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

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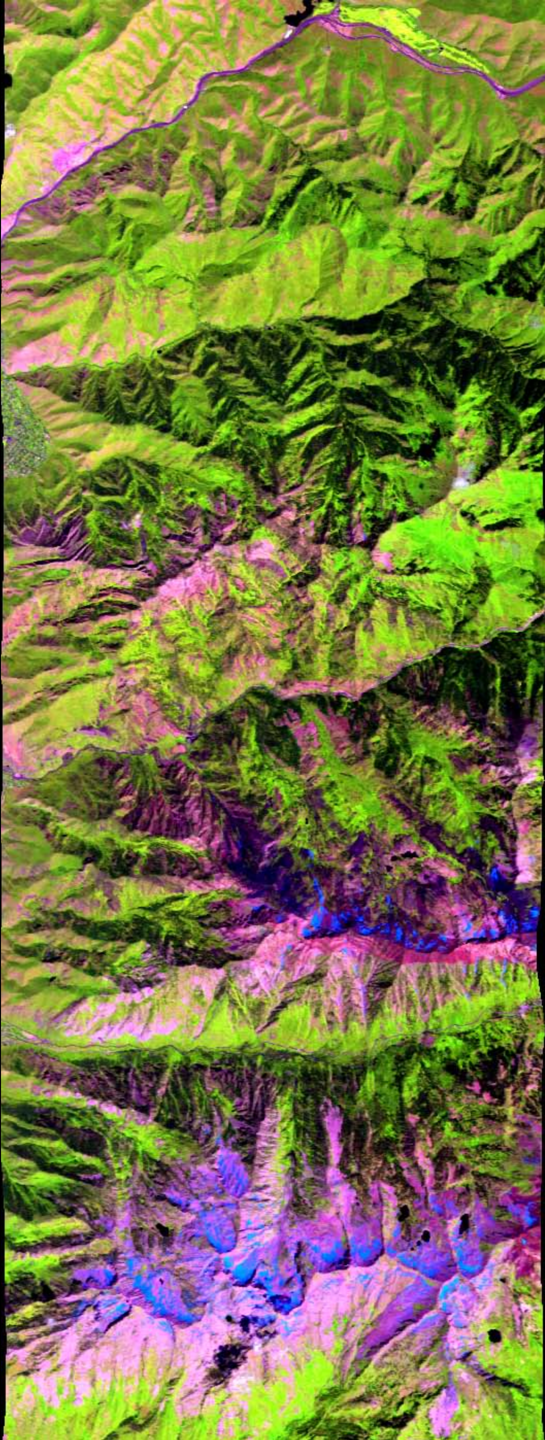
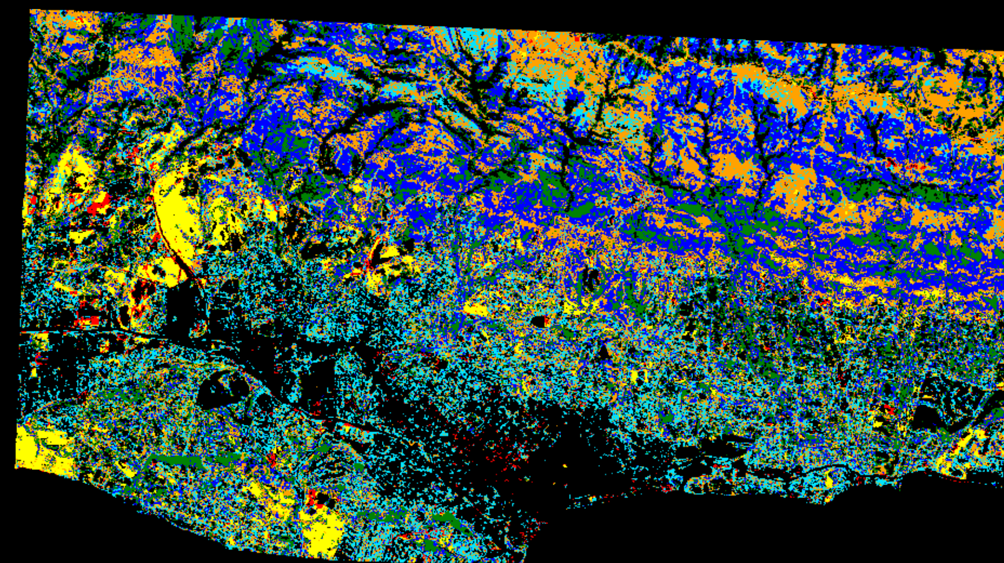
Utah Remote Sensing Applications Lab
University of Utah



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



Chamise
Big Pod Ceanothus
Manzanita
Coast Live Oak
Grass
Soil

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

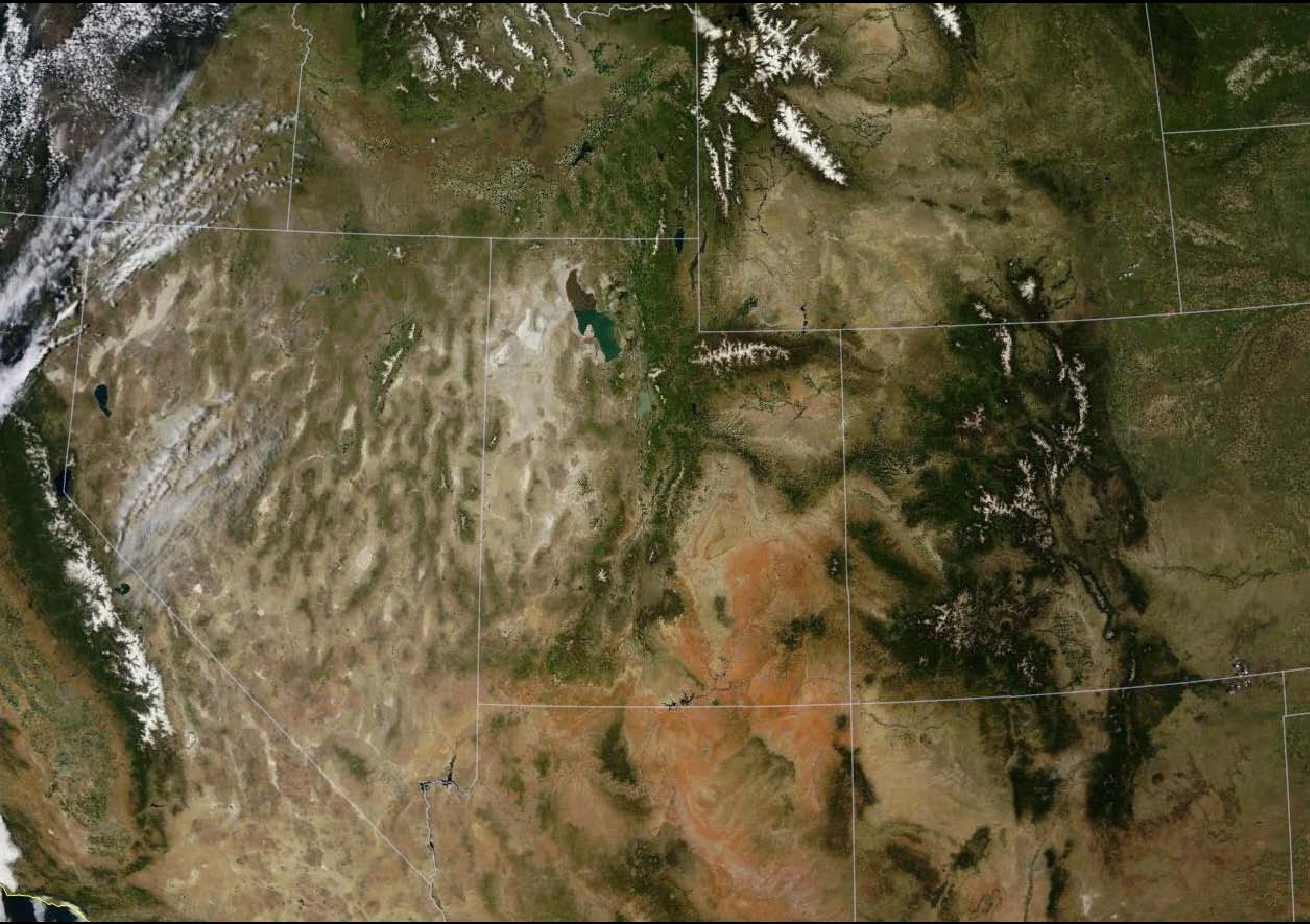
- Montane ecosystems are vulnerable to climate change
  - Favorable climates for individual species may move hundreds of meters upslope with a few degrees warming
  - Earlier snowmelt
  - Increased threat of insect outbreak (e.g. mountain pine beetle)
  - Increased summer evapotranspiration may not be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

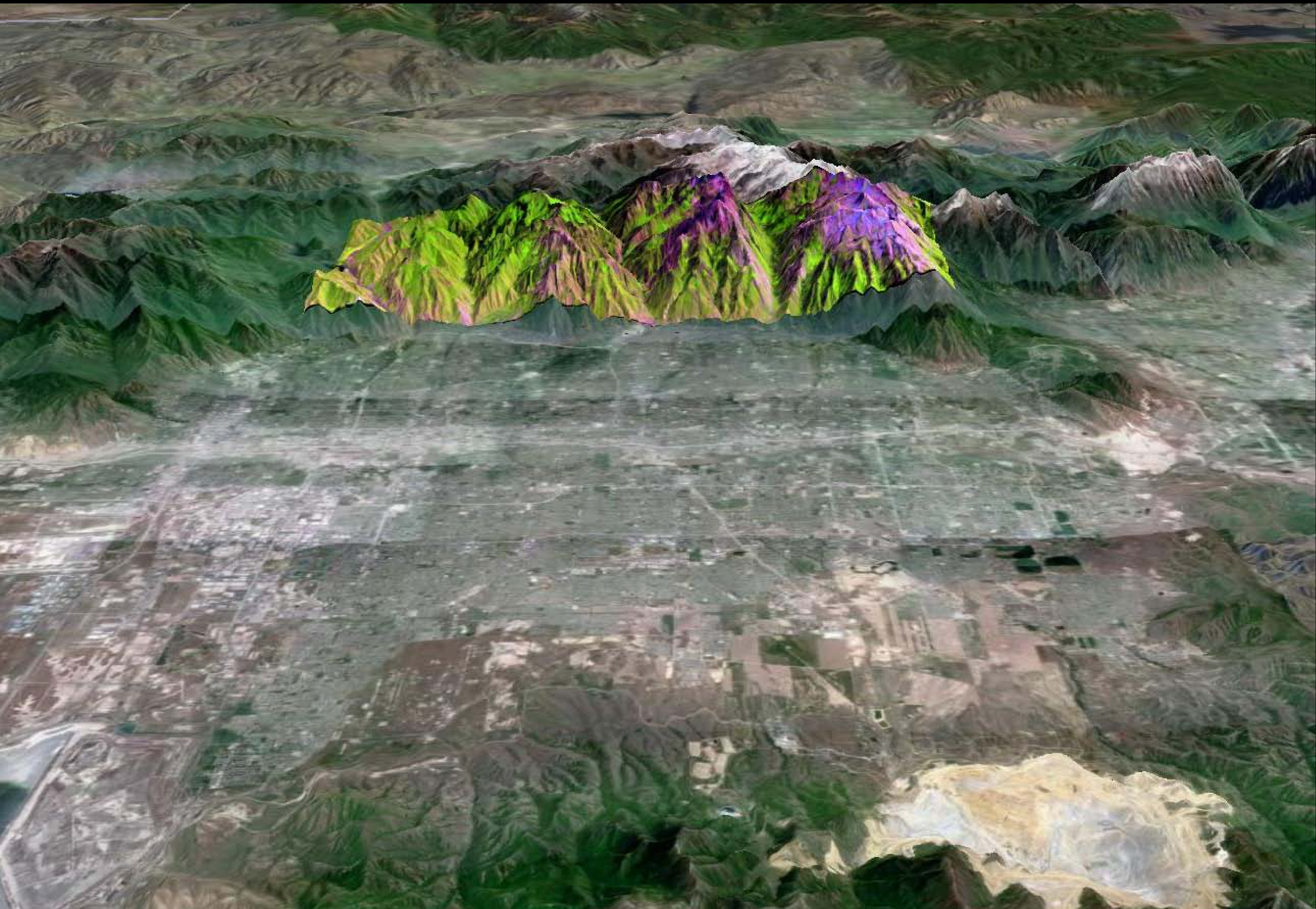
- How does vegetation mapping accuracy change with spatial and spectral resolution?
  - Can VNIR/SWIR imaging spectrometer data accurately map plant functional types at 60 m resolution in montane ecosystems?

