Spectroscopy of Wildfire Burned Products

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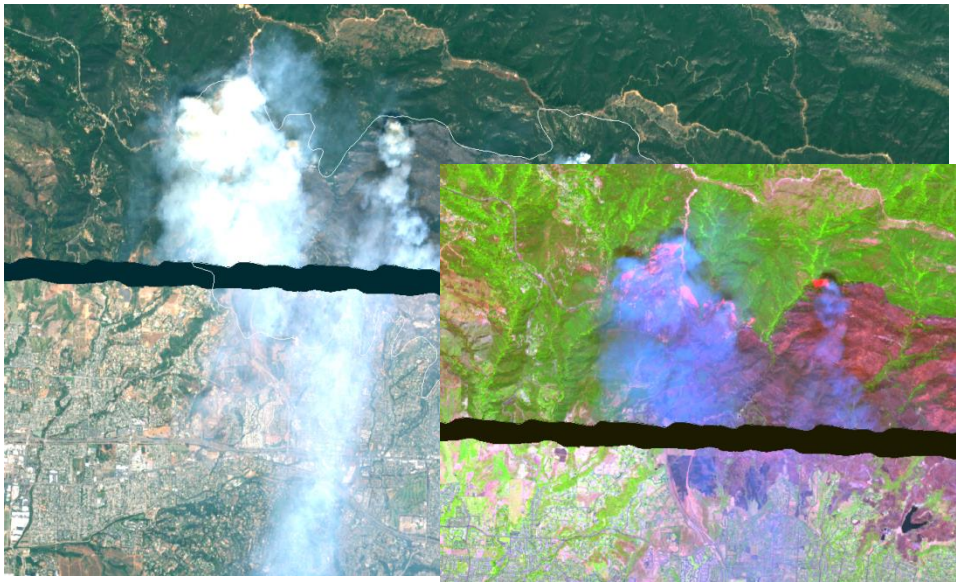
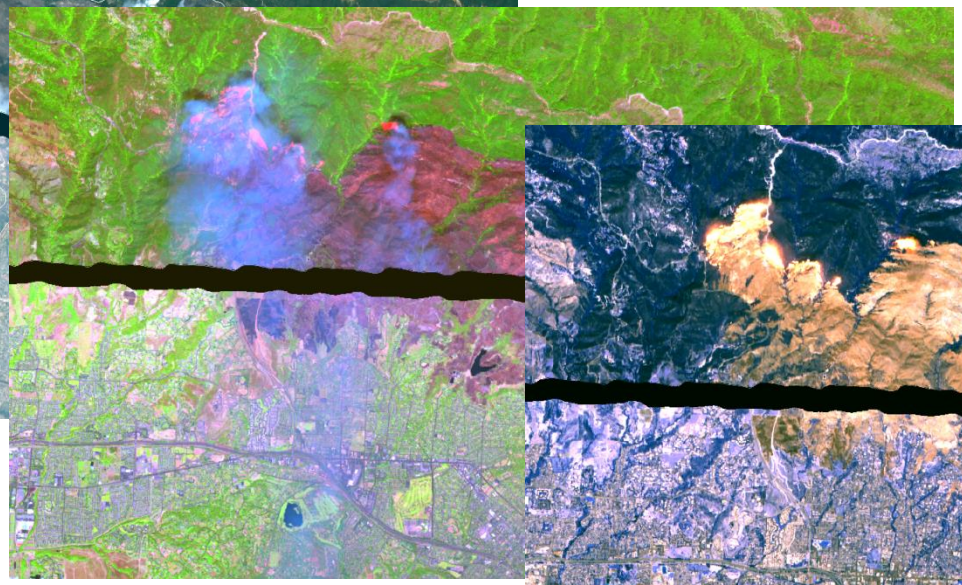
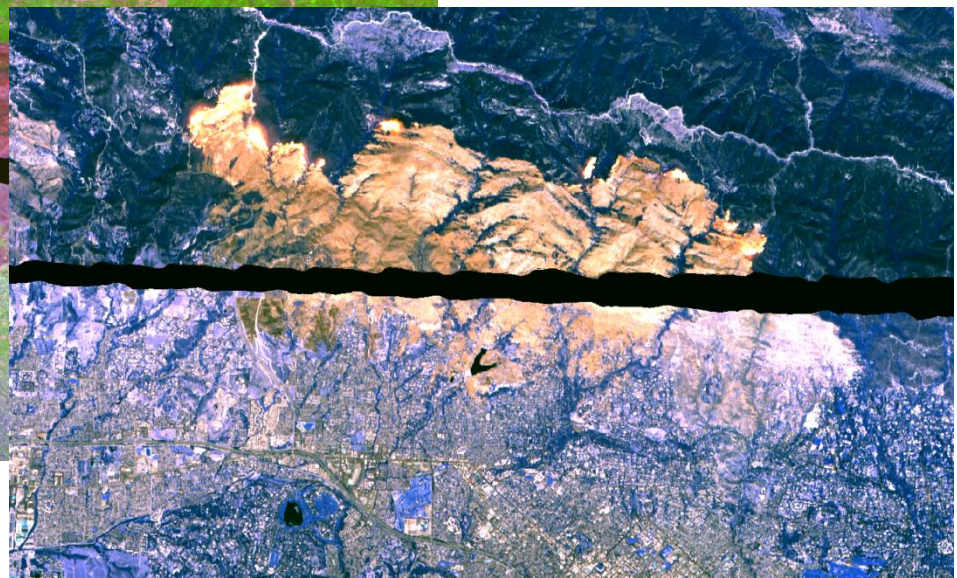




