Combining Forest Inventory, Satellite Remote Sensing, and Geospatial Data for Mapping Forest Attributes of the Conterminous United States

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***Abstract**: Analysis and display of forest composition, structure, and pattern provides information for a variety of assessments and management decision support. The objective of this study was to produce geospatial datasets and maps of conterminous United States forest land ownership, forest site productivity, timberland, and reserved forest land. Satellite image-based maps of forest land cover, geospatial datasets of land protection and ownership, and data from the U.S. Department of Agriculture Forest Service's Forest Inventory and Analysis (FIA) program were integrated to produce forest land maps. Forest land cover was derived from the U.S. Forest Service Forest Types Map; land ownership and protection is derived from the Conservation Biology Institute's Protected Areas Database; and forest attributes are derived from FIA, summarized by a hexagon sampling array from the Environmental Protection Agency Environmental Monitoring and Assessment Program. This approach provides a technique for efficiently producing forest resource maps over large geographic extents.*

Key words: Forest, inventory, FIA, mapping, CONUS

Introduction

The U.S. Department of Agriculture Forest Service's Forest Inventory and Analysis (FIA) program produces estimates of United States forest land composition and structure across all classes of land ownership. These estimates provide information about the amount, condition, health, and change in forest resources. As a sample-based inventory, FIA reports estimates for defined estimation units, typically states and counties.

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Spatial analysis and map display of forest information provides support for a variety of assessments and management decisions of natural resources. Displaying FIA attributes spatially across typical estimation units is a straightforward procedure, however, many natural resource practitioners desire maps with more spatial specificity and better integration with supporting geospatial datasets than are available from traditional FIA estimates.

This paper describes one approach to combine data from FIA, satellite remote sensing, and other geospatial products for mapping forest attributes across the conterminous United States (CONUS). We produced geospatial datasets and maps of CONUS forest land ownership, forest site productivity, timberland, and reserved forest land by integrating satellite image-based maps of forest land cover, geospatial datasets of land protection and ownership, and FIA data. Previous mapping efforts (Stein et al. 2006, Nelson and Liknes 2007, Nelson and Vissage 2007) provide the basis for this approach.

Data

FIA data

FIA conducts inventories across land of all ownership categories, using a nationally consistent plot with four fixed-radius subplots, and a systematic national sampling design based on a hexagonal grid. At least one FIA plot is established within each hexagon, representing approximately 6,000 acres each.

Forest land is defined by FIA as "land that is at least 10 percent stocked by forest trees of any size, or land formerly having such tree cover, and not currently developed for a nonforest use." (Bechtold and Patterson 2005, glossary). Additional requirements include minimum forest patch size (1 acre) and minimum forest patch width (120 ft).

Three subcategories of FIA forest land include reserved forest land, timberland, and other forest land. Reserved forest land is defined as "land permanently reserved from wood products utilization through statute or administrative designation." Timberland is defined as "forest land that is capable of producing in excess of 20 cubic feet/acre/year of wood at culmination of mean annual increment (MAI)", excluding reserved forest lands. Other forest land comprises the remainder of forest land, being neither timberland nor reserved forest land (Bechtold and Patterson 2005, glossary).

FIA plot data from each state are aggregated to form a nationwide database U.S. Forest Service 2008) for producing forest resource assessments of the United States as mandated by the Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA), P.L. 93-378, 99 Stat. 4765.

RPA 2007 data (Smith et al., in press) on forest site productivity are assigned to one of seven categories, based on the culmination of mean annual increment of

fully stocked natural stands, recorded in units of cubic feet/acre/year. Plots were assigned the approximate midpoints of their productivity class, with one exception (Table 1).

Table 1: Forest site productivity.

SITECLCD	Class range (cubic feet/acre/year)	Midpoint
1	225+	225
2	165-224	195
3	120-164	142
4	85-119	102
5	50-84	68
6	20-49	35
7	0-19	10

RPA 2007 data on forest land ownership differentiates public vs. private, corporate vs. noncorporate, and various other ownership classes. Corporate owners include "forest industry and forest management companies, timber investment management organizations, and other companies that may or may not have forest management as a primary ownership objective" (Smith et al., in press).

