ENVI Tutorial: Vegetation Hyperspectral Analysis

Vegetation Hyperspectral Analysis

This tutorial presents a case history for use of hyperspectral techniques for vegetation analysis using 1999 HyMap data of Jasper Ridge, California, USA. It is designed to be a self-directed example using ENVI's complete end-to-end hyperspectral tools to produce image-derived endmember spectra and image maps. For more detail and step-by-step procedures on performing such a hyperspectral analysis, please execute the detailed hyperspectral ENVI tutorials prior to attempting this tutorial.

This tutorial examines ENVI's end-to-end hyperspectral processing methodology applied to a vegetation case study. It is designed to give you hands-on experience in running the procedures rather than reviewing pre-calculated results (preprocessed results are provided for comparison). It will guide you through performing data exploration in a loosely structured framework and allow you to compare analysis results with known ground information.

In this tutorial, you will:

- Examine HyMap radiance data and evaluate data characteristics and quality.
- Evaluate atmospherically corrected, EFFORT-corrected HyMap data and compare to radiance data.
- Conduct spatial/spectral browsing to evaluate data, determine presence and nature of spectral variability, and to select wavelength range (s) for further analysis.
- Reduce data dimensionality using MNF transform.
- Select spectral endmember candidates using PPI.
- Evaluate linearity and select endmembers using n-D Visualizer.
- Map endmember distribution and abundance using ENVI mapping methods. Compare and contrast results.
- Reconcile image and field spectra/ground information.

Selected data files have been converted to integer format by multiplying the reflectance values by 10,000 because of disk space considerations. Values of 10,000 in the files represent reflectance values of 1.0.

Files Used in this Tutorial

All files are on the ENVI Resource DVD.

1999 HyMap data of Jasper Ridge, California, used for the tutorial are copyright 1999 Analytical Imaging and Geophysics (AIG) and HyVista Corporation (All Rights Reserved), and may not be redistributed without explicit permission from AIG (info@aigllc.com).

Directory: `Data/spec_lib/veg_lib`

File	Description
`usgs_veg.sli`	USGS vegetation spectral library
`usgs_veg.hdr`	ENVI header for above
`veg_2grn.sli`	Jasper Ridge, spectral library
`veg_2grn.hdr`	ENVI header for above

Directory: `Data/spec_lib/usgs_min`

File	Description
`usgs_min.sli`	USGS mineral spectral library
`usgs_min.hdr`	ENVI header for above

Directory: `Data/jsp99hym`

| File	Description
`jsp99hym_rad.bil`	HyMap Radiance, VNIR (60 bands)
`jsp99hym_rad.hdr`	ENVI header for above
`jsp99hym.eff`	HyMap apparent reflectance data
`jsp99hym.hdr`	ENVI header for above
`jsp99hym_mnf.bil`	VNIR MNF transformed data (60 bands)
`jsp99hym_mnf.hdr`	ENVI header for above
`jsp99hym_mnf_ns.sta`	VNIR MNF noise statistics
`jsp99hym_mnf.txt`	ASCII file of MNF Eigenvalues
`jsp99hym_ppi.img`	VNIR PPI image
`jsp99hym_ppi.hdr`	ENVI header for above
`jsp99hym_ppi.cnt`	PPI count file
`jsp99hym_ppi.roi`	ENVI PPI ROI file for use with n-D Visualizer
`jsp99hym_ppi.ndv`	n-D Visualizer save state from PPI
`jsp99hym_ndv_em.roi`	VNIR ROI file of n-D Visualizer endmember locations
`jsp99hym_ndv_em.txt`	VNIR ASCII file of endmember spectra
`jsp99hym_sam.img`	VNIR SAM classes
`jsp99hym_sam.hdr`	ENVI header for above
`jsp99hym_rul.img`	VNIR SAM rules
`jsp99hym_rul.hdr`	ENVI header for above
`jsp99hym_glt.img`	Geometry lookup file for HyMap geocorrection
`jsp99hym_glt.hdr`	ENVI header for above
`copyright.txt`	HyMap copyright statement

Jasper Ridge Background

Jasper Ridge Biological Preserve is a 1200 acre natural area owned by Stanford University. For additional information on the site, please see the Jasper Ridge homepage at http://jasper1.stanford.edu/.

