Identification of hydrilla using hyperspectral image analysis and field spectroscopy

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Abstract:

Hydrilla vertillicata is one of the most aggressive invasive aquatic weeds throughout the world. There is a tremendous need to develop more accurate, large-scale, efficient, and timely methods for identifying hydrilla in waterways as nutrient loadings and climate change continue to exert pressures on estuarine habitats. Since 1984, a majority of all baseline Submerged Aquatic Vegetation (SAV) maps, including hydrilla maps, are currently produced through ground surveys and manual aerial photos. Annual aerial SAV maps by the Virginia Institute of Marine Sciences (VIMS) were obtained to validate the hydrilla images processed from the Hyperion images. The Hyperion image was processed in ENVI with several imaging analyses consisting of the Minimum Noise Fraction-Transformation (MNF) for data quality assessment and noise reduction, 2 D Scatter plot for selecting Regions of Interest (ROI's), and the Spectral Angle Mapper (SAM) for image classification. The specific objectives of the research were: first, to develop a different approach for identifying and mapping hydrilla using remote sensing techniques in ENVI, and image validation with aerial photos to an existing spectral library. The second objective was to match the spectral signatures collected from the spectral library with the spectra collected from the Hyperion image. The third objective was to classify the hydrilla in the study area. The use of such mapping techniques provides for a more cost-effective (eventually), timely, and repeatable method for identifying and mapping hydrilla infestation. It was determined from the MNF and SAM results that most of the hydrilla infestation occurs in the shallow areas of coastal estuaries or near shore where tidal influences are minimal. The results obtained can be used for identifying and classifying hydrilla infestation in different aquatic environments.

Hydrilla problems:

Waterways can be impaired by infestations of hydrilla. These hydrilla infestations create several problems for the transportation industry and the environment. The impact of dense hydrilla mats cause impacts such as:

- Blocking commercial and recreational traffic
- Excessive pressure on water infrastructure such as bridge abutments , etc
- Clogging problems on power plants

Figure 1: hydrilla photographed at the study site

Hydrilla benefits:

- Protection for shelter, food and habitat for aquatic life
- Controls erosion
- Improves water quality
- Good indicator for climate change

Study Objectives:

- To develop a different approach for identification and mapping hydrilla when there is a spatial-temporal differences
- Validation of hyperspectral image with aerial photography
- Matching the spectral signatures from the ground measurements spectral library with End Member Spectra collected from the Hyperion image
- Identification and classification of hydrilla infestation by using hyperspectral imaging techniques (ENVI) such as the Minimum Noise Transformation, 2 D Scatter Plot, Pixel Purity Index AND Spectral Angle Mapper (SAM)

Field Study Site:

The study area where this research is focused is called Otter Point Creek (OPC).

- Otter Point Creek location in the Chesapeake bay National estuarine Research Reserve System in Harford County, Maryland.
- Otter Point Creek is the last freshwater estuary in the Chesapeake Bay
- Otter Point Creek is near the Aberdeen Proving Grounds south of the Susquehanna River and it is a shallow tributary to the Bush River
- It covers 672 acres of open water, wetlands , uplands, forest
- Various Submerged Aquatic vegetation populate the Creek, but Hydrilla is the dominant species

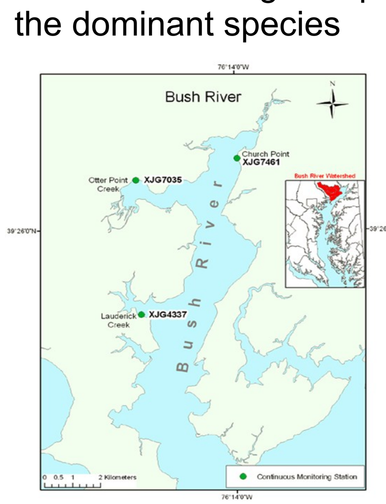

Figure 2: Map overview of region

Figure 3: Aerial view of Otter Creek area near Edgewood, Maryland

Hyperspectral Sensor:

- Hyperion is a push broom type imaging spectrometer
- Agency- NASA responsible Earth Observing -1 (EO-1)
- Number of Bands- 242 hyperspectral bands
- Spectral range- 400-2500 nm
- Spatial Resolution- 30 m
- Swath- .5 km x 185 km
- Altitude – 705 km
- Image Acquisition- July 20, 2011 download Earth Explorer

Figure 4: Hyperion Raw Image of the study area

Aerial Photography:

- Virginia Institute of Marine Sciences (VIMS) provided the aerial photos of the study area
- Aerial photos collected in July 2011. They were scanned and orthorectified
- SAV beds shown as dark areas to create ortho-photo mosaics with aerial photo from VIMS

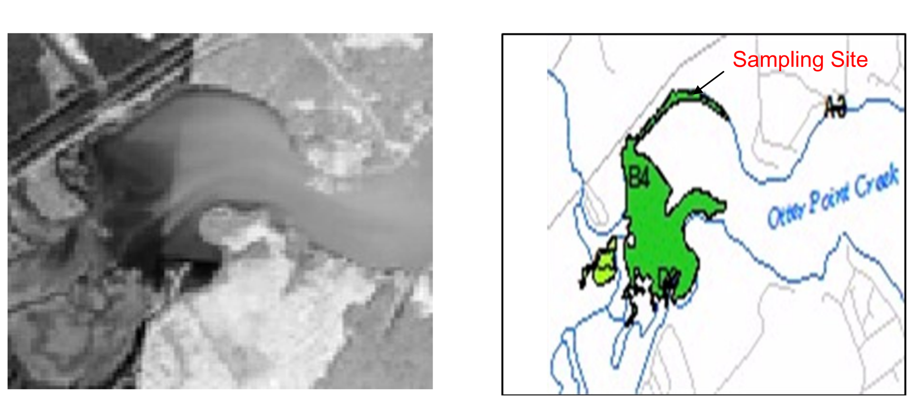

Figure 5: Aerial image showing darker areas of hydrilla footprint and a derived map showing hydrilla areas in green and the sampling site. Note that Area B4 has a hydrilla density of 70-100% as determined by VIMS, 2011

Data processing and analysis:

- *Atmospheric Correction*: The Hyperion image was atmospherically corrected using Quick Atmospheric Correction (QUAC) which is part of the Atmospheric Correction Module, which is added to core ENVI version 4.8 (ITT-Exelis). QUAC provides an automated atmospheric correction of hyperspectral data in the solar reflective spectral region (400 to 2500 nm).
- *Band selection:* The Hyperion image was resized and atmospherically corrected using Quick Atmospheric Correction (QUAC). 185 Bands were selected from the hyperion image for additional processing.

It is noticed that the Zoom exhibits green patches (see figure 8), which coincide with similar patches observed in the aerial photo taken by VIMS Figure 3. The 242 bands were viewed one by one to select noise-free bands for further processing.

