The Dynamics of a Semi-Arid Region in Response to Climate and Water-Use Policy

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PROJECT OBJECTIVES

5 Principal Areas of Investigation:

1) Response of bajada and valley floor shrub communities to a pronounced drought
2) Response of riparian and phreatophyte communities to a pronounced drought
3) Response of riparian and phreatophyte communities to additional stress imposed by groundwater drawdown
4) Response of all of these groups to increased precipitation and groundwater recharge, and reduced groundwater pumping (recovery)
5) Characteristics and magnitude of change of both the natural and managed systems of Owens Valley over 15 years in response to natural and socially-driven forces

Project Objectives

What are the modes of response of arid and semi-arid systems to climatic variability and anthropogenic stress?

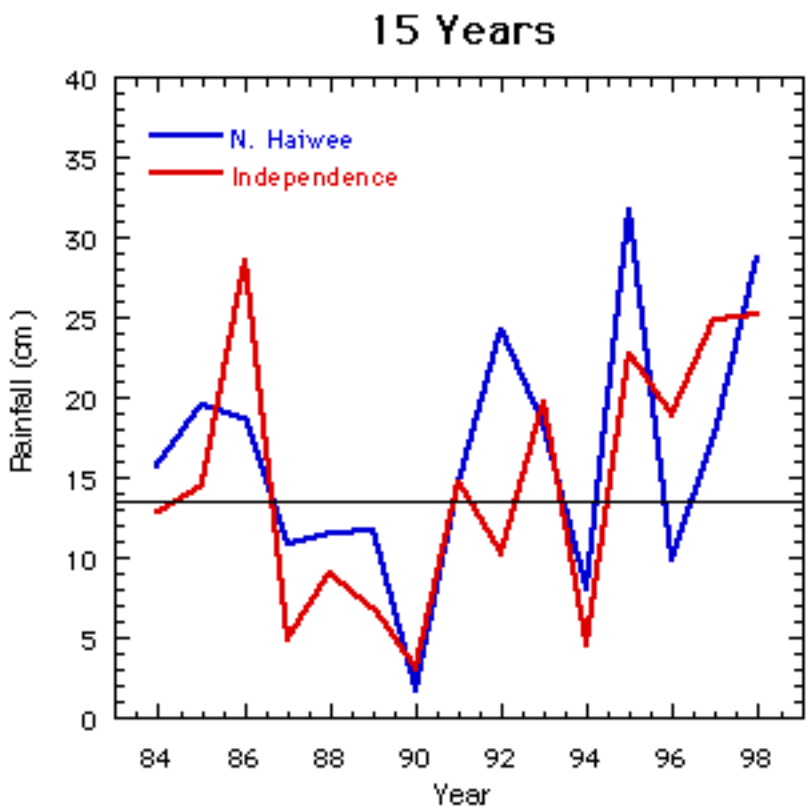
Case Study in Owens Valley CA

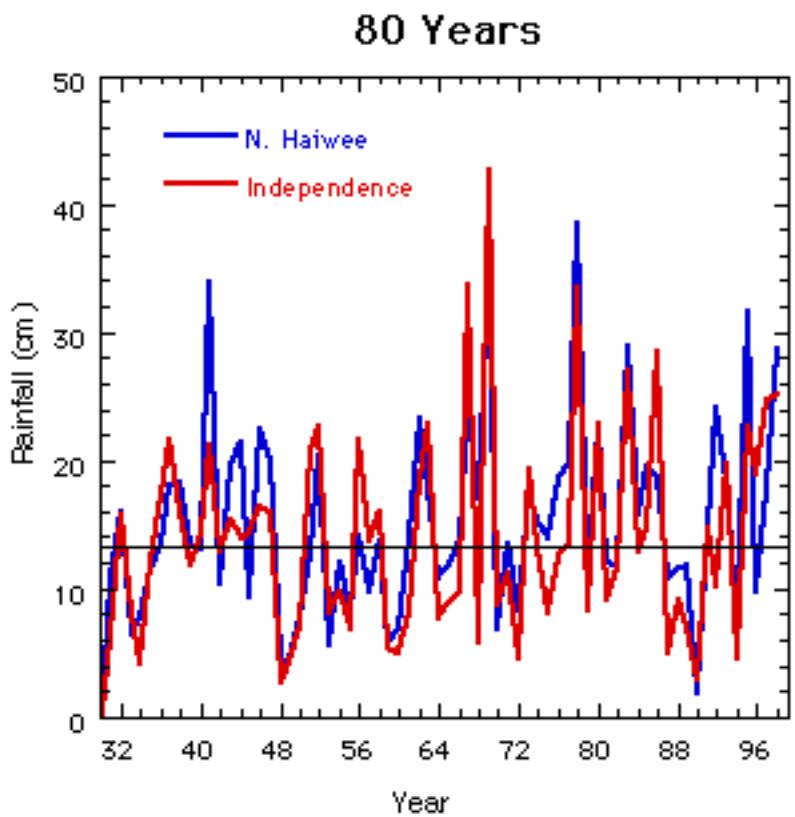
- Climate variability over the last 20 years
- Mosaic of ecosystems (riparian => shrubland)
- Competition for water resources:
  - Ecosystems ⇔ Local ⇔ Regional
- Large changes observed
- Excellent ground control at specific sites
- Management of resources tied to ecological health
- Remotely sensed data required to scale local observations to regional perspectives

Methodology and Approach

- Reduction of Remote Sensing Data to obtain estimates of green vegetation abundance, validation of technique
- Classify change vectors into functional response groups
- Establish relationships between functional groups and physical/climatological/land-use data base
- Determine response of systems to both climatic variability and anthropogenic stress

