# Mapping the Future for EAB Readiness and Response Planning in Milwaukee: An Update

*by David Sivyer, Forestry Services Manager, City of Milwaukee*

Field spectral data collection (ash) • Photo: Randy Krouse, City of Milwaukee

### Introduction

Communities threatened by Emerald Ash Borer (EAB) are aggressively pursuing best practices for early detection and management including improved reconnaissance tools (geospatially accurate forest risk maps) and new suppression strategies. Emergent research and frontline intelligence is desperately needed by coordinating federal, state, and local officials working to revise management strategies for EAB.

Expensive eradication attempts repeatedly thwarted by the elusive EAB have forced many neighboring communities to concede defeat and pursue preemptive removal of public ash trees. Other communities further removed from the advancing front share a time advantage needed to evaluate and integrate new tools aimed at slowing the spread of EAB. Fundamentally important to both management strategies is the need for an accurate risk assessment.

As reported in the May/June 2008 issue of *City Trees,* Milwaukee's multi-faceted strategy for EAB readiness and response planning is highly dependent on an accurate host inventory. Milwaukee completed the final phase of a five-year computerized street tree inventory project in 2009. The inventory identifies the number, size distribution, condition, and location of ash street trees at risk. This information is fundamental to accurate budget forecasting and cost-benefit analysis of various EAB management strategies. Planned post processing of the street tree inventory data into i-Tree Streets (formerly known as STRATUM) will quantify the ecological services provided by the City's ash street trees.

Municipal arborists armed with a current street and park tree inventory can easily quantify the number of ash trees at risk and evaluate various management strategies. However, communities like Milwaukee that have statutory responsibility for abating dead and hazardous trees on private property need other tools to more fully assess community risk associated with aggressive invasive forest pests such as EAB. i-Tree Eco (formerly known as UFORE) gives municipal arborists the tools needed to quantify the number of ash trees and associated ecological services in their community. Milwaukee's UFORE project completed in 2008 estimated the citywide ash population at 573,000 trees, representing 17.4% of urban tree canopy and providing $221 million and $600,000 in structural and annual functional value, respectively.

Knowing the number of ash trees at risk in the City of Milwaukee is helpful as a planning tool for assessing canopy loss impacts, projecting associated wood waste volume, and budget forecasting code enforcement staffing needs. i-Tree Eco and other conventional survey techniques are of limited assistance, however, in managing an actual EAB outbreak. To effectively manage risk to public safety associated with 573,000 ash trees in a highly urbanized community, the specific location, in addition to the number of trees at risk, was needed. To solve the ominous task of locating 573,000 trees in the sights of a rapidly advancing enemy, the Milwaukee Forestry Division looked to an emergent remote sensed technology called hyperspectral imagery (HSI).

Airborne HSI is an advanced digital imaging process that utilizes high-powered sensors to record hundreds of contiguous narrow bands of electromagnetic energy reflected from objects or materials on the Earth's surface. Each substance, such as green and white ash, yields a unique reflectance or "spectral signature" based on the molecular and electromagnetic properties of the substance that can be targeted and extracted from the hyperspectral data.

HSI has been utilized successfully for military reconnaissance, counter-narcotics surveillance, and in natural resources management applications including mineral exploration, water and soil analysis, fire risk assessment, and—to a limited extent—vegetation mapping. HSI has also been successfully utilized to classify the health and condition of vegetation. Thus, it shows incredible potential for early detection and improved delimitation of incipient forest pest infestations by mapping tree stress (or perhaps defense induced chemicals such as phenols or terpenes) that is imperceptible to the human eye.

I began having discussions related to a hyperspectral imaging (HSI) project with Ian Hanou, formerly of Native Communities Development Corporation Imaging (NCDC) in February 2007. While HSI had not been successfully demonstrated as a tool for mapping ash or any trees in urban areas, Ian assured me that that it was simply a matter of collecting hyperspectral data over the entire electromagnetic spectrum and applying the correct algorithms to extract the target feature from a dataset approximating a terabyte in size. I remember thinking, “Oh, is that all there is to it?” at the same time trying to remember what an algorithm is from one of my college math classes.