Big Cottonwood Canyon, Wasatch Mtns



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



Elevation (1300-3400 m)

Hillshade (illuminated from N)

SWIR/NIR/red composite

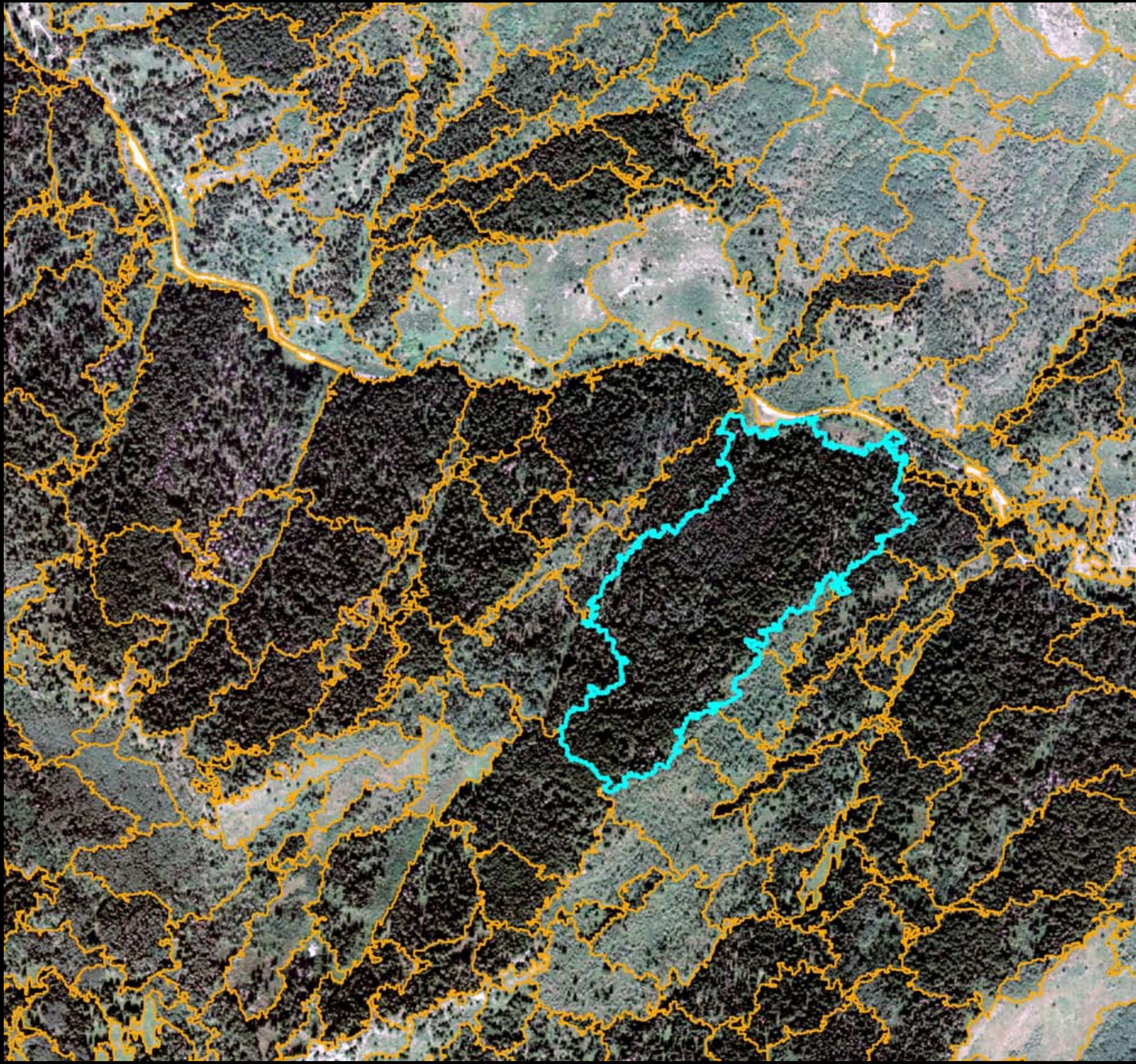
Wasatch Plant Functional Types

- 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

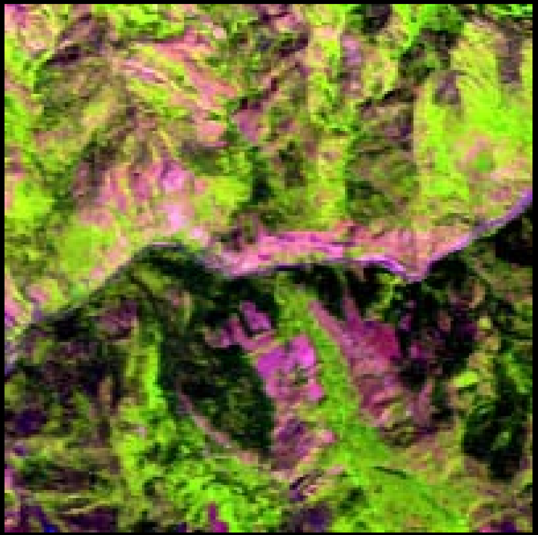
- Training and accuracy assessment polygons were derived from 1 m National Agriculture Imagery Program (NAIP) orthophotos
  - Polygons were created using image segmentation (eCognition)
  - Polygons were assigned a PFT identity in the field
  - Polygons were required to be at least 60 m by 60 m and at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

Needleleaf evergreen tree polygon

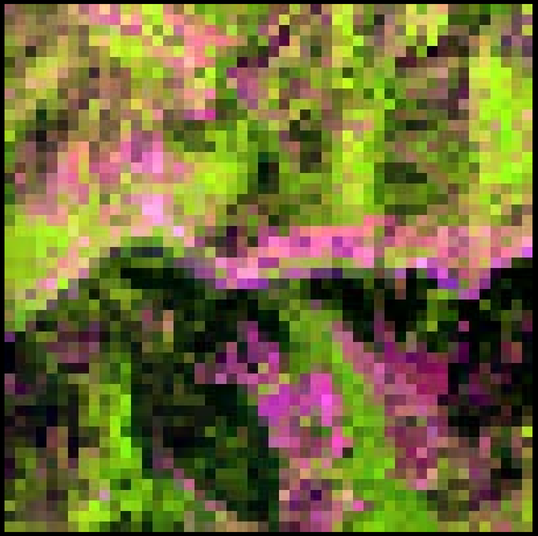


Spatial and Spectral Resampling

- 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



20 m



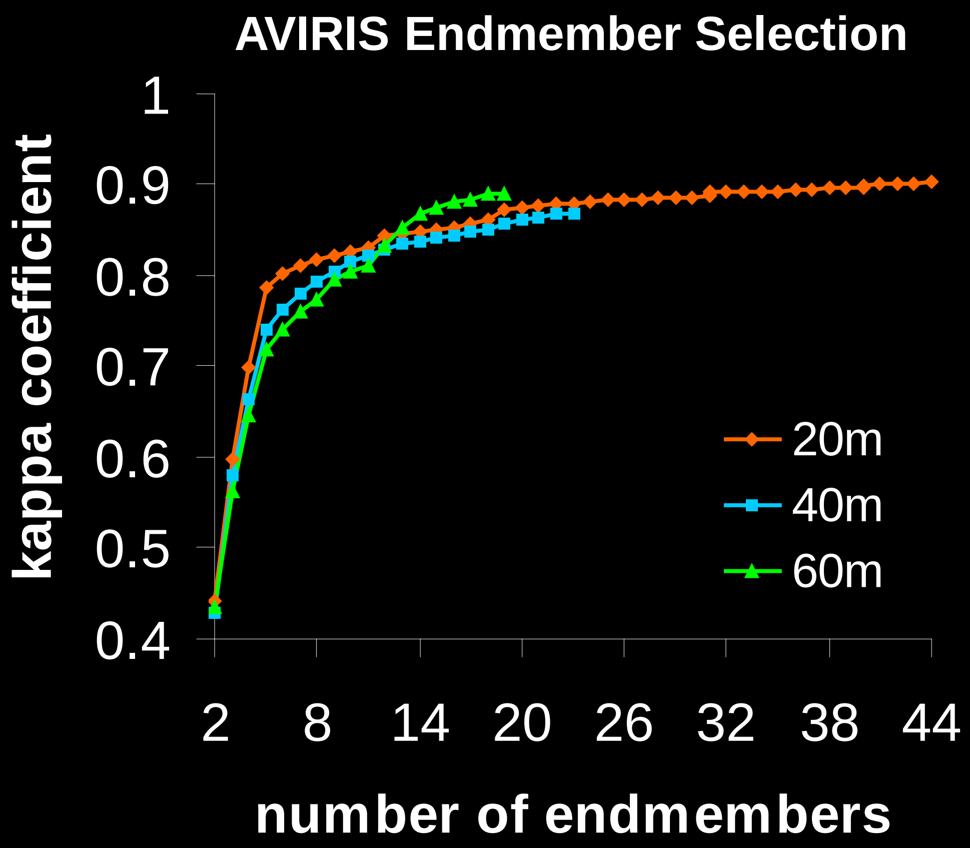
60 m

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

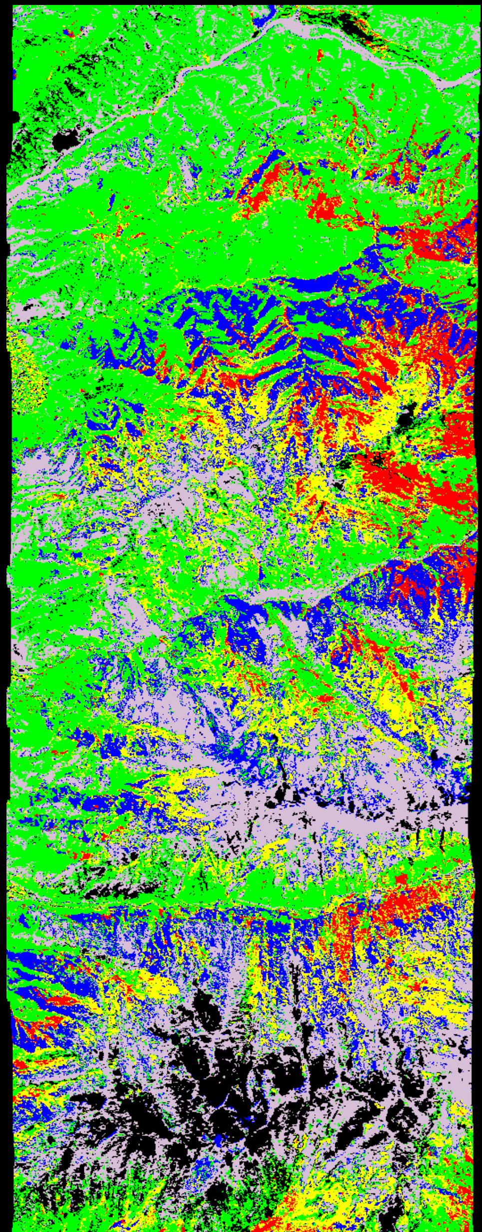


MESMA Classification

Endmembers	Used to Classify: 20 m	40 m	60 m
AVIRIS 20 m	X	X	X
AVIRIS 40 m		X	
AVIRIS 60 m			X
TM 20 m	X	X	X
TM 40 m		X	
TM 60 m			X

