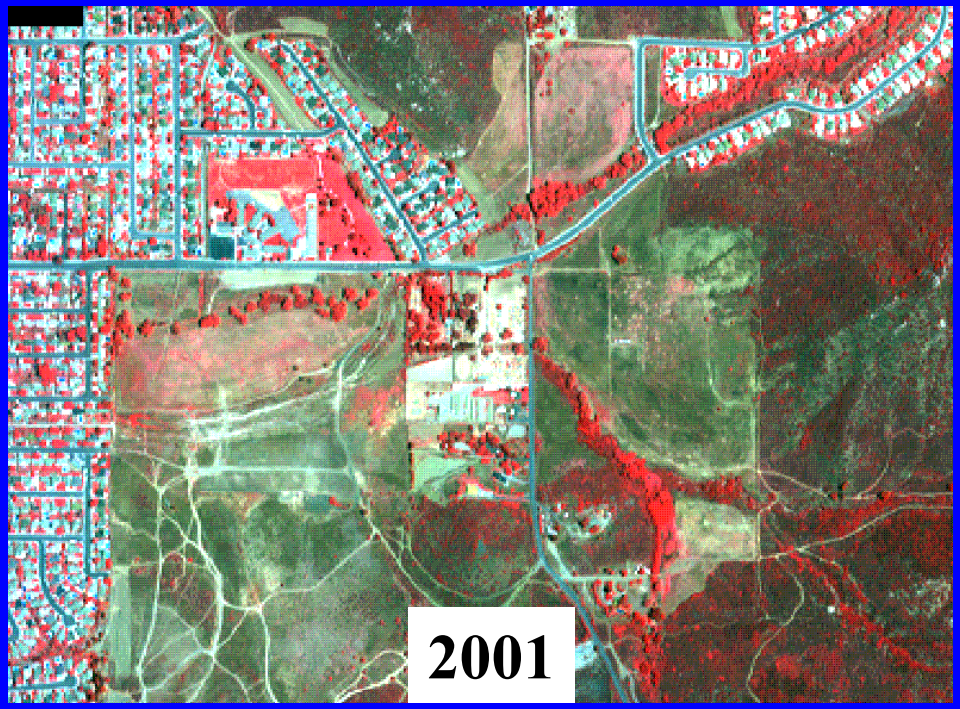


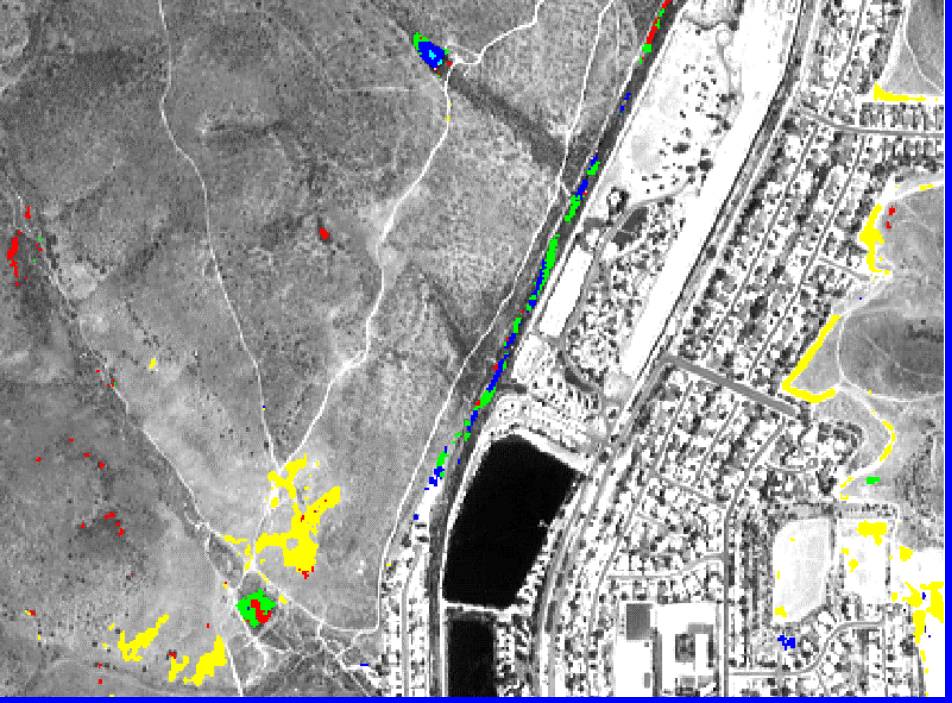
Change Vector Classes

- NPV to Clear, Rad. Increase
- Ponding, Rad. Decrease
- NPV/Bare to Green Veg.
- Green Veg. to Bare/NPV
- Phenological Increase
- Phenological Decrease