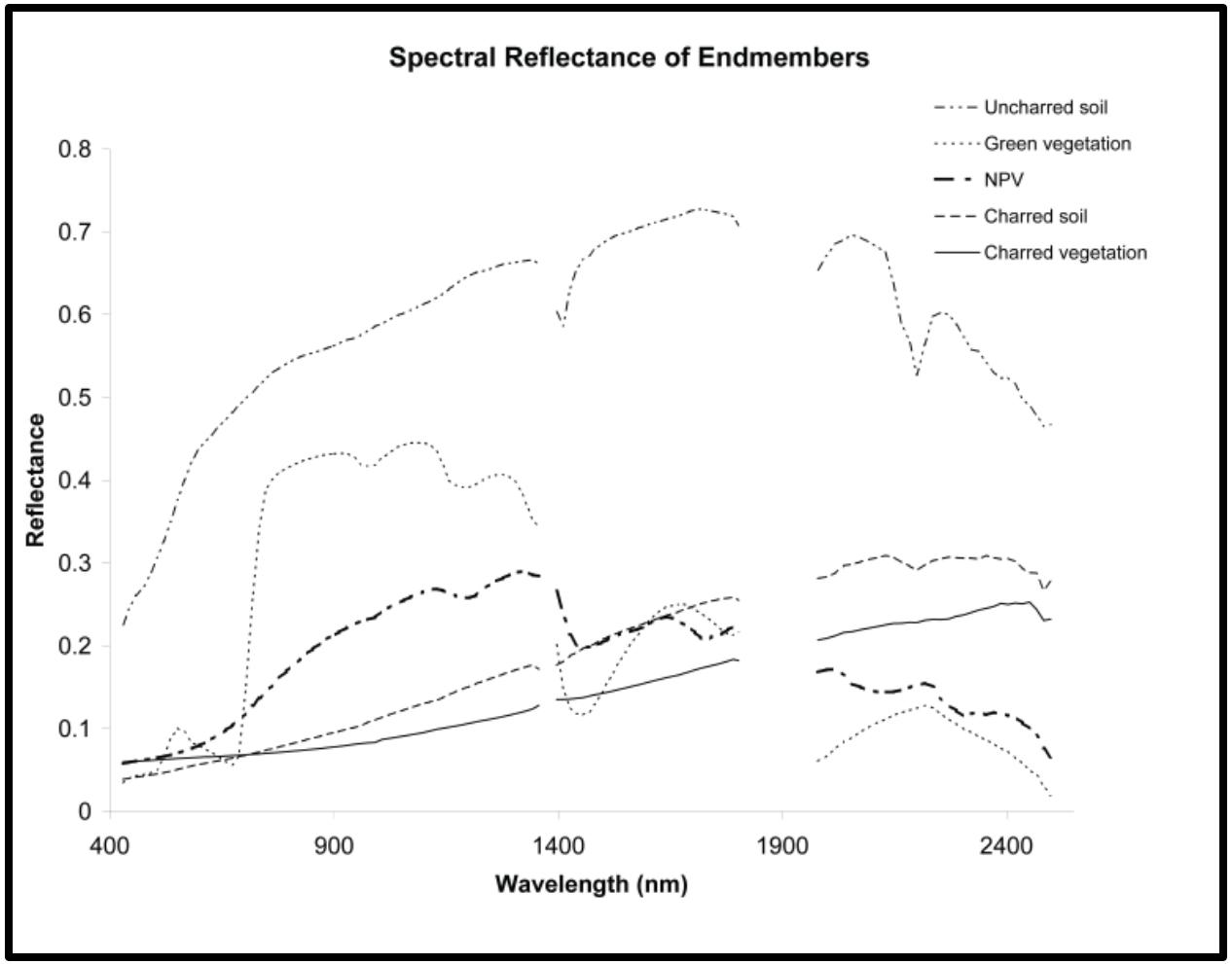


United States – Israel
Binational Science Foundation

Why Map Wildfire Burned Products?

- **Burned Area**
  - **Required for post-fire recovery efforts**
  - **Hydrological/geomorphological modeling**
    - **Mass wasting, erosion, flooding**
- **Measures of Fire Severity**
  - **Post-fire recovery, soil hydrophobicity**
- **Biogeochemistry**
  - **Trace gas emissions (CO_2, CH_4), aerosols**
  - **Fuel Consumption**
  - **Ash transport**
  - **Soil chemistry**

Typical Spectra of Burned Products



From Lewis et al., 2007: Fire Ecology, 3(1), 109-128

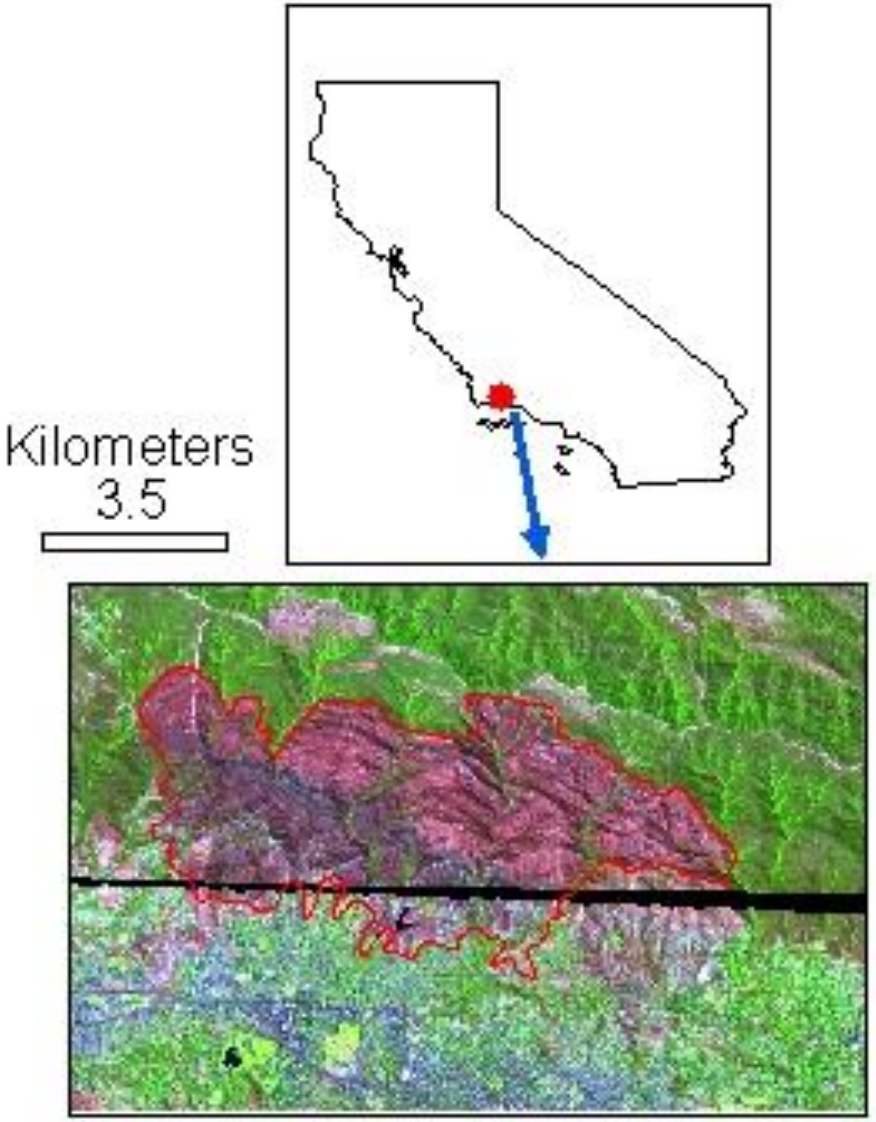
Objectives / Research Questions

Objective: To develop spectral libraries of ash from multiple fires using the post-fire AVIRIS data

Key Research Questions

1. Are ash spectral libraries portable between fires?
2. Is there a relationship between fire severity and ash type?
3. Is there a relationship between pre-fire fuels and ash?
4. What can ash spectral libraries tell us about fire properties?

Study Sites



Jesusita Fire

Start Date: **9 May 2009**
Containment Date: **18 May 2009**
Image Date: **26 August 2009**

Fire Size: **35 km^2**
Cause: **Human (Accidental)**
Fire Severity: **Primarily High**

Primary Fuels:
- **83% Shrub**
- **11% Hardwood**
- **3% Herbaceous**
- **2% Urban**
- **1% Other**