EMAP hexagons

A hexagon sampling array from the Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP) was used for summarizing RPA plot data (White et al. 2005). The original EMAP grid of hexagons provide a CONUS sampling grid with each hexagon measuring approximately 648 square kilometers (160,000 acres) in area (U.S. Environmental Protection Agency 2002). Unlike states and counties, EMAP hexagons are equal-sized estimation units, and therefore are likely to contain similar numbers of plots. A number of natural resource monitoring activities are based on the EMAP sampling array and EMAP hexagon IDs have been assigned to each plot in the FIA database. Because the vast majority of EMAP hexagons in CONUS contain multiple RPA plots, per-hexagon estimates of forest attributes can be produced for each hexagon. These hexagons allow information to be analyzed and mapped at a finer spatial resolution than is available from typical FIA estimation units. RPA mean forest site productivity and percent corporate ownership of private forest land was calculated within each EMAP hexagon.

Land cover

We employed a raster geospatial dataset of 2001 CONUS and Alaska forest types for portraying forest and nonforest classes. This map of forest types was produced by the U.S. Forest Service at 250 m pixel resolution from Moderate-resolution Imaging Spectroradiometer satellite image data, ancillary geospatial data, and FIA plot data (Ruefenacht et al. 2008).

Land ownership

Land ownership data was derived from the Conservation Biology Institute's Protected Areas Database (PAD), version 4.6 (DellaSala et al. 2001), with revisions by FIA. To match FIA definitions, PAD polygons having International Union for Conservation of Nature (IUCN) protection classes I through V were defined as 'reserved' land, and areas not labeled as public were assumed to be in private ownership.

Mapping

A geographic information system (GIS) was used to prepare and manage geospatial datasets in Albers Conic Equal Area projection with standard U.S. Geologic Survey (USGS) parameters, North American Datum of 1983, and converted to raster format with 250 m pixel resolution. Figure 1 illustrates the spatial pattern of attributes from the four categories of data described above. For all maps, geographic base data are from the USDA National Agricultural Statistics Service (http://www.nass.usda.gov/census/census02/atlas02/CoGenAll_D02>) and the National Atlas of the United States (http://www.nationalatlas.gov/maplayers.html).

