Forest Carbon Modeling Resource Guide

Topic 3: Accessing and Applications of FIA Data for Modeling

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Data Applications of the USFS Forest Inventory and Analysis Program

The USDA Forest Service's Forest Inventory and Analysis (FIA) program is a publicly available national level inventory with broad applications for forest planning and policy, forest carbon estimation, forest health applications, and climate applications (Shaw 2008; Tinkham et al. 2018; Wurtzebach et al. 2020). The program has undergone numerous changes in protocol and design to expand its scope and focus to facilitate additional assessments and incorporate newer variables. This has led to further development of statistical and data tools utilized in direct applications of multiscale assessment and monitoring of forests for adaptive management (Wurtzebach et al. 2020). More recent growth in the program to meet user needs has included: expanding sampling protocols to include urban forest areas (Vogt and Smith 2017), increasing sampling intensity in certain areas, expansion in trainings and workshops (Shaw 2017), and further inclusion of timber product monitoring and information about woodland owners (Tinkham et al. 2018).

The integration of FIA with remote sensing datasets has helped to improve both regional- and national-level reporting of FIA (McRoberts et al. 2002), forest area estimation (Hansen and Wendt 2000), and the development of models to inform remote sensing data using FIA field observations. The integration of FIA data has not been limited to spatial and data applications; data have additionally been integrated into other modeling frameworks with direct forest carbon applications, such as the Land Use and Carbon Simulation (LUCAS) modeling framework (Sleeter et al. 2022) and the CBM-CFS3, a carbon budget model developed for use in Canada (Dugan et al. 2018).

At its most basic, the FIA program has been employed for broadscale estimation of forest characteristics and distributions. The continual development of publicly available data and tools has only furthered the application and validation of FIA data in a variety of models and modeling frameworks, moving the paradigm of assessing forest *statuses* to assessing and understanding forests *trends.* Further advancements in both modeling and data tools are needed to better inform forest planning and decision-making to meet current and future climate goals and needs.

Accessing FIA Data and Data Tools

The FIA database, or FIADB, provides the information and data needed to process, analyze, and visualize the status, trends, and condition of US forests. Further, the USFS, through collaboration with partners and universities, has created a series of tools, web applications, reports, and dashboards to allow users to more easily access and use the FIADB. The FIA DataMart allows users to download raw data files, standardized tables, SQLite databases, state reports, desktop reporting tools, and user guides. FIA has also created a variety of tools, models, and dashboards to access both raw and processed (i.e., structured, categorized, etc.) data to suit diverse user needs. **Table 1** outlines several ways to access FIA data, alongside data modeling tools developed by FIA for FIA data application, in a variety of formats with differing degrees of difficulty of use. Applicability and relevance of each method is dependent on individual user needs and goals.

Table 1. Software, Coding, and Reporting Tools for the Use and Interpretation of Forest Inventory Data

Tool & How to Access	What it Is	What it Shows	How it Functions	Difficulty
COLE (Carbon On Line Estimator) Coming soon	Web-based tool (Java-based program)	Forest carbon inventory estimates (tons carbon per hectare) for any area of the continental United States. Used for voluntary reporting, monitoring land use changes, and sustainability efforts.	**Input:** Generated carbon estimates are based on gross cubic foot volume per acre from USDA Forest Service Forest Inventory and Analysis (FIA), converted to carbon using published conversion coefficients. Natural Resources Conservation Service's STATSGO is the source for soil organic carbon estimates. **Output:** Analysis output is available in HTML and PDF formats, and the output is summarized in various tables, graphs and maps.	Medium
EVALIDator https://apps.fs.usda.gov/fiadb-api/evalidator	Interactive, online tool	Allows users to produce a large variety of population estimates with sampling errors based on the current Forest Inventory and Analysis Database (FIADB).	**Input:** FIA data of forest area, number of trees, biomass, volume, carbon, growth, removals, and mortality **Output:** Estimates (including ratio estimates) for different carbon pools (total forest, aboveground, belowground, soil, standing dead trees, etc.) or other forest attributes including forest area, number of trees, biomass, volume, growth, removals, and mortality	Medium
DATIM (Design and Analysis Toolkit for Inventory and Monitoring) https://www.fs.usda.gov/emc/rig/DATIM/index.shtml	A suite of tools used for designing inventory and monitoring programs and for analyzing the results of those programs	**Design Tool for Inventory and Monitoring (DTIM)** assists managers in determining objectives, questions, and metrics for monitoring plans for regional broad scale programs. **Analysis Tool for Inventory and Monitoring (ATIM)** enables users to analyze vegetation data to derive estimates of	**This toolkit has four separate but integrated tools:** 1) ATIM - a reporting tool to derive estimates and analyze trends; 2) SIT - a spatial intersection tool to add spatial attributes to datasets for use in ATIM; 3) DTIM - a design tool to assist with developing objectives, questions, and metrics; and 4) DCS - a tool to allow users to add FVS attributes or other external data to meet specific regional needs **Input:** Forest inventory datasets such as the FIADB, DATIM datamart, or FSVeg database along with custom analysis datasets inputted by the user. Spatial data to denote the area of interest if using the SIT tool. These datasets are collections of	Hard