0 Kilometers 1.5



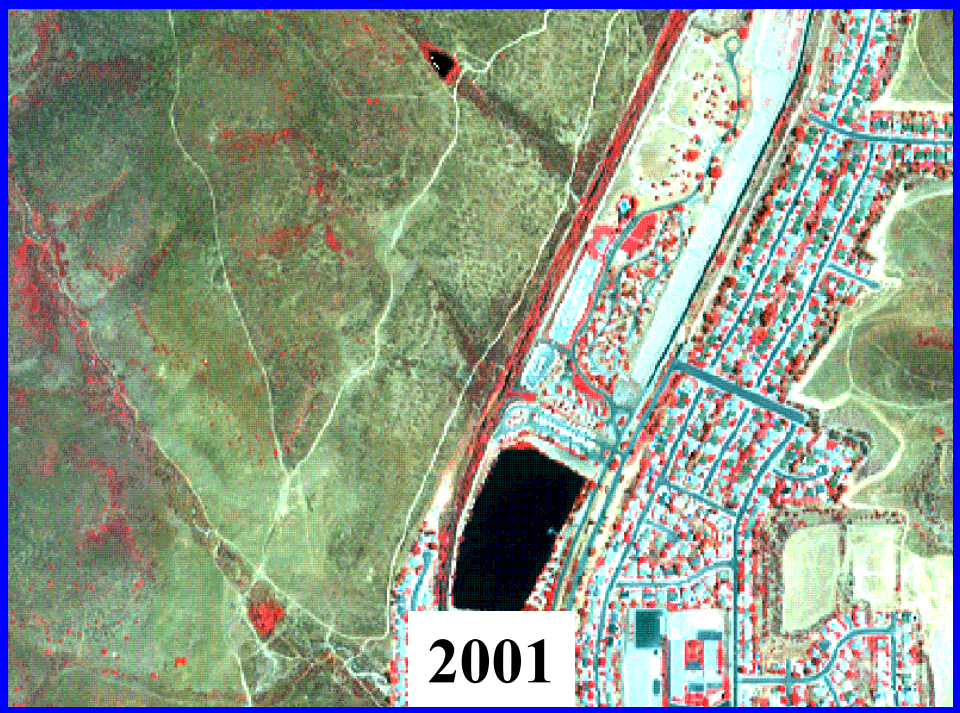


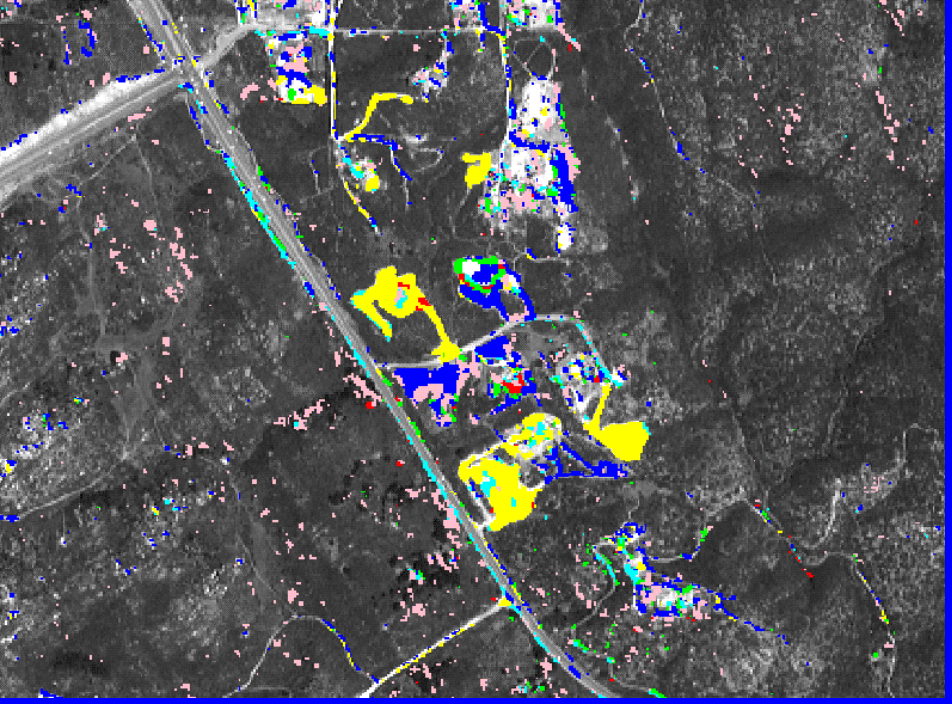


Change Vector Classes

- NPV to Clear, Rad. Increase
- Ponding, Rad. Decrease
- NPV/Bare to Green Veg.
- Green Veg. to Bare/NPV
- Phenological Increase
- Phenological Decrease