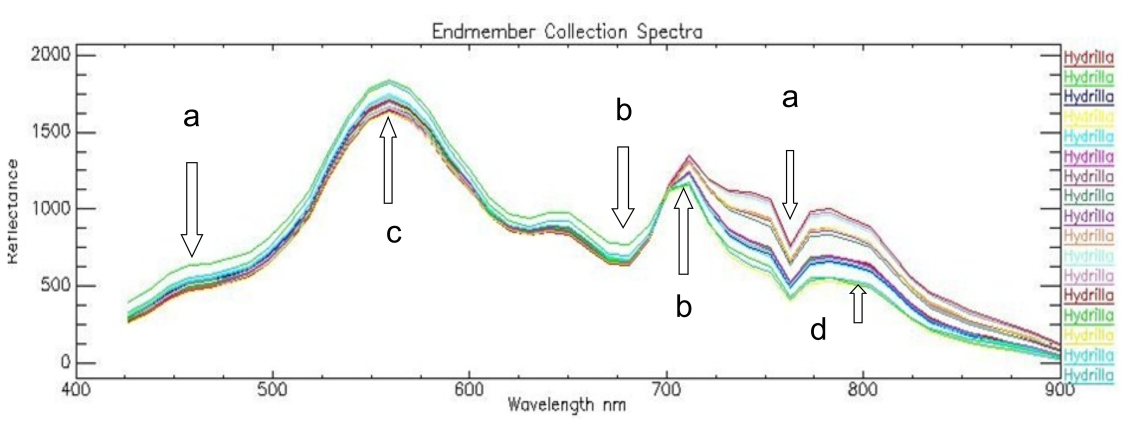

Figure 6: Spectra Profile collected from subset of raw image
a- Chl a- Absorption at 440 nm and 775 nm
b- Phycocyanin absorption at 675 nm and fluorscence at 710 nm
c- Scattering in the green region 550 nm
d. Near-infrared scattering by phytoplankton cells at 790 nm

- Main feature common to the chlorophyll spectra are the absorption bands 675 nm and the fluroscence at 710 nm
- There are other algae which is absorbed in the blue band
- Atmospheric Correction with Quick Atmospheric Correction (QUAC) which is a module in ENVI