		current conditions and trends on the Forest and surrounding landscapes. **Spatial Intersection Tool (SIT)** enables users to add spatial attributes to DATIM datasets for use in ATIM. **Data Compilation System (DCS)** allows users to add FVS attributes to DATIM datasets	estimation units and data points for a pre-defined area of known size that share the same plot design, sampling intensity and sets of attributes utilizing the same protocol **Output:** Reports in various formats such as HTML outputs or CSVs that assess a variety of forest characteristics (e.g., forest growth) to improve monitoring designs and analyses.	
FVS (Forest Vegetation Simulator) https://www.fs.usda.gov/fvs/	Forest growth simulation model. Downloadable modeling software (15-30 MB, depending on region), with a variety of optional downloadable variant files, pre-processors, post-processors, and an optional Windows-based graphical user interface	Simulates a wide range of silvicultural treatments for most major forest tree species, forest types, and stand conditions to answer questions about how forest vegetation will change in response to natural succession, disturbances, proposed management actions, and how such changes affect ecosystem values. They allow users to explore how silvicultural treatments may affect growth and yield (and, therefore, carbon stocks).	**Input:** Basic forest inventory and stand examination information (species, DBH, sampling design, etc.), where the more data provided by the user, the more accurate and the less uncertain the model results are. A variety of data sources can be modified or translated to serve as input for FVS, including local field-gathered inventory data, FIA data, or data from the Natural Resources Information System (NRIS) Field Sampled Vegetation (FSVeg), which includes plot vegetation data from FIA and elsewhere. **Output:** Text files of growth and yield calculations. A variety of post-processor applications, including Windows-based "Suppose", are available to translate these text outputs into a variety of graphical displays and reports. Can also export results in formats usable by other programming language-based environments, such as 'R' or 'Python', for graphical displays and additional analyses.	Hard
FORCARB2 https://www.fs.usda.gov/t	An updated version of the U.S. FORest CARBon	Produces estimates of carbon stocks and stock	The program is written in FORTRAN and is text based, though virtually every parameter is defined by input text-based	Hard

reesearch/pubs/35613	Budget Model (FORCARB)	changes for forest ecosystems and forest products at 5-year intervals. The model has been used to provide estimates and projections for policy-related needs, including the Resources Planning Act timber resource assessment and forest-related greenhouse gas inventories of the United States, and has provided the basis for an analysis of forest carbon for Ontario, Canada.	files that can be modified or built by the user. **Input:** Forest Inventory datasets such as the FIADB for initial inventories, construction of growth-yield curves, and for harvest information such as utilization rates **Output:** Text files of summary data that can include combinations of results for carbon stocks by age classes, carbon removed from harvests, aggregated carbon stocks by regions or subregions, or changes in carbon stocks from Land-use change	
iTree https://www.itreetools.org/	A suite of online tools and freely available software packages developed by the Forest Service and cooperators to support ecosystem service assessment, including carbon sequestration from urban and rural forest management	Quantifies forest structure and the environmental benefits that trees provide. Can be used for forest and tree-level analysis, effects of tree canopy on water quantity and quality, for planting recommendations, for benefits of new tree planting projects, and for carbon stored in harvested wood products.	Inputs & outputs vary by iTree application **General Input:** Defined project study area, general land use data, and information on trees in the area (species, size, health) either from a new or existing dataset **Example Outputs:** Urban forest structure analyzed by land-use type, air-quality & pollution control benefits of urban forests, total and annual carbon sequestration and energy savings benefits, total carbon storage, potential impacts of pests on tree populations, impact of tree pollen on allergies, the monetary value of tree populations or individual trees, possible management needs (tree diversity, planting, pruning), overall cost vs. benefit of tree maintenance, tree canopy projections and available space, and storm water interception benefits.	Easy
rFIA https://rfia.netlify.app/	An R script package aimed at increasing the accessibility and use of the	Queries and analyzes FIA Data and produces space-time indexed summaries of	**Input:** User loads FIA data into R, specifies the desired space-time database subset, and selects the rFIA estimator function of interest (e.g., biomass, trees per acre).	Hard