Fuel Type Source:
US Forest Service CWHR Layer

Study Sites

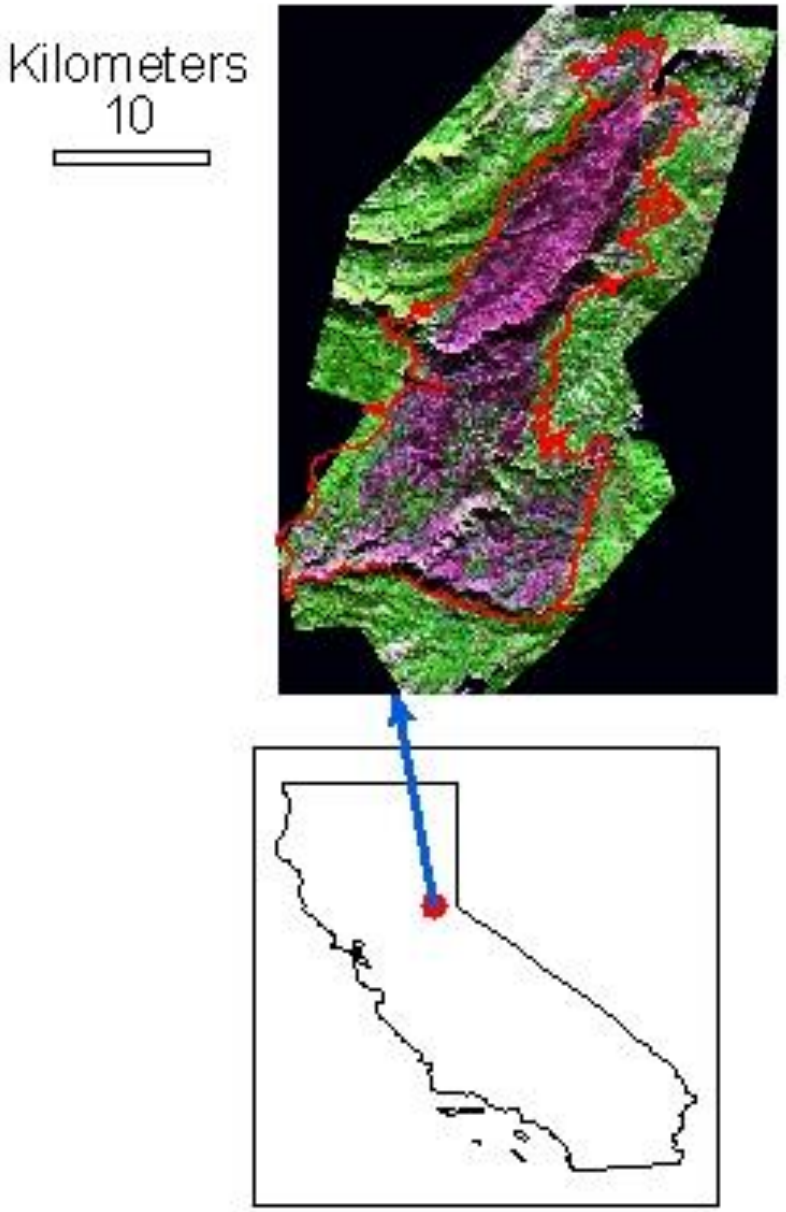
King Fire

Start Date: **13 September 2014**
Containment Date: **9 October 2014**
Image Date: **17 November 2014**

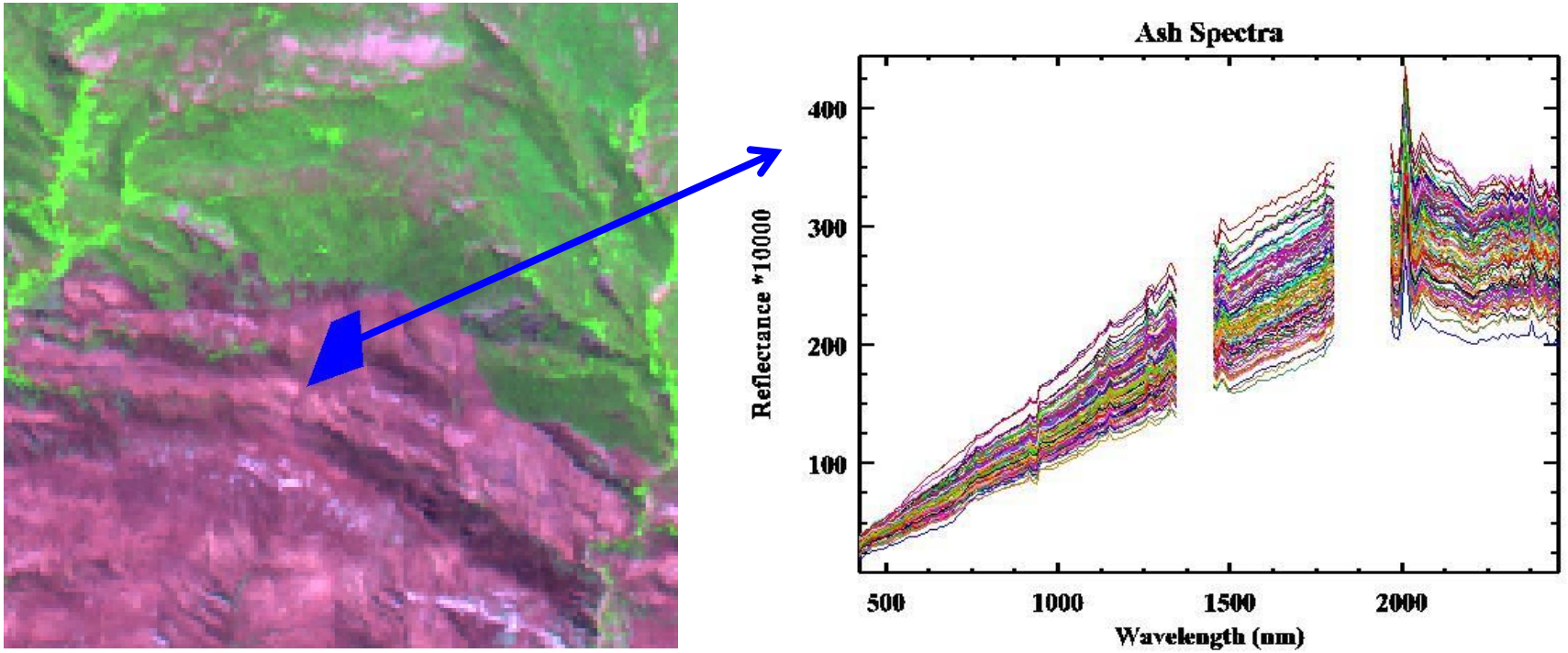
Fire Size: **392.96 km^2**
Cause: **Human (Arson)**
Fire Severity: **Primarily High**

Primary Fuels:
- **77% Conifer**
- **13% Hardwood**
- **5% Mix**
- **4% Shrub**
- **1% Urban**

Fuel Type Source:
US Forest Service CWHR Layer



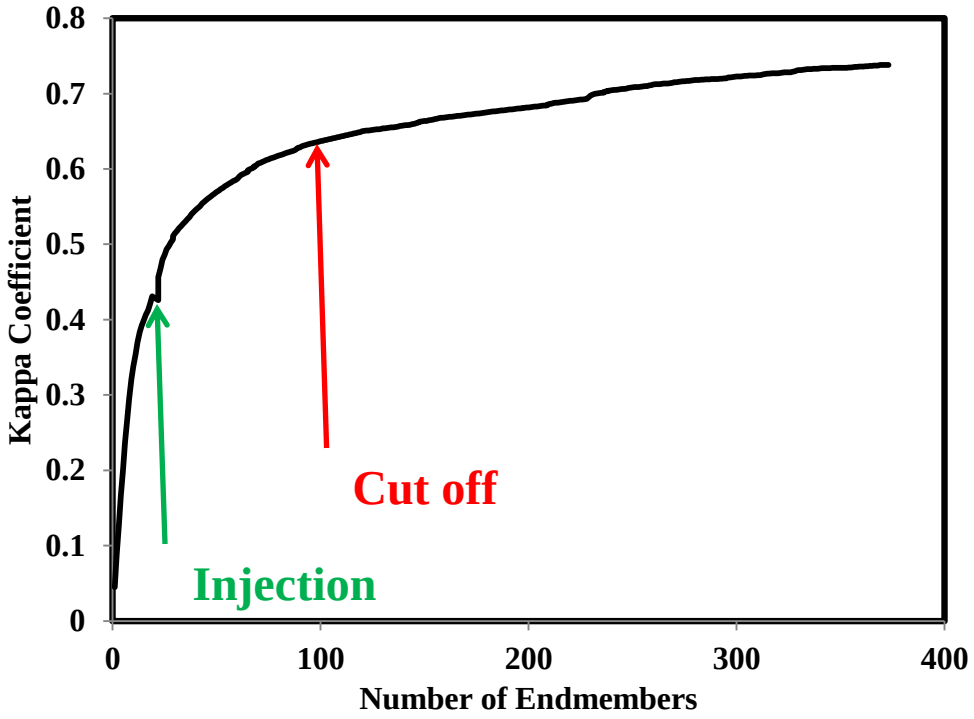
Spectral Libraries and Severity



- **Spectra extracted from polygons within the image**
- **Fire Severity: dNBR (NBR=(ρ788-ρ2370)/(ρ788+ρ2370))**
  - Pre-fire: King 19 September 2013
  - Pre-fire: Jesusita 6 August 2004