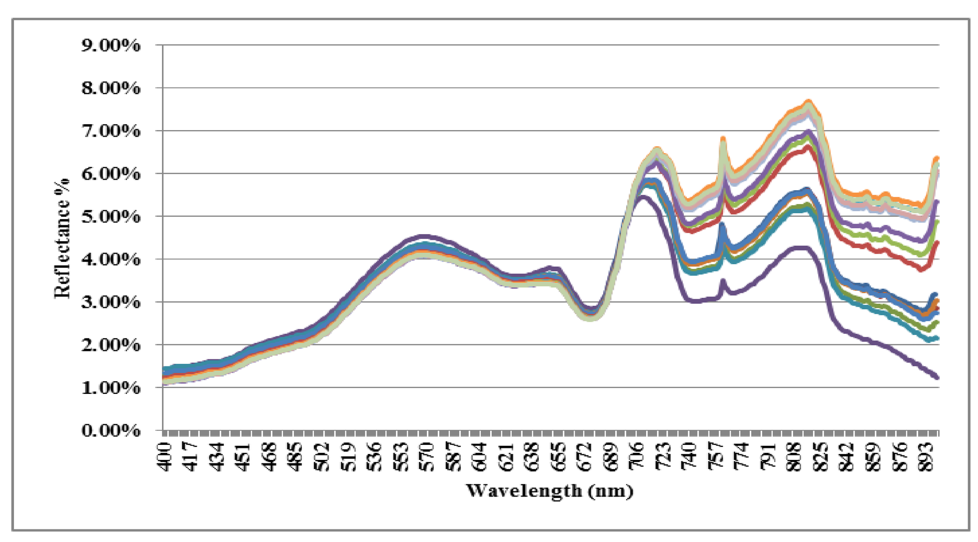

Figure 7: Spectral ground measurements of hydrilla collected on the water

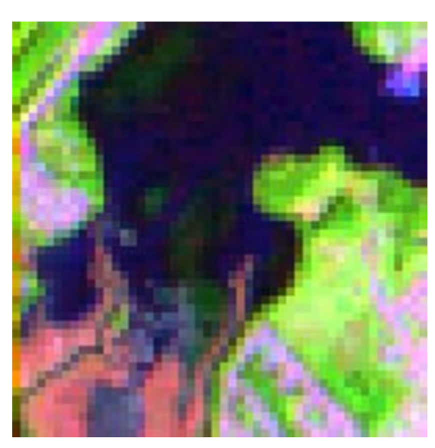

Figure 8: subset of Raw image data as processed by the ENVI software

Figure 9: mage process with the minimum noise fraction analysis using ENVI

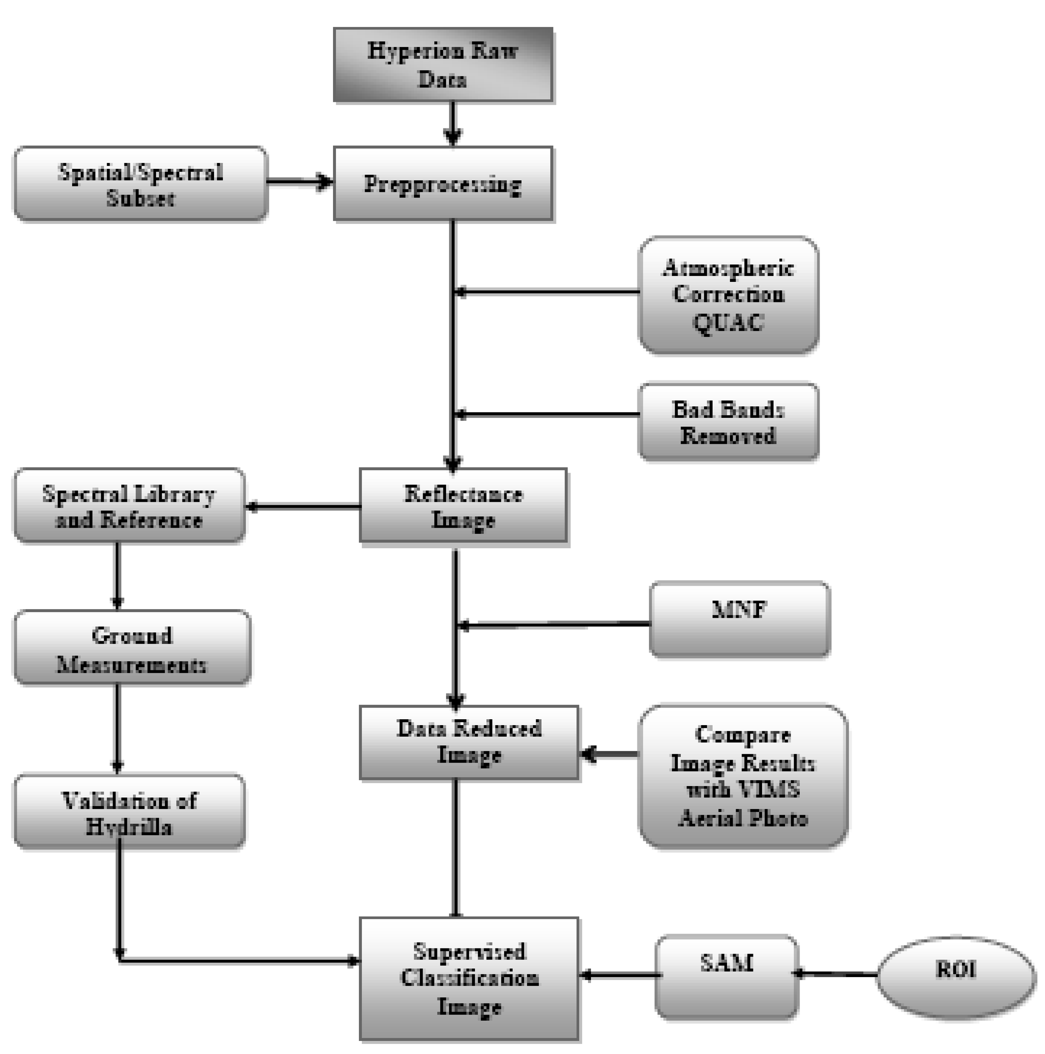

Figure 10: Flow Process Diagram for Image Preprocessing and Validation

- Band Selection- 185 bands were selected from the Hyperion image.
- Image subset was analyzed with ENVI and it shows visible green mats of SAV. Image agrees with spectral profile extracted from the subset of the Hyperion image in ENVI and shown on Figure 8.
- Average surface reflectance for hydrilla was 12% at 750 nm
- Image was processed with ENVI software for data reduction with Minimum Noise Fraction (MNF) Figure 10, 2 D Scatter plot, and Pixel Purity Index. Regions of Interests (ROI's were exported to the subset image and hydrilla, water, and land vegetation classified

