

# Forest Inventory and Analysis in the United States: Remote Sensing and Geospatial Activities

by Mark Nelson, Gretchen Moisen, Mark Finco, and Ken Brewer

## Introduction

Our Nation's forests provide a wealth of ecological, social, and economic resources. These forest lands cover over 300 million hectares of the United States, or about one third of the total land area. Accurate and timely information about them is essential to their wise management and use. The mission of the Forest Service's Forest Inventory and Analysis (FIA) program is to "...improve the understanding and management of our Nation's forests." Remote sensing-based maps and geospatial datasets are playing an increasing role in improving that understanding. Examples of maps portraying forest composition and spatial distribution, seen on the cover of this issue and described within in an article by Ruefenacht and others, were produced by a collaboration of three USDA Forest Service entities: the Remote Sensing Applications Center (RSAC), Forest Health Monitoring, and FIA. In this article, the FIA program is introduced and FIA's remote sensing and geospatial activities are highlighted.

## FIA Program

Initially known as "Forest Survey", FIA has been gathering and disseminating unbiased and objective forest resource data for more than 75 years. Initially, the FIA program focused on estimating the extent, volume, and condition of live trees as a source of marketable timber available for harvest. Over the years the scope of the FIA program has expanded and it now provides more diverse forest resource information on the status and trends of the Country's forest ecosystems, the use of the forests, and the health of those ecosystems. While timber is still important, the FIA inventory also addresses plant diversity; fuels and potential fire hazard; condition of wildlife habitats; mortality and risk associated with fire, insects, or disease; biomass; carbon storage; forest health, and other general characteristics of forest ecosystems. FIA conducts inventories and analyzes data for public and private forest lands in the United States, including Alaska, Hawaii, Puerto Rico, the U.S. Virgin Islands, and U.S. Pacific Territories. Remote sensing data and geospatial technologies are improving the quality, timeliness, and cost effectiveness of FIA inventory and monitoring products.

## FIA Data

Nationally, FIA collects a common set of data by using field methods that are consistent across the country (Figure 1). FIA defines "forest land" as land not developed for a non-forest land use and meeting minimum criteria for tree stocking, evidence of past stocking, area, and width. FIA's base federal program addresses biophysical, social, and economic information about forest land. Biophysical forest data are obtained via a three phase inventory. In Phase 1, remote sensing data and land cover maps are prepared for post-sampling stratification of field data. Phase 2 involves field observations at a sample of ground plots that are selected from a hexagon sampling array derived from the U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program. Most Phase 2 data are related to tree and understory vegetation components of the forest such as species, size, density and biomass. Digital aerial photography from the National Agriculture Imagery Program and other sources are used to interpret land-use and aid in field navigation, while global positioning system technology is used to obtain plot location coordinates. In Phase 3, an extended suite of ecosystem attributes are measured on a subset of Phase 2 plots. Examples of Phase 3 attributes include soil, down woody material, plant species occurrence, lichen diversity, and the extent of ozone injury. In addition to this three phase sample a National Woodland Owner Survey is conducted to obtain social data, and economic data are obtained by surveying primary wood products output within each state.

FIA's sample design involves re-measurement of permanent plots. Satellite image-based land cover maps are used to post-stratify the sample to improve precision in forest population



Figure 1. Collecting, processing, and analyzing data from field plots are the major activities within FIA, Minnesota, USA.

Cover Image. Examples of forest composition and spatial distribution, a) aspen-spruce-fir, Utah, USA (Photograph courtesy of Thore Christensen).

*continued on page 730*

estimates. The National Land Cover Dataset (NLCD), when used for stratification, provides substantial increases in the precision of FIA's forest land area estimates. Currently, procedures are being implemented to use 2001 NLCD percent tree canopy density data for stratifying FIA plots to produce more precise estimates of forest attributes.

To protect land owner privacy, true plot location coordinates cannot be publicly released; however, approximate locations are made available, along with many corresponding forest attributes. To meet the needs for more precise registration between plot locations and remote sensing datasets, FIA has established regional and national Spatial Data Service Centers, which facilitate access to FIA data without compromising the security of the plot locations or land owner privacy. Dozens of researchers in government agencies, universities, non-governmental organizations, and industries have benefited from these services. For example, the U.S. Geological Survey used FIA Spatial Data Services to improve the 2001 NLCD. Similarly, FIA plot data are being used in support of the Landscape Fire and Resource Management Planning Tools Project. Beyond simply accessing data through SDS, many researchers take advantage of collaborative ventures with FIA scientists. Through collaboration, they access in-house data, resources, technical knowledge, and explore the potential to port new technologies into FIA operations.