0 Kilometers 1.5

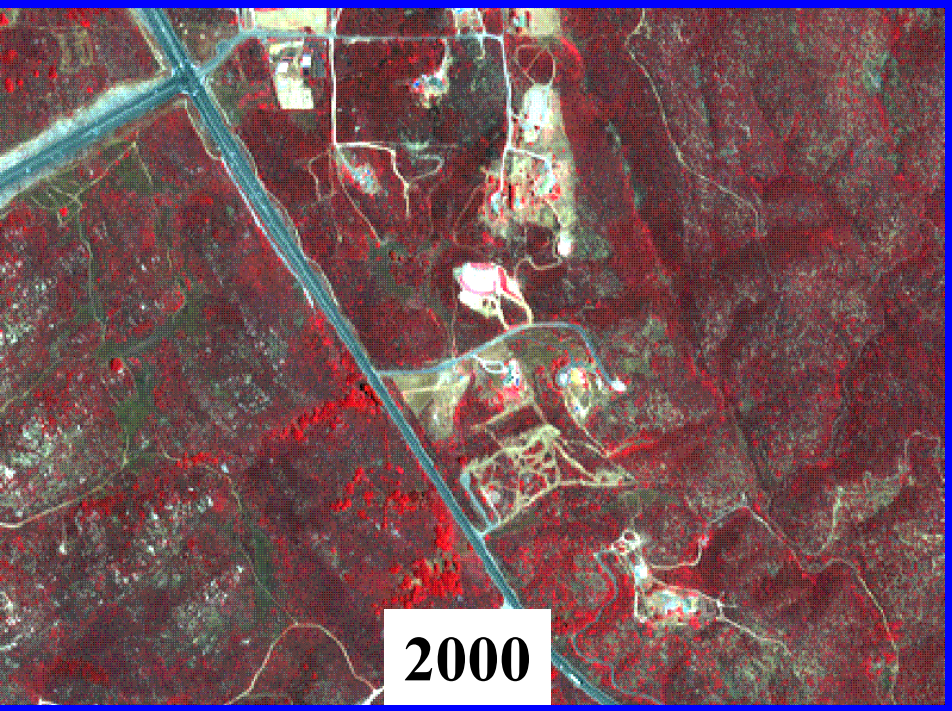


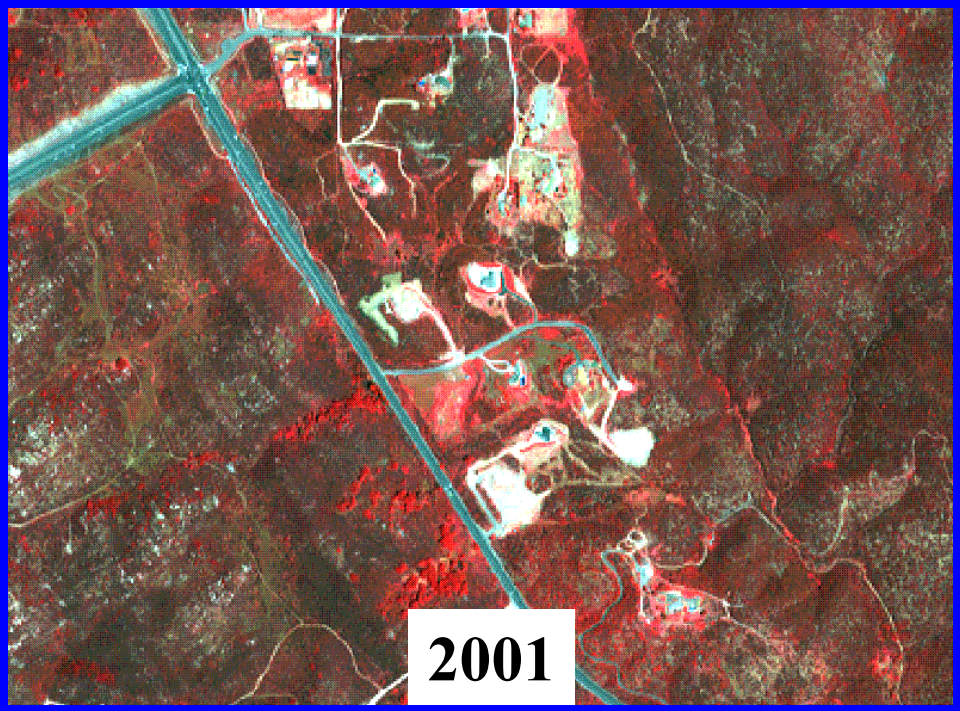


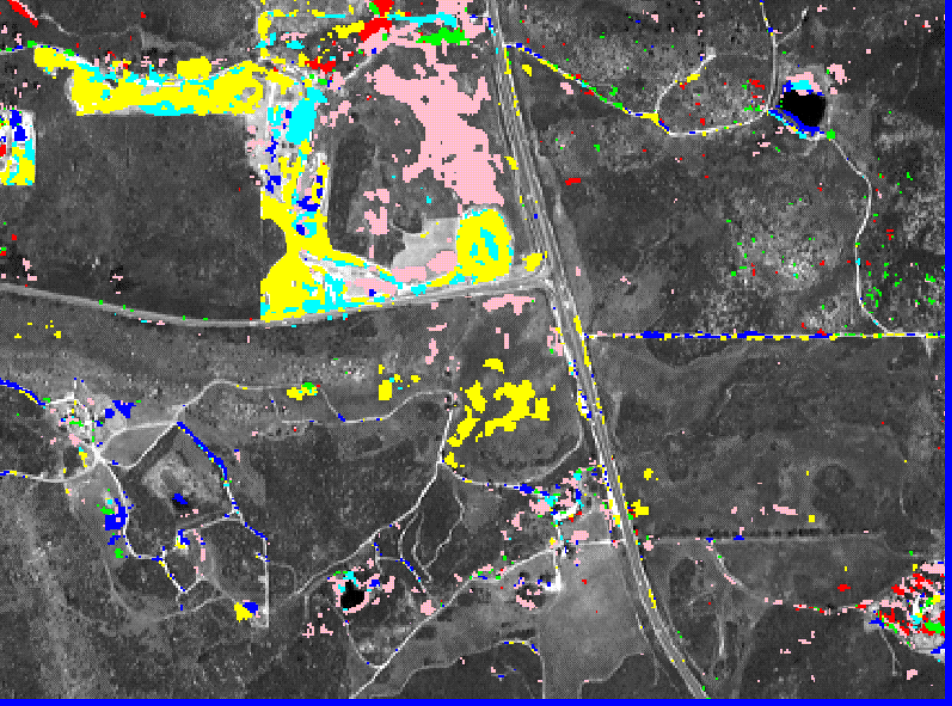
Change Vector Classes

- NPV to Clear, Rad. Increase
- Ponding, Rad. Decrease
- NPV/Bare to Green Veg.
- Green Veg. to Bare/NPV
- Phenological Increase
- Phenological Decrease