Precipitation



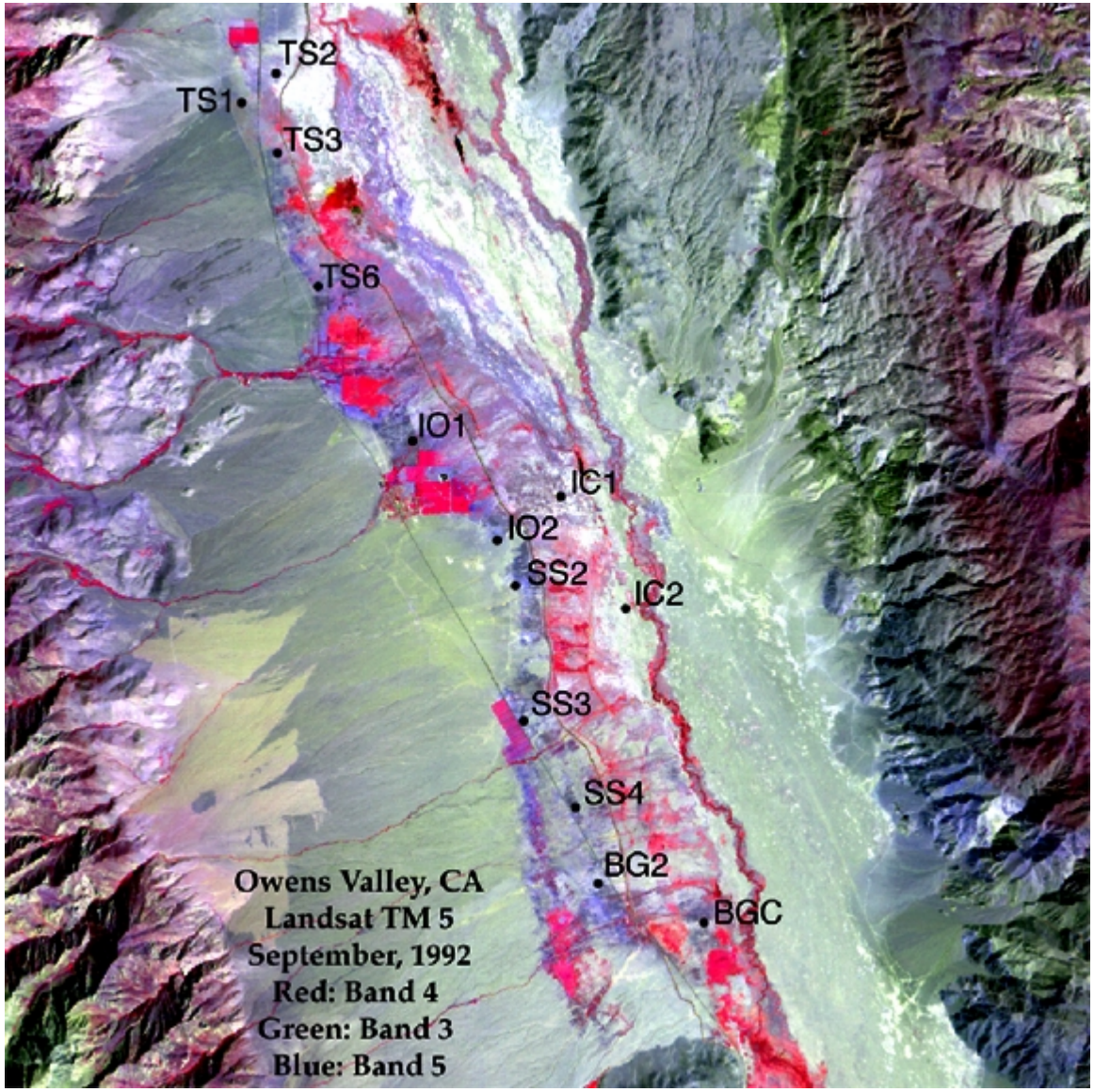


Processing Steps

- Co-registration
- Geo-referencing
- Spectral Calibration

- Spectral Mixing Model
- Field Measurements
- Field Site Location Finding

- Statistical Analysis

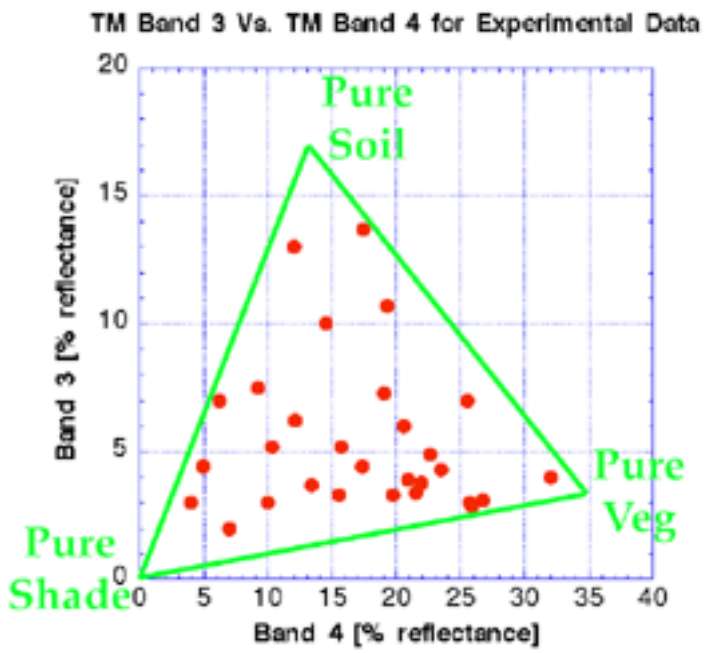

TS2
TS1
TS3
TS6
IO1
IC1
IO2
SS2
IC2
SS3
SS4
BG2
BGC
Owens Valley, CA
Landsat TM 5
September, 1992
Red: Band 4
Green: Band 3
Blue: Band 5