### Maps and Geospatial Tools

In addition to linking plot locations with ancillary geospatial data, FIA is producing satellite remote sensing-based datasets and maps that spatially portray FIA attributes. For example, a 1992 FIA map and geospatial dataset of forest cover types has been widely used and currently is distributed via the National Atlas. The forest type map featured in this issue provides an update to the 1992 map and benefits from more detailed spatial and thematic resolution. FIA and RSAC recently produced two other nationwide geospatial datasets, forest/non-forest and per-pixel forest biomass.

FIA data, estimates, and maps are distributed freely to the public. In addition to distributing data, FIA has developed several geospatial tools. The Forest Inventory Mapmaker provides users with the ability to easily generate tables and maps by using a web browser. Likewise, the Timber Products Output Mapmaker generates tables and maps of forest resource utilization. Using information from the national Resources Planning Act (RPA) assessment dataset, the RPA DataWiz is freely distributed software that allows users to create summary tables, graphs, and maps. The Forest Inventory Data Online (FIDO) tool is in beta testing and will generate tables and maps, including satellite image-based maps (Figure 2). Several collaborating agencies and organizations are developing their own applications, based on freely available FIA data.

### Emerging Activities

As outlined in its recent Strategic Plan, FIA is expanding its use of remote sensing technologies to improve efficiency, increase the rate at which information is delivered, and shed new light on difficult problems. A wide variety of collaborative research projects are fueling this expansion. For example, studies are being conducted to evaluate the use of large scale aerial photography and/or lidar in conjunction with field data to improve the efficiency of inventories and reduce the costs of field data collection, particularly in

forest lands with sparse tree cover (Figure 3). Other studies are looking at coupling large scale photography with MODIS imagery to provide inexpensive image-based estimates of forest and other vegetation cover in areas where field data are unavailable. Work is also underway to explore a variety of new statistical methods for capitalizing on the relationships between remotely sensed and field data to further improve the quality of forest population estimates. These investigations are enhancing FIA's ability to produce small area estimates, like those needed to assess resources affected by wildfire, account for rare elements, or address local resource issues (Figure 4).

There is a need to provide agency leaders, elected officials, and the general public with summary information regarding disturbances that affect the Nation's forests. In conjunction with the North American Carbon Program, a collaborative effort is underway

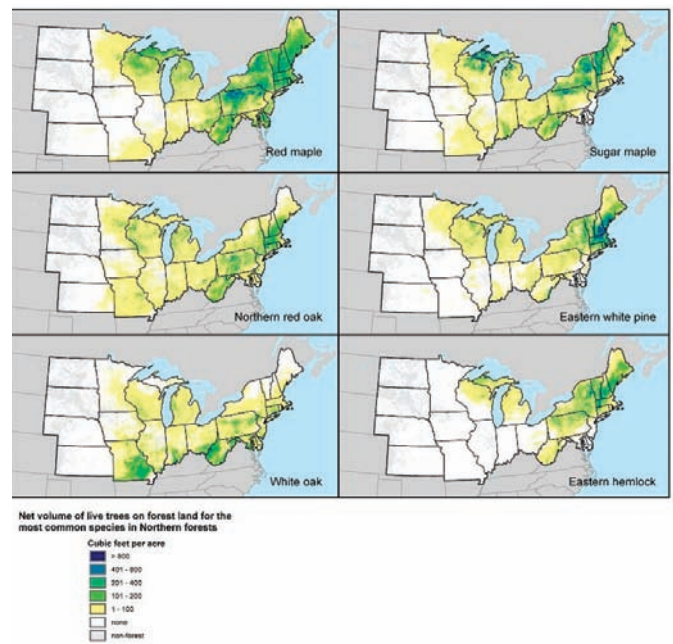


Figure 2. Maps of volume by tree species were produced via nearest neighbor imputation of annual FIA field plots using 250-m MODIS imagery with climatologic and topographic data, Northern FIA region, USA.