The Jasper Ridge site has been used as a remote sensing test site by JPL and others since the early 1980s. AVIRIS standard datasets are available from JPL for the years of 1992-98. Detailed maps and ground spectra have been published and are available from Stanford University. This remote sensing test site has been used by JPL and others since early 1980s.

The following figure shows a portion of Jasper Ridge from a USGS Digital Orthophoto Quad, copyright 1997, Center for Conservation Biology and JRPB, Stanford University (used with permission).
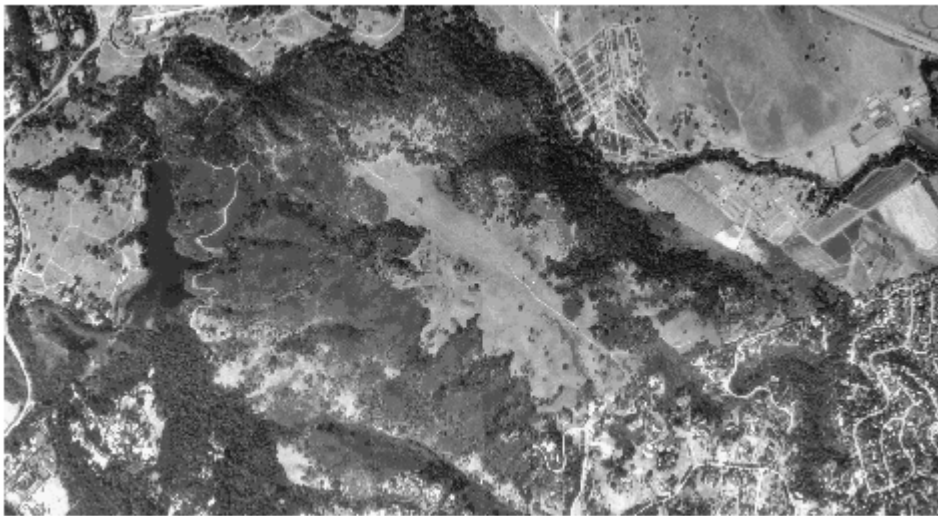
