Mapping Vegetation Across Spatial and Spectral Scales Using Multiple Endmember Spectral Mixture Analysis

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Vegetation Mapping

- Past research has shown imaging spectroscopy is capable of mapping vegetation species and functional types at 4-30 m spatial resolutions.
- Little work on mapping vegetation using coarser resolution imaging spectrometer data.

Santa Barbara Front Range, 20 m AVIRIS

Dennison and Roberts, 2003
Mapping Vegetation in Montane Ecosystems

- Mapping vegetation in montane ecosystems can be particularly challenging
  - Spatial variation in elevation, slope, aspect, precipitation, and insolation produce spatial variation in vegetation type
  - Cloud cover, shorter summer season at higher elevation can limit remote sensing opportunities

Little Cottonwood Canyon, Wasatch Mtns
Mapping Vegetation in Montane Ecosystems

- Montane ecosystems are vulnerable to climate change
  - Favorable climates for individual species may move hundreds of meters upslope with a few degrees warming
  - Earlier snowmelt
  - Increased threat of insect outbreak (e.g. mountain pine beetle)
  - Increased summer evapotranspiration may not be offset by increased precipitation

- Vegetation mapping is essential for understanding impacts of climate change, human activity, and other disturbance on montane ecosystems

Lodgepole pine, Medicine Bow Mtns.
Mapping Vegetation in Montane Ecosystems

• How does vegetation mapping accuracy change with spatial and spectral resolution?
  – Can VNIR/SWIR imaging spectrometer data accurately map plant functional types at 60 m resolution in montane ecosystems?
AVIRIS Data

• Acquired August 5, 1998
• 20 m IFOV
• Covers 28 km by 11 km study area within the Wasatch Range east of the Salt Lake Valley
Wasatch Plant Functional Types

• 4 broad PFTs were defined based on leaf type and lifeform
  – broadleaf deciduous shrub (Gambel oak)
  – broadleaf deciduous tree (aspen)
  – needleleaf evergreen tree (white and subalpine fir, Douglas fir, and Engelmann spruce)
  – grass/herbaceous (meadows)
• A fifth rock/soil class was also mapped
Ground Reference Data

- Training and accuracy assessment polygons were derived from 1 m National Agriculture Imagery Program (NAIP) orthophotos
  - Polygons were created using image segmentation (eCognition)
  - Polygons were assigned a PFT identity in the field
  - Polygons were required to be at least 60 m by 60 m and at least 75% dominated by one PFT
  - 221 polygons were randomly partitioned into training and accuracy sets
Needleleaf evergreen tree polygon
Spatial and Spectral Resampling

- The 20 m AVIRIS radiance image was spatially resampled to 40 m and 60 m resolutions
- These 3 images were separately run through FLAASH to retrieve apparent surface reflectance
- AVIRIS reflectance images were also spectrally resampled to match the spectral response function of Landsat 5 TM
Image Classification

• Multiple Endmember Spectral Mixture Analysis
  – Models image spectra as a linear combination of endmembers
  – MESMA allows endmembers to vary on a per pixel basis
  – Endmembers were extracted from the training polygons
  – A 2-endmember model was used to classify the image
    • The best fit PFT (or rock/soil) endmember + shade
Endmember Selection

• Spectra extracted from polygons were run through an automated iterative endmember selection program.

• The program models a spectral library using 2 endmember MESMA and iteratively adds and subtracts endmembers to maximize the accuracy of the classification.

![AVIRIS Endmember Selection](image)
# MESMA Classification

<table>
<thead>
<tr>
<th>Endmembers</th>
<th>20 m</th>
<th>40 m</th>
<th>60 m</th>
</tr>
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<tbody>
<tr>
<td>AVIRIS 20 m</td>
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<td>X</td>
<td>X</td>
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<tr>
<td>AVIRIS 40 m</td>
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<td>X</td>
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<tr>
<td>AVIRIS 60 m</td>
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<tr>
<td>TM 20 m</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>TM 40 m</td>
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</tr>
<tr>
<td>TM 60 m</td>
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</tbody>
</table>
20m AVIRIS, 20m em

Accuracy 87.6%

Kappa .838
20m AVIRIS, 20m em

Accuracy 87.6%
Kappa .838

60m AVIRIS, 60m em

Accuracy 78.8%
Kappa .730
20m AVIRIS, 20m em

Accuracy 87.6%
Kappa .838

60m AVIRIS, 20m em

Accuracy 83.3%
Kappa .782
20m AVIRIS, 20m em

20m TM5, 20m em

Accuracy
87.6%

Kappa
.838

Accuracy
81.0%

Kappa
.754
Accuracy: 87.6% for 20m AVIRIS, 20m em
Accuracy: 74.5% for 60m TM5, 60m em
Kappa: 0.838 for 20m AVIRIS, 20m em
Kappa: 0.607 for 60m TM5, 60m em

