# Inventory of Trees in Nonforest Areas in the Great Plains States

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**ABSTRACT**: The U.S. Forest Service's Forest Inventory and Analysis (FIA) program collects information on trees in areas that meet its definition of forest. However, the inventory excludes trees in areas that do not meet this definition, such as those found in isolated patches, in areas with sparse or predominantly herbaceous vegetation, in narrow strips (e.g., shelterbelts), or in riparian areas. In the Plains States, little is known about the tree resource in these noninventoried, nonforest areas, and there is a great deal of concern about the potential impact that invasive pests, such as the emerald ash borer, might have. To address this knowledge gap, the National Inventory and Monitoring Applications Center (NIMAC) has partnered with state cooperators to design and implement an inventory of trees in nonforest areas. The goal of the inventory is to characterize the tree resource using methods compatible with those of FIA so a holistic understanding of the resource can be obtained by integrating the two surveys. The goal of this paper is to give an overview of the goals and objectives of the inventory and to describe the plot and sample designs. Key findings related to the planning and establishment of the inventory are also provided.

**KEYWORDS**: Trees outside of forest, nonforest tree inventory, emerald ash borer, isolated trees, Great Plains forest inventory, multiphase sample.

#### Introduction

The U.S. Forest Service's Forest Inventory and Analysis (FIA) program conducts an inventory of trees in areas meeting its definition of forested land use. This definition includes areas that are at least 1 acre in size, with certain geometric properties (e.g., at least 120 feet wide), of a current or former stocking level of at least 10 percent, and that are not subject to activities like mowing or understory clearing that would prevent normal regeneration (U.S. Forest Service 2007). FIA produces estimates of several forest parameters and creates statistical and analytical reports that are used by many customers including local, state, national

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In: McWilliams, Will; Moisen, Gretchen; Czaplewski, Ray, comps. 2009. 2008 Forest Inventory and Analysis (FIA) Symposium; October 21-23, 2008: Park City, UT. Proc. RMRS-P-56CD. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 1 CD.

and international scientists, land managers and other decision makers (Gillespie 1999).

North Dakota, South Dakota, Nebraska, and Kansas (hereafter referred to as the Plains States) are approximately 97 percent nonforest (Smith et al. 2004), and consist mostly of agricultural and grassland vegetation communities. Plains State resource agencies have recognized the lack of available information on the nonforest tree (NFT) resource, and how this knowledge gap might hinder wise management of these areas. Of particular concern is the spread of the emerald ash borer (EAB) (Agrilus planipennis Fairmaire), which, since being identified in 2002 near Detroit, MI, has been found in nine other Midwest and eastern states and into Canada. Although EAB has yet to be confirmed in the Plains States (as of January, 2009), this region has some of the highest relative density of EAB hosts (Fraxinus spp.), with mostly green ash (Fraxinus pennsylvanica) found along riparian areas, in conservation tree plantings and as a common tree in the communities across the plains (Figure 1). State forestry agencies in the Plains States, with funding assistance from the U.S. Forest Service's State & Private Forestry division, have undertaken an assessment of the potential economic and ecological impacts of EAB-induced ash mortality. The National Inventory and Monitoring Applications Center (NIMAC) was asked to assist with an inventory of the NFT resource to supplement the information that FIA collects on the tree resource in forested areas.

The goals of the inventory included obtaining state-level estimates of NFT parameters including area of land with different classes of NFT land use and estimates of total amounts of several continuous variables (e.g., basal area, volume, and biomass by species). An additional component of the inventory, not reported here, focused on NFTs in urban areas, with results serving as input to the Urban Forests Effects (UFORE) model, which, among other things, assigns estimates of value to urban forest components (Nowak and Crane 2000). Results from both inventories will be used by Plains States' resource agencies to gauge the economic and ecological impacts of potential ash species mortality, explore NFT utilization potential, develop educational materials, and to help formulate EAB mitigation strategies<sup>4</sup>.

NIMAC helped incorporate FIA methodology into the design of the inventory to make NFT parameter estimates compatible with those obtained by the FIA program. In addition, the FIA data collection and processing infrastructure lends itself to being used in other, similar resource inventories. This paper describes how NIMAC extended traditional FIA plot and sample design methodology to the nontraditional Plains States NFT inventory.