The following is the "Jasper Ridge Trail Map and Shaded Relief Map", copyright 1996, Center for Conservation Biology and JRPB, Stanford University (used with permission).
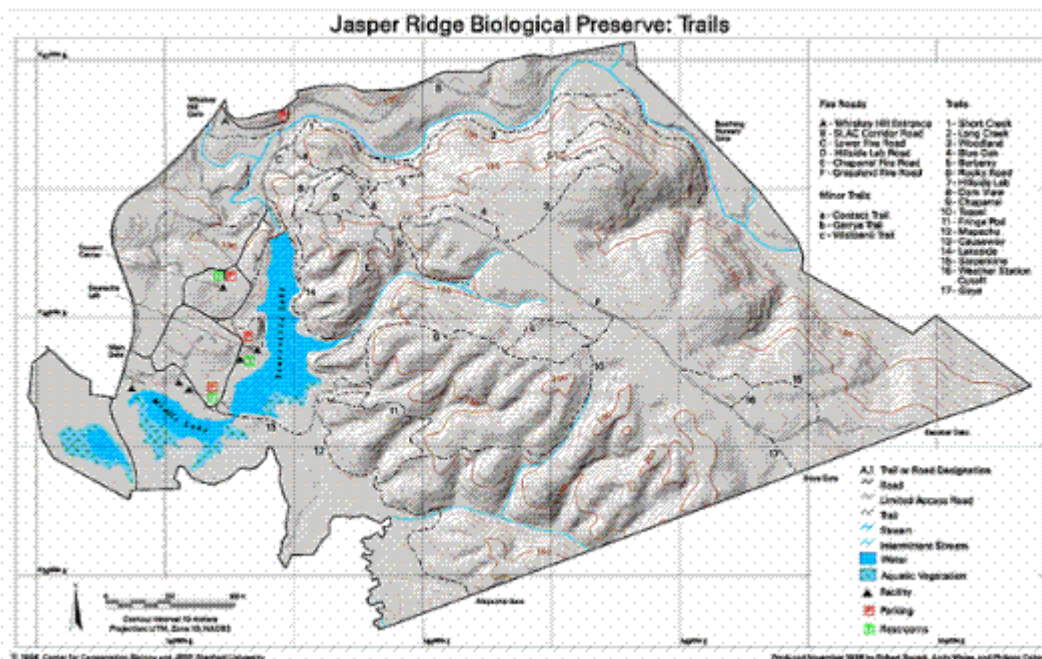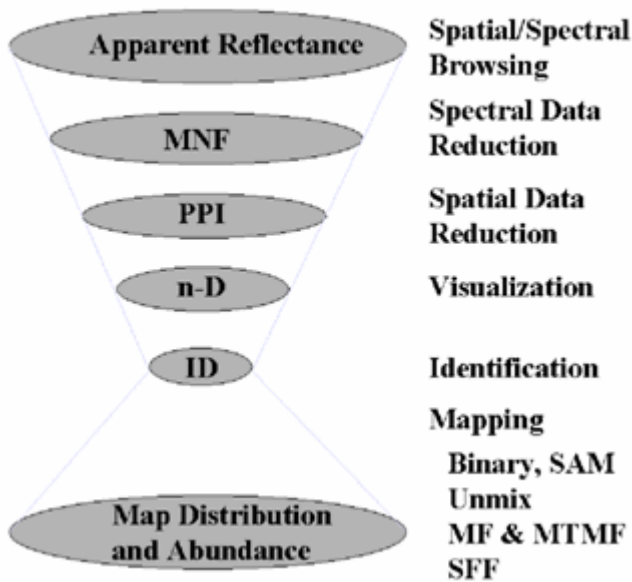
The following is the "Jasper Ridge Vegetation Map", copyright 1996, Center for Conservation Biology and JRPB, Stanford University (used with permission).
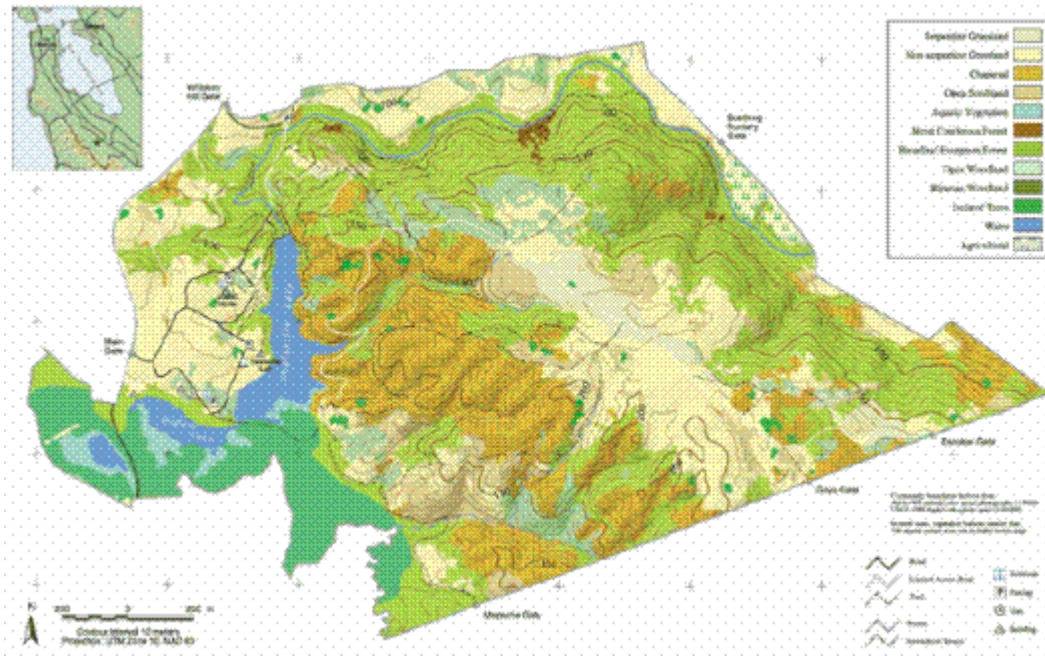
Processing Flow

This diagram illustrates an approach for analysis of hyperspectral data that is implemented with ENVI.