Library Pruning: Iterative Endmember Selection

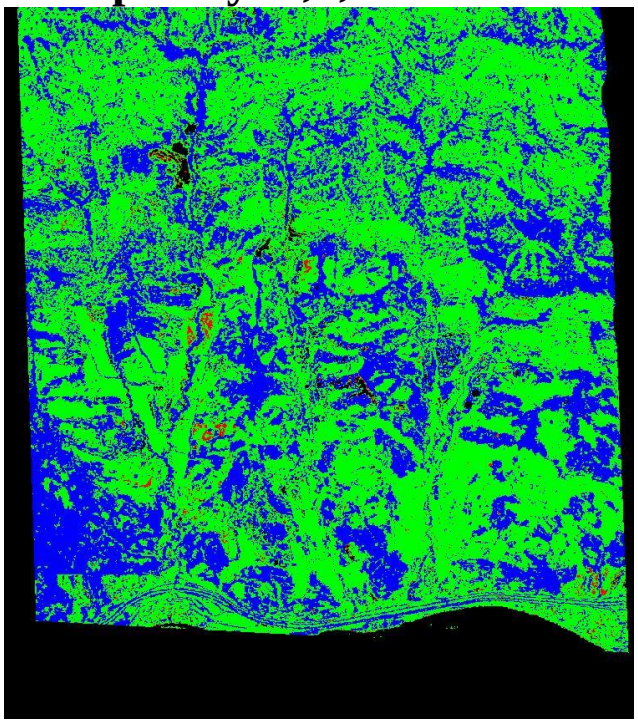
- **Iterative Endmember Selection (IES) (Schaaf/Roth)**
  - **Iteratively selects endmembers to maximize classification accuracy**
  - **Implemented in Viper Tools 2.0**
- **Fire specific and combined libraries**



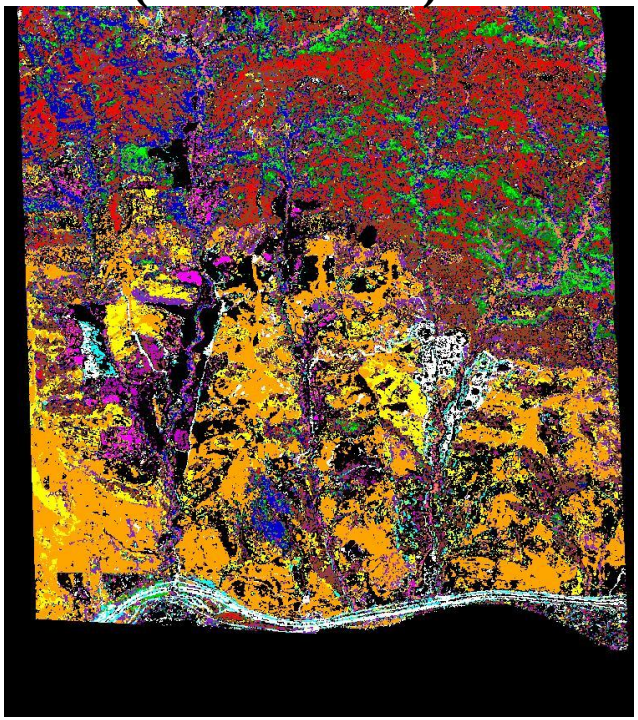
Roth et al., 2012

Multiple Endmember Spectral Mixture Analysis (MESMA)

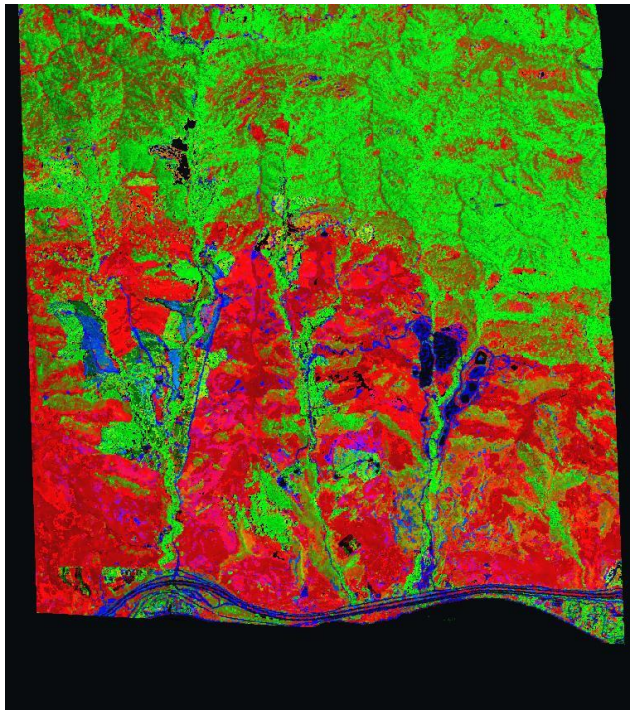
Complexity: 3,2,1 RGB



Class (from model #)