0 Kilometers 1.5



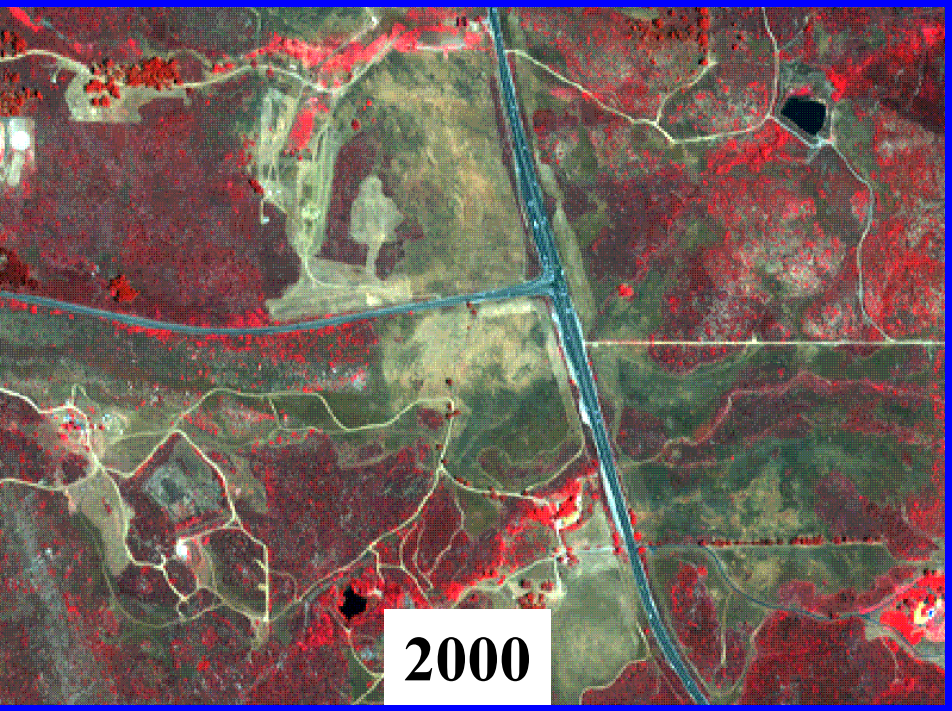


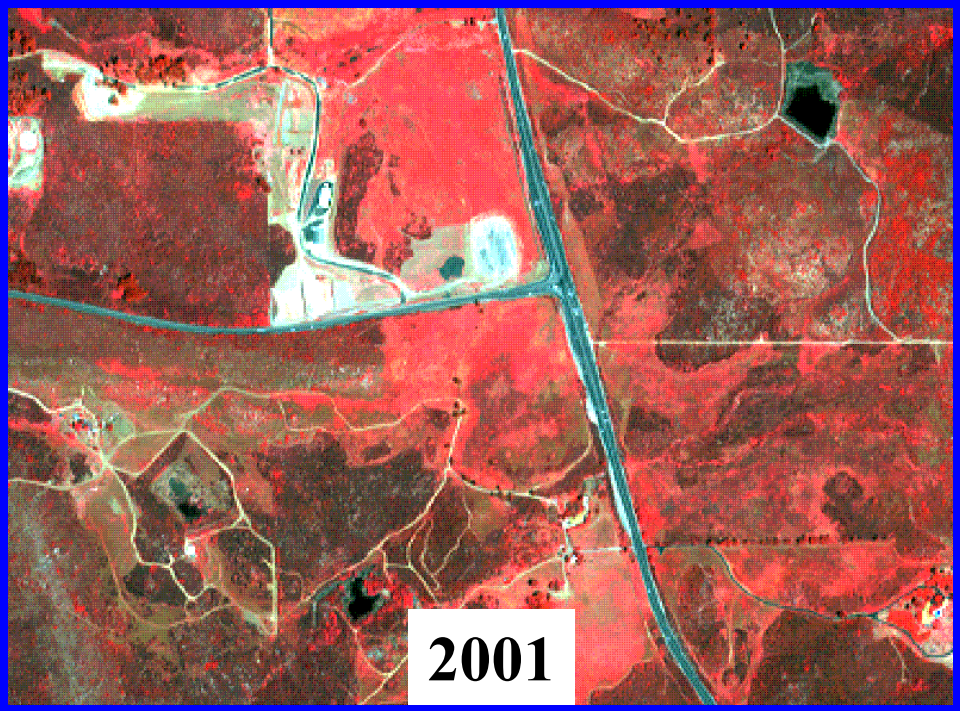


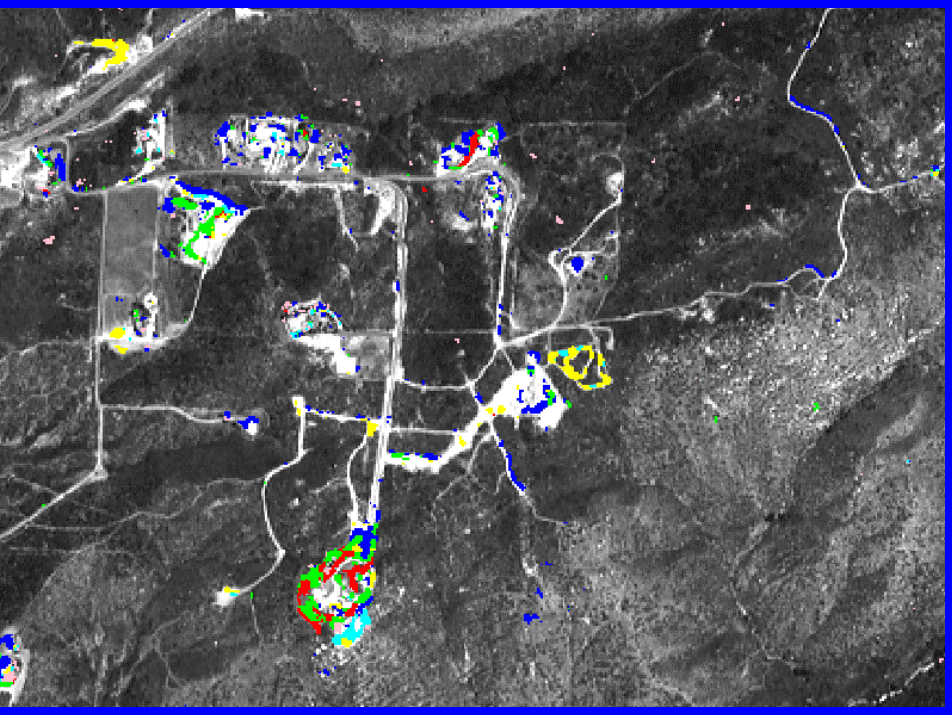
Change Vector Classes

- NPV to Clear, Rad. Increase
- Ponding, Rad. Decrease
- NPV/Bare to Green Veg.
- Green Veg. to Bare/NPV
- Phenological Increase
- Phenological Decrease