Vegetation Hyperspectral Analysis

The following procedures outline, in general terms, the implementation of the approach outlined in the diagram above. It is expected that you follow the procedures, referring to previous tutorials and the ENVI User's Guide or application help for guidance in performing specific tasks where required. The purpose of this tutorial isn't to teach you how to run the ENVI tools, but how to apply the methodology and tools to a general hyperspectral remote sensing problem.

Examine the Jasper Ridge HyMap Radiance Data

1. Navigate to the `Data\jsp99hym` directory, select the file `jsp99hym_rad.bil` from the list, and click **Open**.

2. Load HyMap data as grayscale images.

3. Perform animation.

4. Extract radiance signatures for areas of high variability.

5. Examine radiance spectra for evidence of absorption features.

6. Determine bad spectral bands.

7. Load color composite images designed to enhance spectral contrast.

8. Determine spectral subset(s) to use for materials mapping for vegetation and/or minerals.
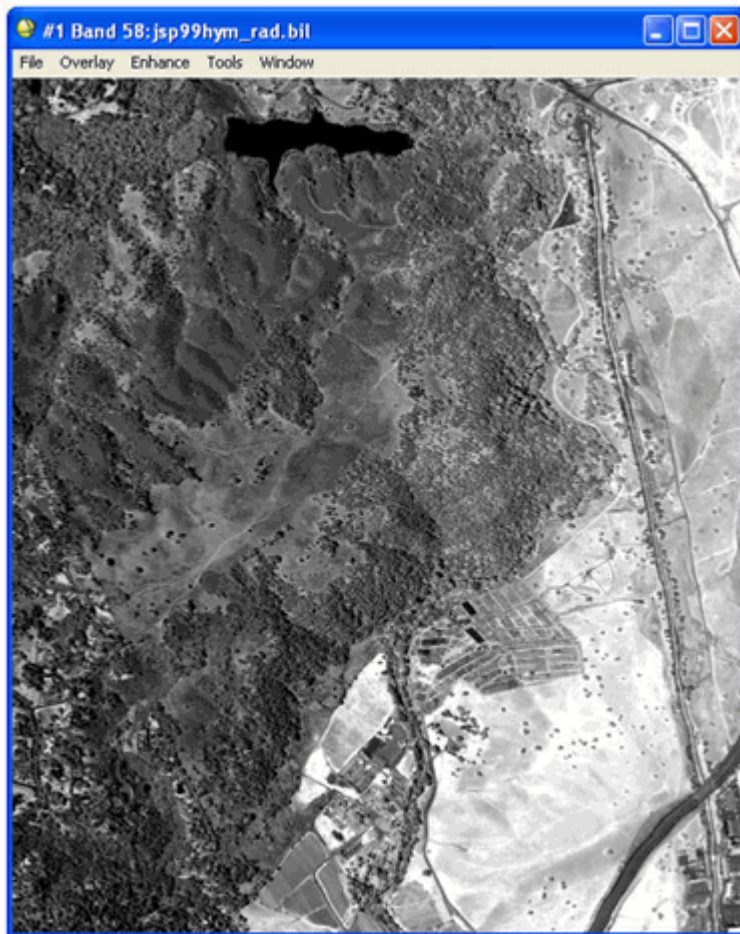
Extract Reflection Signatures

In this exercise, you will evaluate atmospherically corrected, EFFORT-polished HyMap data and compare it to radiance data. You will then conduct spatial/spectral browsing to evaluate data, determine presence and nature of spectral variability, and select wavelength range (s) for further analysis.

1. Evaluate the atmospheric correction applied to the HyMap spectral radiance to remove the bulk of the solar and atmospheric effects, transforming the data from radiance to apparent surface reflectance.

