Hyperspectral Remote Sensing for Vegetation Surveys

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ABSTRACT

Hemlock woolly adelgid (HWA), *Adelges tsugae*, and other forest pests, including invasives species, are a problem for our forests and ecosystems. Surveying and monitoring these problems are done at great cost in both money and time. With the use of hyperspectral remote sensing, vegetation identification and stress can be analyzed remotely, saving time and surveying a larger area. Hyperspectral Remote Sensing is the process of gathering spectral signatures remotely. Everything has its own signature, similar to that of a fingerprint, making each unique. Helicopter Applicators Incorporated utilizes an AISA Eagle 1K sensor system to gather and analyze these spectral signatures.

Helicopter Applicators Incorporated (HAI) was established in 1974 as an aerial application company and has since branched into the field of remote sensing. The AISA Eagle 1K has a wider swath ability, which allows it to be flown higher and thereby gather more data in less time and at the same or better resolution than other sensors. With customized hardware and software, HAI offers a full end product.

To demonstrate this, Helicopter Applicators was involved with two vegetation management projects in 2004. HAI flew 400 linear miles in the Kiski-Conemaugh Watershed for invasives identification. West Virginia University gathered spectra via a handheld spectrometer. The mission was to search for 13 invasives species and then compare results to volunteer data throughout the watershed. HAI conclusively located mile-a-minute weed (*Polygonum perfoliatum*), tree of heaven (Sumac) (*Allanthus altissima*), garlic mustard (*Alliaria petiolata*), purple loosestrife (*Lythrum salicarla*), Norway maple (*Acer platanoides*), and common reed (*Phragmites australis*).

The second mission was in the Catskill Mountains in New York in cooperation with The University of New Hampshire (UNH). HAI flew two polygons to determine eastern hemlock (*Tsuga canadensis*) locations and hemlock health, based on GPS ground truthing by UNH. Results are still pending, but preliminary results are encouraging, with both classification and health distributions being qualitatively appropriate.

Despite the lack of conclusive results from these two missions, both have shown that hyperspectral imaging will be valuable for detection and delineation, especially with the bands and flexibility of this sensor flown by Helicopter Applicators Inc.

KEYWORDS

Hyperspectral, remote sensing, detection, aerial survey.

INTRODUCTION TO HELICOPTER APPLICATORS AND HYPERSPECTRAL REMOTE SENSING

Helicopter Applicators Incorporated (HAI) began in 1974 as an aerial application operation. Since then, it has established bases in Pennsylvania, Florida, Delaware, and Mississippi. Currently it has over 30 employees, and owns and operates 15 aircraft. In 2002, HAI branched into remote sensing. It now operates three remote sensing systems including a Radiometric Infrared system, a Three-Chip Digital Daytime camera, and a Hyperspectral Sensor system. All systems are housed in gyro-stabilized gimbals, which are mounted on helicopters.

HAI utilizes an AISA Eagle 1K Hyperspectral Sensor (Figures 1 and 2). It was manufactured in Finland by Specim. The system covers a spectral range from 400 to 1000nm in 272 bands. The sensor is housed in a gyro-stabilized ball with a GPS/INS unit accounting for roll, pitch, and yaw. It is capable of collecting a 1024-pixel swath that can cut flight time by 50% when compared to other sensors. The sensor is capable of sub-meter resolution and has adjustable bandwidth down to 2.5 nm. This allows HAI to collect only areas of the spectrum pertinent to the mission, reducing data size and thereby saving time and money by reducing processing time. The data acquisition hardware consists of a laptop computer, Magma PCI frame grabber, inverter box, hot-swappable disc chassis, and C-MIGITS III GPS and IMU.

The AISA Eagle 1K is classified as a “pushbroom” sensor: as the aircraft moves forward, the sensor collects “lines” or “frames” of data to build an image, each line 1024 pixels wide and one pixel tall. The customized hardware for this system allows for storage and acquisition of large datacubes. The AISA Eagle 1K is a next-generation sensor manufactured by Specim, having one distinct advantage over other sensors: it can be flown at twice the altitude of other sensors, thereby doubling the swath width while still maintaining the same spatial resolution. This allows HAI to cut flight times in half, saving both time and money.

Figure 1. HAI Hyperspectrsl System.

Figure 2. System Mounted on MD 500.

The AISA Eagle 1K spectral range spans from the edge of ultraviolet through the visible and into near infrared of the electromagnetic spectrum. Being able to detect this area of the electromagnetic spectrum is what allows HAI to distinguish among species of vegetation and/or identify levels of vegetative stress. Each species of vegetation has a distinct spectral signature, similar to a fingerprint, making each species unique. As a species becomes stressed, the amount of absorption/reflectance changes altering its spectral signature, which results in the ability to identify vegetative stress. The AISA Eagle 1K can monitor plant health and detect invasive species.