<sup>&</sup>lt;sup>4</sup> Nebraska Forest Service. 2007. Great Plains Tree and Forest Invasives Initiative; A multi-state cooperative effort for education, mitigation and utilization. Grant proposal. Unpublished document, on file at the Nebraska Forest Service, Lincoln, Nebraska.



Emerald Ash Borer Susceptibility - Known Host

## **Methods**

NIMAC and Plains States forestry officials undertook a planning process that identified desired outcomes, precision requirements of NFT parameter estimates, existing FIA data sources, and new variables that were required to meet goals. The result of this process was the choice of a plot design that represents a tradeoff between a desire for compatibility with FIA methodology and cost effectiveness in the field. The field plot consisted of a single, 1/6-acre circular plot on which a variety of FIA, UFORE, and other site and tree-level attributes were recorded<sup>5</sup>. The FIA field guide, data recorder software program, and database storage system were adapted to accommodate the Plains States variables.

An assessment of the field data collection budget for the summer months of 2008 (the first year of data collection) revealed that 100 plots per state could be measured with the existing funding, which was divided equally among the states. This small number of plots compounded the concern that the attributes of interest,

Figure 1. Map of relative density of species susceptible to the Emerald Ash Borer (from <a href="http://www.fs.fed.us/ne/syracuse/Data/Nation/data\_list\_eab.htm">http://www.fs.fed.us/ne/syracuse/Data/Nation/data\_list\_eab.htm</a>, accessed 11/15/2008).

<sup>&</sup>lt;sup>5</sup> Great Plains Initiative Inventory Project, Data Collection Procedures. Version 1.0. Unpublished report on file at U.S. Forest Service, FIA Program, 11 Campus Blvd, Ste. 200, Newtown Square, PA 19073.

which are associated with NFT land use, occurred in only approximately 1 percent of the overall land area of the four states based on FIA estimates. In situations where there is potential to collect less costly information on a large number of elements in the population and to collect more costly, direct measurements of the attribute of interest on a subset, multi-phase sampling is suggested (Cochran 1977). For example, Holmgren et al. (1994) performed a study in which multi-phase sampling was found to be effective at characterizing the NFT resource in Africa. We chose a stratified, two-phase sample design for the NFT survey of the Plains States.

The first step was to stratify the four-state area into two strata (canopy and no canopy) using a derivative of the National Land Cover Dataset (NLCD). NLCD is a set of satellite image-based products produced by a consortium of federal agencies, led by the U.S. Geological Survey (Homer et al. 2007). These products are comprised of 30-m pixels, each labeled with a land cover category, percent impervious surface, and percent canopy cover estimates. To create the strata, a spatial filtering approach was applied to the percent canopy cover map. For each 3 x 3 block of pixels in the image (the focal window), the count of pixels with any estimated canopy cover in them was assigned to the center pixel of the block. The focal window was then shifted over one pixel, and the process was repeated for each pixel in the image. This resulted in an image containing pixel values of 0 (no canopy cover in the focal window) to 9 (all 9 input pixels contained canopy cover). This image was then recoded into the final stratum map: values of 0 were assigned to stratum 1, and all other values were assigned to stratum 2. For the four-state area, approximately 90 percent of the area fell into stratum 1, which we considered more likely to be devoid of trees.

The next step was to select elements within each stratum for the first phase of the two-phase sample. Phase 1 consisted of a large number of photo-interpretation (PI) plots overlaid on circa 2006 National Aerial Imagery Program (NAIP) imagery. Each plot consisted of 21 uniformly spaced points located within the footprint of potential ground plots – a 1/6-ac circle. Twenty-one points were chosen based on prior experience and a tradeoff between time cost per plot and completeness of area coverage for NFT assessment. The land use (using FIA definitions [U.S. Forest Service 2007]) of each of the 21 points was assessed and the count of points falling in the NFT land use category was recorded for each PI plot.

Based on consultation with PI specialists and a pilot assessment of the PI methodology, it was determined that the project budget allowed for 18,000 PI plots to be completed for each state. The number of PI plots per stratum was determined by optimal allocation because it was relatively inexpensive to perform the PI, and the population size and variability within some of these strata were large (Cochran 1977). To determine these optima, existing FIA ground plots were first assigned a stratum by intersecting them with the stratum map in a GIS. The variance of the binary-coded land-use category (NFT/non-NFT) of the center of

the center FIA subplots was then calculated for each stratum. These variances were used to proportionally allocate PI points to each stratum.