20m AVIRIS, 20m em

SWIR/NIR/red composite



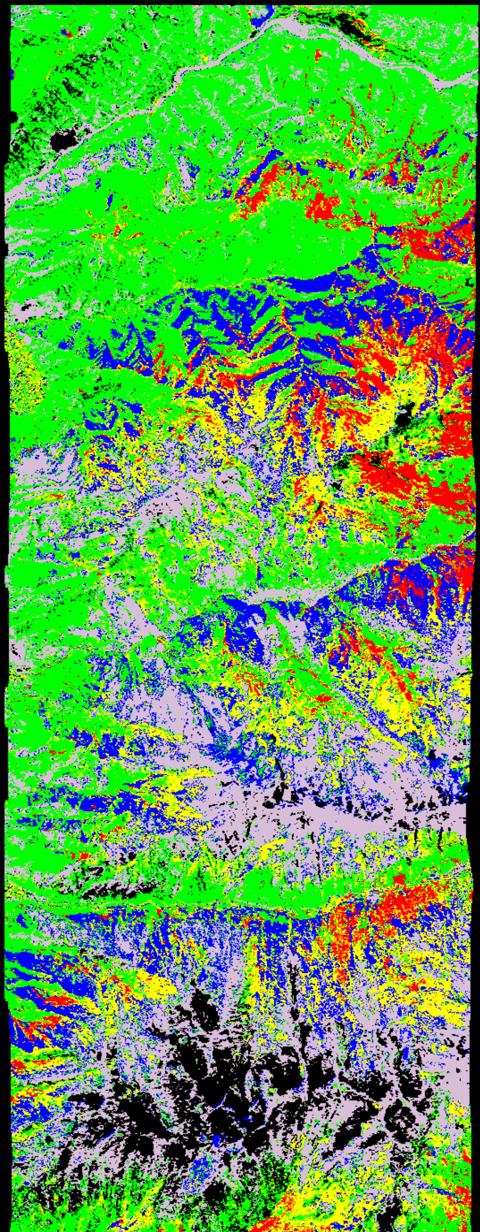
Broadleaf Deciduous Tree
Needleleaf Evergreen Tree
Broadleaf Deciduous Shrub
Grass/Herbaceous
Soil/Rock

Accuracy
87.6%

Kappa
.838

20m AVIRIS, 20m em

60m AVIRIS, 60m em



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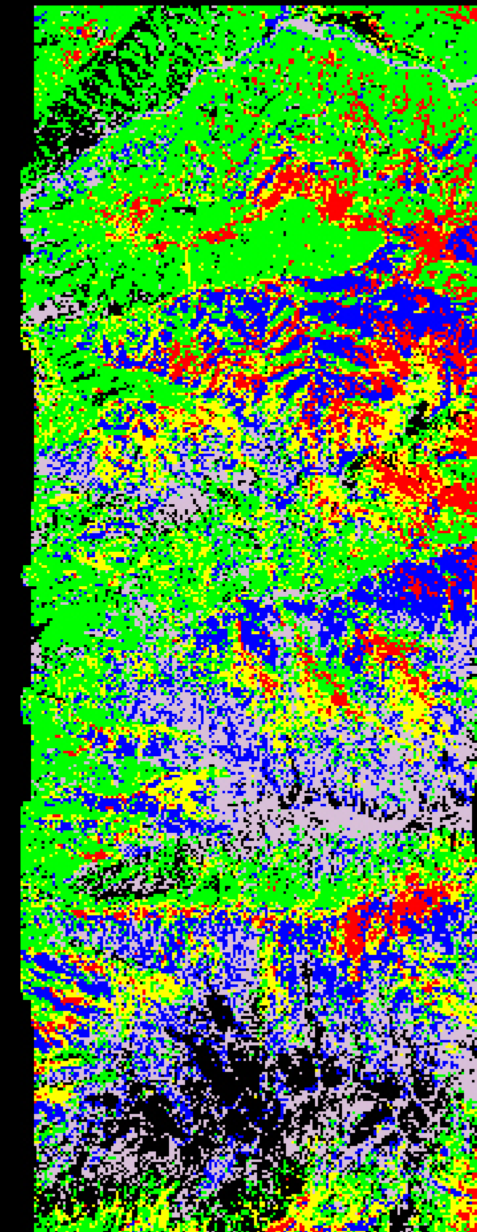
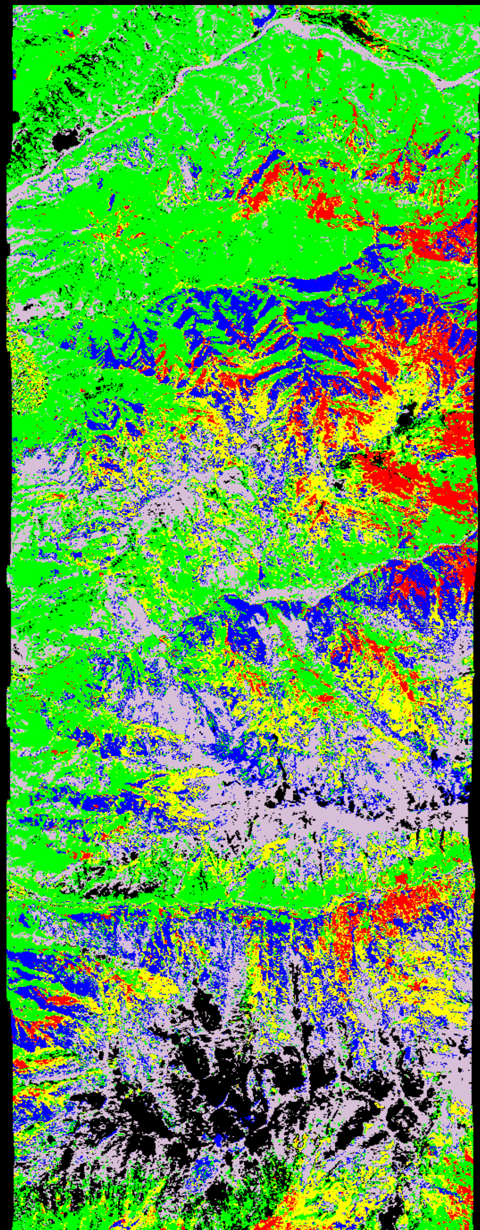


