Effect of image spatial and spectral characteristics on mapping semi-arid rangeland vegetation using MESMA

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Introduction

• Rangeland degradation
  – Livestock overgrazing
  – Drought
  – Climate change

• Invasive shrub encroachment

• Reduced grass vegetation

• Permanent landscape effects
  – Soil erosion
  – Hydrologic alterations
  – Reduced biodiversity

• Novel remote sensing technology
  – Instrumentation
  – Algorithms
  – Vegetation mapping and monitoring
Introduction

• Instrumentation
  – HyspIRI imaging spectrometer
    – 380 nm to 2500 nm in 10 nm bands
    – 60 m spatial resolution
  – Simulated with existing AVIRIS data (15 m)

• Algorithm
  – Multiple Endmember Spectral Mixture Analysis (MESMA)
  – Unmix image spectra using “pure” endmember spectra
  – Tests multiple endmember combinations for each image pixel
  – Obtain fractional cover maps for each endmember

• Objectives
  – Investigate MESMA for mapping rangeland vegetation
  – Test MESMA sensitivity to spatial and spectral degradations
Study Site

- Jornada Experimental Range
  - Field research lab
  - Established 1912 by USDA
  - 783 km²
  - 37 km NE Las Cruces, NM
  - 40 km W White Sands
Imaging Spectroscopy

- AVIRIS imagery
  - Jornada overflights
    - June 15, 2001
    - October 9, 2002
    - Five flightlines
  - Simulate HyspIRI spectral data
- Georeferenced to an orthophoto
- Atmospheric correction using “6S” algorithm
- Mosaic five flightlines for each date
Endmember Spectra

- Field spectroradiometer
  - ASD FieldSpec Pro
  - 350 nm to 2500 nm in 1 nm bands
  - 99% Spectralon panel
  - Prior to AVIRIS overflights
  - Five transects across the range
    - Shrubs: mesquite, creosote, tarbush
    - Grass
    - Transition
  - Documentation

- Dr. Jerry Ritchie (1937-2009)
Endmember Spectra

- Selection of endmember spectra
  - Graphical methods
  - Quantitative methods
  - MESMA methods
  - Goal: spectral separability

- Three final endmembers
  - Green shrub vegetation
  - Nonphotosynthetic grass vegetation
  - Bare soil

- Waveband elimination
  - Ground spectra & AVIRIS data
  - Low signal-to-noise ratio
  - Errors in atmospheric correction
MESMA

• VIPER Tools (www.vipertools.org)
  – Plug-in for ENVI software
  – Conducts MESMA and related algorithms
• Analysis
  – Independent MESMA for each year (2001 & 2002)
  – Four endmembers (Shrub, Grass, Soil & Shade)
  – Resulting fractional cover map for each endmember
• Evaluation
  – Compare MESMA to Jornada vegetation map
  – Compare MESMA between 2001 and 2002 years
  – Compare MESMA to spectral indices from AVIRIS (15 m)
  – Compare MESMA to spectral indices from IKONOS (4 m)
MESMA Results

June 15, 2001

October 9, 2002

1998

Gibbens et al. (2005)
MESMA Results

• Pearson’s r correlations
  – Between 2001 & 2002 MESMAs
    • Shrubs (0.66), Grass (0.67), Soil (0.39)
  – Between shrub endmember and AVIRIS NDVI
    • 2001 (0.73), 2002 (0.58)
  – Between shrub+grass endmembers and AVIRIS CAI
    • 2001 (0.59), 2002 (0.60)
  – Between soil endmember and AVIRIS CAI
    • 2001 (-0.89), 2002 (-0.79)
  – Between 2001 shrub endmember and IKONOS NDVI
    • Southwest subset (0.71), Northwest subset (0.57)
Image Spatial Degradations

- Spatial degradations
  - Ten multiples of original resolution
  - Aggregate AVIRIS images
  - Run MESMA on degraded AVIRIS
  - Aggregate original MESMA as ‘Truth’
  - Compare fractional cover results

<table>
<thead>
<tr>
<th>Multiple</th>
<th>AVIRIS</th>
<th>Degraded MESMA</th>
<th>‘Truth’ MESMA</th>
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<td>Aggr. 10x</td>
<td>MESMA</td>
<td>Aggr. 10x</td>
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</tbody>
</table>
2001 Spatial Scale Effects

- Avg. Bias < 0.006
- 2\textsuperscript{nd} Multiple:
  - 45% pixels
  - < 1% different
- 10\textsuperscript{th} Multiple:
  - 30% pixels
  - < 1% different
- 90% pixels < 10% different
2002 Spatial Scale Effects

- Avg. Bias < 0.02
- 2\textsuperscript{nd} Multiple:
  - 40% pixels
  - < 1\% different
- 10\textsuperscript{th} Multiple:
  - 25% pixels
  - < 1\% different
- 90\% pixels < 10\% different

[Diagram showing spatial resolution effects with bars for different spatial resolutions (31.0-155.0 m), grouped into 0%-1\%, 1%-10\%, and 10%-120\% difference categories for EM1, EM2, EM3, and EM4.]
Spatial Scale Effects at Jornada

- Method of Woodcock and Strahler (1987)
- Effect of spatial scale to resolve ‘truth’ image features
- Calculate local standard deviation of each endmember
- 60 m HyspIRI will not resolve spatial features at Jornada
Image Spectral Degradations

• Spectral degradations
  – 6 cases with key waveband eliminated
    • Exclude VIS/NIR (422 nm to 1088 nm)
    • Exclude SWIR1 (1513 nm to 1712 nm)
    • Exclude SWIR2 (2030 nm to 2339 nm)
    • VIS/NIR only (422 nm to 1088 nm)
    • SWIR1 only (1513 nm to 1712 nm)
    • SWIR2 only (2030 nm to 2339 nm)
  – Run MESMA for each case
  – Compare results to original MESMA with all wavelengths included
2001 Spectral Waveband Effects

- Avg. Bias > 0.01
  - 10 or 100 times greater than for spatial effects
- Few pixels < 1% different
- More pixels >10% different
- Need VIS/NIR
2002 Spectral Waveband Effects

- Avg. Bias > 0.01
  - 10 or 100 times greater than for spatial effects
- Few pixels < 1% different
- More pixels >10% different
- Need VIS/NIR
Conclusions

• MESMA
  – MESMA effective for distinguishing grass from shrubs
  – MESMA not effective at distinguishing between shrub species
  – MESMA very sensitive to spectral wavebands included
  – MESMA substantially less sensitive to image spatial resolution

• HyspIRI
  – HyspIRI not able to resolve spatial feature at Jornada
  – AVIRIS not able to resolve spatial features at Jornada
  – Optimum spatial resolution < 15 m at Jornada
  – MESMA works at suboptimal spatial resolution
  – Spectral considerations are more important than spatial
Questions?