2. Examine the data using spectral/spatial browsing and color composites to characterize spectral variability and determine residual errors.

3. Extract reflectance signatures for vegetation and geologic materials. Compare to spectral libraries.

Following are the required files from the ENVI Resource DVD that you will use.

Directory: `Data\spec_lib\veg_lib`

File	Description
veg_2grn.sli	Jasper Ridge, spectral library
veg_2grn.hdr	ENVI header for above

Directory: Data\spec_lib\usgs_min

File	Description
usgs_min.sli	USGS mineral spectral library
usgs_min.hdr	ENVI header for above

Directory: Data\jsp99hym

File	Description
jsp99hym.eff	HyMap apparent surface reflectance data
jsp99hym.hdr	ENVI header for above

Reduce Data Dimensionality using Minimum Noise Fraction (MNF) Transform

In this exercise, you will perform tasks related to minimum noise fraction.

1. Apply MNF transform to the EFFORT data to find the data's inherent dimensionality.

2. Review MNF Eigenvalue images to determine break-in-slope and relate to spatial coherency in MNF Eigenimages.

3. Determine MNF cut-off between "signal" and "noise" for further analysis.

4. Make your own MNF-transformed dataset or review the results in the files below. These files are on the ENVI Resource DVD.
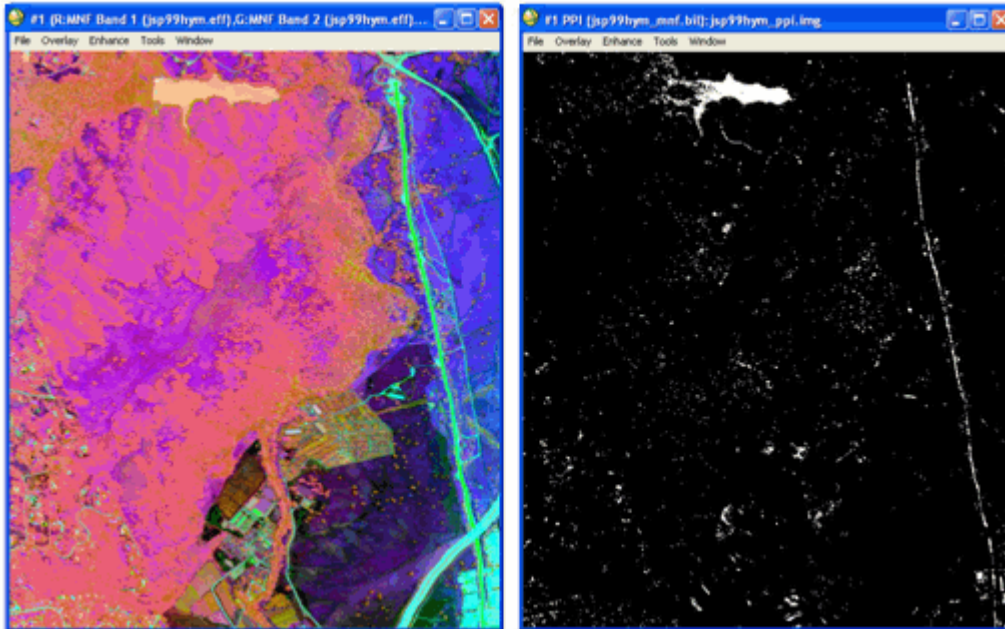
Directory: Data\jsp99hym

File	Description
jsp99hym_mnf.bil	VNIR MNF transformed data (60 Bands)
jsp99hym_mnf.hdr	ENVI header for above
jsp99hym_mnf_ns.sta	VNIR MNF noise statistics
jsp99hym_mnf.txt	ASCII file of MNF Eigenvalues

Select Spectral Endmember Candidates using Pixel Purity Index (PPI)

In this exercise, you will rank pixels based on relative purity and spectral extremity, create and display a PPI image, and create a list of the purest pixels.

1. Apply PPI analysis to the MNF output to rank the pixels based on relative purity and spectral extremity.

2. Use the FAST PPI option to perform calculations quickly in system memory, creating the PPI image.

3. Display the PPI image, examine the histogram, and threshold to create a list of the purest pixels, spatially compressing the data.