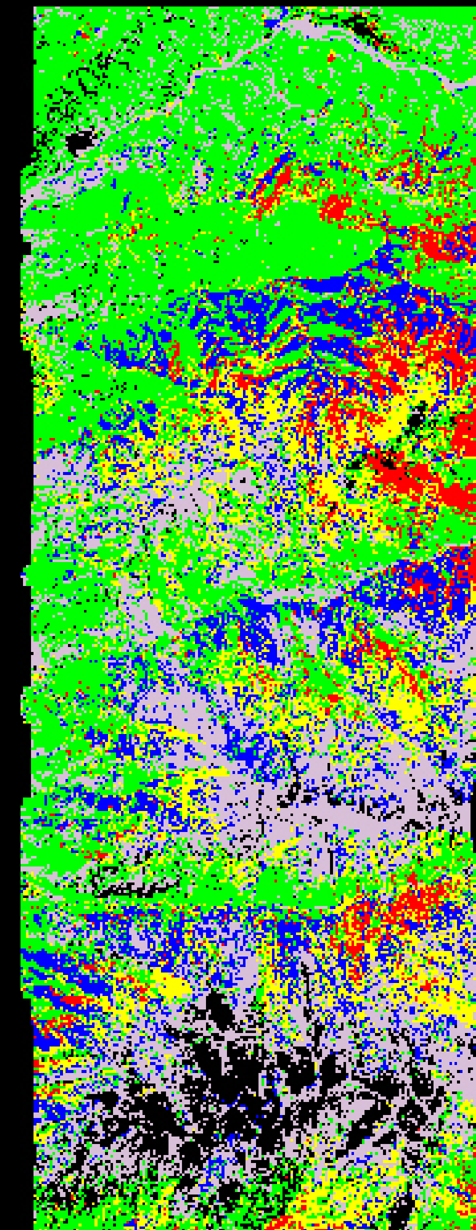
Accuracy
78.8%

Kappa
.730

20m AVIRIS, 20m em

60m AVIRIS, 20m em

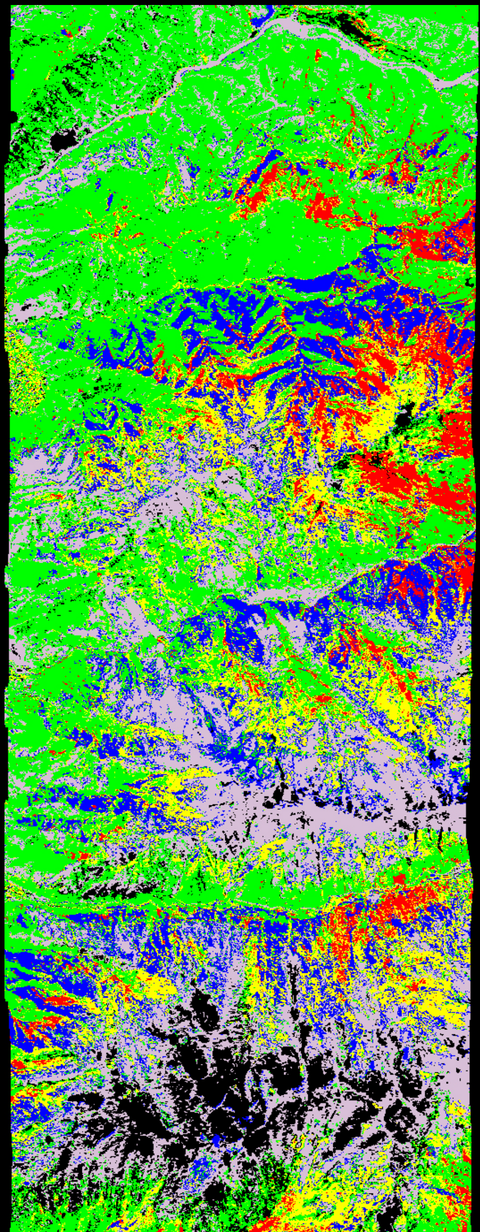




	20m AVIRIS, 20m em	60m AVIRIS, 20m em
Accuracy	87.6%	83.3%
Kappa	.838	.782

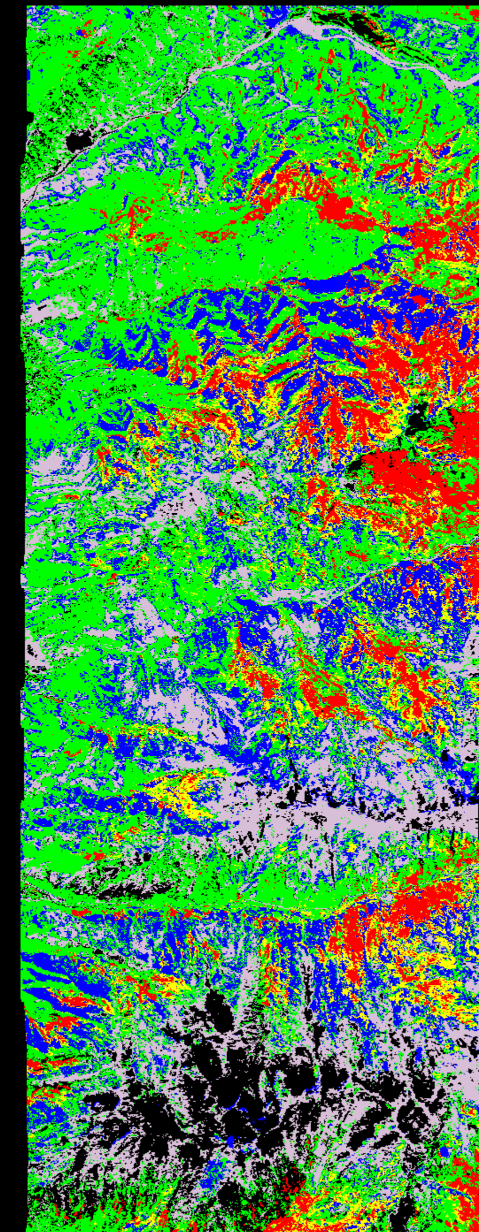
20m AVIRIS, 20m em

20m TM5, 20m em



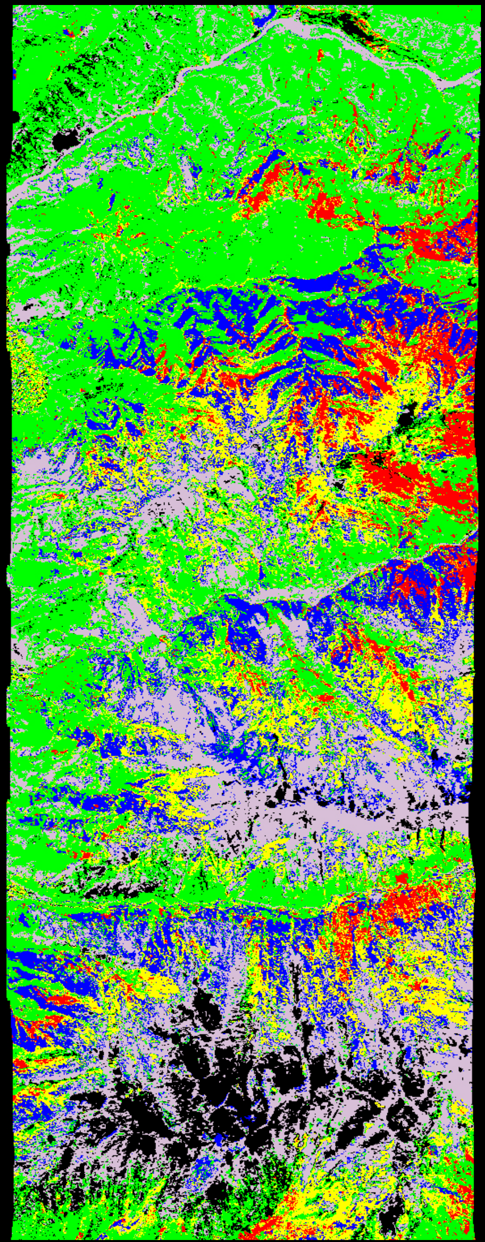
Broadleaf Deciduous Tree
Needleleaf Evergreen Tree
Broadleaf Deciduous Shrub
Grass/Herbaceous
Soil/Rock

<u>Accuracy</u>	<u>Accuracy</u>
87.6%	81.0%
<u>Kappa</u>	<u>Kappa</u>
.838	.754

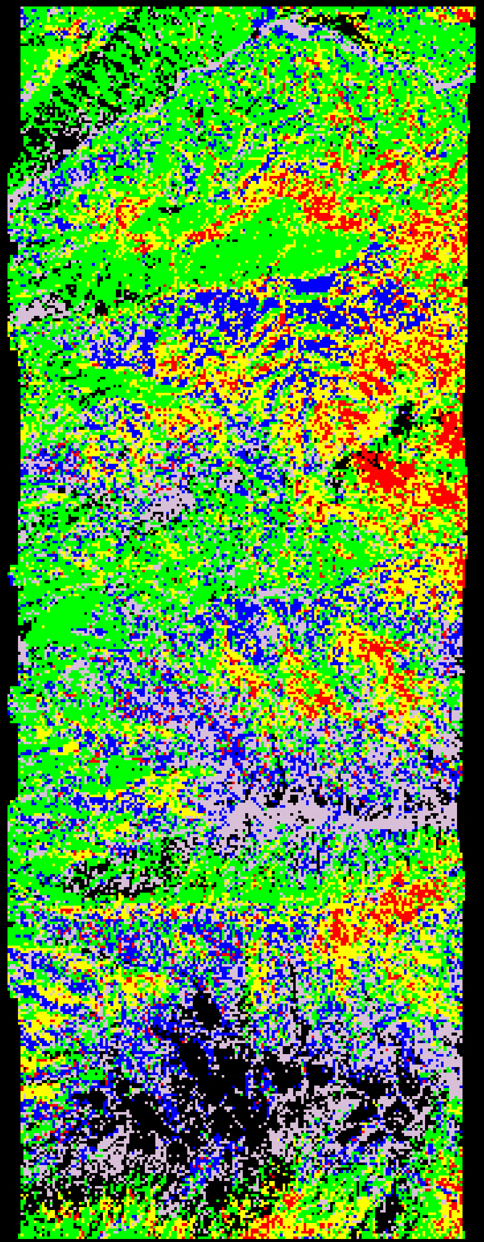


20m AVIRIS, 20m em

60m TM5, 60m em

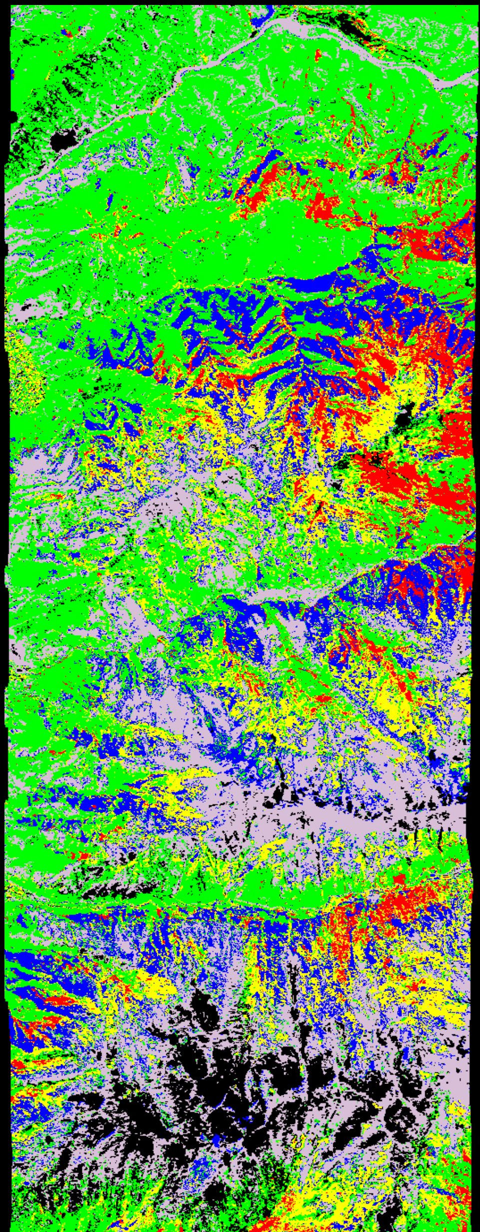


Broadleaf Deciduous Tree
Needleleaf Evergreen Tree
Broadleaf Deciduous Shrub
Grass/Herbaceous
Soil/Rock

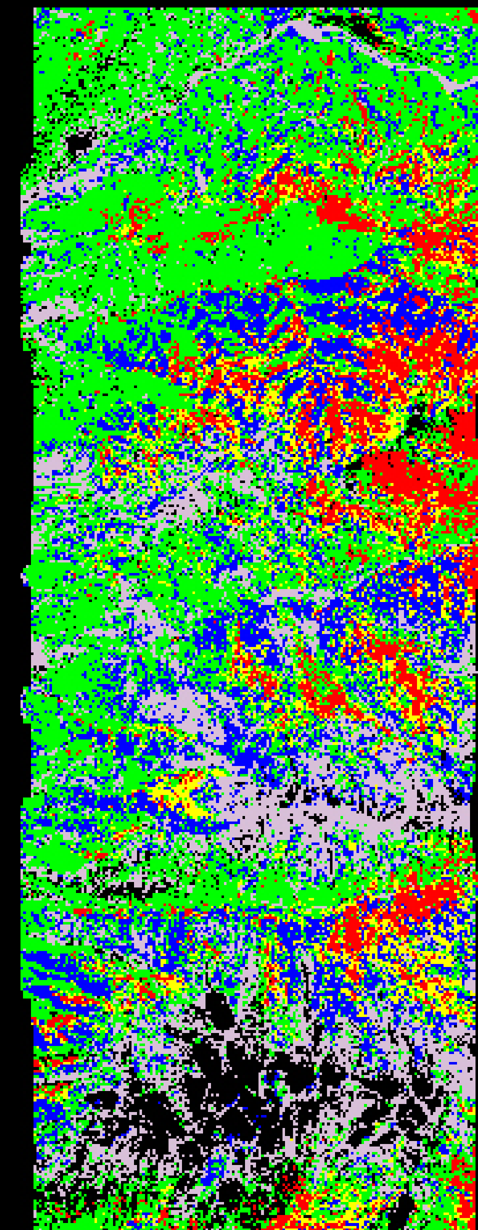


Accuracy	Accuracy
87.6%	74.5%
Kappa	Kappa
.838	.607

20m AVIRIS, 20m em



60m TM5, 20m em



Broadleaf Deciduous Tree
Needleleaf Evergreen Tree
Broadleaf Deciduous Shrub
Grass/Herbaceous
Soil/Rock

20m AVIRIS, 20m em	60m TM5, 20m em
Accuracy 87.6%	Accuracy 78.6%
Kappa .838	Kappa .722

Accuracy Comparison

Spectral Resolution	Image Resolution	Em Resolution	Overall Accuracy	Kappa
AVIRIS	20	20	87.6%	0.84
AVIRIS	40	20	86.1%	0.82
AVIRIS	60	20	83.3%	0.78
TM5	20	20	81.0%	0.75
TM5	40	20	81.0%	0.75
AVIRIS	60	60	78.8%	0.73
TM5	60	20	78.6%	0.72
AVIRIS	40	40	77.8%	0.72
TM5	40	40	76.5%	0.70
TM5	60	60	74.5%	0.61

User’s Accuracy (%)

Spectral Res.	Image Res.	Em Res.	Broadleaf Deciduous Tree	Needleleaf Evergreen Tree	Broadleaf Deciduous Shrub	Grass/ Herbaceous	Soil/Rock
AVIRIS	20	20	75.6	99.1	87.1	80.2	98.2
AVIRIS	40	40	57.5	99.0	82.4	62.4	91.4
AVIRIS	40	20	76.9	97.8	84.4	78.1	95.8
AVIRIS	60	60	59.7	97.5	90.2	53.2	96.0
AVIRIS	60	20	72.1	98.3	82.0	78.1	91.1
TM5	20	20	58.3	98.6	84.3	46.1	97.5
TM5	40	40	65.5	99.6	86.7	44.3	91.5
TM5	40	20	61.0	98.2	84.4	46.6	95.3
TM5	60	60	74.6	89.5	84.4	41.2	87.6
TM5	60	20	55.7	97.5	82.6	45.5	91.1

Producer's Accuracy (%)