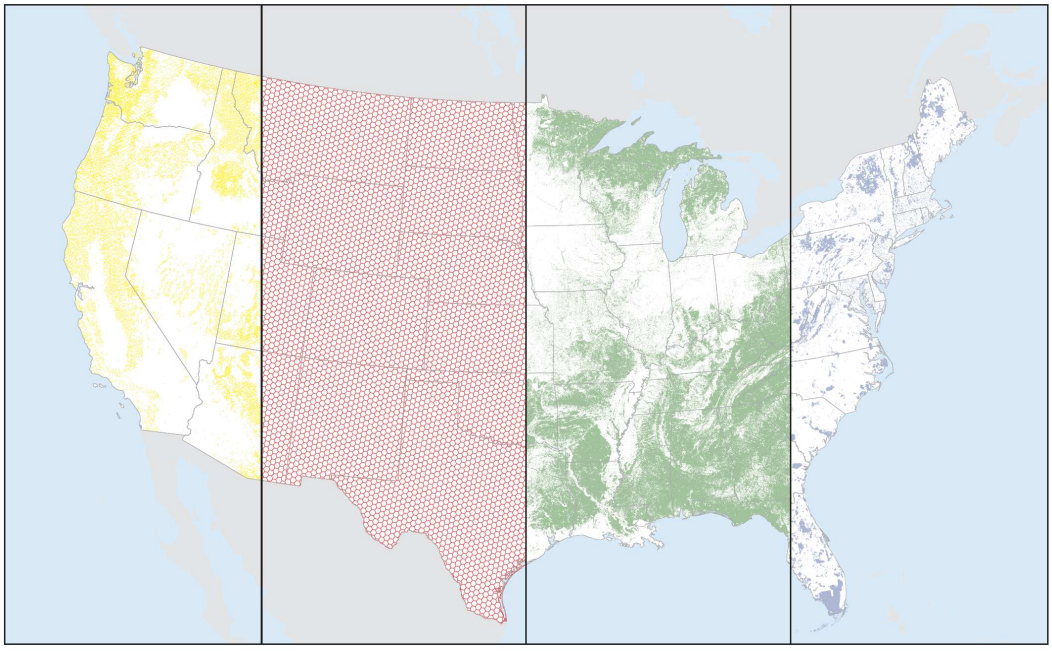

Figure 1: Geospatial datasets used for mapping forest attributes in CONUS, from left to right: approximate locations of forested FIA plots (U.S. Forest Service 2008), EMAP hexagon sampling array (U.S. Environmental Protection Agency 2002), forest land cover (Ruefenacht et al. 2008), and delineation of protected areas and land ownership (DellaSala et al. 2001).

Forest land ownership

Land ownership was mapped for all pixels labeled forest in the forest type map. Forest pixels were labeled as public or private ownership based on PAD. The percentage of private forest land in corporate ownership (FIA data) within each EMAP hexagon was assigned to each private forest pixel (Fig. 2).

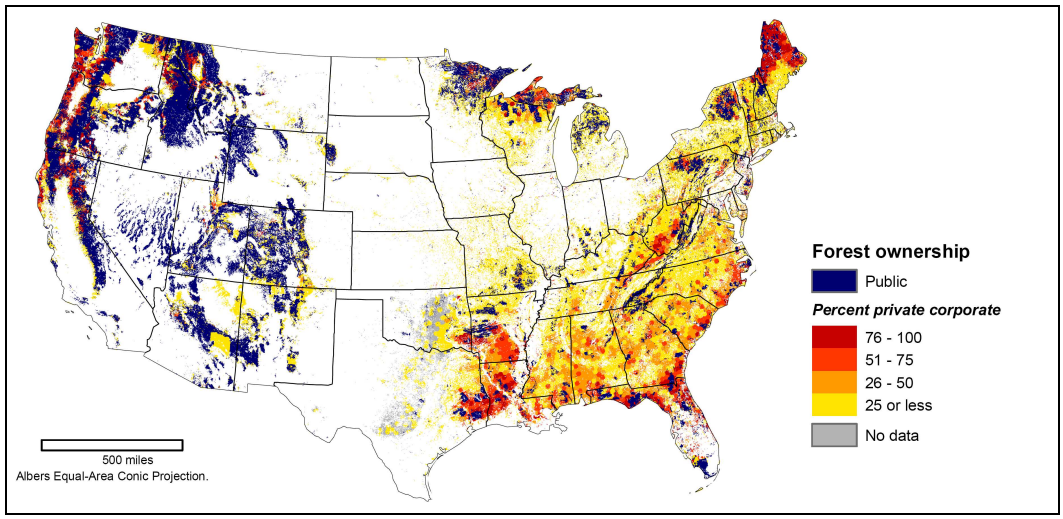

Figure 2: Public, private, and corporate forest land ownership in CONUS.

Forest site productivity

A map of net forest site productivity was produced by classifying mean site productivity within each hexagon into standard RPA classes, and assigning this class to all forest pixels (Fig. 3).