	USFS FIA Database	forest variables within user-defined population boundaries (e.g., geographic, temporal, biophysical).	**Output:** Estimates of user-defined FIA database subsets, (e.g., volume per acre for a subregion, removals per acre by state, temporal estimation of biomass growth over time, forest extent by ownership type for a county) which can subsequently be processed by rFIA to produce data visualizations (e.g., graphs, maps)	
SQLite State Databases https://apps.fs.usda.gov/fia/datamart/datamart_sqlite.html	Programming language used primarily for database management and querying.	The SQLite State databases contain all the FIADB tables and FVS-ready tables for a state or U.S. territory	**SQLite Tables:** Utilizing user-defined coding scripts to query any state or U.S. territory, outputs include any temporal or spatial query of the FIADB supported by a substantial body of documentation. **FVS-ready Tables:** FVS-ready data are provided in the SQLite database as a solution to the 2-gigabyte limit of Access Databases allowing for easier integration of the FIADB and FVS by providing all publicly available FIADB tables in one dataset.	Hard
FIADB / EVALIDator Application Programming Interface (API) https://apps.fs.usda.gov/fia/datamart/images/datamart_api_tutorials.html	Application Programming Interface for EVALIDator web-application	Batch reports to produce multiple estimates simultaneously. Requires SQL, Python, or other programming language for queries using an online web client.	**Input:** Uses inventory data to produce population estimates with associated sampling errors. **Output:** Running the fullreport (API GET) request on EVALIDator can return output in either HTML, JSON, or XML format. Batch EVALIDator reports using MS-Excel and fullreport GET API makes it possible to run multiple reports in batch mode. Multiple reports could be run for a single location, or a single report could be run for multiple locations.	Hard
NWOS (National Woodland Owner Survey) Table Maker / Dashboard https://www.fia.fs.usda.gov/nwos/results/	Table Maker: Application allows users to create customized NWOS summary tables Dashboard: An interactive, on-line tool allowing users	Calculates and visualizes state-level results of the NWOS, a survey conducted among private forest landowners across the US to assess forest management behavior and perspectives. Data can be	**Table Maker:** Users select one or more states to analyze and select an attribute from a menu of options for the column, and another for the row. The user can also choose to limit the retrieval by size of ownership forest land holdings. Then they click the "submit" button to produce summary tables and graphs based on the specified criteria.	Easy

https://ffrc.shinyapps.io/NWOSdashboard/	to more easily access, explore, and visualize NWOS data and findings	assessed and visualized across a series of attributes (e.g., state, year, ownership size, ownership type, etc.). Raw data also available.	**Dashboard:** Users select a variable of interest (e.g., size of forest holdings, ownership type), a unit (e.g., acres, ownership), the state or region of interest (including entire US), the population of interest (e.g., private, large corporate), a minimum domain threshold for acreage to be assessed, and the desired NWOS cycle year's data. Once these options have been customized to the users' preferences and needs, processed results are shown in a plot and table within the online tool, and are also available for download in CSV or JSON file formats.	
TPO (Timber Products Output) Toolkit https://www.fia.fs.usda.gov/program-features/tpo/	Hub for TPO analysis materials featuring factsheets, a reporting tool, a data download tool, and a legacy reporting tool	**One-click Factsheets:** Allows visitors to view TPO fact sheets via an interactive experience **Interactive Reporting Tool:** Allows visitors to view TPO data via an interactive experience **Data Download:** Allows visitors to download Timber Product Output Survey data at the state and county level **Legacy Reporting Tool:** Tool to produce TPO data estimates with the inclusion of legacy data.	**One-click Factsheets:** Users click on the desired state on the map to produce a real-time fact sheet of that state based on current TPO data. Data include state-wide production, products, number of primary mills and types, roundwood exports/imports and retained production. **Interactive Reporting Tool:** Users Click on the desired state(s) or counties on the map to produce TPO data based on the geographic area and year of interest. The TPO Interactive Tool includes estimates of timber products, logging residue, mill residue, residential fuelwood, and other removals based on the selected area. **Data Download:** Provides TPO data in .xlsx file format. Data included for download are the most granular state and county level data publicly available to users. These files allow visitors to produce estimates of timber products, logging residue, mill residue, residential fuelwood, and other removals at the state and county level. **Legacy Reporting Tool:** Allows visitors to produce estimates of timber products, logging residue, mill residue, residential fuelwood, and other removals at the county and state level in table format.	Easy