Spectral Res.	Image Res.	Em Res.	Broadleaf Deciduous Tree	Needleleaf Evergreen Tree	Broadleaf Deciduous Shrub	Grass/ Herbaceous	Soil/Rock
AVIRIS	20	20	91.0	83.0	97.1	85.6	80.6
AVIRIS	40	40	92.0	60.9	90.5	70.8	80.9
AVIRIS	40	20	92.0	78.8	97.9	84.3	78.3
AVIRIS	60	60	86.0	76.1	84.5	80.5	70.6
AVIRIS	60	20	88.0	72.9	96.5	78.1	80.4
TM5	20	20	93.9	82.1	93.4	27.0	78.2
TM5	40	40	84.8	74.7	80.0	56.2	77.9
TM5	40	20	96.4	77.9	94.8	30.3	78.3
TM5	60	60	88.0	60.7	80.3	85.4	76.5
TM5	60	20	88.0	74.8	93.7	24.4	80.4

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

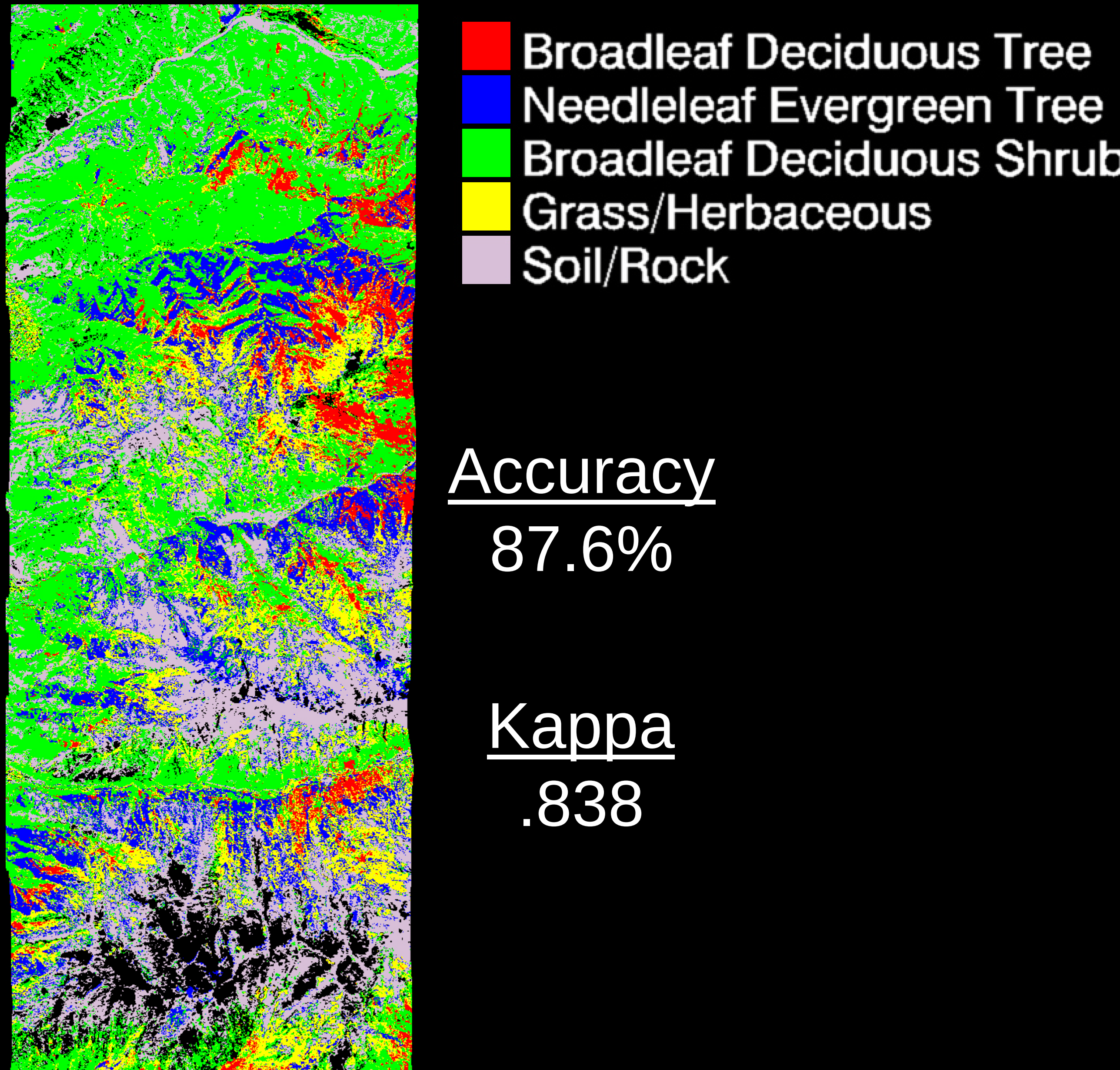
- Finer spatial and spectral resolutions increased PFT mapping accuracy
- High classification accuracies are possible at 60 m (for contiguous vegetation patches > 60 m)
- Finer spatial resolution airborne or spaceborne sensors may have a role creating training data for HyspIRI classification

Acknowledgements

- JPL: Rob Green, Sarah Lundeen
- Seminar students: Bob Benton, Annie Bryant, McKenzie Skiles, Jamie Turrin, Yuan Zhang

20m AVIRIS, 20m em

SWIR/NIR/red composite

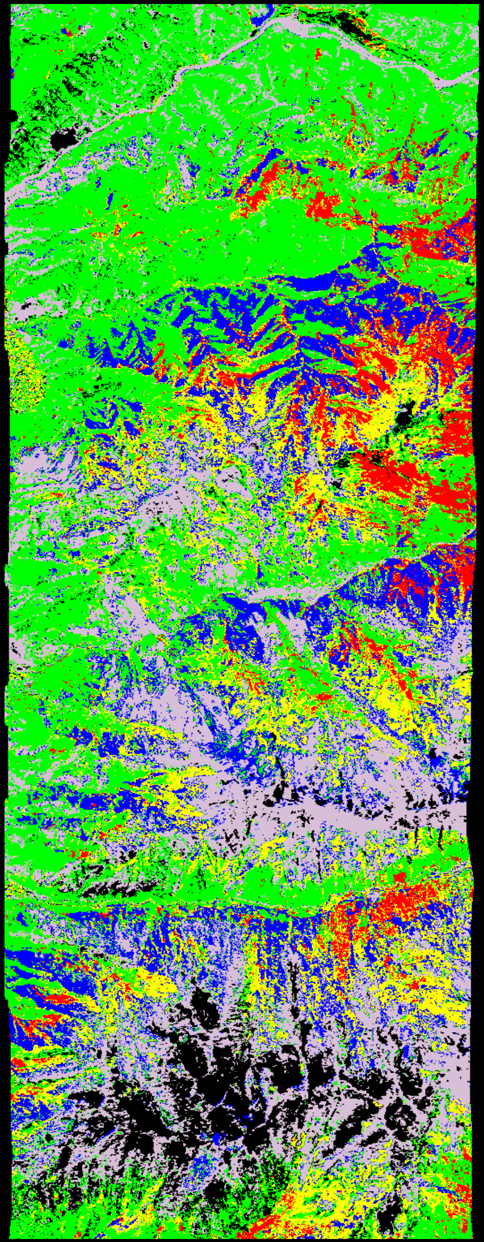


<u>Accuracy</u>
87.6%

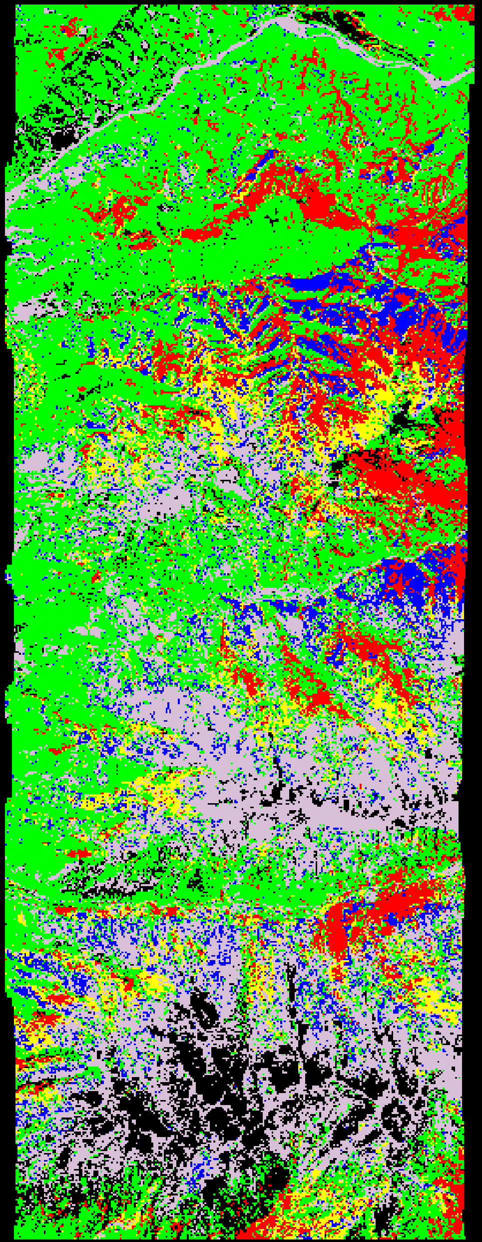
<u>Kappa</u>
.838

20m AVIRIS, 20m em

40 m AVIRIS, 40 m em

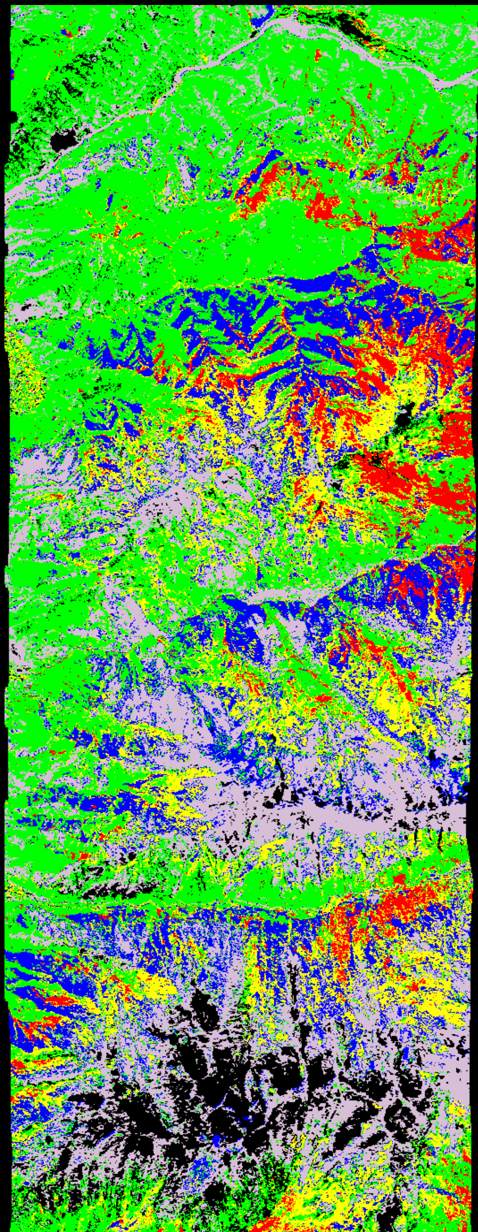


Broadleaf Deciduous Tree
Needleleaf Evergreen Tree
Broadleaf Deciduous Shrub
Grass/Herbaceous
Soil/Rock