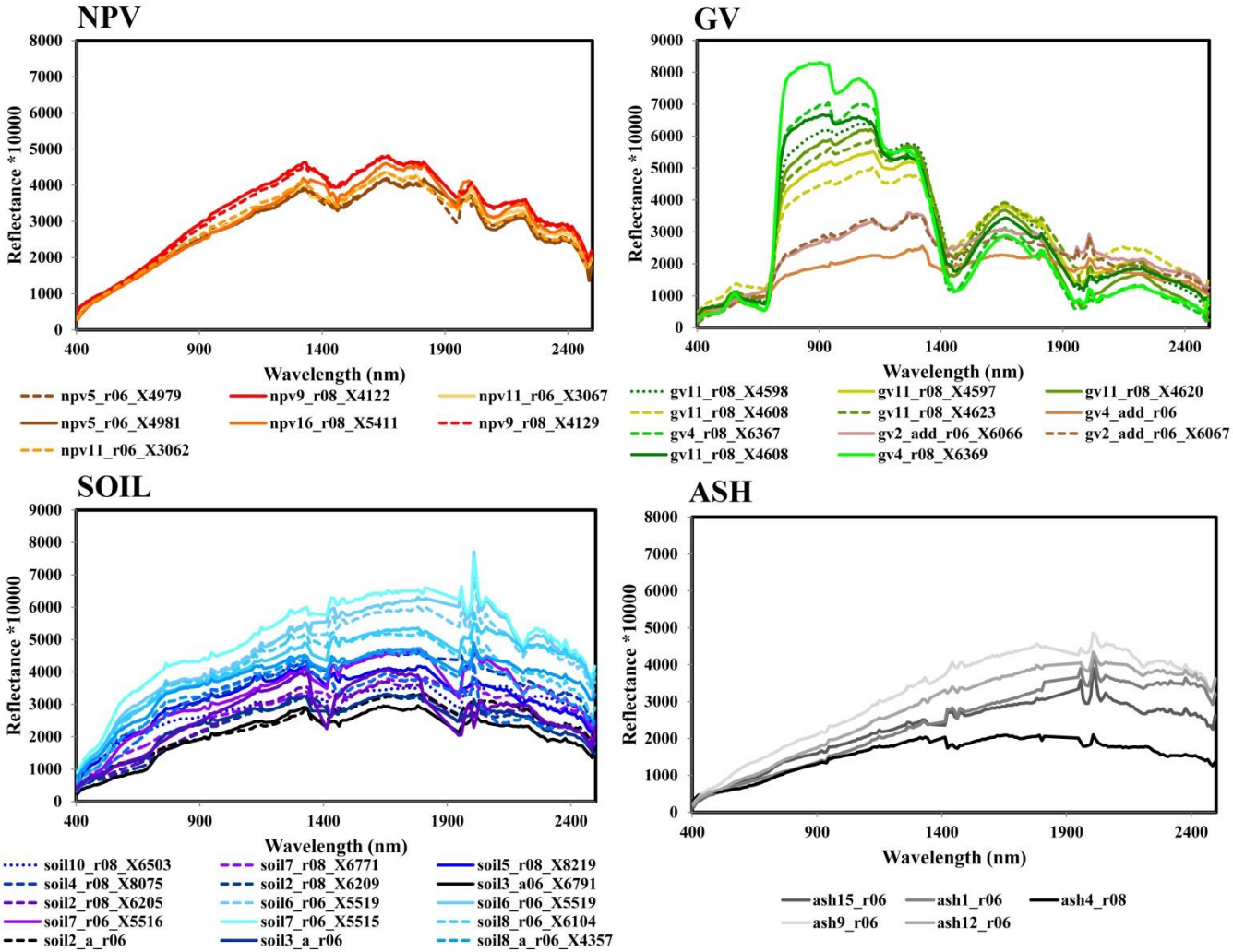


Composition: NPV-GV-Soil RGB



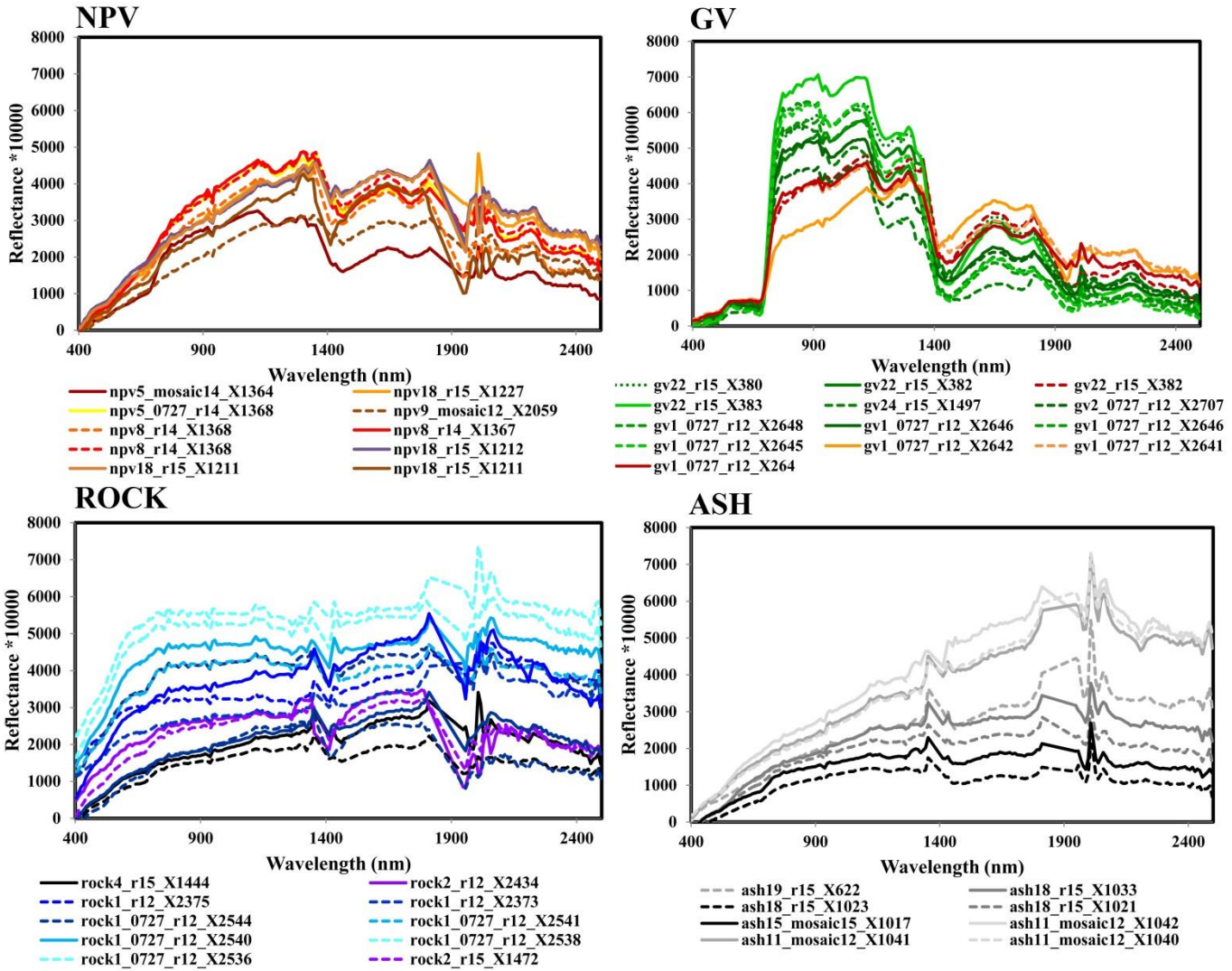
- **Extension of Linear Spectral Mixture Analysis**
- **Allows the number and types of Endmembers to vary per pixel**
  - **Candidate models must meet fit and fraction constraints**
- **Models Selected on minimum RMS**
- **Complexity level based on change in RMS**

Results: Jesusita Spectra



- **NPV (7), GV (11), Soil (19), Ash (5)**

Results: King Spectra



- **NPV (10), GV (12), Rock (14), Ash (7)**
- **Both: NPV (25 (12/13)), GV (19(15/4)), Soil/Rock (32(22/10)), Ash (13 (2/11))**

Results: Mapping Fire Products with MESMA

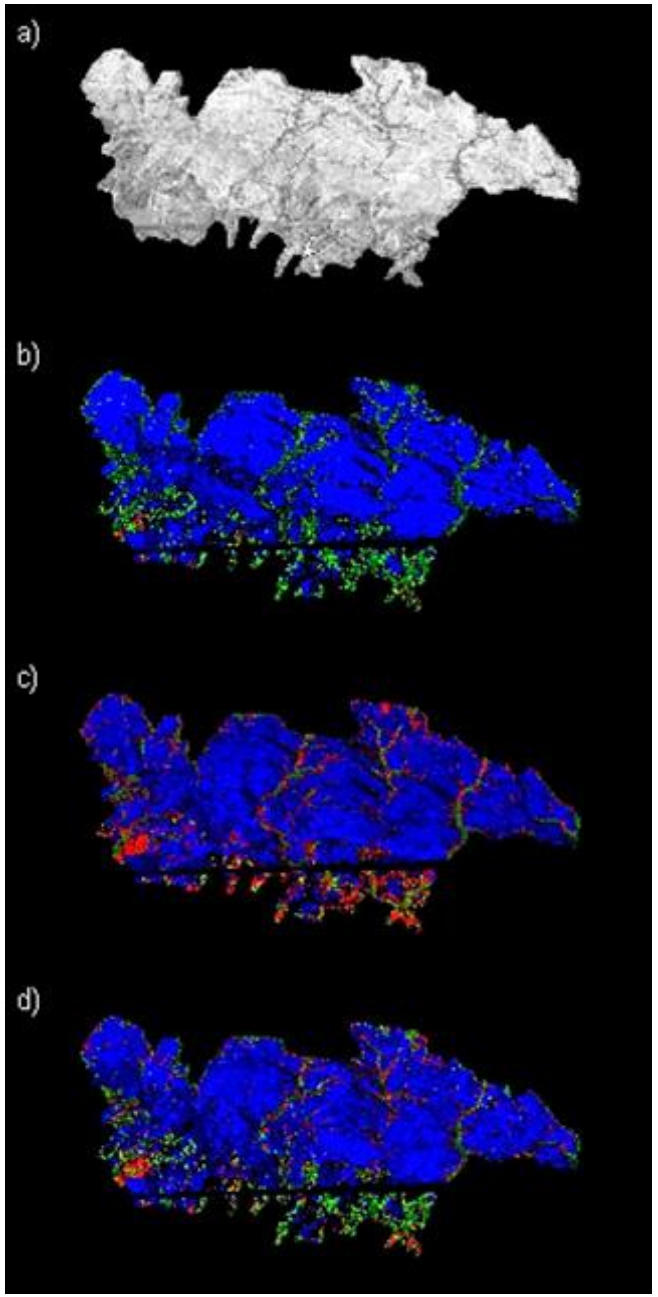
dNBR

Jesusita Fire

Jesusita fire only spectral library:

King fire only spectral library:

Both fire spectral library:

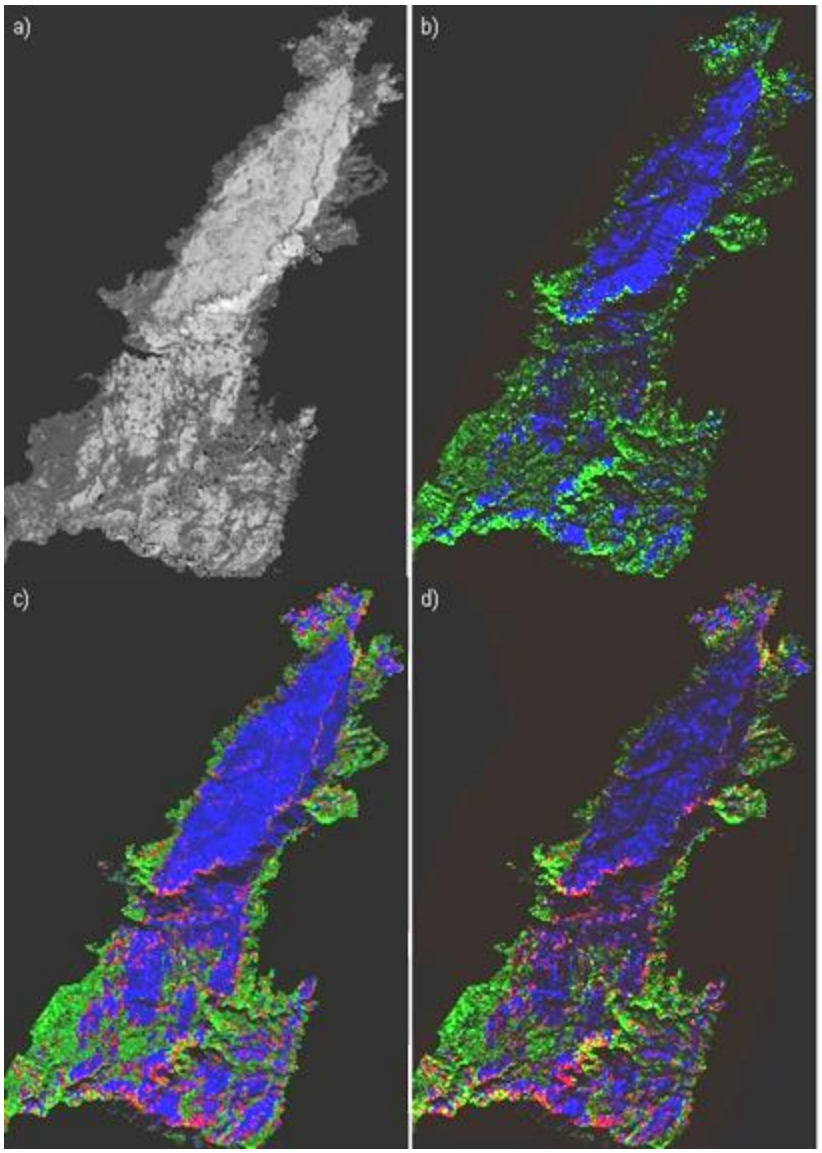


NPV, GV, Ash: RGB

Results: Mapping Fire Products with MESMA

King Fire

dNBR



Jesusita fire only spectral library:

Both fire spectral library:

King fire only spectral library:

NPV, GV, Ash: RGB

Results: Spectral Library & Cover

King Fire

Percent Pixels in Endmember Class

Library Source	Ash	GV	NPV	Soil	No model
King	44.2%	30.5%	14.9%	0.9%	9.5%
Jesusita	32.3%	42.4%	0.5%	6.2%	18.6%
Both	42.8%	30.7%	16.9%	0.6%	9.0%

Pixel Source for Both by Class

	Ash	GV	NPV	Soil
King	75.5%	71.1%	97.3%	37.8%
Jesusita	24.5%	28.9%	2.7%	62.2%

Jesusita Fire

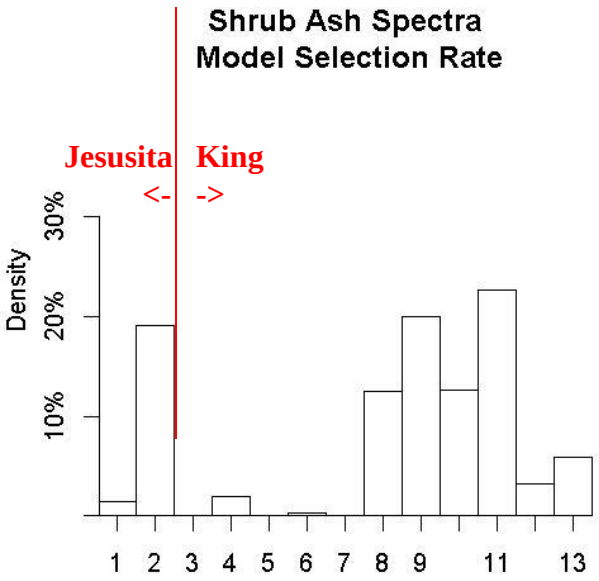
Percent Pixels in Endmember Class

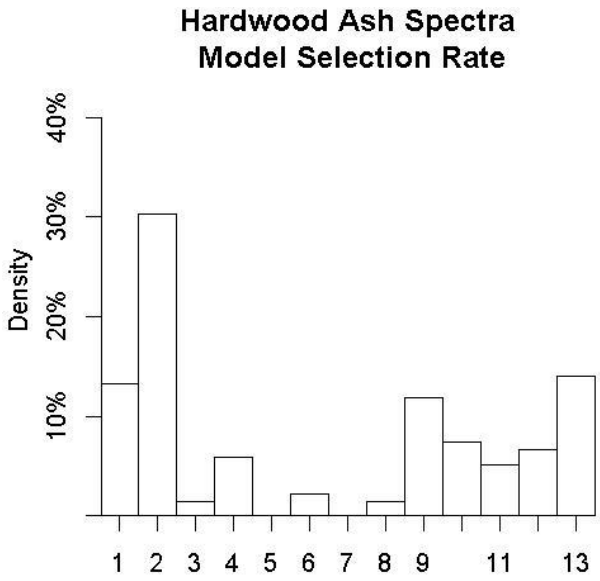
Library Source	Ash	GV	NPV	Soil	No model
King	68.5%	7.2%	15.2%	6.3%	2.9%
Jesusita	61.5%	16.9%	1.3%	18.9%	1.4%
Both	64.7%	12.3%	8.6%	13.3%	1.1%