			This tool includes Legacy data, but data will not be updated or added.	
Urban DataMart https://experience.arcgis.com/experience/3641cea45d614ab88791aef54f3a1849/page/Urban-Datamart/	Interactive webpage that allows visitors to download raw urban data, as well as Urban FIADB User Guides	Page shows an interactive map of the US featuring cities that have a complete set of sampled FIA data, as well as those with FIA sampling in progress.	Users can zoom in on the map to urban municipalities with completed inventories to view specific geographic delineations of areas included in city sample data (shown as color-shaded polygons). Additionally, users can view metadata for these municipalities' urban inventories including metrics such as sample area, inventory begin year, regular and accelerated cycle lengths, and plot intensity. Additionally, users can download Urban DataMart files for municipalities with completed inventories in SQLite zip files or CSV zip files. These files contain a collection of raw data tables that can be combined in a relational database to produce population-level estimates. Data include an intensified sample of plots within the city and a less intensified sample in Census Urban Areas within the city's Core Based Statistical Area (CBSA).	Easy
GTR-343 https://www.fs.usda.gov/treesearch/pubs/22954	GTR (General Technical Report) publication with methods and standard estimates of forest ecosystem and harvested carbon	Methods for calculating forest ecosystem and harvested carbon with standard estimates for forest types of the United States & accompanying spreadsheet-based carbon calculator offers methods, sample calculations, and regional average carbon stocks as tables (aka 'look-up tables') for 51 major forest types across ten geographic regions in the conterminous U.S.	This methodology for consistent standard forest carbon estimates was adopted by the U.S. Voluntary Greenhouse Gas Reporting Program, also referred to as 1605(b). The estimates and methods also follow guidelines for reporting forest carbon as developed by the Intergovernmental Panel on Climate Change. Lookup tables for carbon in forests and harvested wood are based on linked empirical models and forest statistics. Data sources and level of detail are likely to vary among users. The methods were developed to produce consistent estimates across scale or source of data. Downloadable default and customizable tables of carbon in forest ecosystems and harvested wood products.	Medium

Emerging Applications of FIA Data

The systematic design of the FIA program's temporal continuity, spatial balance, and consistent protocols nationwide provides a dataset well-suited for a wide range of direct (Tinkham et al. 2018) and region-specific applications (Hoover et al. 2020; Hoover et al. 2022). That said, continual advancement of data and modeling tools is necessary to move toward better informed decision-making under a changing climate. Some areas of recent improvement and future emerging applications include:

Improvements to volume, carbon, and biomass estimation. The component ratio method was developed by FIA to create a nationally standardized method for estimating tree biomass attributes built upon sub-regional volume models (Domke et al 2012; Domke et al. 2013). To address the need for a nationwide modeling framework, a collaboration of university investigators and forest industry actors embarked on a large endeavor to obtain the best available and most robust data to develop models to estimate tree volume, biomass, and carbon. To do this, they combined data from >3,000 destructively sampled trees with other publicly available data, resulting in flexible models to estimate the carbon, volume, or biomass of any tree section (Westfall, 2022).

Improvements in assessing forest health for decision-making. FIA provides valuable information to assess and predict forest health vulnerabilities and species information necessary to make data-informed decisions for future forest planning and management. Recently, advancements have been made in modeling small-tree growth (Tinkham et al 2021), stability monitoring and species distributions (Stanke et al. 2021a; Stanke et al. 2021b), tree damage assessments (KaDonna et al. 2021), and mortality (McNellis et al. 2021).

Improved small area estimation and temporal trends. Increased demands for finer-scale temporal and spatial estimation to inform forest planning has led to novel statistical approaches to improve the precision of traditional post-stratified estimators (Stanke et al. 2021) and improvements to carbon-specific models using relatively few plots (Bell et al. 2022).

Advancements in integration with remote sensing applications. FIA data has both *informed remote sensing datasets and been informed by* remote sensing datasets. Recent advances in remote sensing have led to: FIA data being incorporated with LiDAR data (Hughes et al. 2018), improved aboveground biomass mapping using climate and topographic metrics (Hudak et al. 2020), and the development of spatial machine learning methods for volume estimation (Obata et al. 2021) among other spatial applications.