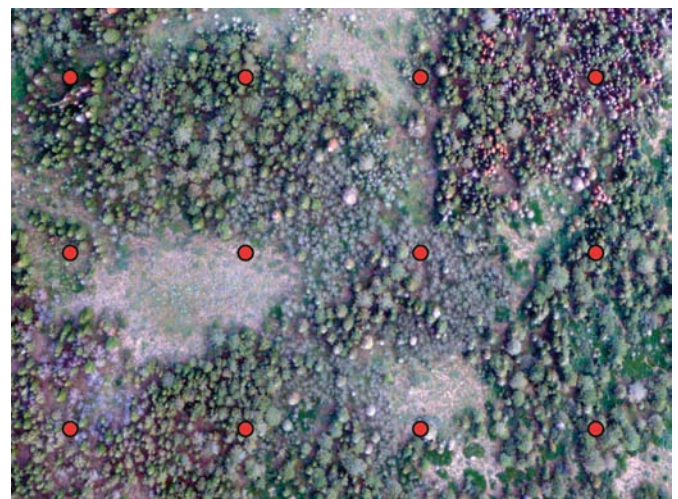


Figure 3. Large scale aerial photography is being used with FIA plot data to estimate vegetation cover and other attributes, Nevada, USA.

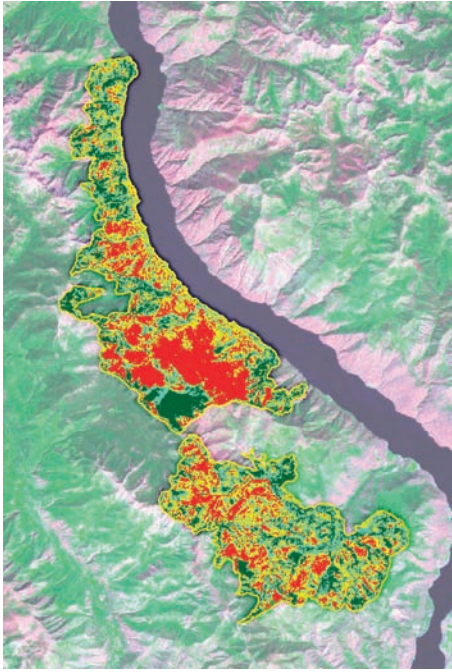


Figure 4. FIA data are used to quantify burn severity classes mapped by the Monitoring Trends in Burn Severity (MTBS) project, Pot Peak Fire, 2004, Washington, USA.

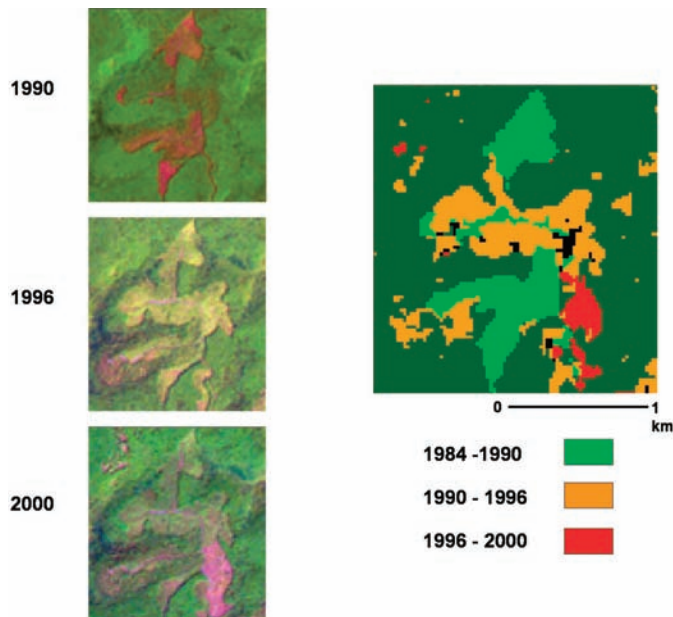


Figure 5. History of forest disturbance (biomass change) derived from Landsat Thematic Mapper time series imagery and FIA plot data, Allegheny National Forest, Pennsylvania, USA.

to develop a 30+ year historical record of forest disturbance and regrowth dynamics for North America using Landsat and FIA data (Figure 5). In addition, FIA is building a rapid assessment process using a wide variety of remotely-sensed data that will quickly estimate and report the effects of catastrophic events on forest resources.