Spectral Mixture Analysis

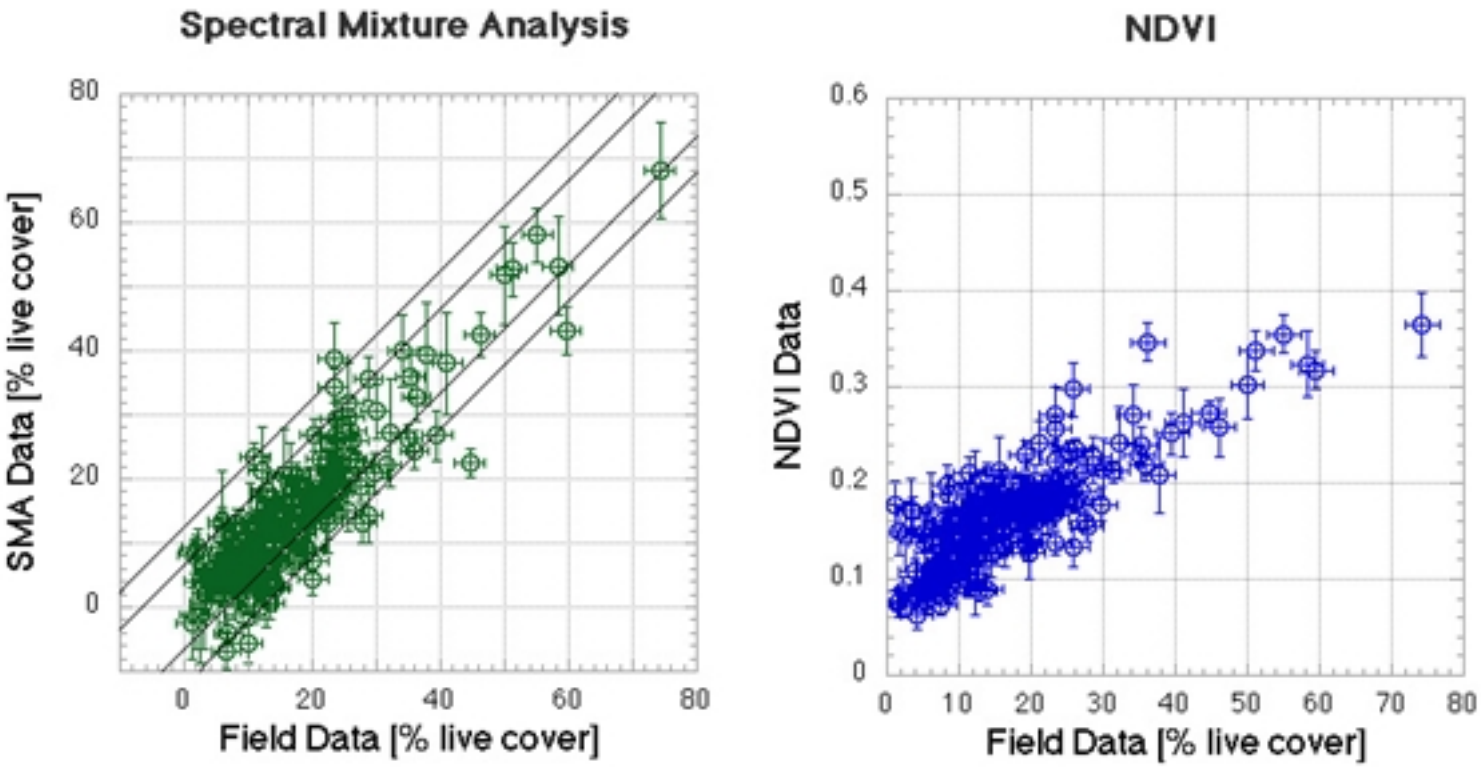
$$DN_b = \sum_{i=1}^{N} F_i DN_{i,b} + E_b$$

$$\sum_{i=1}^{N} F_i = 1$$

- These two equations utilize all 6 (non-thermal) TM bands.
- Constrained so that the sum of the fractions must equal 1.