Over the next year, while Ian began assembling a team of remote sensing and imaging experts to tackle the project, my focus turned to funding sources and local project partners. Remote sensing and imaging partners that contributed to the project included NCDC Imaging, RFP Mapping LLC, SRA International, ASD Inc, and Terra Remote Sensing Inc. Efforts to secure funding through various USFS grant programs and NUCFAC were unsuccessful.

Ultimately, it was the UFORE study and EAB risk analysis completed by our forestry division coupled with the recognition of the public safety risk accompanying an EAB outbreak and potential benefits of a city-wide ash map that convinced Milwaukee Mayor Tom Barrett and the Milwaukee Common Council to fund the project in Forestry’s 2009 budget. Milwaukee’s total project cost was partially offset by Wisconsin Energy’s participation in the project to map ash trees located in close proximity to electrical utility easements in the city.

## Project Overview

This project applied advanced geospatial technology, including high resolution remote sensed HSI and LIDAR* data in conjunction with GIS analytical applications to develop new tools needed for improved species mapping, risk assessment, forest health monitoring, rapid early detection, and management of EAB.

The specific objectives of the project were to:

1. Utilize HSI to geospatially map the location and condition of ash species in the City of Milwaukee with 80% or greater accuracy
2. Develop replicable protocols for ash species identification in urbanized areas utilizing remote-sensed HSI
3. Integrate HSI-derived ash species maps with existing GIS analytical tools to provide specific property ownership and contact information for ash trees throughout the city
4. Evaluate the use of HSI in conjunction with UFORE analysis data for predicting the volume of wood waste generated by an EAB outbreak
5. Utilize remote-sensed HSI to establish new best practices for EAB and invasive species risk assessment

## Project Methodology

The project was completed in four steps: field HSI data collection and analysis, airborne HSI and LIDAR data collection, HSI data analysis and processing, and target data integration with GIS analytical tools.

Both ground and airborne HSI and LIDAR data was collected simultaneously in August 2008. While city funding for the project was not available until 2009, RFP Mapping LLC fronted the cost of the project to allow the data collection and much of the analysis to be completed in 2008. The leadership commitment and risk assumed by RFP Mapping enabled the project to be completed prior to the August 2009 detection of EAB in Milwaukee County. More importantly, it enabled the City to purchase a completed ash classification “off-the-shelf” as a sole-source procurement, thereby avoiding the complexity and uncertainty of results accompanying an RFP procurement. This is particularly significant given that no known company had successfully completed a remote-sensed HSI derived ash classification.

NCDC Imaging, SRA International, ASD Inc, and RFP Mapping LLC partnered with Milwaukee forestry staff to collect “canopy level” spectral signatures from ash species as well as several other common trees and vegetation in the Milwaukee area. The spectral signatures were collected with a hand-held spectrometer from a lift truck positioned at the top of the canopy. This was done to eliminate potential differences in spectral radiance or reflectance readings between the hand-held spectrometers and airborne sensors due to physiological differences in leaf chemistry (e.g., chlorophyll content), anatomy, or health within the crown.

Following ground (canopy) spectral collection, the team conducted initial analysis to determine the spectral separability of ash species from other trees and common vegetation in the Milwaukee area. While enough spectral differences were noted to proceed with the project, team member Daniel Puchalsi of SRA International—who in his thirteen years working with 20 different sensors and hundreds of targets, found ash to be the hardest target to separate from its background with limited false alarms (incorrect species classification)—said, “The difference between an ash tree and some of the other common trees in the Milwaukee area are unbelievably subtle, and when you add things like plant health and stage of growth, it is an amazingly complex problem.”

Data classification can be significantly more complex in urban areas due to interference or "noise" created by a wide array and variance among surface materials. To facilitate the ash classification in Milwaukee, NCDC Imaging utilized hyperspectral imagery rescaled by SRA International to 4-band multispectral imagery to create a base forest canopy layer. This segmentation of forest canopy from non-forest vegetation increased ash classification accuracy by limiting HSI analysis to pixels within the area of interest only.