0 Kilometers 1.5



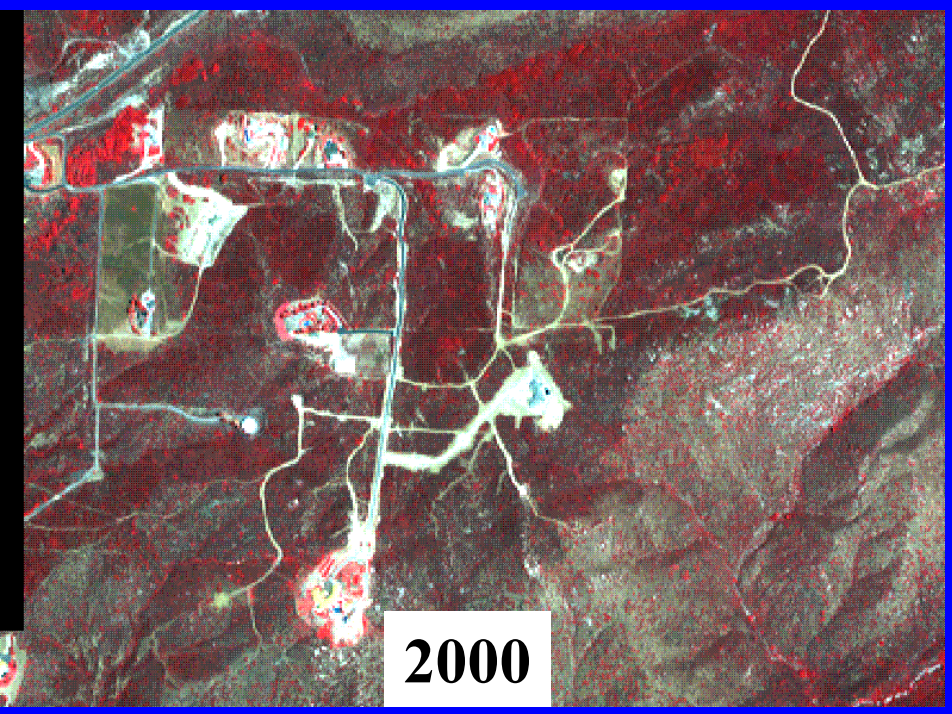


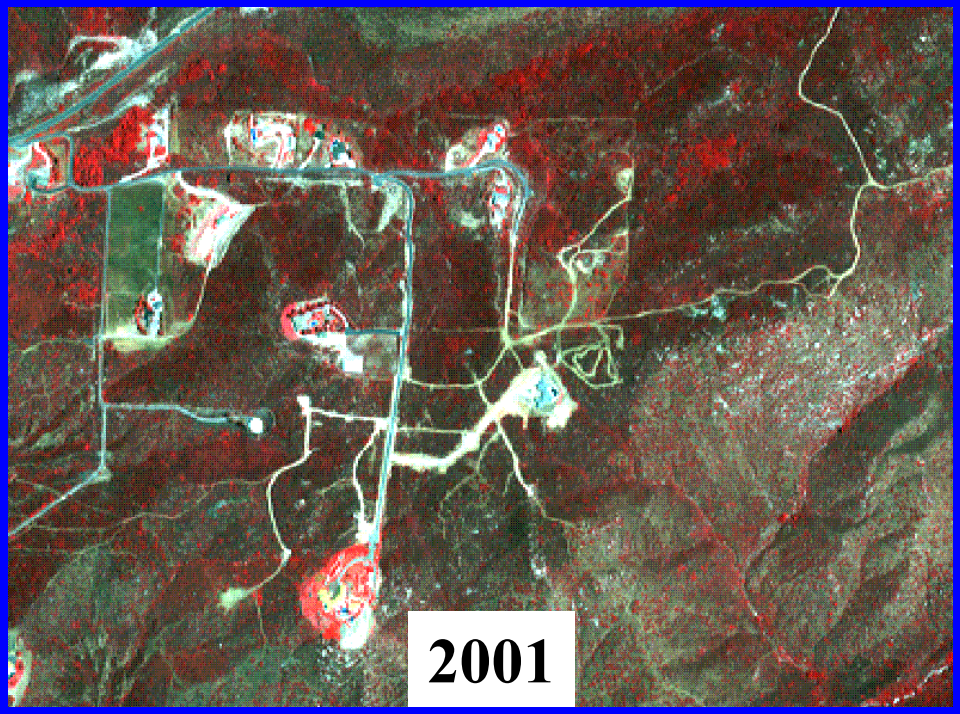


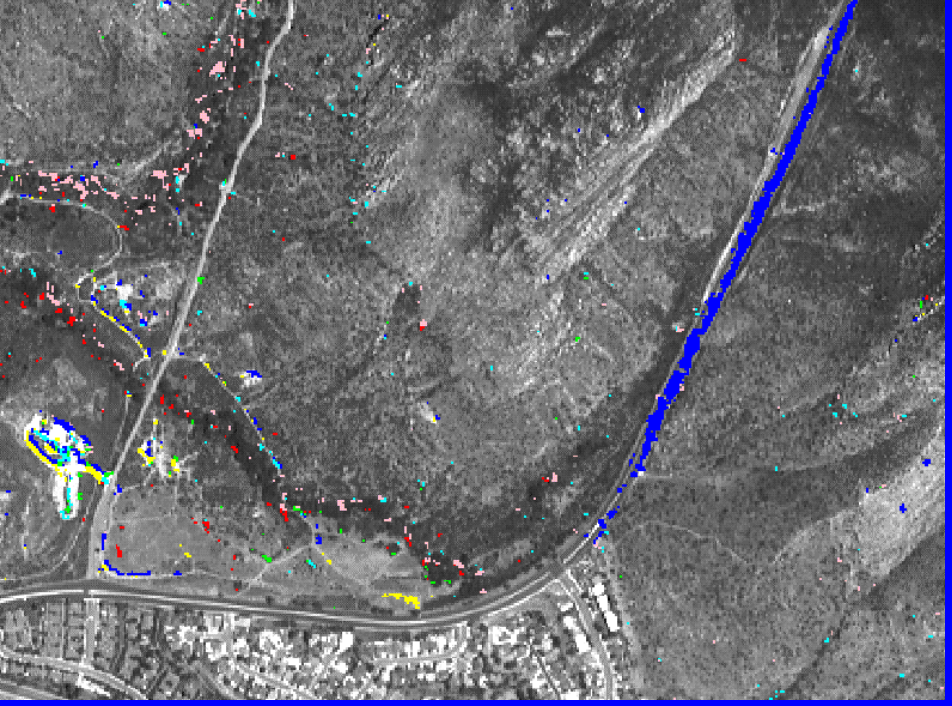
Change Vector Classes

- NPV to Clear, Rad. Increase
- Ponding, Rad. Decrease
- NPV/Bare to Green Veg.
- Green Veg. to Bare/NPV
- Phenological Increase
- Phenological Decrease