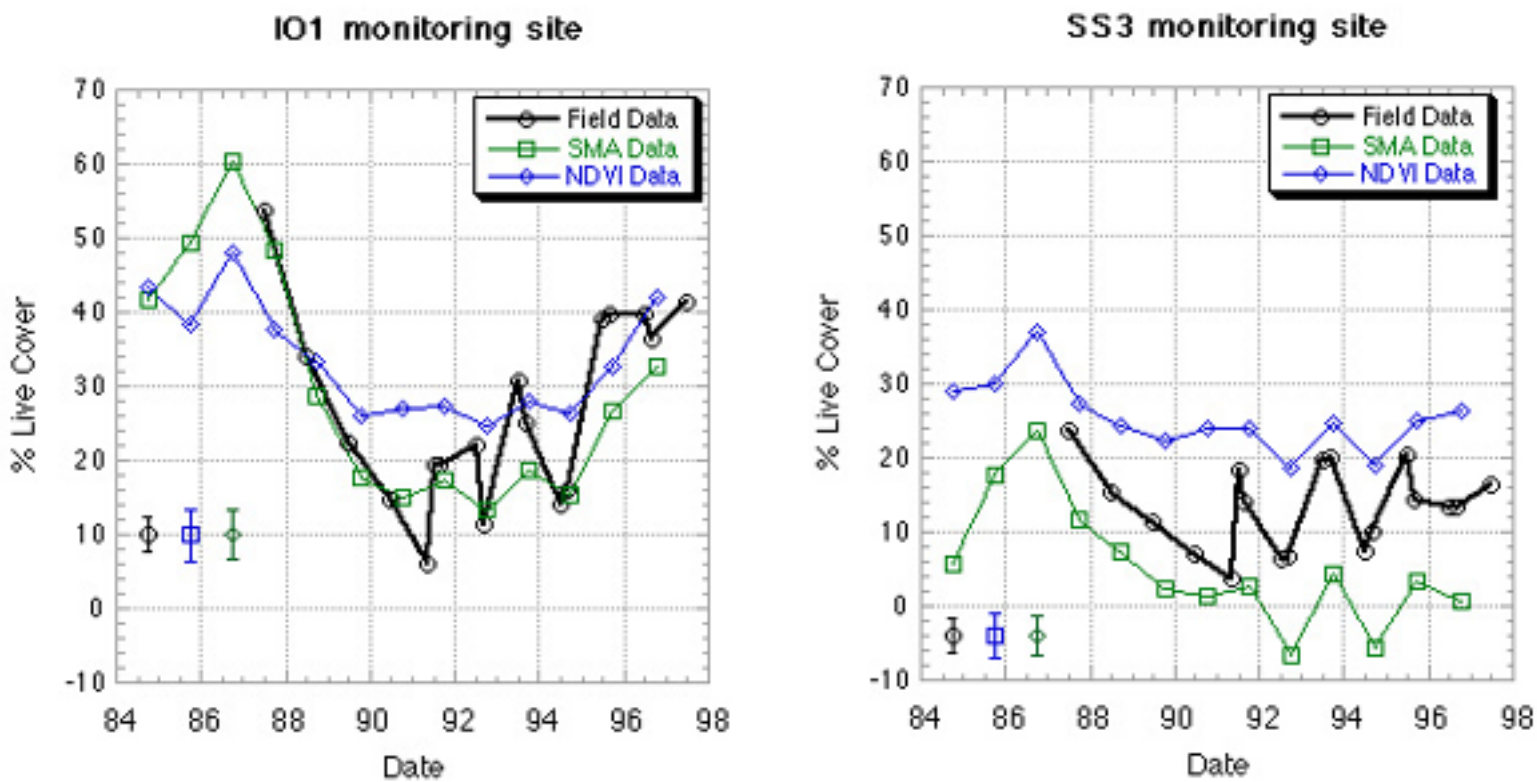


Absolute Abundance



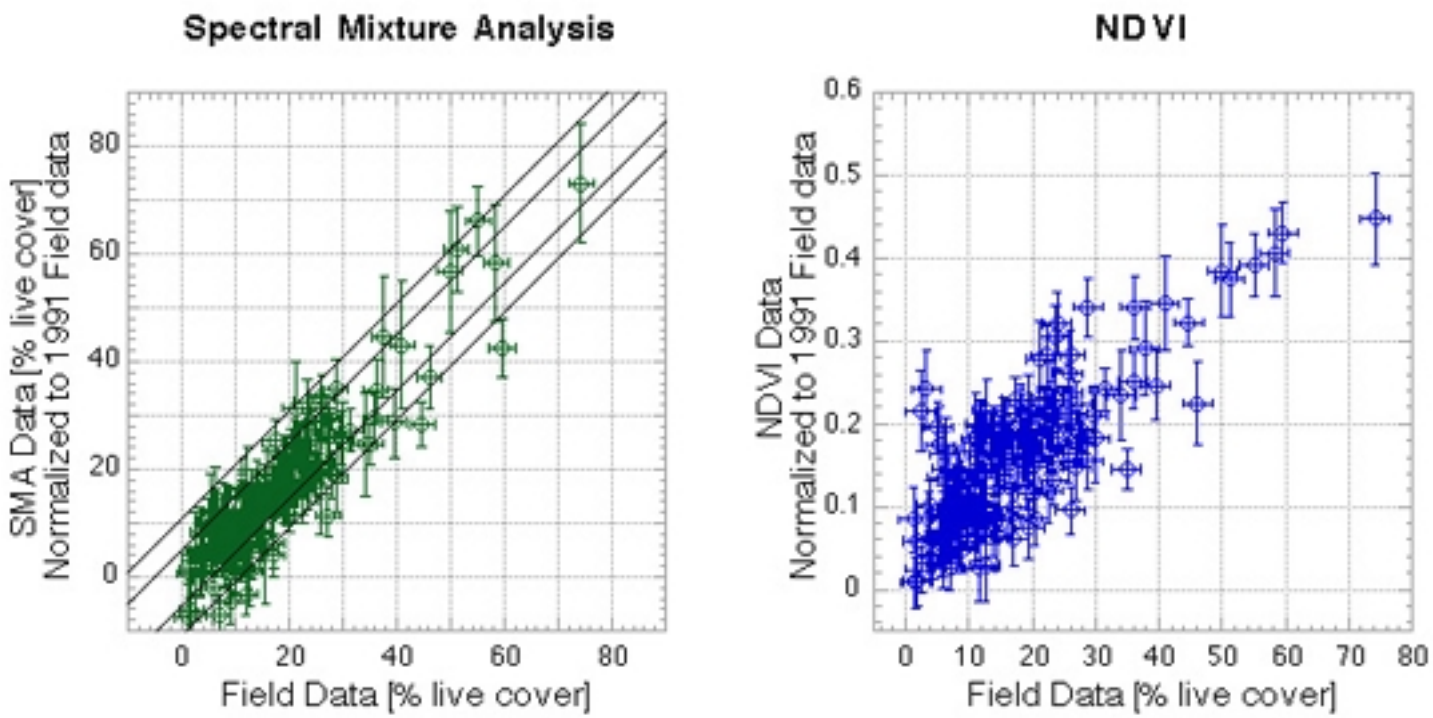
Correlation between field data (x-axis) and remotely sensed parameters (y-axis) showing a linear relationship for SMA. However, NDVI saturates at high vegetation abundance.

Field, SMA, and NDVI Data for Two Sites



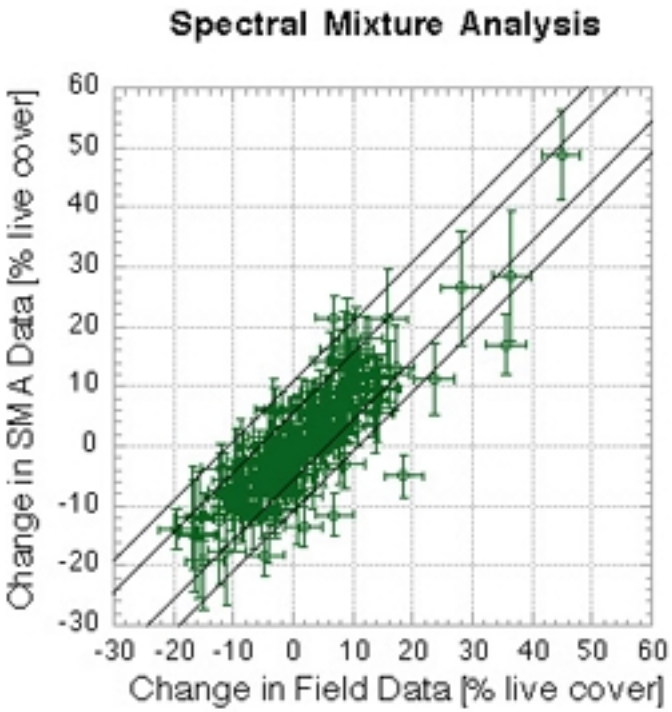
Some field sites show one to one correlation between SMA and Field data (IO1 - left) while others are correlated but offset (SS3 - right). NDVI is also correlated but the offset often varies through time.