Spectral Angle Mapper (SAM):

SAM was applied to the MNF bands. The spectral signatures generated from the image using ENVI were similar to the spectral signatures generated in-situ at the OPC pier.

It has been reported in several literature reviews that the Spectral Angle Mapper technique gives better results in comparison to Linear Spectral Unmixing, and the Mixture–Tuned Matched Filtering.

Figure 11: Spectral angle mapper (SAM) results showing hydrilla areas highlighted in red.

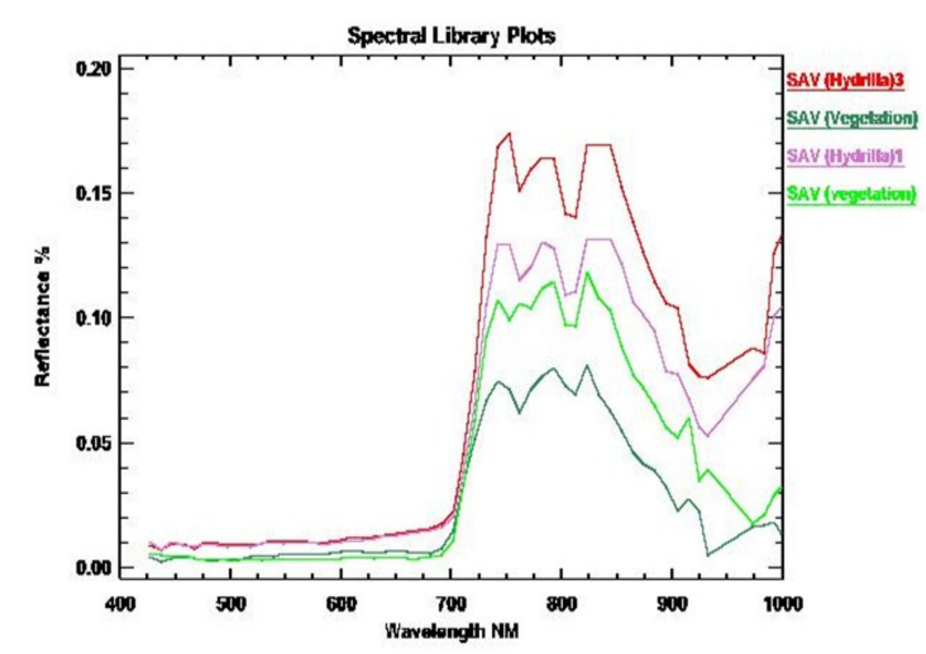

Figure 12: Spectral library plots of hydrilla

Conclusions:

- Hyperion sensor at 30 m spectral resolution gave very good results for identifying and classifying hydrilla
- ENVI software produced very good results for the data reduction MNF and the Spectral Angle Mapper
- Ground measurements spectral signatures concur with the spectra extracted from the Hyperion image. However, with the Hyperion image higher reflectance were obtained due to atmospheric interference and, water canopy, and substances in the water column. The ground measurements were taken close to the source so it minimized the error. The ground measurements were more accurate.
- The aerial photo validation method was accurate because it agrees with the MNF and the SAM

Future Research:

- Collect ground measurements for every SAV species including algae in the estuary
- Evaluate water quality parameters at the same time that ground and satellite measurements are collected
- Analyze different areas of the estuary at different times and different seasons