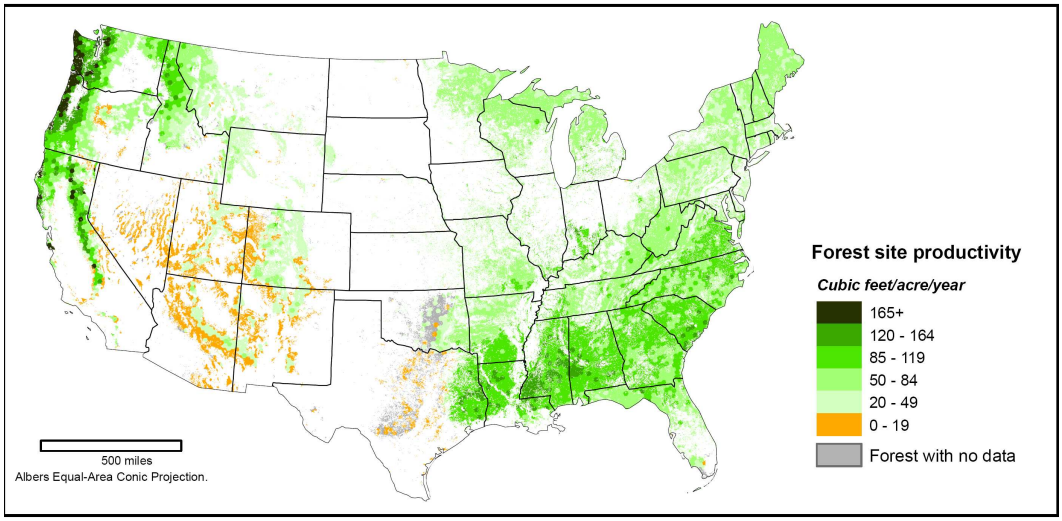

Figure 3: Net primary forest site productivity in CONUS.

Timberland, reserved forest land, and other forest land

Three subcategories of forest land were mapped: reserved forest land, timberland, and other forest land. Forest pixels in IUCN protection categories I through V were classified as reserved forest land. These lands are managed primarily for science, protection, conservation, or recreation. Nonreserved forest pixels were combined with the preceding forest site productivity map to identify pixels meeting the minimum timberland productivity threshold. All remaining forest pixels, i.e., not timberland and not reserved, were classified as other forest land (Fig. 4).

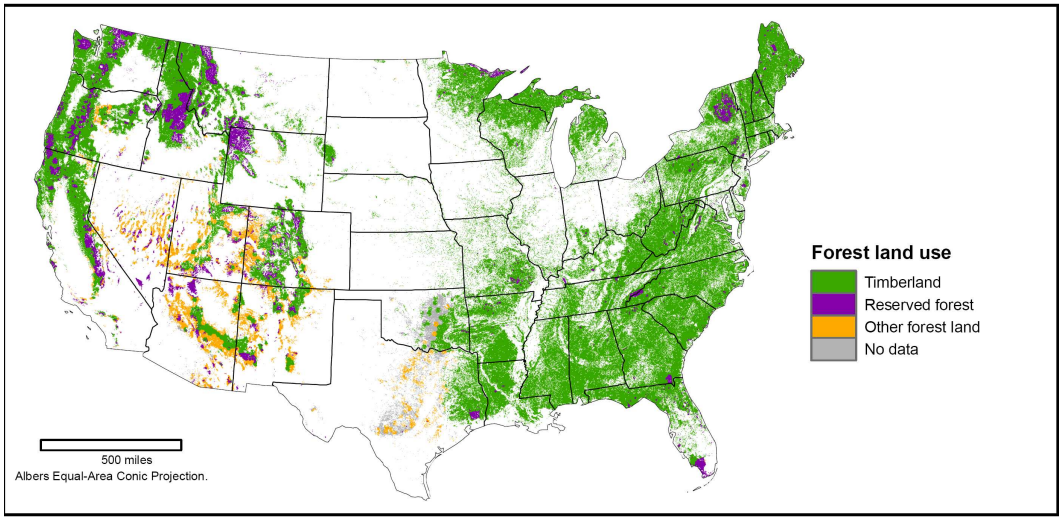

Figure 4: Timberland, reserved forest land, and other forest land in CONUS.