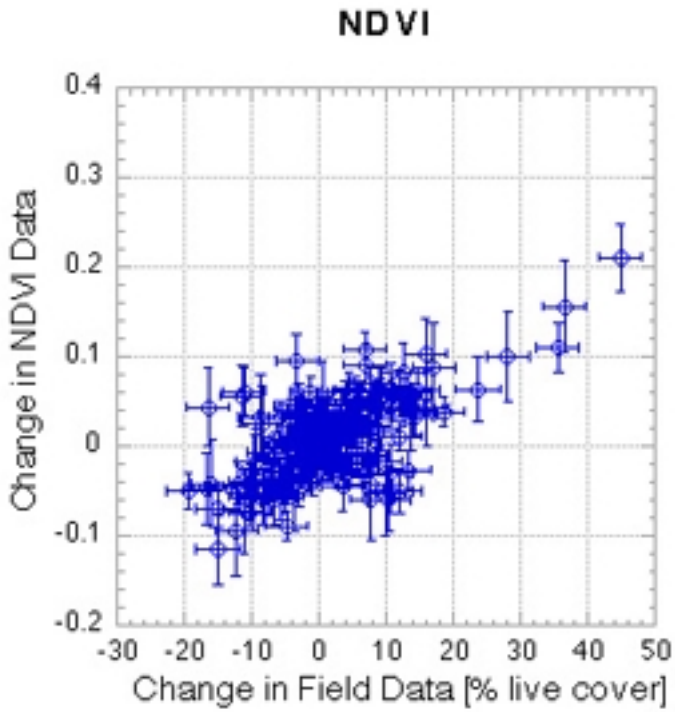
Normalized Abundance



By subtracting the offset seen in the previous graph the remotely measured data can b normalized to the field data at a single date. The SMA results are more correlated to t field measures, while the NDVI correlation becomes worse.

Yearly Change in Abundance





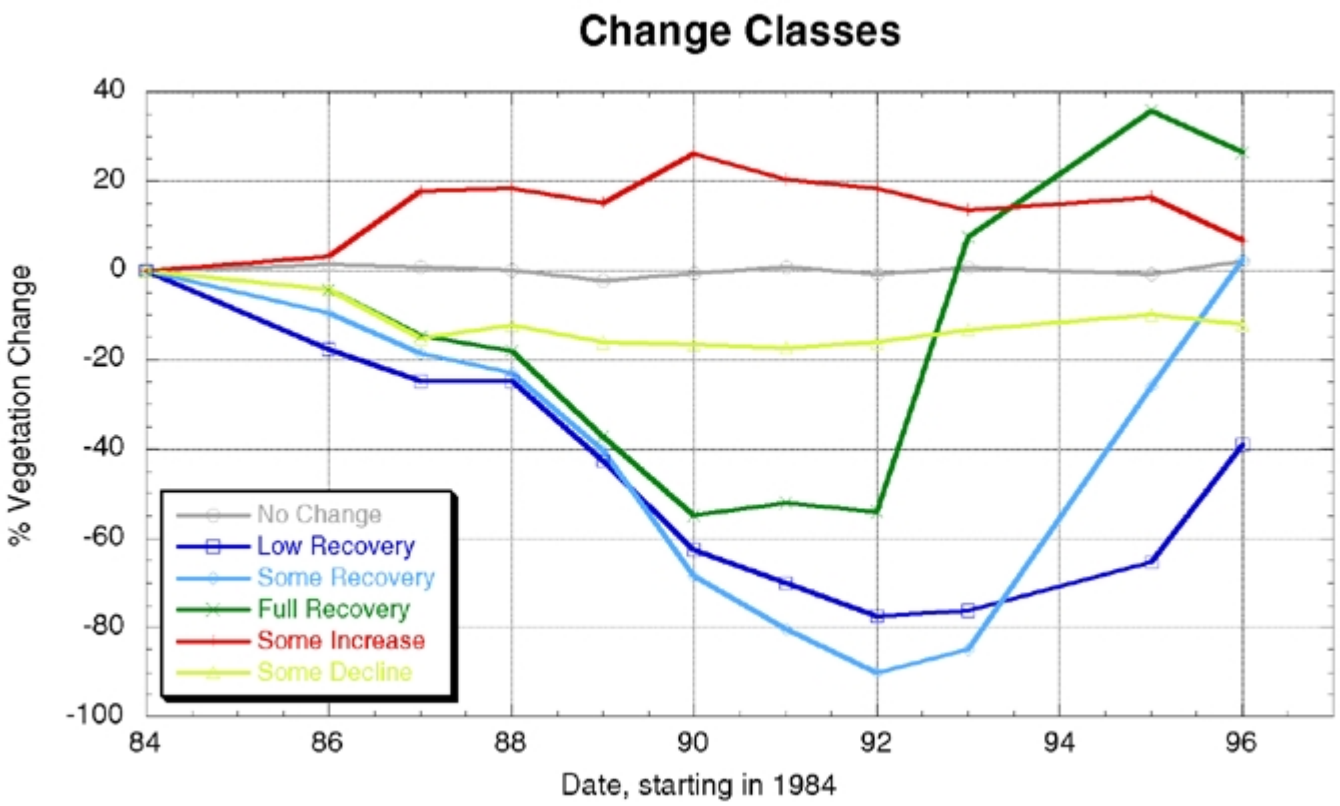
Year to year change in % live cover can be quantified to a +/- 3.8%lc for the SMA results. NDVI, however, quantifies change poorly.