0 Kilometers 1.5



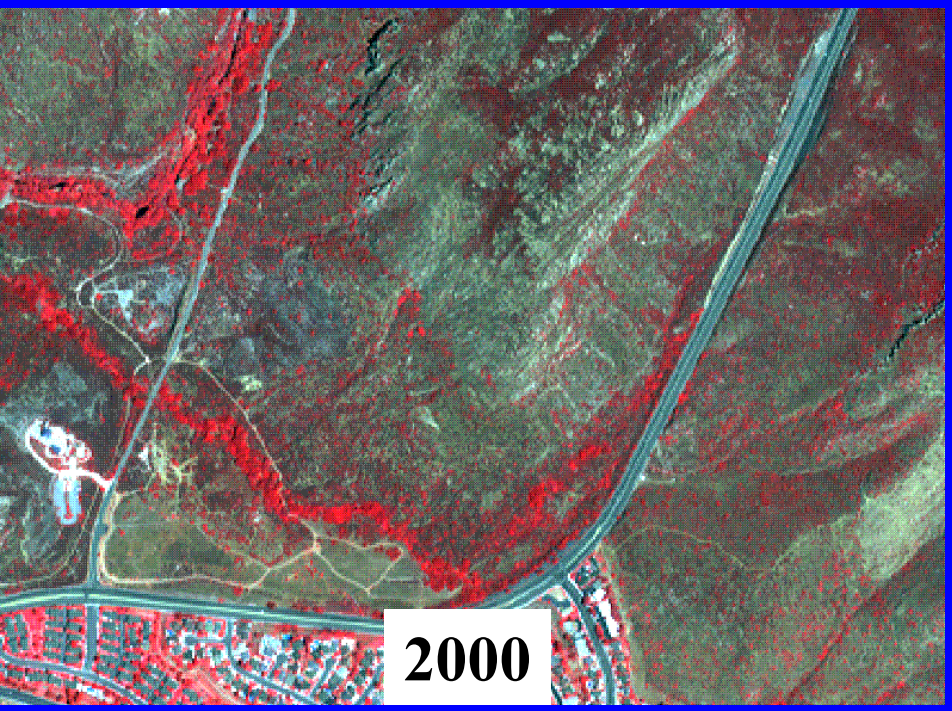


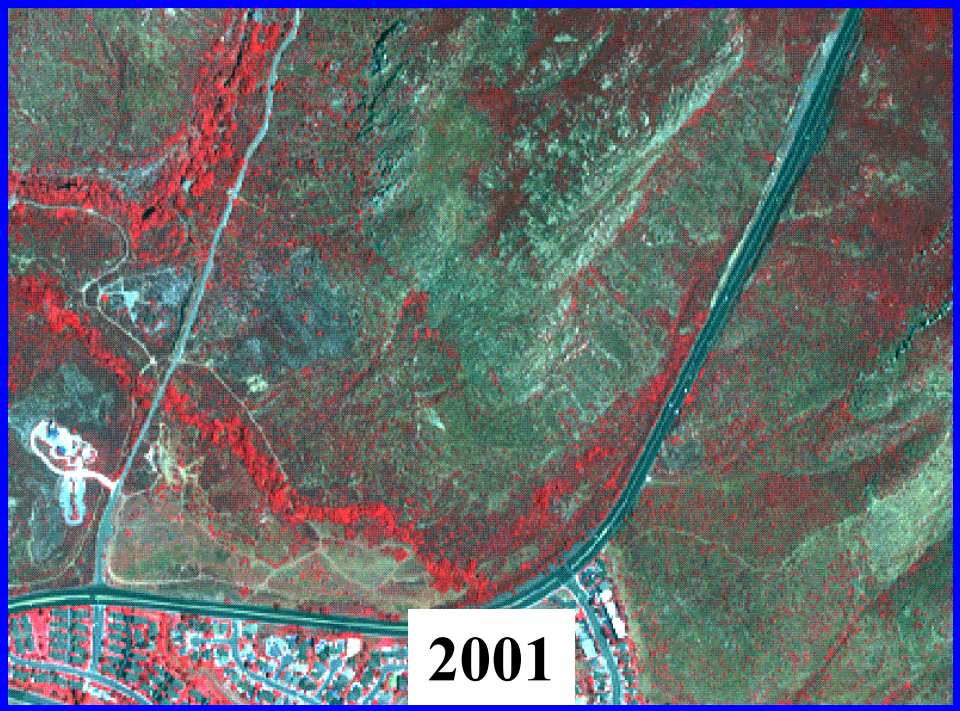


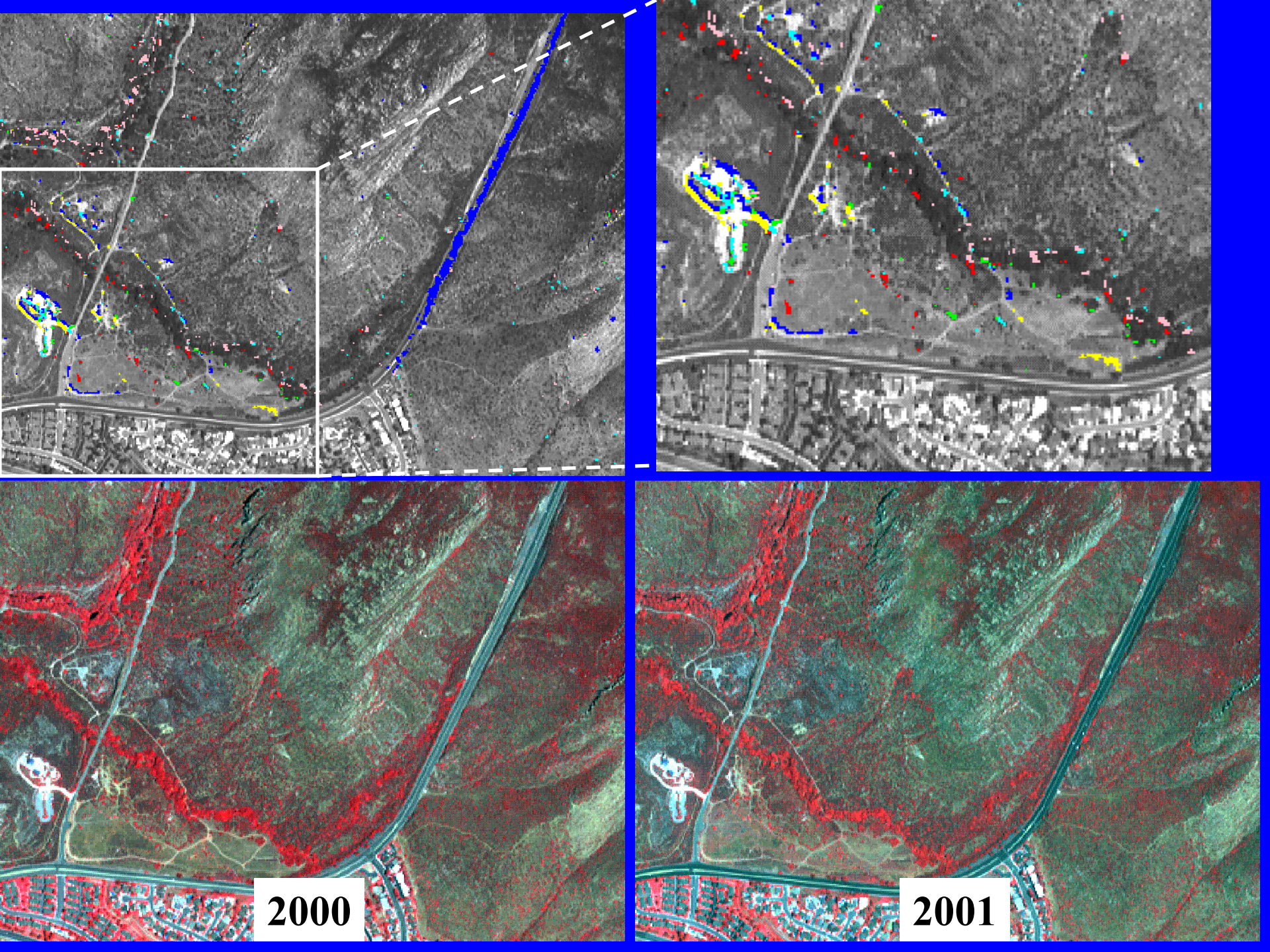
Change Vector Classes

- NPV to Clear, Rad. Increase
- Ponding, Rad. Decrease
- NPV/Bare to Green Veg.
- Green Veg. to Bare/NPV
- Phenological Increase
- Phenological Decrease