MISSIONS IN VEGETATION MANAGEMENT

The applications of this technology are abounding, but HAI has the most experience with vegetation management. HAI has used spectral signatures to distinguish hemlock trees, classify hemlock health, and identify native and non-native invasives.

INVASIVES PROJECT

One such opportunity was in a study area of the Kiski-Conemaugh watershed near Johnstown, Pennsylvania. During this mission, data was collected at an altitude of 1,162 feet with an airspeed of 45 knots and 245 meter sensor swath, resulting in 0.5 meter spatial resolution. Data was collected from the following streams: Kiski, Loyalhanna, Conemaugh, Blacklick, Little Conemaugh, and Stoney Creek.

West Virginia University collected the ground truth for this mission through use of hand- held spectrometers. The flight objectives for this mission were to locate the following invasive species using the AISA Eagle 1K Hyperspectral Sensor: Japanese knotweed (*Polygonum cuspidatum*), giant hogweed* (*Heracleum mantegazzianum*), tree of heaven (sumac) (*Allanthus altissima*), multiflora rose (*Multiflora rosa*), purple loosestrife (*Lythrum salicarla*), kudzu (*Pueraria montana*), common reed (*Phragmites australis*), hydrilla (*Hydrilla verticillata*), and Eurasian watermilfoil (*Myriophyllum spicatum*) (Aquatics)*, mile-a-minute weed (*Polygonum perfoliatum*), bush honeysuckle (*Lonicera* spp.), Canada thistle* (*Cirsium arvense*), Japanese stilt grass* (*Microstegium vimineum*), Norway maple (*Acer platanoides*) and garlic mustard (*Alliaria petiolata*).

No ground spectra were collected for those invasives with asterisks.

Once the data was collected, HAI was able to apply specific bands to the raw imagery in order to create false color images and true color images. The raw imagery was corrected spectrally and atmospherically. Afterward, the data were geo-rectified. Once the data was analyzed, it was compared to ground results collected by volunteers.

Both HAI and the volunteers located garlic mustard, mile-a-minute weed, Norway maple, and tree of heaven. The volunteers also located Japanese knotweed, and while HAI was able to locate this particular invasive, the results did not conclusively prove detection. HAI also located purple loosestrife and common reed, which the volunteers did not. A second iteration is being performed to verify the presence of Japanese knotweed.

Each of these invasives were then divided into Regions of Interest (ROIs) in ENVI, then overlaid on the imagery. These were able to be displayed individually. The individual ROIs are then converted to GIS vectors. This allows for each to be "on or off" and compared from year to year. The imagery is also converted to a GIS format to be viewed as well (Figure 3).

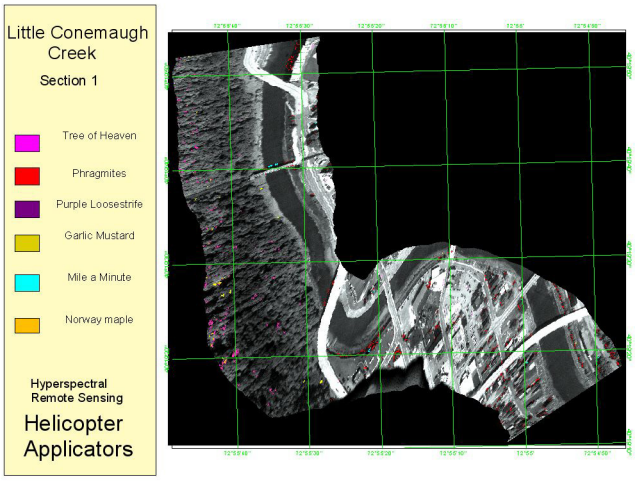

Figure 3. Geo-rectified image with invasive locations in GIS.

HEMLOCK PROJECT

HAI also flew several missions relating to the management of hemlock woolly adelgid. HWA infects the eastern and Carolina hemlock and causes ultimate mortality to hemlocks of all ages. Correct treatment is imperative in rehabilitating hemlocks, as incorrect treatment can accelerate death. Early detection is vital in determining the correct form of treatment and mapping the spread of HWA. In September of 2004, HAI flew a mission in the Catskill Mountains of New York in cooperation with the U.S. Forest Service (USFS) and The University of New Hampshire (UNH).

The goal of the mission was to locate hemlock trees as well as determine their levels of stress. Two blocks were chosen as the study area. The large block was 17,784 acres, and the small block was 4,940 acres. Ground control points were gathered by UNH. The flight time for gathering data for this mission was approximately 45 minutes. The flight parameters for this mission were as follows: data was gathered from an altitude of 4,647 feet at an airspeed of 70 knots. This resulted in an 864-meter swath at a spatial resolution of 2.0 meters.