The maps depicted in Figures 3 and 4 were combined to further differentiate timberland into three general productivity classes (Fig. 5), selected to portray geographic variability:

- Low productivity — 20 to 50 cubic feet/acre/year,
- Medium productivity —50 to 85 cubic feet/acre/year,
- High productivity — 85+ cubic feet/acre /year

. This map (Fig. 5) reveals that timberland comprises most forest land in the East, with highest productivity occurring in the Pacific Northwest and in the South. Reserved forest land is most prevalent in the West where large national parks and wilderness areas are most common, but also is present in the East. Low productivity timberland and other forest land are most noticeable in the arid Southwest.

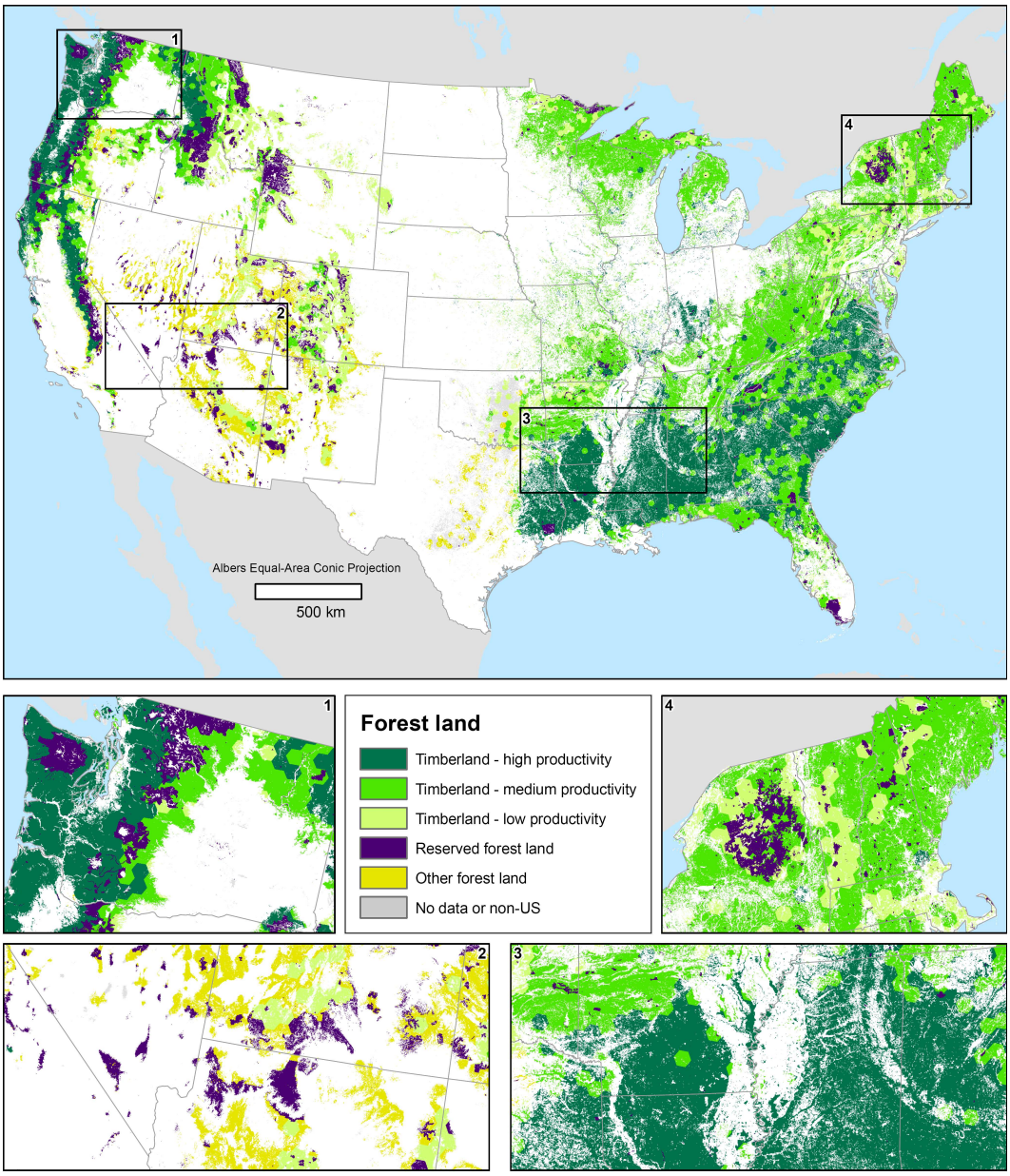

Figure 5: Reserved forest land, other forest land, and forest site productivity on timberland in CONUS.