0 Kilometers 1.5






2000
2001

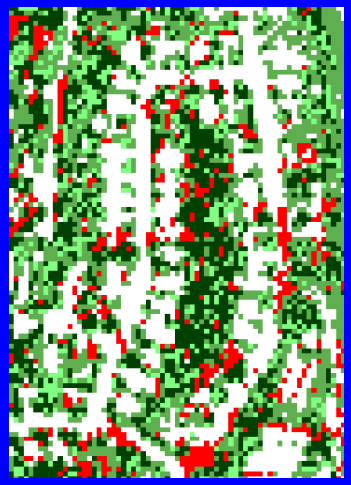
Area and Magnitude of Change

- Inclusion of lower magnitude radiometric changes increases noise in classification
- Computer classification versus human interpretation
  - Magnitude of change
  - Size/number of features
  - Change class labeling precision
- Hiking trail changes in 4 m multispectral IKONOS ??
  - Exploring with spectral mixture analysis (SMA)
  - We are obtaining high shade percentages ??

Conclusions

- Change vector classification with IKONOS imagery highlights changes of interest
- Interpretation of exact nature and implications of change required by analyst or land manager
- Changes at or below the scale of the pixel are not likely to be detected or may be considered noise
- Spatial registration of multidate IKONOS precision master imagery is very good

