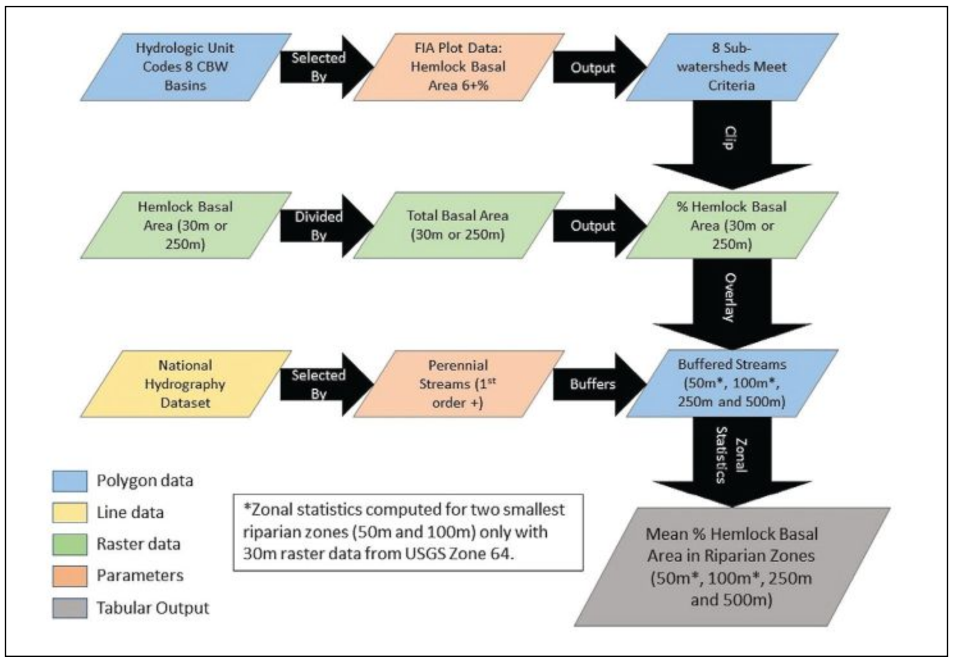
Geospatial Techniques for Identifying Riparian Hemlock Forests Threatened by Hemlock Woolly Adelgid

By Mary Ann Fajvan and Randy Morin

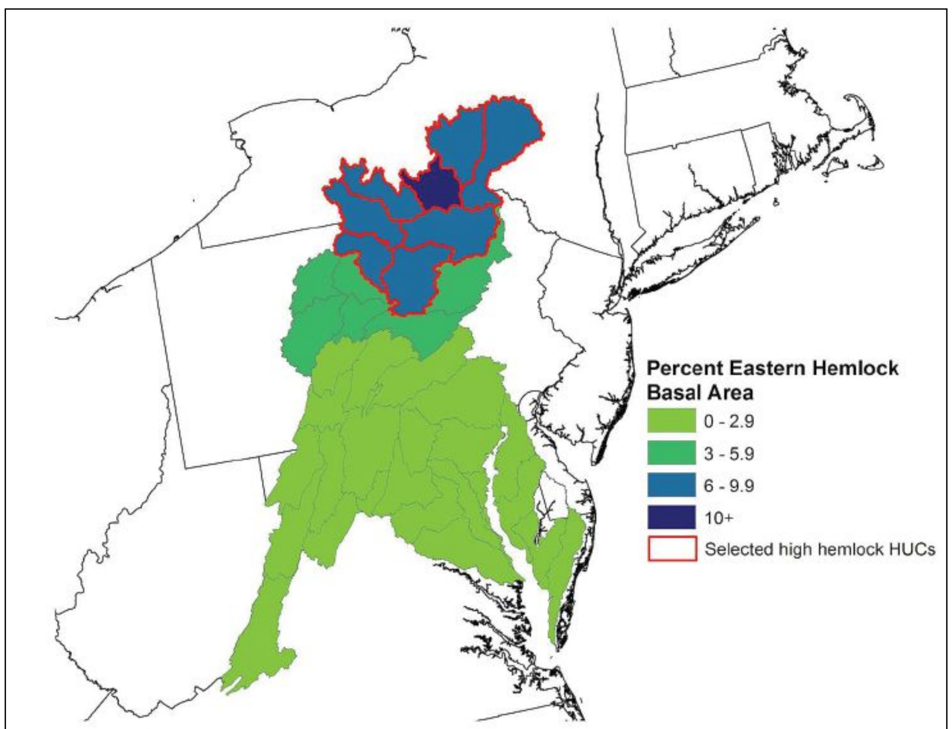
Landscape-scale maps of tree species densities are important tools for developing strategies to manage ecosystems threatened by forest pests. Eastern hemlock (*Tsuga canadensis* Ehrh.) dominates riparian forests in watersheds throughout eastern North America. As a conifer in a primarily deciduous landscape, hemlock plays an ecohydrological role, especially when other species are dormant. The non-native, hemlock woolly adelgid (HWA), *Adelges tsugae*, presents a landscape-scale threat to forest ecosystem health and economic viability of eastern hemlock. Land managers require tools to assess hemlock's spatial distribution for monitoring HWA invasion and planning strategies to reduce ecological and hydrological impacts from hemlock decline. Geographic information system (GIS) products assist managers in synthesizing landscape-scale inventory data to address the HWA threat to forest ecosystem function.