The mission was for UNH to supply HAI with ground truthed latitudes and longitudes, from which spectra were pulled to identify hemlocks. The first iteration of data processed by the GBC Transform resulted in the location of hemlock trees, which were displayed as green on the image (Figure 4). Once the hemlock locations were identified, the GBC Transform was able to classify four different stress levels within the health range of collected hemlocks. These stress levels were 'Healthy', 'Slight Decline', 'Moderate Decline' and 'Unhealthy' (Figure 5). Both hemlock presence and health classification data could be made into GIS vectors for each ROI.

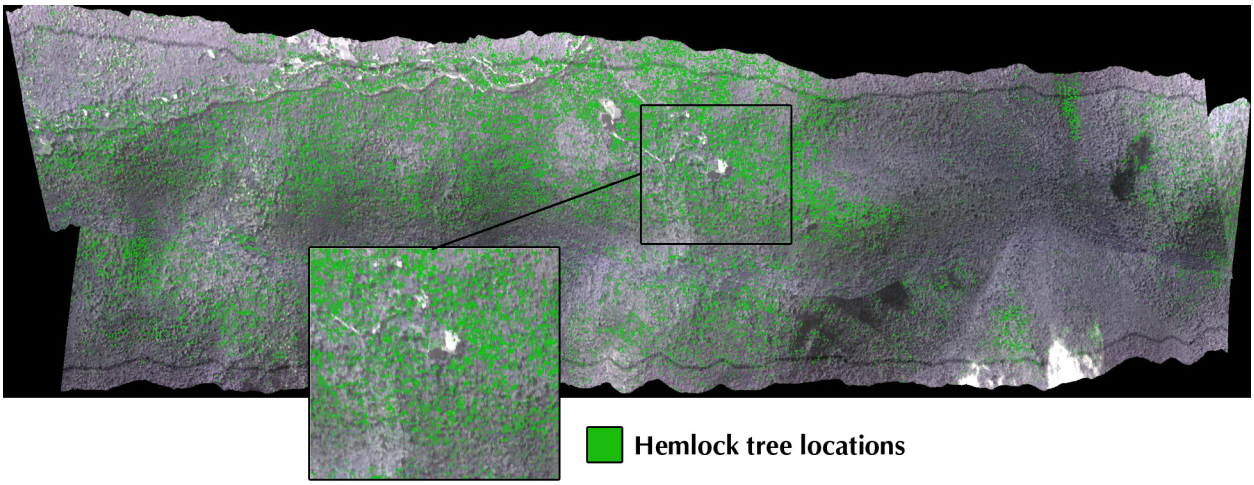

Figure 4: Hemlock locations: small pass 3-4.

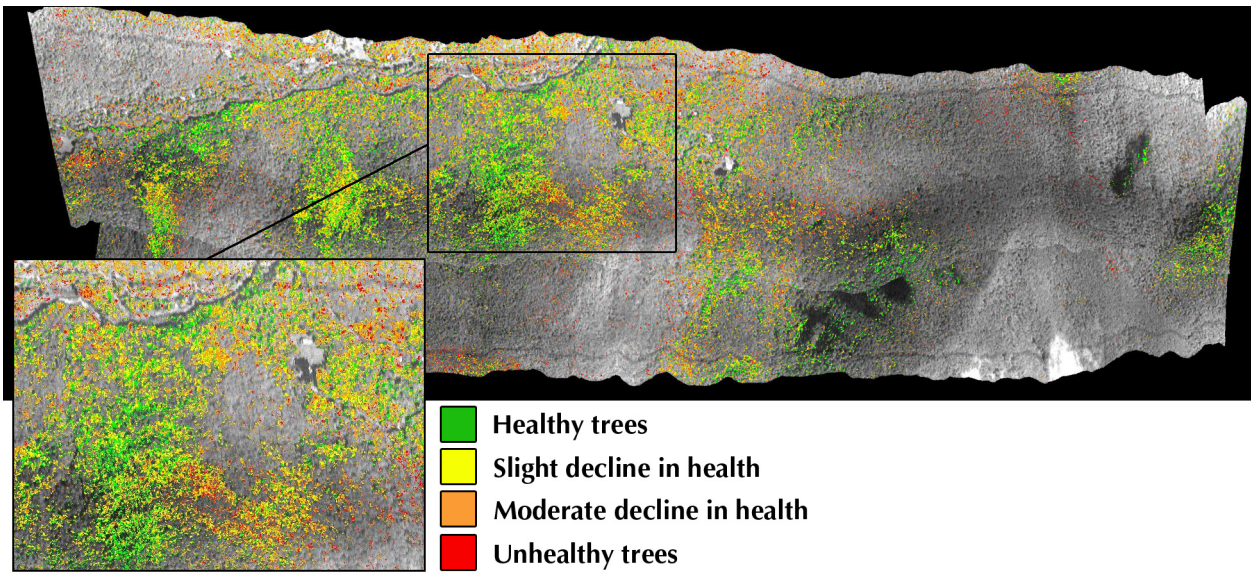

Figure 5: Hemlock health levels: small pass 3-4.