Classifying Urban Landscaped Vegetation

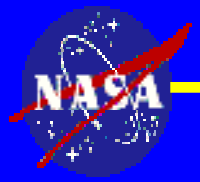


IKONOS Classification

Single Family Residential

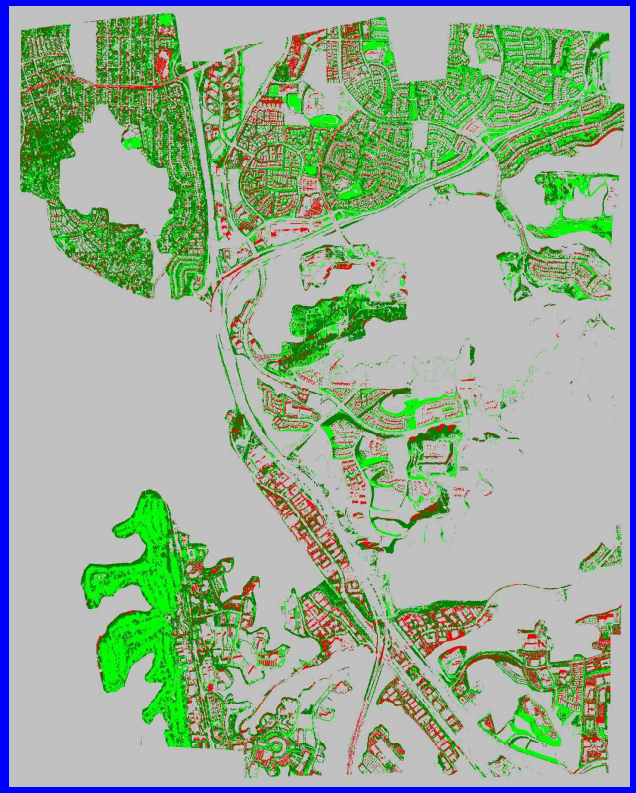
IKONOS Classification

Multiple Family Residential



Classifying Urban Landscaped Vegetation

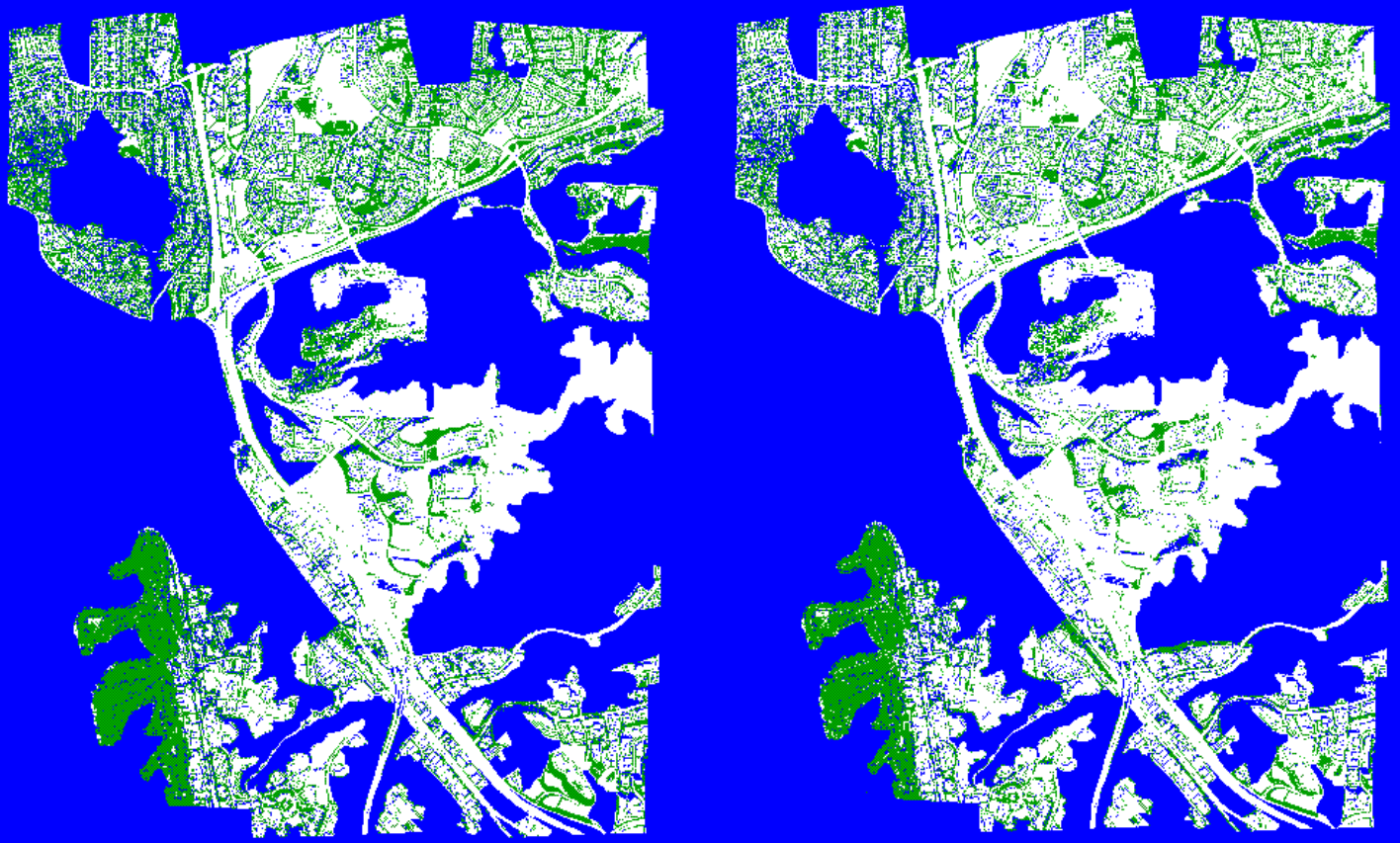
Unsupervised Classification



Supervised Classification

NASA AgriCast SDSU

Classifying Urban Landscaped Vegetation



IKONOS NDVI Classification

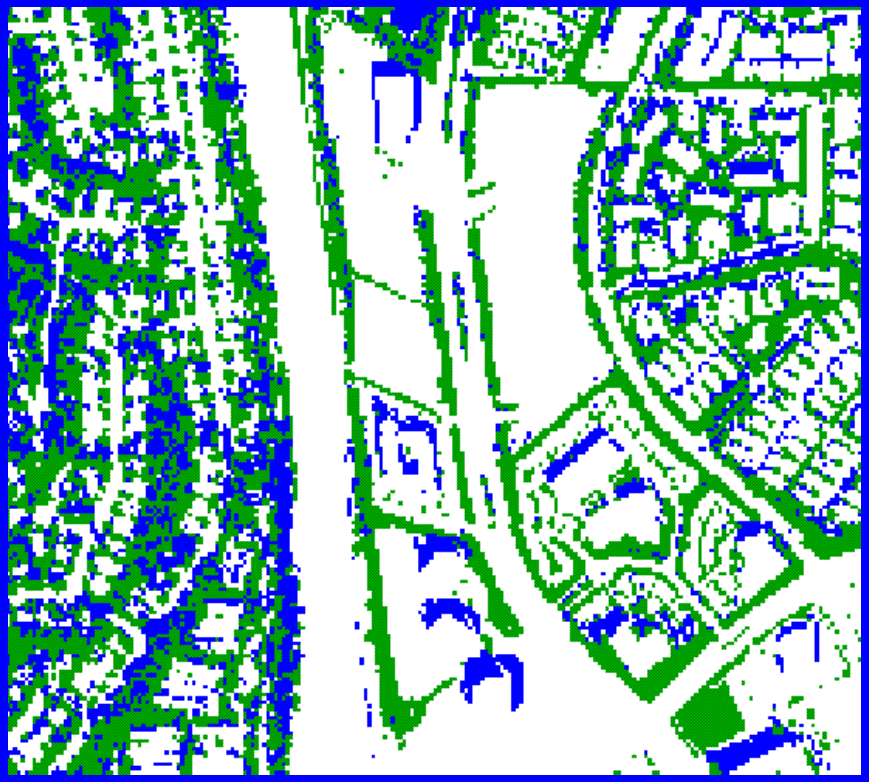
1 m Reference

NASA

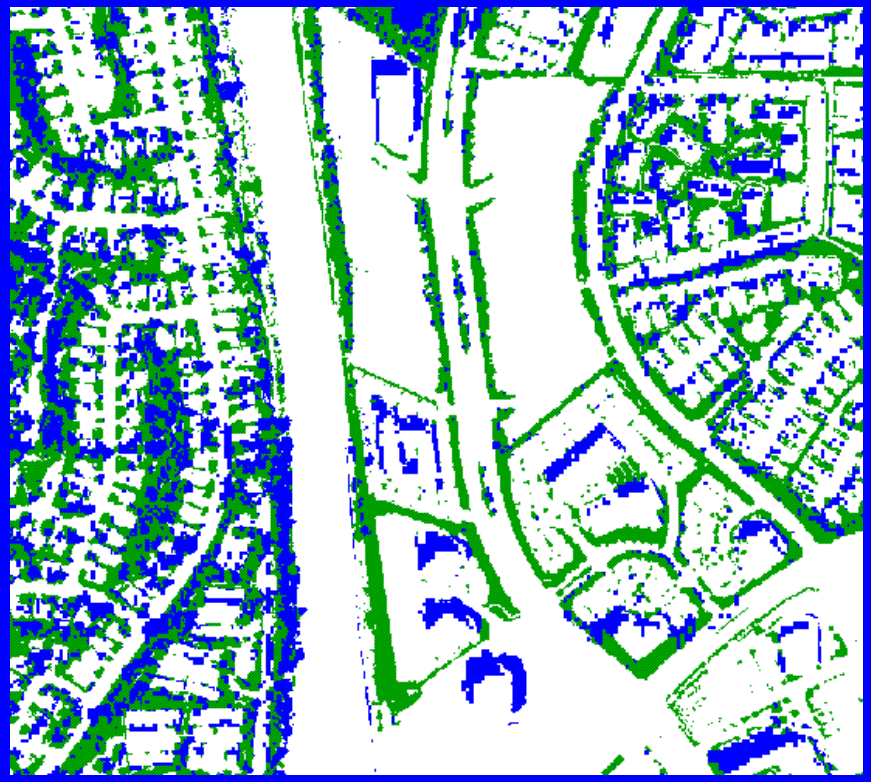
AgriCast

SDSU

Classifying Urban Landscaped Vegetation



IKONOS NDVI Classification



1 m Reference