4. Generate your own PPI results and ROIs or review the results in the files below. These files are on the ENVI Resource DVD.
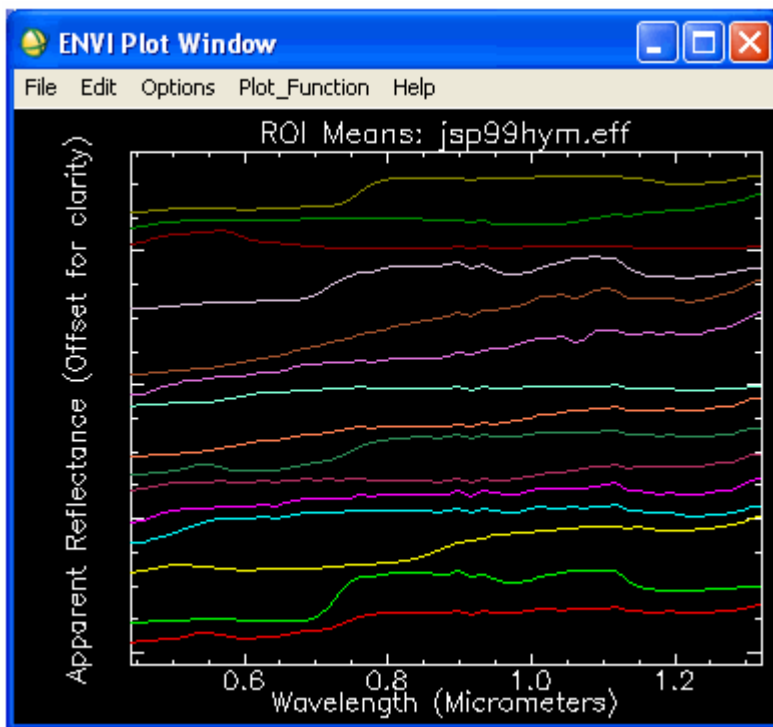
Directory: `Data\jsp99hym`

File	Description
`jsp99hym_ppi.img`	VNIR PPI image
`jsp99hym_ppi.hdr`	ENVI Header for Above
`jsp99hym_ppi.cnt`	PPI Count file
`jsp99hym_ppi.roi`	ENVI PPI ROI file for use with n-D Visualizer

Evaluate Linearity and Select Endmembers using the n-D Visualizer

In this exercise, you will perform n-Dimensional Visualization, rotate data interactively, use Z-Profiles and class collapsing, and evaluate the linearity of vegetation mixing and endmembers.

1. Perform n-Dimensional visualization of the high PPI value pixels using the high signal MNF data bands to cluster the purest pixels into image-derived endmembers.

2. Rotate the MNF data interactively in three-dimensions, or spin in three-or-more dimensions and "paint" pixels that occur on the "points" (extremities) of the scatter plot.

3. Use Z-Profiles connected to the EFFORT apparent reflectance data and the n-D Visualizer to evaluate spectral classes.

4. Use class collapsing to iteratively find all of the endmembers.

5. Evaluate the linearity of vegetation mixing and endmembers.

6. Save your n-D results to a save state file (.ndv).

7. Export classes to ROIs and extract mean spectra.

8. Compare mean spectra to spectral libraries.

9. Use spectral/spatial browsing to compare image spectra to ROI means.

10. Extract endmembers and make your own ROIs, or review the results from the files below. These files are on the ENVI Resource DVD.