RESULTS OF CATSKILLS CASE STUDY

The preliminary results of the validation study in the Catskill Mountains of New York are promising. HAI partnered with the U.S. Forest Service, The University of New Hampshire, and Remote Measurement Services, LLC, and work is ongoing. Preliminary results are encouraging with both classification and health distributions being qualitatively appropriate, with qualitative verification continuing. Although validation work continues, spatial registration errors within the data have not allowed a quantitative estimate of accuracy.

METHODS AND PROCESSING SOFTWARE

HAI utilizes proprietary processing software designed by Dr. James Sokolowski of Remote Measurement Services (RMS),LLC, known as Hyperspectral Data Processing Software (HyDaPS). HyDaPS is designed for high–volume cubes, which is important for hyperspectral processing. This software calibrates radiance, atmospheric and spectral corrections, and produces reflectance cubes. HAI also utilizes CaliGeo, geo-rectification software, designed by Specim. CaliGeo performs radiometric correction, and geo-rectification. This software also adjusts for elevation through the use of Digital Elevation Models (DEM) or WGS84 Planar Surface elevation. The GBC transform, also a proprietary software designed by Dr. Sokolowski, is used for analysis. This software was specifically designed for the analysis of vegetation. It is capable of differentiating species from species, classifying within a species, and delineating spectral signatures.

In order to perform hyperspectral flights and determine pricing, HAI is given GIS vectors to create a flight plan for the pilot. These vectors are imported into the aircraft's AgNav computer system and display the appropriate flight lines. Once these flight lines are established, a data collection flight is performed. After the data is collected, it is transferred to computers in HAI's processing lab where HyDaPS correction is performed on the data. Next the imagery is geo-rectified with CaliGeo. Imagery spectra are then analyzed by the GBC transform to produce requested results. Finally, new GIS vectors from ENVI ROI's are created, allowing HAI to offer the possibility of a complete end-product.

Prior to each data collection flight, flight parameters are inserted into a "Flight Calculations" spread sheet. This performs the necessary calculations in order to determine resolution, altitude, speed, swath, frame rate, approximate flight time, and amount of data to be collected.

PREVIOUS EXPERIENCE

In a relatively short time, HAI gained substantial experience in the field of Hyperspectral Remote Imaging. HAI has conducted the following data-collection missions:

- October 2003: Perry County, Pennsylvania, Hemlock Study
- November 2003: Perry County, Pennsylvania, Hemlock Study
- November 2003: Appoquinimick Creek, Deleware, Phragmites Study
- March 2004: Perry County, Pennsylvania, Hemlock Study
- May 2004: Department of Defense, Chicken Little Sensor Week, Classified
- June 2004: Kennedy Space Center, Florida (Indian River Lagoon), Submerged Vegetation
- June 2004: City of Houston and EPA, Water Pollution Survey
- June 2004: Department of Homeland Security, Texas, Target Identification
- August 2004: Kiski-Conemaugh Watershed, Pennsylvania, Invasive Species Study
- September 2004: Catskills, New York, Hemlock Study

CONCLUSIONS AND FUTURE DEVELOPMENTS

In conclusion, Helicopter Applicators, Incorporated, is proud to be able to offer hyperspectral remote sensing. Based on our experience, we can provide a complete end-product that includes sub-meter image resolution, classification of vegetation health, differentiation of vegetation species and analysis of data. These full end products of hyperspectral remote sensing can help forest health administrations to identify potential health threats to the forest and take appropriate action. Through the identification of invasives, eradication efforts can be planned. With regards to health levels, proper treatment and priority sites may be established.

HAI is currently completing enhancements to its remose sensing capabilities, including upgrading computer systems for faster processing and upgrading the gimbal system to allow for more accurate data collection. New methods are also being implemented for the collection of ground spectra, as accurate ground truthing is imperative: one such method is for HAI to receive ground coordinates of the species from which spectral cubes can be gathered aerially. This will be more accurate then trying to pull spectra from coordinates in processed data. To further accuracy, HAI is working in cooperation with Research Systems Incorporated (RSI) in order to develop new geo-processing software that will allow for geo-rectification and geo-referencing of high volume cubes. The software will also allow the output of GIS shapefiles, which will allow for identification of individual species and comparison from year to year. Helicopter Applicators strives to keep pace with ever-changing technological advancements in order to meet the needs of the customer.

ACKNOWLEDGEMENTS

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