Airborne HSI and LIDAR data collection over Milwaukee's 95 square miles and initial data processing was conducted by Terra Remote Sensing and the University of Victoria. NCDC Imaging conducted the LIDAR analysis and SRA International conducted follow-up analysis of the hyperspectral data utilizing spectral signature exploitation, proprietary algorithms, and analysis methodology. Hyperspectral feature analysis modified with spectral angle mapping technology was also utilized to identify ash trees of various health and stages of growth and to reduce false alarms.

LIDAR fusion with the hyperspectral data improved the positional accuracy of the hyperspectral imagery and resulted in a high-precision tree polygon layer and a tree point dataset with tree height, crown width, and stem-diameter attributes. NCDC Imaging analysts utilized GIS analytical tools to convert the HSI raster data into a vector data format. They merged the vector data with tree point data from the LIDAR extraction to improve classification confidence of individual ash trees based on polygon attributes. The resultant GIS ash layer enabled the ash classification to be overlaid onto the City's GIS parcel map, which provided address based location and property owner information for ash trees in the city. GIS integration also supported a comprehensive urban tree canopy analysis to quantify existing urban tree cover and plantable space on an aldermanic district and city-wide basis.

## Project Results

Following initial delivery of the GIS ash classification layer in March 2009, the SRA analysis team worked with NCDC Imaging and Milwaukee Forestry Division to conduct an initial accuracy assessment (ground verification). Initial results provided approximately 80% overall accuracy for ash classification with certain honey locust, maple (mostly silver but also some Norway and sugar), and red oak constituting the majority of false alarms. Subsequent adjustments to the spectral angle mapping process yielded a dramatic reduction in false alarms, with 85% overall accuracy for all ash trees and as high as 93% accuracy for larger ash trees. Following reprocessing of the data, false alarms with similar reflectance levels were limited to red oak and catalpa, neither of which occur in abundance in the Milwaukee area and are easily distinguishable on the ground from ash species.

The plantable space analysis that was also included in the project deliverables analyzed existing urban tree canopy and other vegetation (predominately grass) to quantify existing and projected urban canopy in each of Milwaukee's 15 aldermanic districts, based on actual available plantable space.

Work utilizing i-Tree Eco data and LIDAR tree attributes (tree height, crown width, and stem diameter) to estimate ash tree volume in the city is ongoing and will be reported in a future *City Trees* article.

## Conclusions

This project demonstrated the use of advanced geospatial technology, including high-resolution remote sensed hyperspectral and LIDAR data in conjunction with GIS analytical tools, to geospatially map the location and condition of ash species in the City of Milwaukee. A geospatially mapped host inventory represents the frontier for urban and rural forest management, and constitutes a significant new tool needed for improved species mapping, risk assessment, forest health monitoring, early rapid detection, and management of invasive species such as EAB.

High-resolution remote-sensed hyperspectral imagery provides the foundation for new invasive species best practices. The ability to overlay an orthorectified mosaic species map with 85% or greater accuracy onto an existing GIS parcel map represents a powerful new application for invasive species detection and response planning. This technology will permit coordinating federal, state, and local personnel to efficiently target property owners with high ash concentrations for EAB inspections, monitoring, control, and dissemination of outreach materials.

Armed with a HIS-derived GIS ash classification layer, the Milwaukee Forestry Division plans to conduct an extensive outreach campaign during the summer of 2009 to over 27,000 households identified as having ash trees. Residents will be alerted to the presence of ash on their property and provided with information related to EAB risk and management options. It is hoped that the increased awareness and opportunity for advanced planning will lead residents to take appropriate action to either treat or remove their ash tree(s) in advance of EAB, and ultimately reduce code enforcement action required by Milwaukee forestry staff.

The ash classification affords Milwaukee a unique opportunity to be more proactive in managing the highly elusive EAB by increasing the probability for early rapid detection and the potential to more accurately predict EAB movement within a community based on known host distribution.