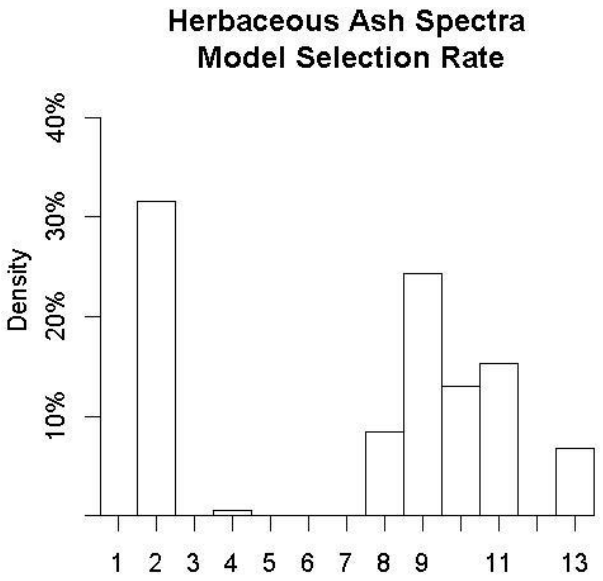
Pixel Source for Both by Class

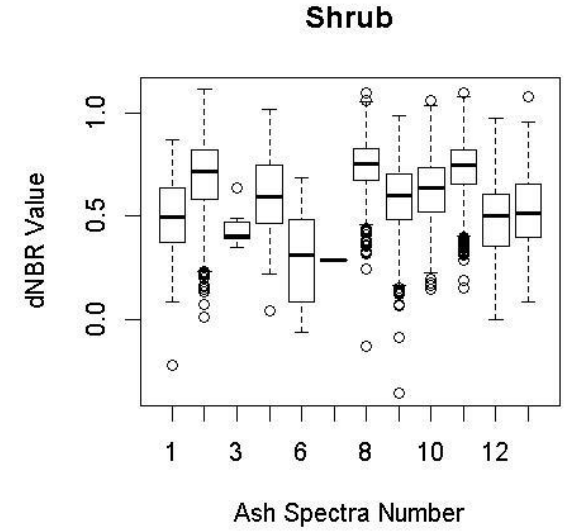
	Ash	GV	NPV	Soil
King	78.5%	6.9%	70.8%	14.1%
Jesusita	21.5%	93.1%	29.2%	85.9%