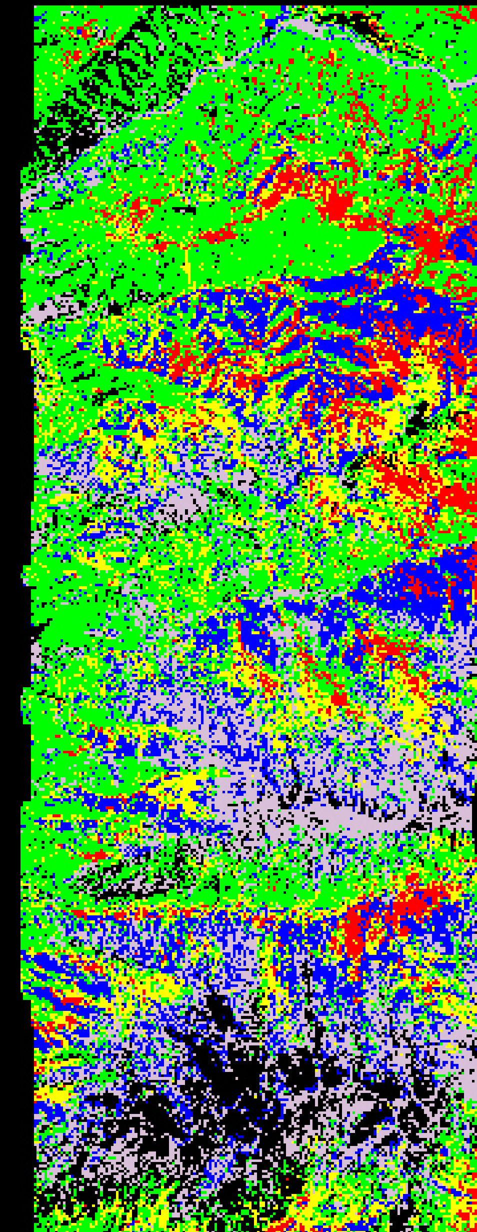


	20m AVIRIS, 20m em	40 m AVIRIS, 40 m em
Accuracy	87.6%	77.8%
Kappa	.838	.716

20m AVIRIS, 20m em



60m AVIRIS, 60m em

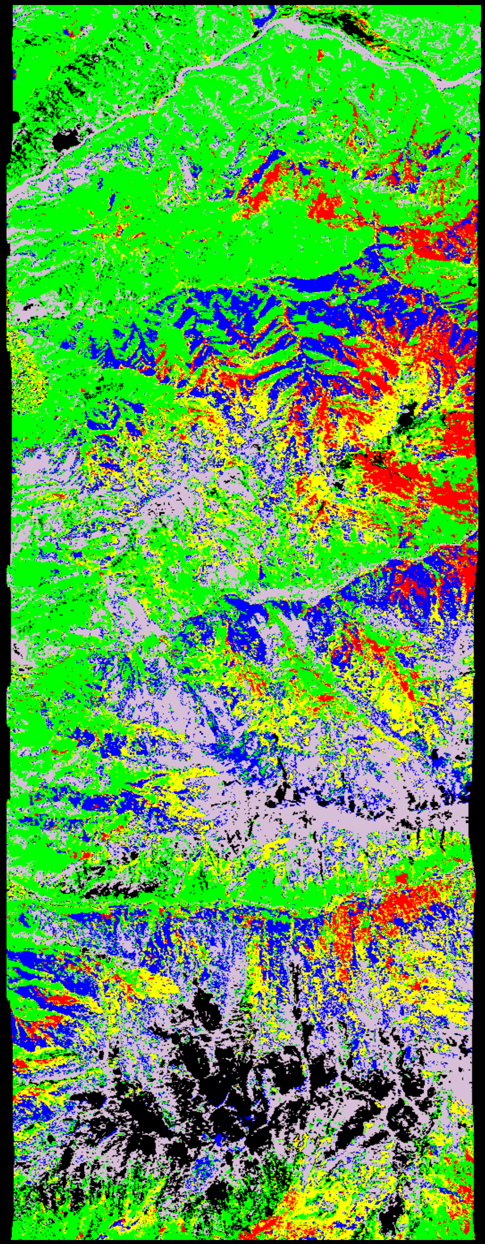


Broadleaf Deciduous Tree
Needleleaf Evergreen Tree
Broadleaf Deciduous Shrub
Grass/Herbaceous
Soil/Rock

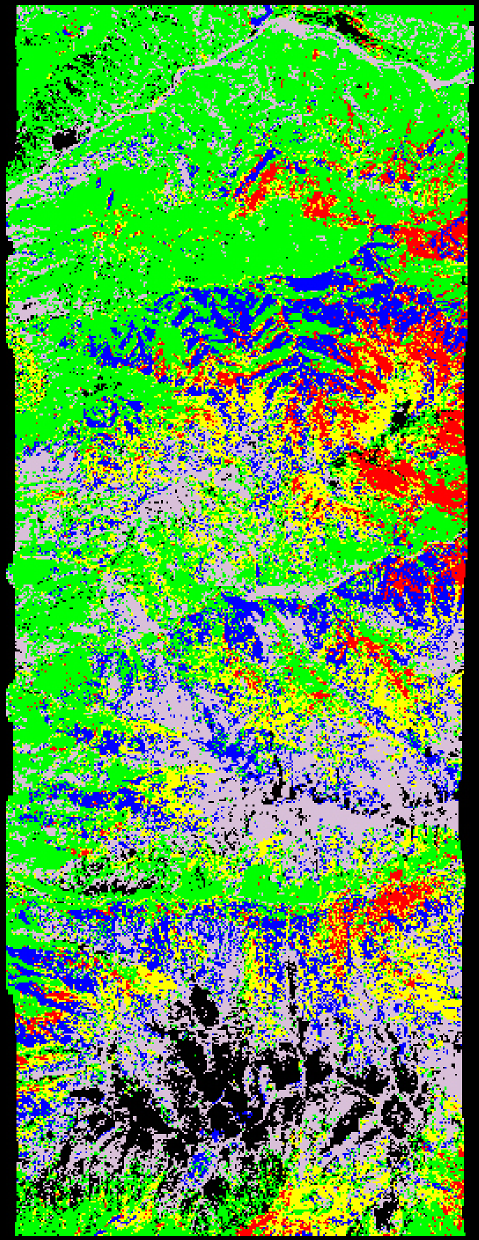
20m AVIRIS, 20m em	60m AVIRIS, 60m em
Accuracy 87.6%	Accuracy 78.8%
Kappa .838	Kappa .730

20m AVIRIS, 20m em

40m AVIRIS, 20m em



Broadleaf Deciduous Tree
Needleleaf Evergreen Tree
Broadleaf Deciduous Shrub
Grass/Herbaceous
Soil/Rock

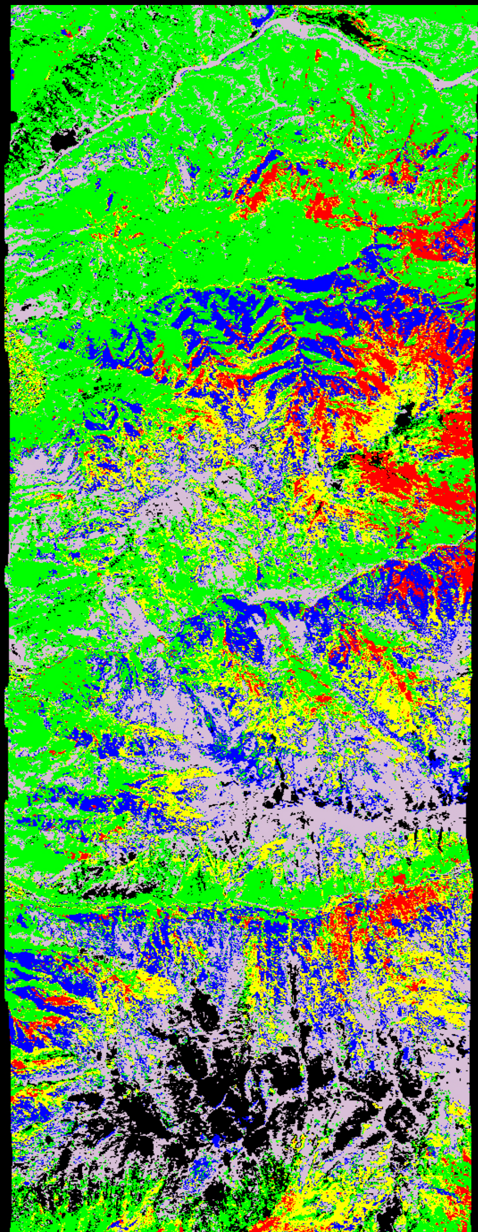


Accuracy	Accuracy
87.6%	86.1%

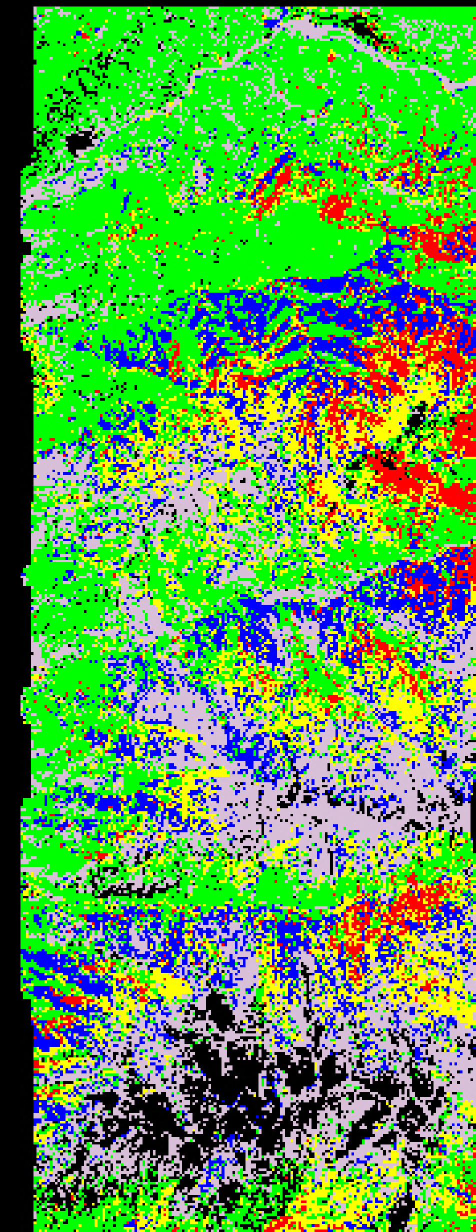
Kappa	Kappa
.838	.818

20m AVIRIS, 20m em

60m AVIRIS, 20m em



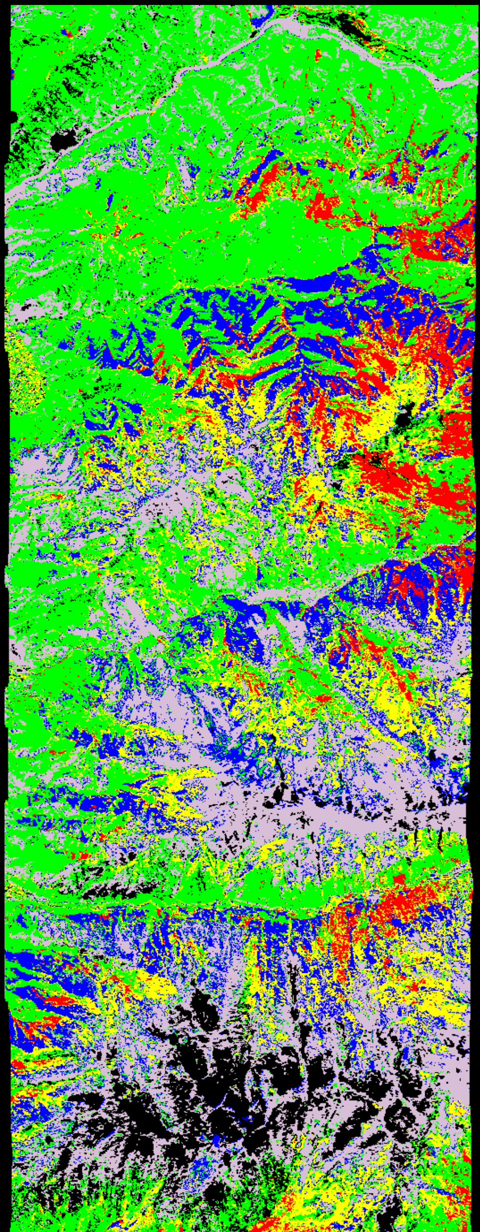
Broadleaf Deciduous Tree
Needleleaf Evergreen Tree
Broadleaf Deciduous Shrub
Grass/Herbaceous
Soil/Rock