SMA Results

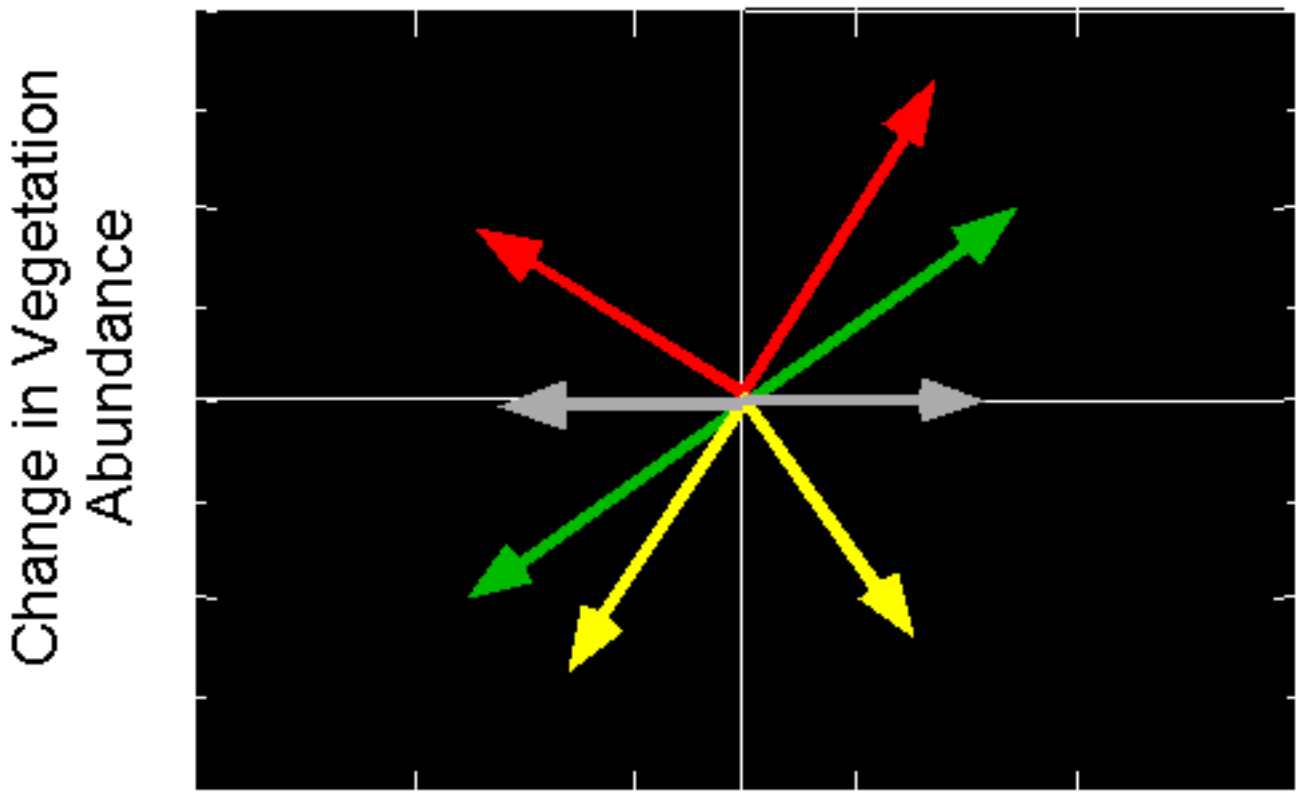
- SMA is linearly correlated with field measures of % live cover.
- Absolute % live cover accuracy +/- 4.0%
- Yearly change in % live cover precision +/- 3.8%
- SMA produces the correct sense of change in 86% of the data vs. 67% for NDVI.

Response Analysis

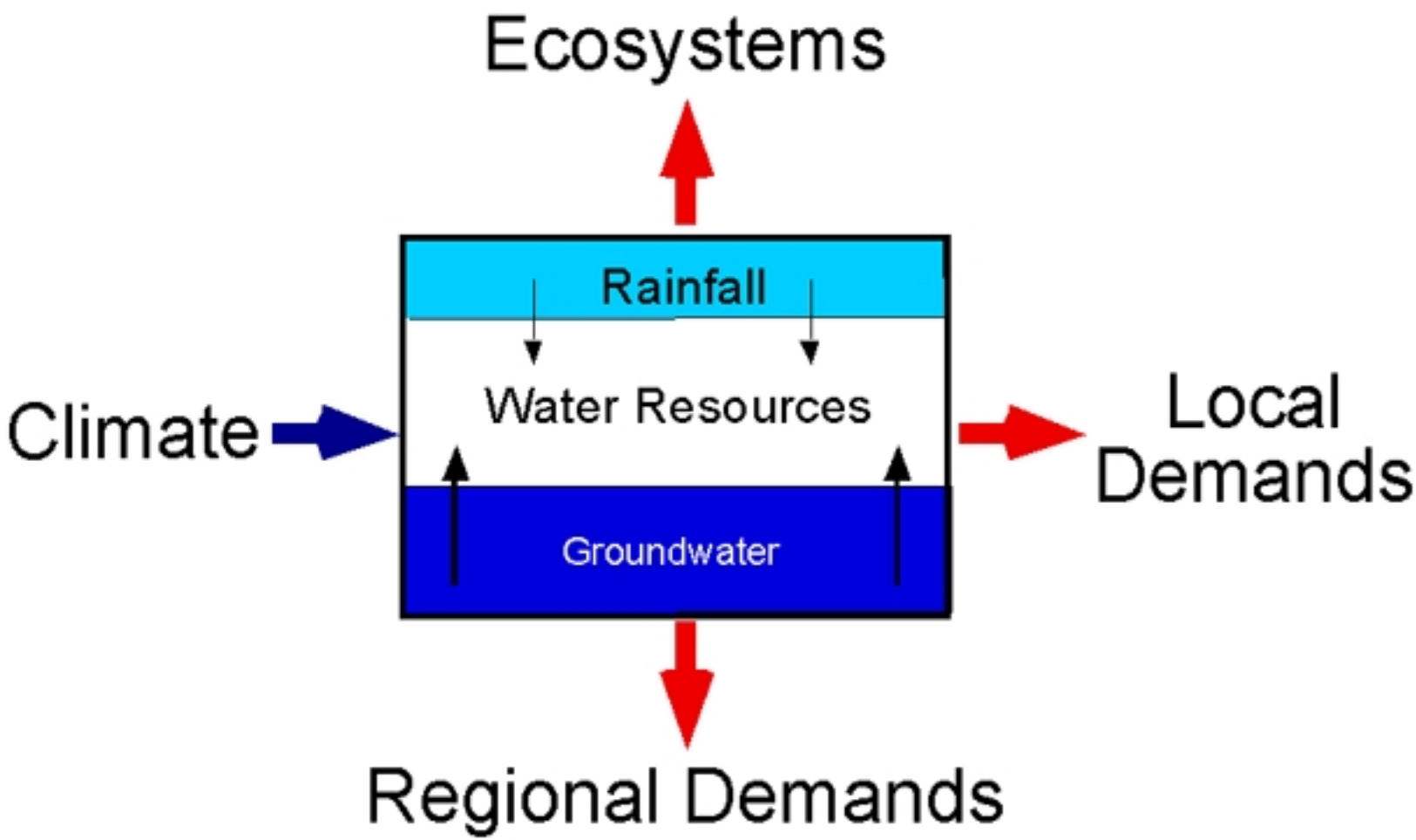
- Identify and map common modes of response from remotely sensed data
- Link common modes to the permanent monitoring sites and then to the key physiographic, land-use history, and water resource history
- Scale the detailed site analysis up to the regional perspective
- Bring analytical modeling in as a tool to relate observed patterns of change to water resource, ecosystem, and management issues