Phase 2 of the two-phase sample was established by assigning ground plots into substrata created from the PI results. Within each stratum, subsamples of PI plots were randomly chosen in a spatially balanced manner (Lister and Scott 2008) for ground visits based on a second stratification of the PI plots using NFT land use counts. The 0-21 range of potential NFT land-use count values was collapsed into three substrata within each primary stratum using information from FIA plot data as a guide. FIA plots all have a "percent forest" value assigned to them based on a ground mapping of land-use categories found on the plot. We assumed that the percent forest estimate on FIA plots is analogous to the proportion (out of 21) NFT land use estimate found on a PI plot. By making that assumption, we heuristically assessed how collapsing the FIA plots. We chose a count of three strata subjectively, guided by our desire to have an adequate number of sample plots in each stratum.

Once we arrived at a configuration of the FIA percent forest strata generally yielding the lowest variance for both tree density and total cubic foot volume (given an acceptable number of plots per stratum), we translated the stratum boundaries from the FIA percent forest scale (0-100 percent forest land use) to PI plot scale (0-21 NFT points/plot). We then used the resulting PI plot stratum boundaries and associated stratum areas to optimally allocate ground plots (phase 2) into each substratum. No ground plots were sampled in the first substratum of each stratum (the substrata with 0 NFT points). These substrata were assumed to have no NFT because of the high quality of the imagery and the cost of sampling the substratum. For example, Table 1 lists the area percentage in each primary stratum and the number of PI and ground plots by substrata for Kansas. The optimal allocation clearly shifts PI plots into stratum 2, eliminates substratum 0, and emphasizes substratum 2 versus 1.

KANSAS	0-21 splits	Area (%)	Photo- interpretation Plots	Ground Plots
Stratum 1:		86.8%	10156	63
Substratum 0	0		9658	0
Substratum 1	1-6		300	25
Substratum 2	7-21		198	38
Stratum 2:		13.2%	7874	37
Substratum 0	0		6798	0
Substratum 1	1-8		630	16
Substratum 2	9-21		446	21

**TABLE 1**: Example of allocation of photo-interpretation plots and ground plots by stratum and substratum for Kansas.

#### Conclusions

We learned much from the process of planning and establishing the Plains States NFT inventory. The process of setting inventory goals and choosing variables to meet these goals was a time-consuming, iterative process. Frequent meetings with all interested parties, as well as establishing expectations in light of the available budget, helped to ensure that the inventory would efficiently provide the answers to management questions.

Another finding was that photo-interpretation of nearly 80,000 plots (1,680,000 individual points to assess) required a great deal of effort to develop an efficient procedure, construct a manual, and manage and train analysts. We discovered a GIS procedure that vastly increased our productivity level and lowered costs. Furthermore, photo-interpreting plots in the Plains States was less complex because the vast majority of the plots assessed were completely devoid of trees. The experience we gained in this work will speed up future photo studies we conduct.

Finally, we learned that some of the existing FIA infrastructure, including the field guide and data recorder software, is adaptable for use in other, FIA-like resource inventories. By going through the process of adapting the FIA methodology to fit the NFT inventory, the project not only benefits from using pre-existing infrastructure, but also from the potential for integration of NFT results with those from FIA. Since the 800 urban plots and the 400 rural plots were collected with nearly identical, FIA-compatible methods, we plan to generate state-level estimates of tree parameters across all lands. The FIA program will benefit from this study by gaining additional information on the tree resource in these states for use in analytical reporting. It also will acquire new institutional knowledge related to its own inventory methodology as well as new techniques that can be implemented to address emerging resource issues.

Ground data from the 400 plot subsample of the PI plots, and more than 800 urban plots, were collected from the rural portions of the Plains States in the summer of 2008. As of December 2008, we are beginning data analysis. Results will be reported in future work.

### Acknowledgments

We would like to offer special thanks to Eunice Alexander, Aaron Clark, Doug Griffith, and Andrea Stoneman for their many hours of hard work at helping develop and conduct the PI. We'd also like to thank Tom Albright, Dan Kaisershot, Cassie Kurtz, and Greg Liknes for their advice on FIA PI methods and logistics. Finally, we'd like to thank James Blehm, Katherine Johnson, Mary Miller, and Jay Solomakos for their efforts to develop a field guide, data recorder, and training program for the project's field crews.

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