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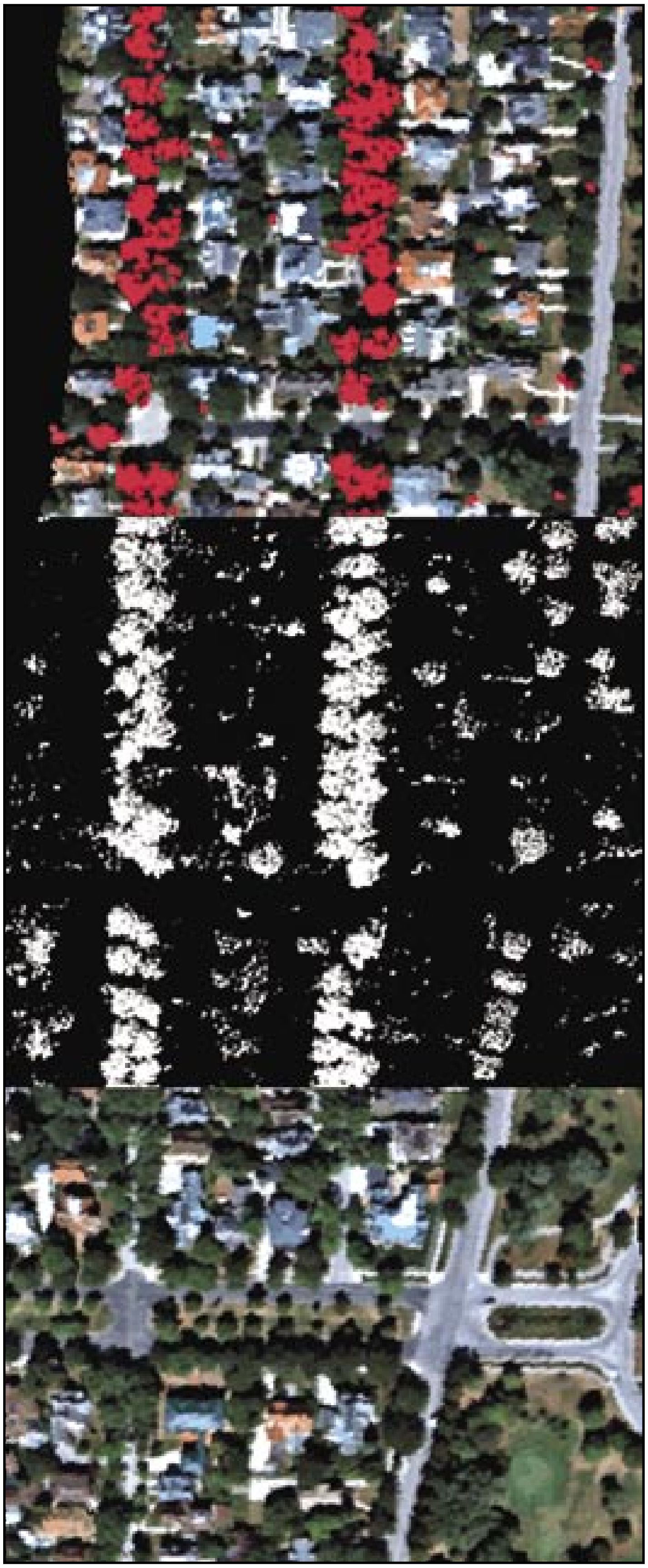

At bottom, you see the hyperspectral true color of the urban forest in Milwaukee, Wisconsin. The middle pane shows the hyperspectral feature extraction of ash trees, and the pane at top shows the hyperspectral feature mapping of ash. • Image Credit: RFP Mapping LLC

Hyperspectrally derived ash classification GIS layer in northwest Milwaukee (top) and the south central portion of the city (bottom). Image: RFP Mapping, LLC

*LIDAR: Light Detection and Ranging, from *nasa.gov: A Lidar transmits coherent laser light, at various visible or NIR (Near-IR) wavelengths, as a series of pulses (100s per second) to the surface, from which some of the light reflects. In this sense, it is similar to radar. Travel times for the round-trip are the measured parameter.*

**Key Words:**

Hyperspectral Imaging (HSI)
Milwaukee Urban Forest
Emerald Ash Borer
i-Tree
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GIS