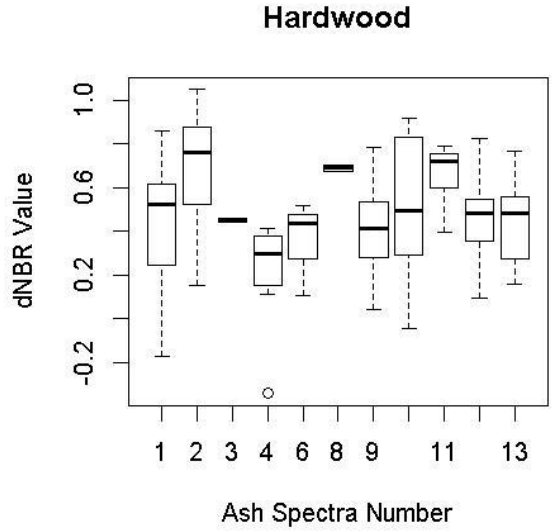
Ash and Fuels: Jesusita Fire

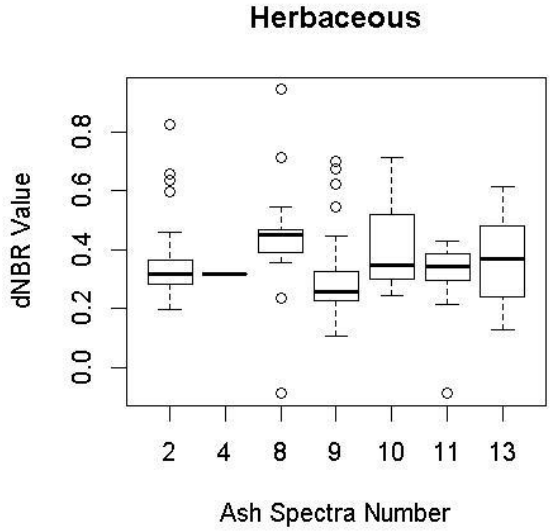




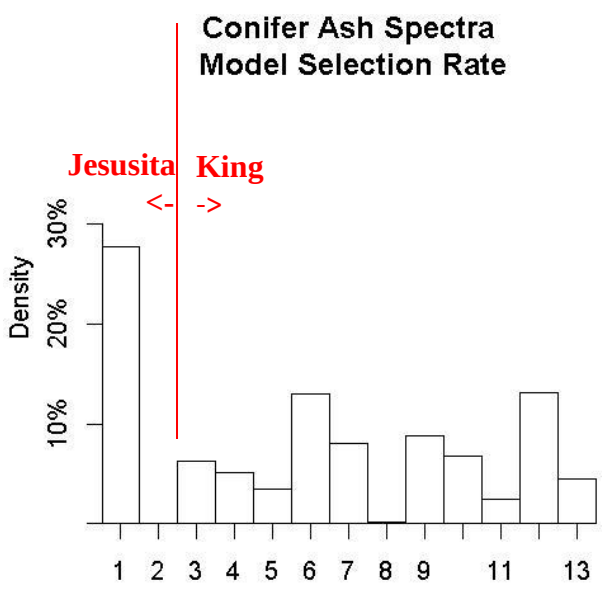


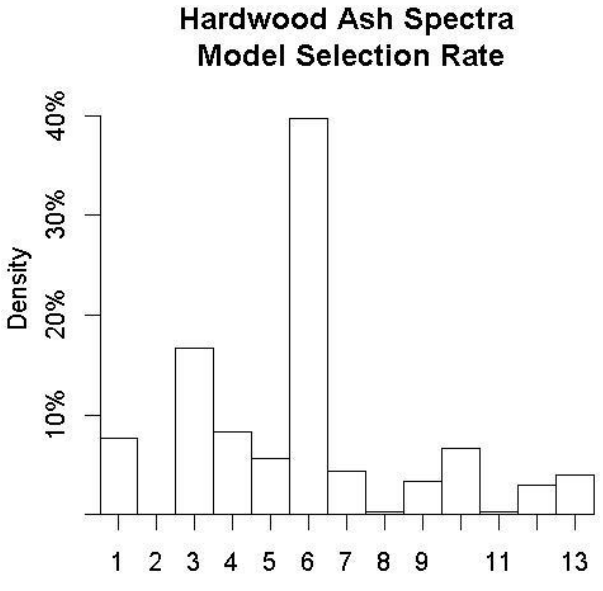


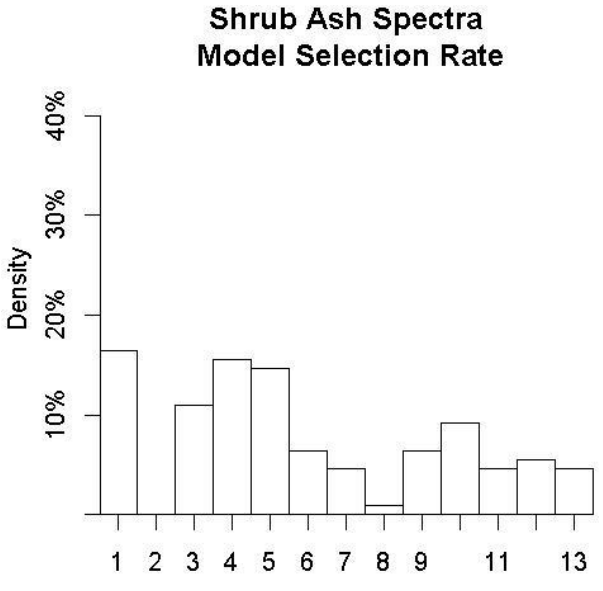


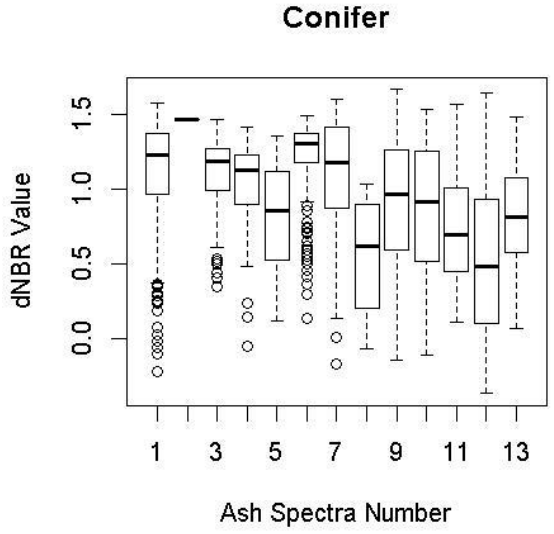


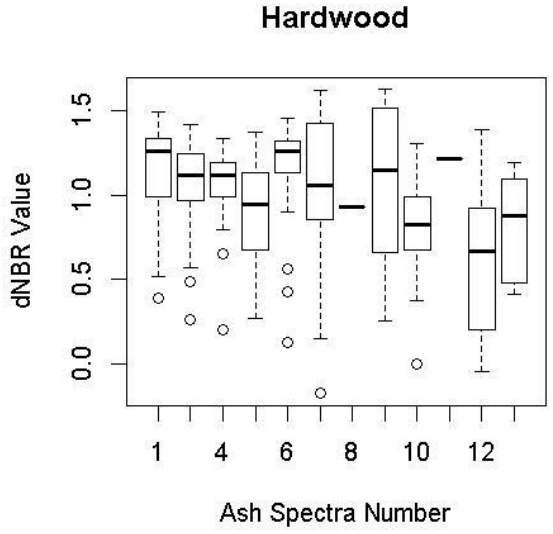
Ash and Fuels: King Fire

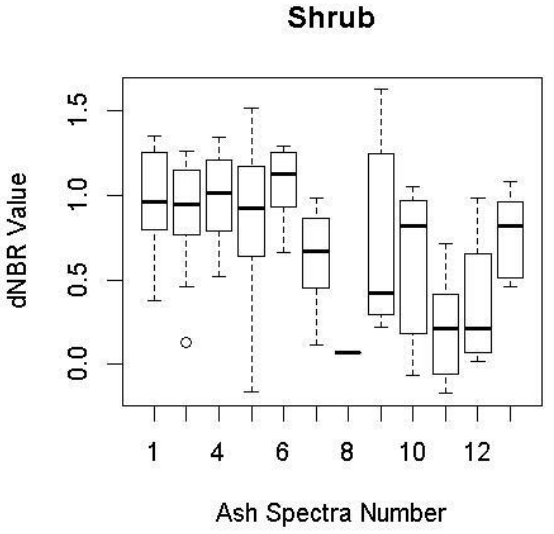




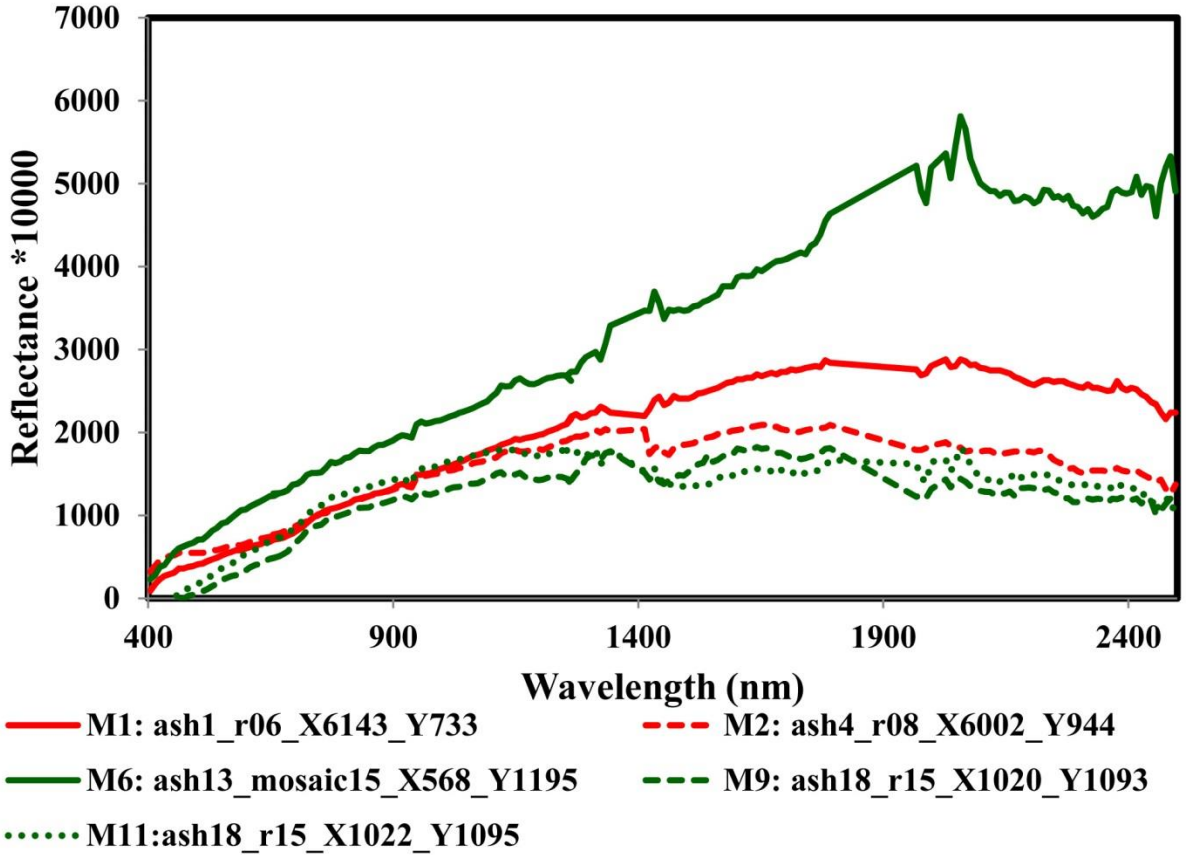








Ash and Fuels



- **Jesusita (M1-2)**
  - **M1: Conifers, King (30%)**
  - **M2; All Fuels, Jesusita (20-30%)**
- **King (M6, 9 and 11)**
  - **M6: Hardwoods, King (40%)**
  - **M9: Herbaceous, Jesusita (25%)**
  - **M11: Shrub, Jesusita (20%)**

Conclusions

- **Burned product spectra were moderately portable between images**
  - **Fractions shifted by as much as 14%, with highest shifts between soils and NPV**
  - **Ash and NPV from the King fire were favored for both fires**
  - **GV and Soil tended to be fire specific**
- **A combined spectral library modeled the most area (least error?)**
- **The most common ash spectra were associated with specific fuels**
- **King fire had higher severity than Jesusita based on dNBR**
- **A subset of ash spectra were associated with the lowest fire severity based on dNBR**
- **Caveats**
  - **Images were acquired at different times of year and processed to reflectance differently**
  - **dNBR varies by vegetation type; Jesusita vegetation would favor lower dNBR**
  - **Only two fires were studied**
  - **Other measures of severity could be employed**
  - **Surfaces change quickly, so ash type and abundance likely changed by the time the fire was imaged**