Accuracy	Accuracy
87.6%	83.3%
Kappa	Kappa
.838	.782

20m AVIRIS, 20m em

20m TM5, 20m em



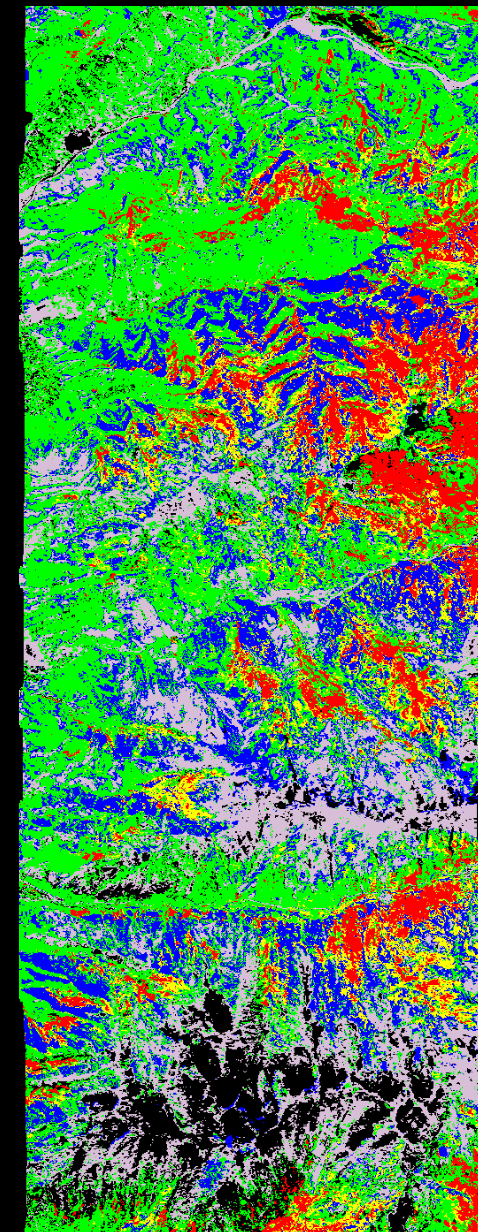
Broadleaf Deciduous Tree
Needleleaf Evergreen Tree
Broadleaf Deciduous Shrub
Grass/Herbaceous
Soil/Rock

Accuracy
87.6%

Kappa
.838

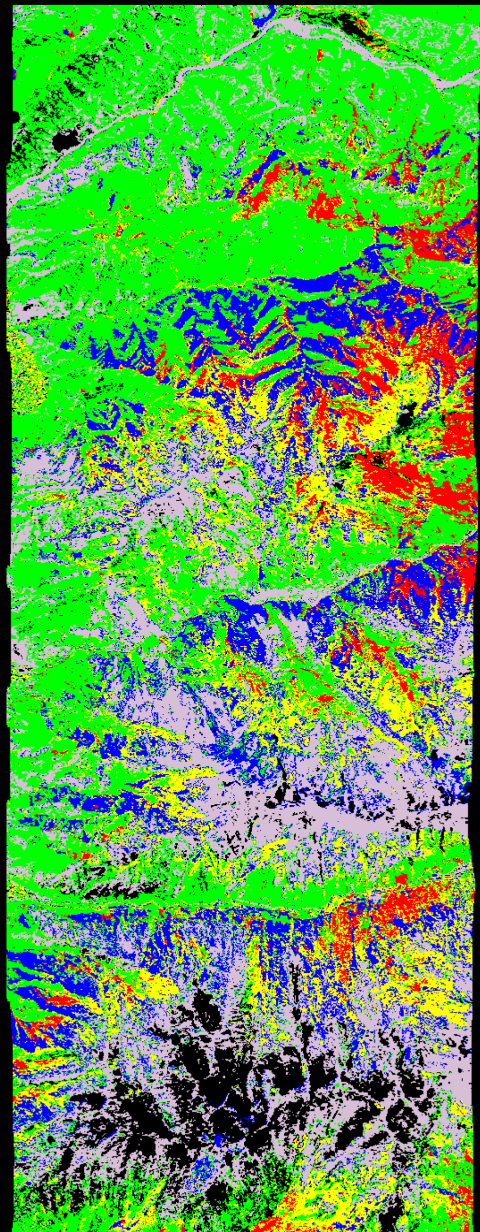
Accuracy
81.0%

Kappa
.754

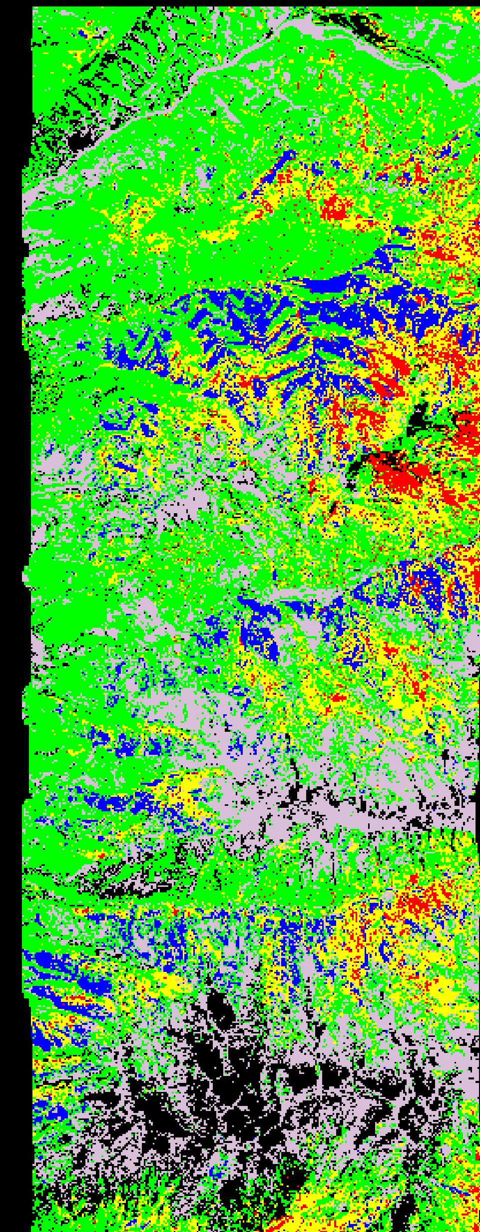


20m AVIRIS, 20m em

40m TM5, 40m em



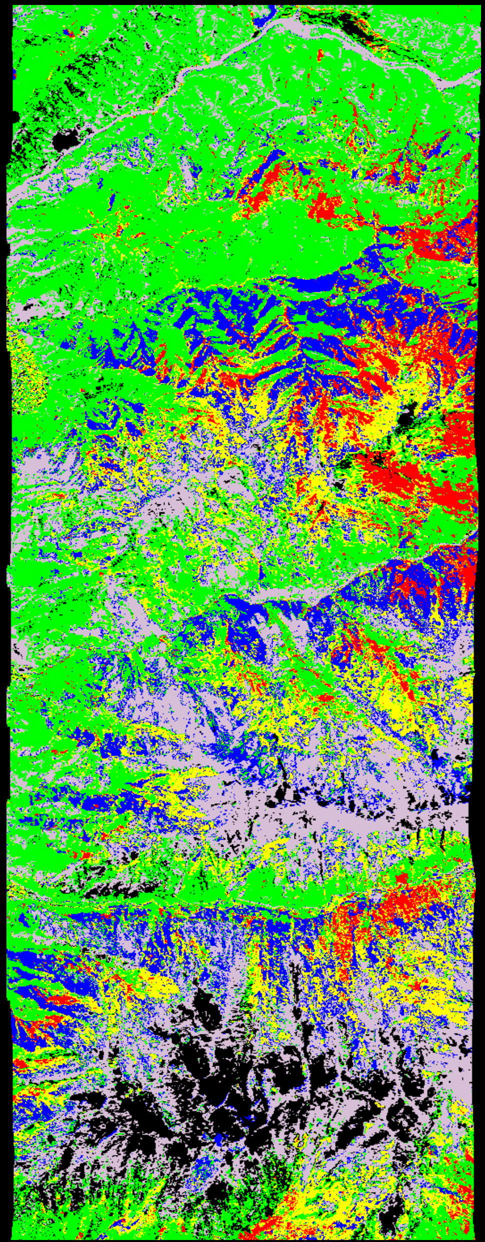
Broadleaf Deciduous Tree
Needleleaf Evergreen Tree
Broadleaf Deciduous Shrub
Grass/Herbaceous
Soil/Rock

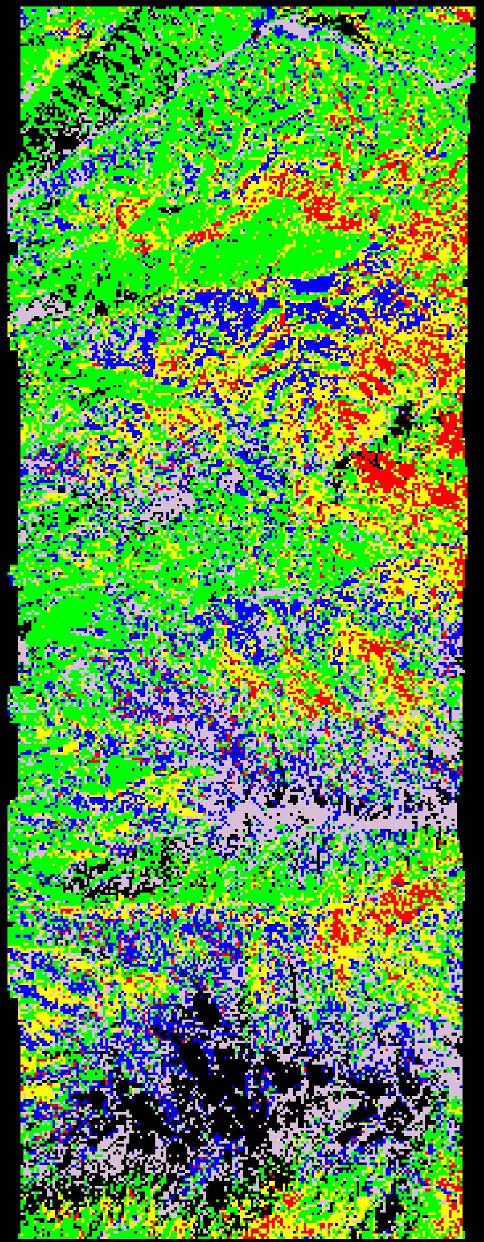


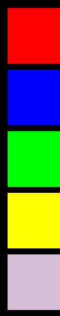
20m AVIRIS, 20m em	40m TM5, 40m em
Accuracy 87.6%	Accuracy 76.5%
Kappa .838	Kappa .701