Streamlined integration with other forest carbon modeling frameworks. One key advancement of FIA data is the utilization of its inherent flexibility (i.e., temporal continuity, spatial unbias, and standardized protocols) to incorporate data into other modeling frameworks, such as urban forestry data (Westfall et al. 2018), novel applications using the USFS-produced Forest Vegetation Simulator (FVS) (Tinkham et al. 2021), forest carbon budget models (Dugan et al. 2018), and land-use and carbon models (Sleeter et al. 2022).

Future Directions

The FIA program is uniquely suited to address and fulfill future monitoring requirements of forests and greenhouse gas emissions associated with the forest sector. Greater efficiencies continue to develop and bring about newer opportunities to improve the precision and accuracy of forest monitoring to inform forest planning and decision-making on a continued microscale. Continued development and enhancement of tools is necessary to 'demystify' the FIA database and get information into the hands of all stakeholders, from smallholder forest owners to state legislatures, to increase equity and enable actors to make "bottom-up" decisions using the best available information.

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Additional Resources

Peer Reviewed Resources

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- *Study describes the impact of the transition from the generalized allometric regression models to the component ratio method on the National Greenhouse Gas Inventory estimates by comparing estimates of carbon stocks from both approaches by common tree species and varying spatial scales (e.g., tree to national scale)*

Domke, G.M., Oswalt, C.M., Woodall, C.W., and Turner, J.A. 2013b. Estimation of merchantable bole volume and biomass above sawlog top in the national forest inventory of the United States. J. For. 111(6): 383–387. doi:10.5849/jof.13-042.

- *Article describes a method for estimating merchantable bole biomass for the sawlog component and the component above the minimum sawlog top diameter for timber species in the FIA program.*

Dugan, A.J., Birdsey, R., Mascorro, V.S., Magnan, M., Smyth, C.E., Olguin, M., Kurz, W.A. (2018). A systems approach to assess climate change mitigation options in ladscapes of the United States forest sector. *Carbon Balance and Management.* 13(13):1-14. https://doi.org/10.1186/s13021-018-0100-x

- *Study evaluated forest sector climate change mitigation scenarios from 2018 to 2050 by applying a systems- based approach that accounts for net emissions across four interdependent components: (1) forest ecosystem, (2) land-use change, (3) harvested wood products, and (4) substitution benefits from using wood products and bioenergy*

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- *Overviews the component ratio method (CRM) approach to produce national-level biomass and carbon estimates consistent with FIA volume estimates at the tree-level*

Heath, Linda S.; Nichols, Michael C.; Smith, James E.; Mills, John R. 2010. FORCARB2: An updated version of the U.S. Forest Carbon Budget Model. Gen. Tech. Rep. NRS-67. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 52 p. [CD-ROM].

- *Publication on FORCARB2 includes model description, methodologies, step-by-step instructions for running the program, input and output files, and codes used*

Hoover, C.M, Bush, R, Palmer, M., Treasure, E. (2020). Using Forest Inventory and Analysis data to Support National Forest Management: Regional Case Studies. *Journal of Forestry.* 313-323. doi:10.1093/jofore/fvz073

- *Article presents case studies from three USDA Forest Service regions to highlight a variety of applications of FIA data, from informing the forest*

plan revision process to supplying managers with timely information on important forest attributes at the stand and landscape scales

Hoover, C.M., Bartig, J.L., Bogaczyk, B. Breeden, C., Iverson, L.R., Prout, L., Sheffield, R.M. (2022). Forest inventory and analysis data in action: Examples from eastern national forests. *Trees, Forests and People.* 7:100178. https://doi.org/10.1016/j.tfp.2021.100178

- *Article presents four case studies from National Forests in the eastern United States, to highlight a variety of applications of FIA data, including informing a model to help managers decide where to invest in oak management, quantifying habitat characteristics as part of the Endangered Species Act listing process, developing focal species for forest monitoring, and assessing the health of the black cherry population*

Hughes, R.F., Asner, G.P., Baldwin, J.A., Mascaro, J., Bufil, L.K.K., and Knapp, D.E. (2018) Estimating aboveground carbon density across forest landscapes of Hawaii: combining FIA plot-derived estimates and airborne LiDAR. *For. Ecol. Manage.* 424: 323–337. doi:10.1016/j.foreco.2018.04.053.