FIA is also expanding its production of nationwide maps of forest characteristics in addition to the forest/non-forest, forest type, and forest biomass maps. This expanded production includes land use/land cover maps, and ultimately, a nationwide geospatial database capable of mapping and simultaneously analyzing most plot-based

forest attributes. These remote sensing datasets, along with county choropleth maps, field plot-based maps, and other geospatial datasets, are being compiled to add mapping functionality to online tools such as FIDO and to produce an FIA Atlas that will portray numerous maps of conditions, trends, variables, indicators and related information about U.S. forests. Important applications of such maps include broad-level mapping and assessment of wildlife habitat; documenting forest resources affected by fire, fragmentation, and urbanization; identifying land suitable for timber production; and locating areas at risk for insect or disease outbreaks.

### Important Web Links

- **Forest Inventory and Analysis (FIA) program**  
<http://fia.fs.fed.us/>
- **Biophysical forest data**  
<http://treesearch.fs.fed.us/pubs/20371>
- **Environmental Protection Agency's Environmental Monitoring and Assessment Program**  
<http://www.epa.gov/emap/index.html>
- **FIA Spatial Data Service Centers**  
<http://fia.fs.fed.us/tools-data/spatial/>
- **2001 NLCD**  
[http://www.mrlc.gov/mrlc2k\\_nlcd.asp](http://www.mrlc.gov/mrlc2k_nlcd.asp)
- **Landscape Fire and Resource Management Planning Tools Project (LANDFIRE)**  
<http://www.landfire.gov>
- **National Atlas**  
<http://www.nationalatlas.gov/mld/foresti.html>
- **FIA data, estimates, and maps**  
<http://fia.fs.fed.us/tools-data/data/>
- **Forest Inventory Mapmaker**  
<http://www.ncrs2.fs.fed.us/4801/fiadb/fim21/wcfim21.asp>
- **Timber Products Output Mapmaker**  
[http://ncrs2.fs.fed.us/4801/fiadb/rpa\\_tpo/wc\\_rpa\\_tpo.ASP](http://ncrs2.fs.fed.us/4801/fiadb/rpa_tpo/wc_rpa_tpo.ASP)
- **RPA DataWiz**  
<http://www.ncrs.fs.fed.us/pubs/products/rpadatawiz>
- **Forest Inventory Data Online (FIDO)**  
<http://fiatools.fs.fed.us/fido/statereports/index.html>
- **FIA Strategic Plan**  
[http://fia.fs.fed.us/library/fact-sheets/overview/FIA\\_Strategic\\_Plan2.pdf](http://fia.fs.fed.us/library/fact-sheets/overview/FIA_Strategic_Plan2.pdf)

### Summary

FIA provides the highest quality, most comprehensive data available on forests in the United States. In the last few years, these data have been made more readily available to a variety of clients for managerial, policy, and scientific applications. Beyond provid-

*continued on page 732*

continued from page 731

ing data, FIA is interested in working with a variety of collaborators to make the best use of FIA data in diverse application areas.

In particular, within the FIA program there is an increased emphasis on remote sensing and other geospatial data and analyses. In the uncertain fiscal environments faced by land management agencies, remote sensing data provide opportunities to develop information in a more cost effective manner. Providing forest inventory information spatially facilitates access by the general public, supports land managers, and will result in better understanding of our Nation's forest resources.



## Authors

### Mark Nelson

U.S. Department of Agriculture Forest Service  
Northern Forest Inventory and Analysis Program  
Northern Research Station  
1992 Folwell Avenue, St. Paul, MN, 55108

### Gretchen Moisen

U.S. Department of Agriculture Forest Service  
Interior West Forest Inventory and Analysis Program  
Rocky Mountain Research Station  
507 – 25th Street, Ogden, UT, 84401

### Mark Finco

U.S. Department of Agriculture Forest Service  
Remote Sensing Applications Center – RedCastle Resources, Inc.  
2222 West 2300 South Salt Lake City, Utah, 84119

### Ken Brewer

U.S. Department of Agriculture Forest Service  
Remote Sensing Applications Center  
2222 West 2300 South Salt Lake City, Utah, 84119