20m AVIRIS, 20m em

60m TM5, 60m em



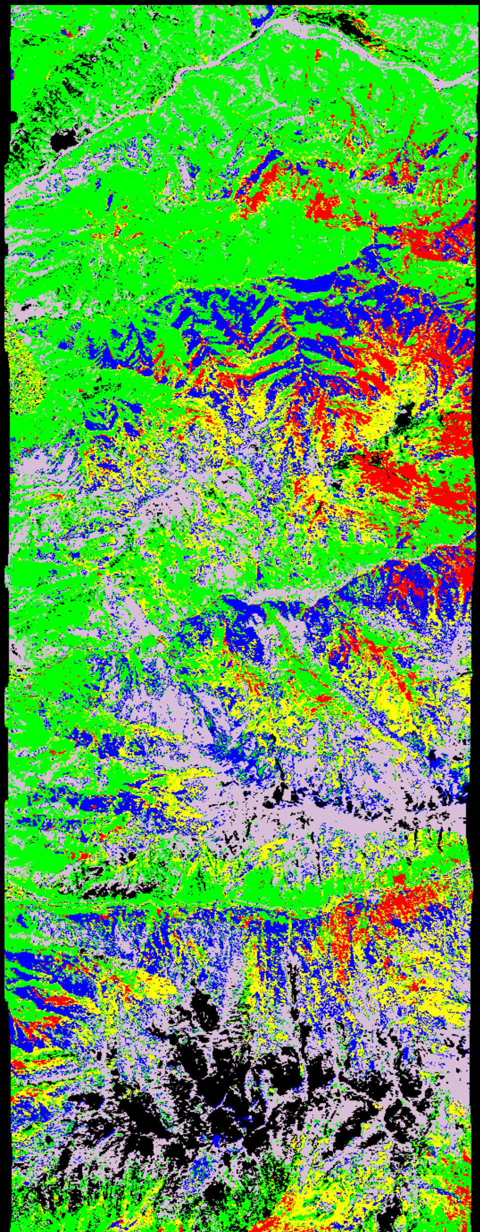




Accuracy	Accuracy
87.6%	68.6%
Kappa	Kappa
.838	.607

20m AVIRIS, 20m em

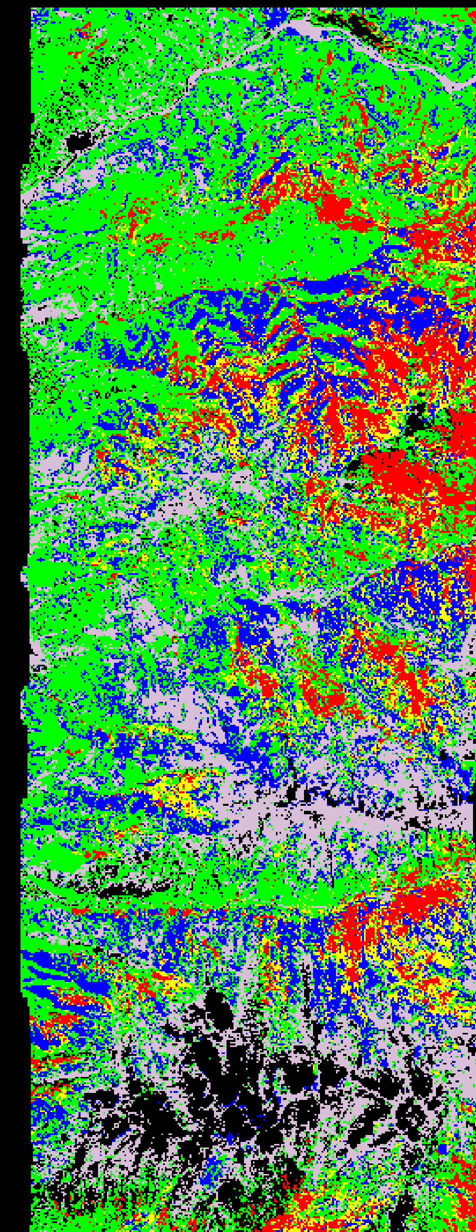
40m TM5, 20m em



Broadleaf Deciduous Tree
Needleleaf Evergreen Tree
Broadleaf Deciduous Shrub
Grass/Herbaceous
Soil/Rock

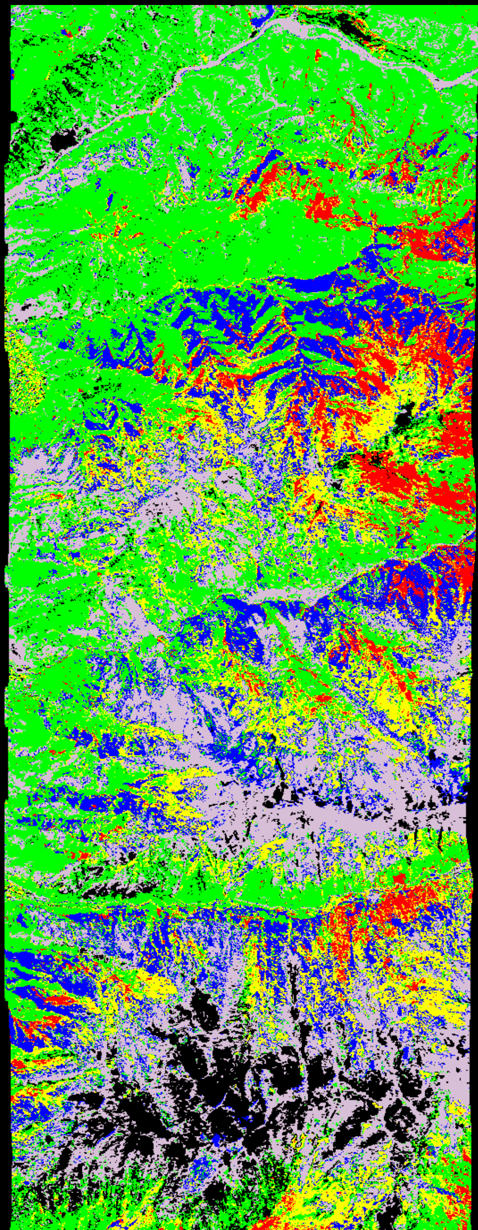
Accuracy	Accuracy
87.6%	81.0%

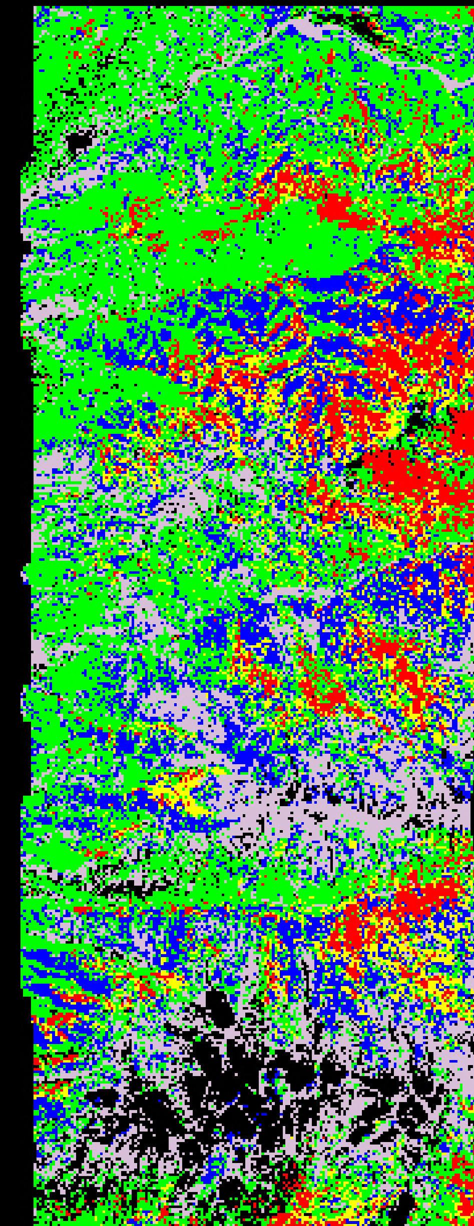
Kappa	Kappa
.838	.753



20m AVIRIS, 20m em

60m TM5, 20m em





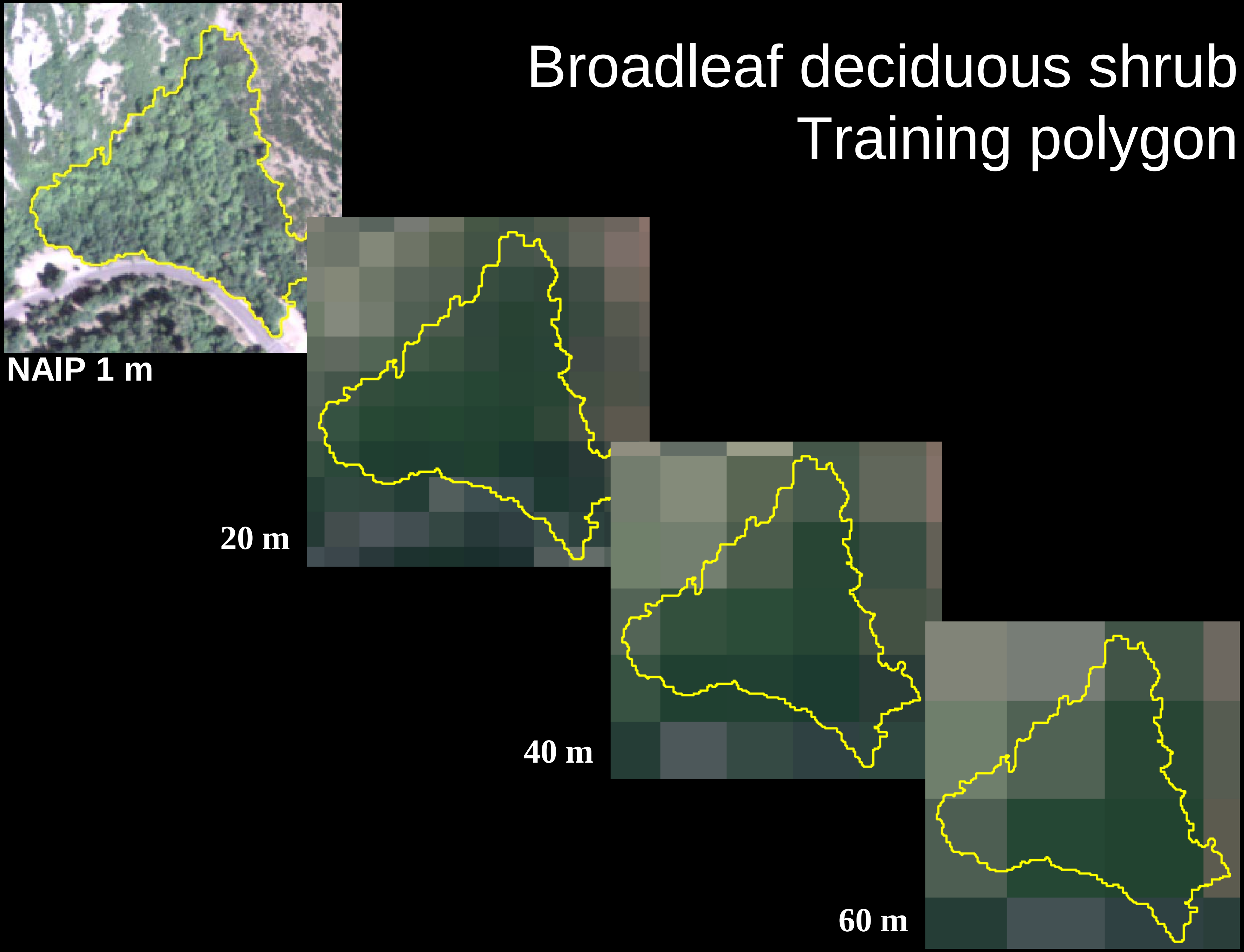
Accuracy
87.6%

Kappa
.838

Accuracy
78.6%

Kappa
.722

Broadleaf deciduous shrub
Training polygon



Broadleaf deciduous tree polygon