Change Classes
% Vegetation Change
40
20
0
-20
-40
-60
-80
-100
84
86
88
90
92
94
96
Date, starting in 1984
No Change
Low Recovery
Some Recovery
Full Recovery
Some Increase
Some Decline

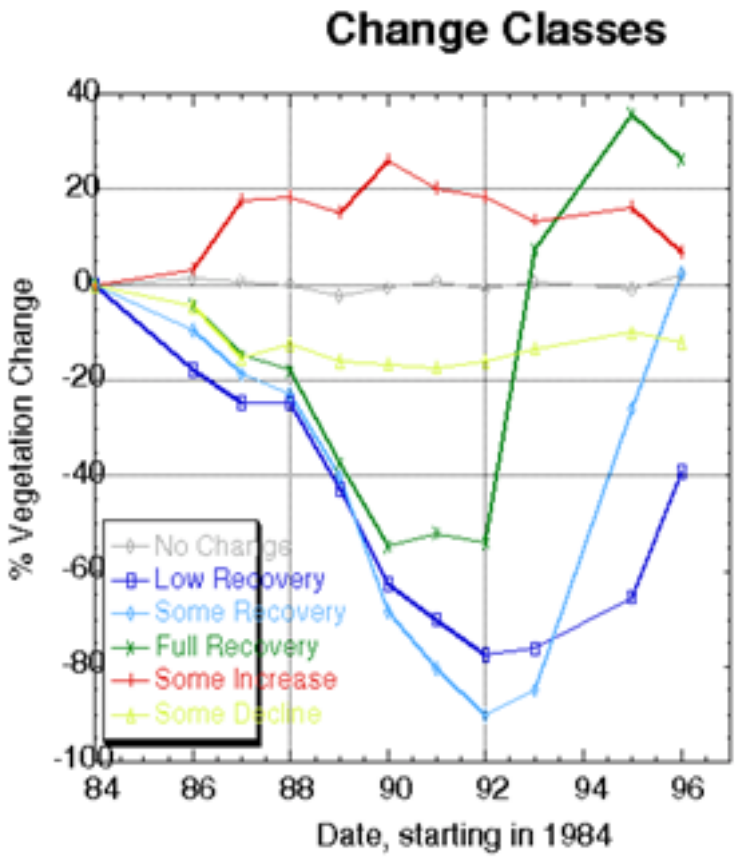
Different Responses to Forcing

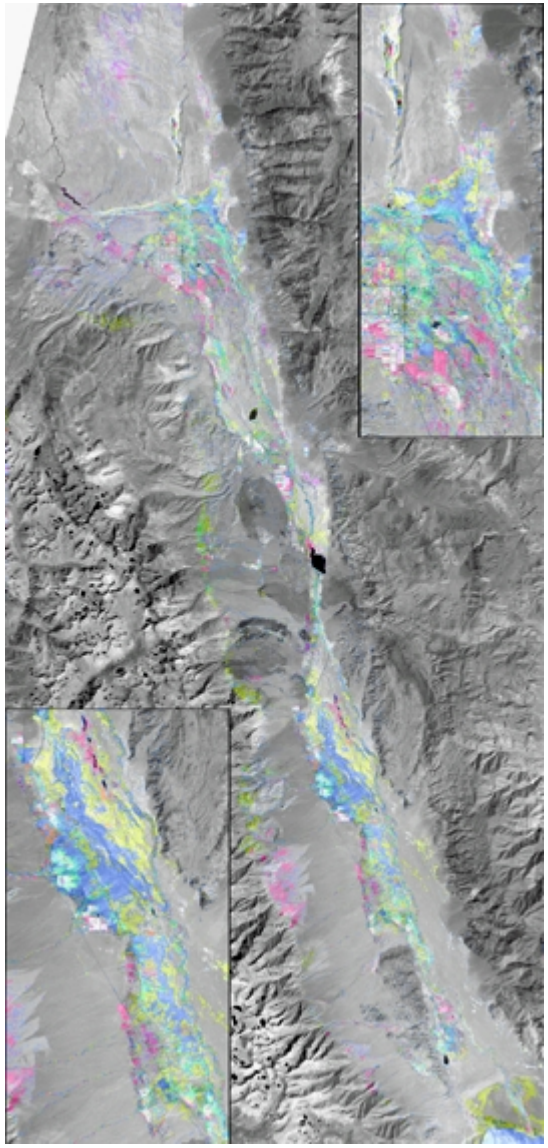


Change in Precipitation

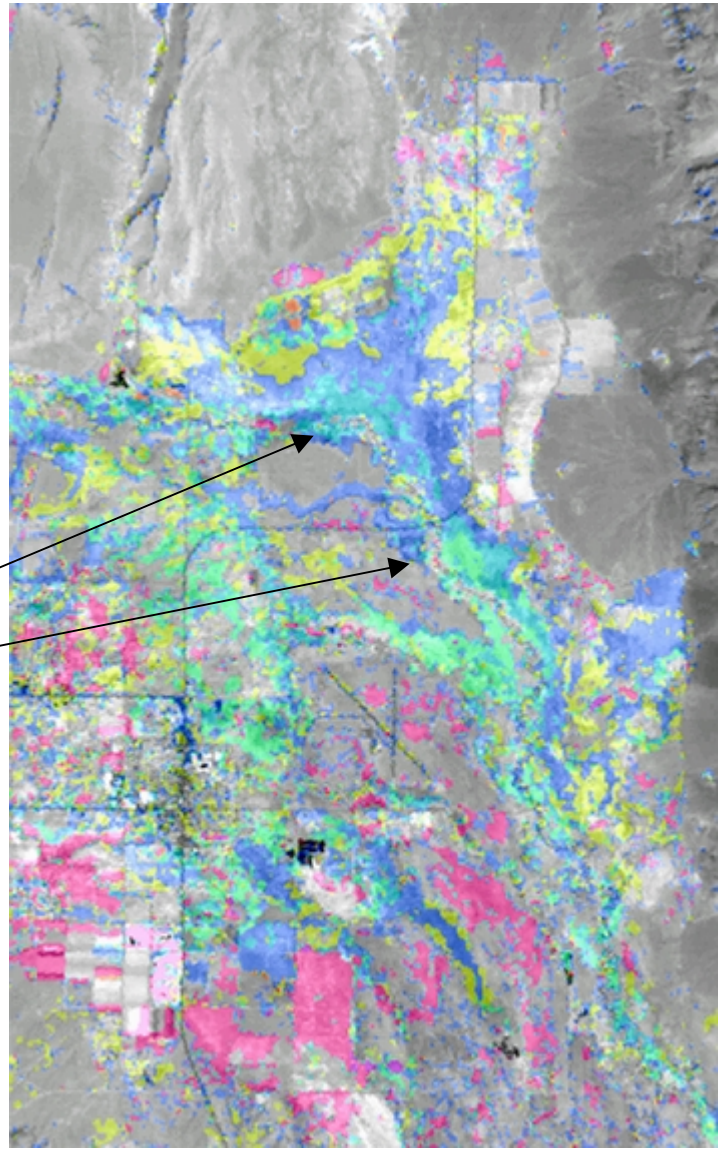

Ecosystems
Rainfall
Water Resources
Groundwater
Climate
Local Demands
Regional Demands

Change Class Image: Each Change Class is represented by a different Color.

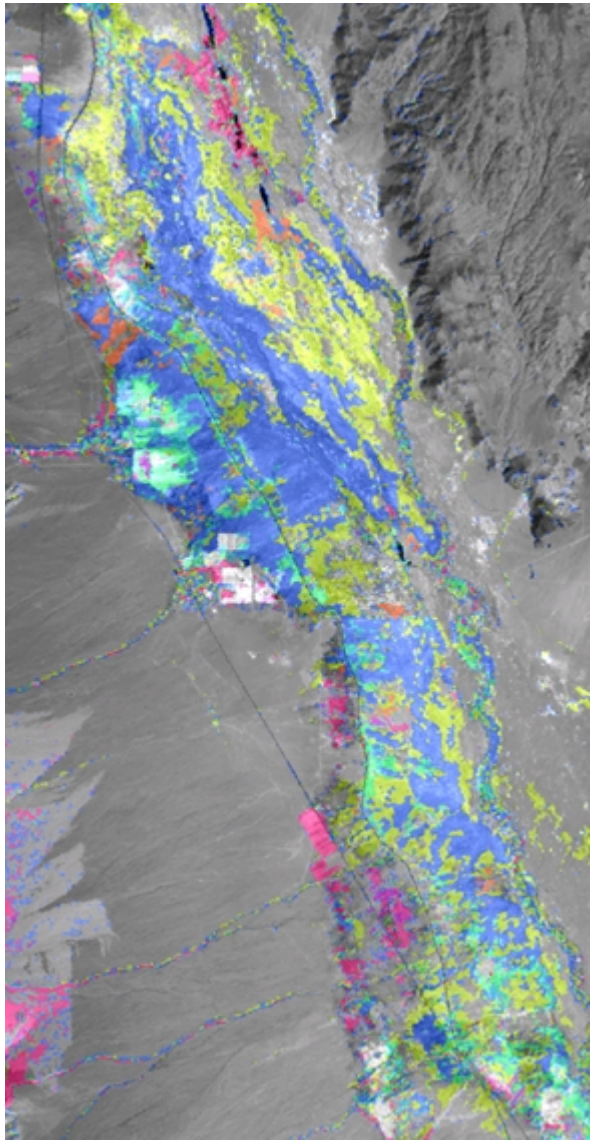




The Laws area is an example of a region where change classes form “bulls-eye” patterns around areas of intense ground water pumping.



The area around Independence is extremely complex - showing many change classes. This is due to ground water draw down coupled with land use practices such as irrigated grazing and controlled surface water flooding to recharge ground water aquifers.



LAND-USE HISTORY

- What is the effect of prior land use on response?
- What is a successional model for semi-arid systems?
- Key stages of land use have been documented:
  - Pre-1900
  - 1926 detailed land use maps
  - Aerial photography 1944, 1969, 1983
- Preliminary work to define history for 3 type localities

Project Status

- Progress is about where we anticipated we'd be at this stage
- Detailed validation and verification of mixture model and remote sensing was required to accommodate the needs of LADWP
- Response analysis is beginning and indicates extraordinary levels of information
- Completion of entire project to the level of full publication of results will extend beyond the formal end date