Widespread hemlock mortality causes permanent reductions in winter transpiration rates because forest canopies are usually replaced with deciduous species. Prior watershed research identified significant relationships between hemlock mortality and water yield where hemlock basal area was at least 6 percent of total forest cover and 26 percent was concentrated in riparian areas (Brantley et al. 2014). Mapping riparian hemlock concentrations could assist planning of mitigation strategies in watersheds with anticipated hemlock decline.

We are research foresters with the US Forest Service's Northern Research Station. We co-authored "Spatial Distribution of Chesapeake Bay Riparian Hemlock Forests Threatened by Hemlock Woolly Adelgid," recently published in the *Journal of Forestry* (doi.org/10.1093/jofore/fvab001). The Chesapeake Bay Watershed (CBW) encompasses more than 44 million acres, is 55 percent forested, and contains the largest estuary in the United States. The bay is a highly productive ecosystem and extremely sensitive to forest cover changes. Although hemlock is more prevalent in the northern region of the CBW where HWA occurs in isolated stands, hemlock density specific to riparian areas is unknown.



The GIS procedure for estimating percent hemlock basal area per acre in riparian zones (50, 100, 250, and 500 meters) of Chesapeake Bay subwatersheds with at least 6 percent hemlock basal area. Raster layers of 250 meters and 30 meters were used to model basal area at two spatial scales.



Study area for "Spatial Distribution of Chesapeake Bay Riparian Hemlock Forests Threatened by Hemlock Woolly Adelgid," *Journal of Forestry* (doi.org/10.1093/jofore/fvab001).

The study objectives used FIA data, satellite imagery, and geospatial data to:

1. Identify CBW sub-watersheds with >6 percent mean hemlock basal areas and compare with hemlock percentages in their riparian zones;
2. Quantify riparian zones in the identified CBW sub-watersheds, which contain >25 percent hemlock basal area, in order to determine those zones most vulnerable to HWA impacts;
3. Identify the location of CBW riparian stands with a significant hemlock component (containing >30 square feet/acre hemlock basal area) for HWA-mitigation purposes.

The demonstrated techniques are presented as a case study mapping riparian hemlock stands in headwater tributaries of the Pine Creek Watershed in Pennsylvania.

Data from the Forest Service's Forest Inventory and Analysis (FIA) program were first used to identify eight sub-watersheds where hemlock basal area was >6 percent of the total forest basal area in the CBW (HUC8). Second, two different raster datasets were used for a more spatially explicit examination of sub-watershed basal areas and hemlock distribution relative to riparian areas. The major difference between the two modeled basal area layers is the resolution: 250 meters vs. 30 meters. The 250-meter resolution product was derived from Moderate Resolution Imaging Spectroradiometer (MODIS) imagery. The 30-meter hemlock basal area surfaces were spatially derived using three-season Landsat imagery and modeled individually within USGS National Land Cover Dataset mapping zones. The two map products were created by applying a spatial model to a stack of geospatial layers including the FIA plots, satellite imagery, and other ecological variables, such as slope, aspect, and soil characteristics. Because basal area is correlated with crown area, it is also correlated with spectral forest characteristics measured with satellite-based sensors.

The 250-meter MODIS-based raster layers of hemlock basal area (per acre) and the National Hydrography Dataset (NHD) were used to categorize total forest basal area, hemlock basal area, and percent hemlock basal area. The eight "high hemlock" HUCs were further examined according to geographic features associated within increasing distances from 1st order and higher perennial streams (riparian zones). These same data were buffered at 250 meters and 500 meters (inclusive) from streams and the mean percentage hemlock basal areas (per acre) for these zones were calculated.

Five sub-watersheds were further examined at a finer spatial resolution (30 meters) to determine riparian zone sizes most likely to contain >25 percent hemlock basal area. Since the 30-meter data are available for download for individual USGS mapping zones, zone 64 contained the Pine Creek Watershed (for the case study) and four adjacent HUC8 sub-watersheds. For these five sub-watersheds, the interpolated raster layers were used to estimate hemlock basal area in riparian zones at four spatial scales. Perennial streams from the NHD were buffered at distances of 50, 100, 250, and 500 meters.

Results indicated that hemlock basal area in the CBW is concentrated in northern Pennsylvania and southern New York, where HWA has had minor impacts to date. Eight sub-watersheds had mean percent hemlock basal areas from 6.2 to 10.2 square feet/acre, which met the criteria of >6 percent. Mean percent hemlock basal area remained generally the same as riparian zone size increased from 250 meters to 500 meters and was similar to the overall average. For the five sub-watersheds evaluated at 30-meter resolution, the percentages of riparian zone pixels containing >25 percent hemlock basal area were always higher than mean percentages for the entire watershed. The 50-meter and 100-meter riparian zones had higher percentages of pixels meeting basal area criteria and decreased as pixels in the 250- and 500-meter zones were included

At the finer spatial resolution (30 meters), higher hemlock densities were detected within 100 meters of streams. This zone is more likely to have negative HWA-caused hydrological/ecological impacts and could be targeted for mitigation efforts. Depending on the watershed, there were some riparian hemlock clusters/stands with sufficient hemlock basal areas for silvicultural thinnings. Reduction of hemlock density in fully to overstocked hemlock-hardwood stands (>30 square feet/acre) increases sunlight to hemlock crowns and can improve resistance to HWA. FS

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References

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