Legend:
- Red: Broadleaf Deciduous Tree
- Blue: Needleleaf Evergreen Tree
- Green: Broadleaf Deciduous Shrub
- Yellow: Grass/Herbaceous
- Purple: Soil/Rock
20m AVIRIS, 20m em

60m TM5, 20m em

Accuracy
87.6%

Kappa
.838

Accuracy
78.6%

Kappa
.722

Legend:
- Broadleaf Deciduous Tree
- Needleleaf Evergreen Tree
- Broadleaf Deciduous Shrub
- Grass/Herbaceous
- Soil/Rock
## Accuracy Comparison

<table>
<thead>
<tr>
<th>Spectral Resolution</th>
<th>Image Resolution</th>
<th>Em Resolution</th>
<th>Overall Accuracy</th>
<th>Kappa</th>
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<td>AVIRIS 40 20</td>
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<td>86.1%</td>
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<td>74.5%</td>
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## User’s Accuracy (%)

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<th>Em Res.</th>
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<th>Broadleaf Deciduous Shrub</th>
<th>Grass/Herbaceous</th>
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## Producer’s Accuracy (%)

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</table>
Results

• Accuracy is higher at finer spatial and spectral resolutions
• Accuracy is higher when endmembers were selected from the 20 m image
  – Purer endmembers at 20 m
  – Spectral mixing at edges of polygons at coarser spatial resolution
• While finer resolution TM bands have similar overall accuracies to coarser resolution AVIRIS, accuracy can be very low for poorly discriminated classes
Limitations

• Polygons were required to have a minimum size and PFT dominance
  – Accuracy would be lower at coarser spatial resolutions if smaller, more heterogeneous polygons were included
• Our PFTs have broad structural and spectral differences
  – More spectrally similar PFTs will be more difficult to map
  – Analysis of additional spatial/spectral resampled datasets is underway for Wind River, Sierra Nevada, Santa Barbara
• Spatial average of 9 20 m pixels is not equivalent to 60 m HyspIRI point spread function
Conclusions

• Finer spatial and spectral resolutions increased PFT mapping accuracy
• High classification accuracies are possible at 60 m (for contiguous vegetation patches > 60 m)
• Finer spatial resolution airborne or spaceborne sensors may have a role creating training data for HyspIRI classification
Acknowledgements

• JPL: Rob Green, Sarah Lundeen
• Seminar students: Bob Benton, Annie Bryant, McKenzie Skiles, Jamie Turrin, Yuan Zhang
20m AVIRIS, 20m em

Accuracy 87.6%

Kappa .838

SWIR/NIR/red composite

- Broadleaf Deciduous Tree
- Needleleaf Evergreen Tree
- Broadleaf Deciduous Shrub
- Grass/Herbaceous
- Soil/Rock
20m AVIRIS, 20m em

Accuracy 87.6%

Kappa .838

40 m AVIRIS, 40 m em

Accuracy 77.8%

Kappa .716
20m AVIRIS, 20m em

Accuracy 87.6%
Kappa .838

60m AVIRIS, 60m em

Accuracy 78.8%
Kappa .730
20m AVIRIS, 20m em

Accuracy 87.6%
Kappa .838

40m AVIRIS, 20m em

Accuracy 86.1%
Kappa .818

Legend:
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Accuracy
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Accuracy
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Kappa
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20m AVIRIS, 20m em

Accuracy 87.6%

Kappa .838

20m TM5, 20m em

Accuracy 81.0%

Kappa .754
20m AVIRIS, 20m em

Accuracy 87.6%

Kappa .838

40m TM5, 40m em

Accuracy 76.5%

Kappa .701
20m AVIRIS, 20m em

Accuracy
87.6%

Kappa
.838

60m TM5, 60m em

Accuracy
68.6%

Kappa
.607
20m AVIRIS, 20m em

40m TM5, 20m em

Accuracy
87.6%

Accuracy
81.0%

Kappa
.838

Kappa
.753

Legend:
- Red: Broadleaf Deciduous Tree
- Blue: Needleleaf Evergreen Tree
- Green: Broadleaf Deciduous Shrub
- Yellow: Grass/Herbaceous
- Pink: Soil/Rock
Broadleaf deciduous shrub
Training polygon

NAIP 1 m

20 m

40 m

60 m
Broadleaf deciduous tree polygon