Summary

We presented an approach for integrating satellite image-based maps of forest land cover, geospatial datasets of land protection and ownership, and forest inventory statistics to produce geospatial datasets and maps of CONUS forest land ownership, forest site productivity, timberland, and reserved forest land. This approach has been employed to produce and publish maps for the ESRI Mapbook, ESRI "Mapping Forestry" book, U.S. Forest Service's "Forests On The Edge" (FOTE) reports, RPA 2007 report, and other products.

Literature Cited

Bechtold, W.A.; Patterson, P.L., eds. 2005. Forest inventory and analysis national sample design and estimation procedures. Gen. Tech. Rep. SRS-80. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 85 p.

DellaSala, D.A.; Staus, N.L.; Strittholt, J.R.; Hackman, A.; Iacobelli, A. 2001. An updated protected areas database for the United States and Canada. Natural Areas Journal. 21:124-135.

Nelson, M.D.; Liknes, G.C. 2007. Forest land ownership in the conterminous United States. In: Law, M., ed. ESRI Map Book. Redlands, CA: ESRI Press: 76.

Nelson, M.D.; Vissage, J. 2007. Mapping forest inventory and analysis forest land use: timberland, reserved forest land, and other forest land. In: McRoberts, R.E.; Reams, G.A.; Van Deusen, P.C.; McWilliams, W.H., eds. Proceedings of the seventh annual forest inventory and analysis symposium. Gen. Tech. Report WO-77. Washington, DC: U.S. Department of Agriculture, Forest Service: 185-190.

Ruefenacht, B.; Finco, M.V.; Nelson, M.D.; Czaplewski, R.L.; Helmer, E.H.; Blackard, J.A.; Holden, G.R.; Lister, A.J.;Salajanu, D.; Weyermann, D.; Winterberger, K.. 2008. Conterminous U.S. and Alaska forest type mapping using Forest Inventory and Analysis data. Photogrammetric Engineering & Remote Sensing. 74:1379-1388.

Smith, W.B.; Miles, P.D.; Perry, C.H.; Pugh, S.A. In press. Forest resources of the United States, 2007. General Technical Report. Washington, DC: U.S. Department of Agriculture, Forest Service.

Stein, S.; McRoberts, R.; Nelson, M.; Theobald, D.; Eley, M.; Dechter, M. 2006. Forests on the edge: A GIS-based approach to projecting housing development on private forests In: Aguirre-Bravo, C.; Pellicane, P.J.; Burns, D.P.; Draggan, S., eds. 2006. Monitoring science and technology symposium: Unifying knowledge for sustainability in the western hemisphere; Proceedings RMRS-P-42CD. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 736-743.

U.S. Forest Service. 2008. The forest inventory and analysis database: database description and users manual version 3.0 for Phase 2, revision 1. Washington, DC: U.S. Department of Agriculture, Forest Service, Forest Inventory and Analysis Progra,. http://www.fia.fs.fed.us/library/database-documentation/FIADB_user_manual_v3-0.pdf

U.S. Environmental Protection Agency. 2002. Original EMAP grid 648 square kilometer hexagons - electronic dataset. Corvallis, OR: U.S. Environmental Protection Agency, Western Ecology Division. http://www.epa.gov/wed/pages/staff/white/getgrid.htm

White, M.A.; Shaw, J.D.; Ramsey, R.D. 2005. Accuracy assessment of the vegetation continuous field tree cover product using 3954 ground plots in the south-western USA. International Journal of Remote Sensing. 26: 2699-2704.