Directory: `Data\spec_lib\veg_lib`

File	Description
usgs_veg.sli	USGS vegetation spectral library
usgs_veg.hdr	ENVI header for above
veg_2grn.sli	Jasper Ridge, spectral library
veg_2grn.hdr	ENVI header for above

Directory: `Data\jsp99hym`

File	Description
jsp99hym.eff	HyMap apparent surface reflectance data
jsp99hym.hdr	ENVI header for above
jsp88hym_mnf.bil	VNIR MNF transformed data (60 Bands)
jsp99hym_mnf.hdr	ENVI header for above
jsp99hym_ppi.ndv	n-D Visualizer save state from PPI
jsp99hym_ndv_em.roi	VNIR ROI file of n-D Visualizer endmember locations
jsp99hym_ndv_em.txt	VNIR ASCII file of endmember spectra

# Map Endmember Distribution and Abundance Using ENVI Mapping Methods

In this exercise, you will use ENVI's wide variety of mapping methods to map the spatial occurrence and abundance of materials at Jasper Ridge.

1. Use the Spectral Angle Mapper (SAM) to determine spectral similarity of image spectra to endmember spectra.

2. Perform your own SAM classification or review the results below. These files are on the ENVI Resource DVD.

   Directory: Data\jsp99hym

File	Description
jsp99hym.eff	HyMap apparent surface reflectance data
jsp99hym.hdr	ENVI header for above
jsp99hym_mnf.bil	VNIR MNF transformed data (60 bands)
jsp99hym_mnf.hdr	ENVI header for above
jsp99hym_ndv_em.roi	VNIR ROI file of n-D Visualizer endmember locations
jsp99hym_ndv_em.txt	VNIR ASCII file of endmember spectra
jsp99hym_sam.img	VNIR SAM classes
jsp99hym_sam.hdr	ENVI header for above
jsp99hym_rul.img	VNIR SAM rules
jsp99hym_rul.hdr	ENVI header for above

3. Try a SAM classification using one of the spectral libraries.
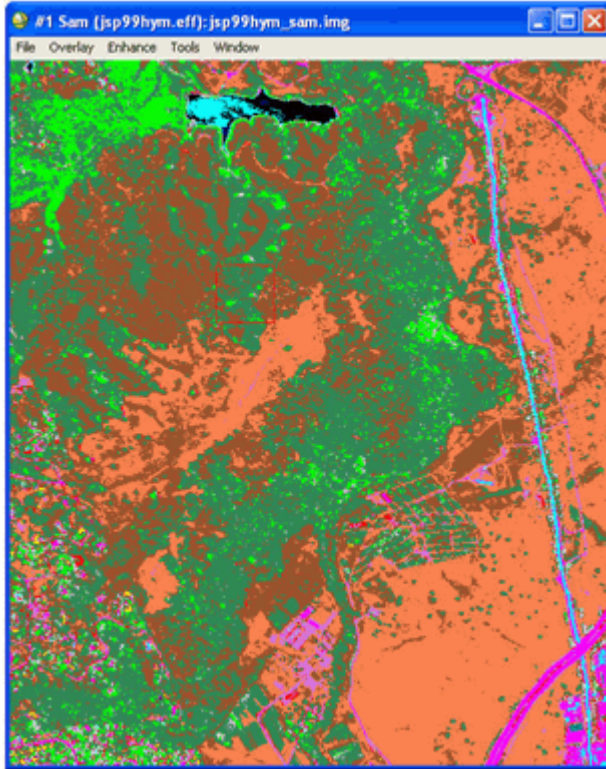
4. Evaluate the rule images.

5. Use the unconstrained linear unmixing to determine material abundances.

6. Examine the RMS error image and evaluate whether the physical constraints of non-negative and sum to unity (1) or less have been satisfied.

7. Iterate.

8. Compare abundance image results to the endmember spectra and spectral libraries using spatial/spectral browsing.

9. Run mixture-tuned matched filtering.

Reconcile Image and Field Spectra/Ground Information

In this exercise, you will geocorrect the processed images of the Jasper Ridge to map coordinates.

1. Use ENVI's georeference from the input geometry function to geocorrect the processed images of the Jasper Ridge to map coordinates.

2. Compare geocorrected images to image maps of conventional vegetation mapping at Jasper Ridge.

Directory: Data\jsp99hym

File	Description
jsp99hym.eff	HyMap apparent surface reflectance data
jsp99hym.hdr	ENVI header for above

File	Description
jsp99hym_glt.img	Geometry lookup file for HyMap geocorrection
jsp99hym_glt.hdr	ENVI header for above