- *Study utilized FIA plot and airborne LiDAR data sets collected across two contrasting landscapes known as Laupahoehoe and Pu'u Wa'awa'a on Hawai'i Island to explore strengths and weaknesses of linking those two data sets to estimate aboveground carbon density (ACD; units of Mg C ha^{-1})*

McRoberts, R.E., Wendt, D.G., Nelson, M.D., and Hansen, M.H. (2002). Using a land cover classification based on satellite imagery to improve the precision of forest inventory area estimates. *Remote Sens. Environ.* 81: 36–44. doi:10.1016/S0034-257(01)00330-3.

- *Study obtained estimates of forest area for four US states using stratified analyses and observations from forest inventory plots; strata were created by aggregating the land cover classes of the National Land Cover Data (NLCD), and strata weights were calculated as proportions of strata pixel counts; analyses focused on improving the precision of unbiased forest area estimates*

Stanke, Hunter; Finley, Andrew O.; Domke, Grant M. (2021a). Chapter 7 - Advancing broad-scale forest health evaluation and monitoring with rFIA. In: Potter, K.M.; Conkling, B.L., eds. Forest health monitoring: national status, trends, and analysis 2020. Gen. Tech. Rep. SRS-261. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 143-154.

- *rFIA (Stanke and others 2020, https://rfia.netlify. app/), an open-source R package (R Core Team 2020), was developed to reduce FIA data accessibility hurdles and unlock the potential of FIA for broad-scale forest health evaluation and monitoring*

Stanke, Hunter; Finley, Andrew O.; Weed, Aaron S.; Walters, Brian F.; Domke, Grant M. 2020. rFIA: An R package for estimation of forest attributes with the US Forest Inventory and Analysis database. Environmental Modelling & Software. 127: 104664. 10 p. https://doi.org/10.1016/j.envsoft.2020.104664.

- *Publication introduces and overviews rFIA, an R package designed to simplify the estimation of forest attributes using data collected by the FIA Program*

Stanke, H., Finley, A.O., Domke, G.M., Weed, A.S., MacFarlane, D.W. (2021b). Over half of western United States' most abundant tree species in decline. Nature Communications. 12:451. https://doi.org/10.1038/s41467-020-20678-z

- *Study developed a standardized forest demographic index and used it to quantify trends in tree population dynamics over the last two decades in the western United States*

Stanke, H., Finley, A.O, Domke, G.M. (2022). Simplifying Small Area Estimation with rFIA: A Demonstration of Tools and Techniques. Frontiers in Forests and Global Change. 5:745874. https://doi.org/10.3389/ffgc.2022.745874

- *Study presents the potential of rFIA, an open-source R package designed to increase the accessibility of FIA data, to simplify the application of a broad suite of small area estimation (SAE) methods to FIA data*

Smith, James E.; Heath, Linda S.; Skog, Kenneth E.; Birdsey, Richard A. 2006. Methods for calculating forest ecosystem and harvested carbon with standard estimates for forest types of the United States. Gen. Tech. Rep. NE-343. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 216 p.

- *Study presents techniques for calculating average net annual additions to carbon in forests and in forest products and includes forest ecosystem carbon yield tables for merchantable volume and carbon pools as a function of stand age*

Tinkham, W. T., Mahoney, P. R., Hudak, A. T., Domke, G. M., Falkowski, M. J., Woodall, C. W., Smith, A.M.S. (2018). Applications of the United States forest inventory and analysis dataset: a review and future directions. *Can. J. For. Res.* **48**, 1251–1268. doi: 10.1139/cjfr-2018-0196

- *Article presents a synthesis of research applications for FIA data, based on a review of > 180 publications that directly utilize FIA data, broken down into broad categories of application and further organized by methodologies and niche research areas*

Wurtzbach Z., DeRose, R.J., Bush, R.R., Goeking, S.A., Healy, S., Menlove, J., Pelz, K.A., Schultz, C., Shaw, J.D., Witt, C. (2020). Supporting National Forest System Planning with Forest Inventory and Analysis Data. *Journal of Forestry.* 118(3):289-306. doi:10.1093/jofore/fvz061

- *Article explores opportunities for using data and products produced by the USDA Forest Service's Forest Inventory and Analysis (FIA) Program to support the implementation of the 2012 Planning Rule*

Non-peer Reviewed Resources

Butler, Brett J.; Miles, Patrick D.; Hansen, Mark H. Fri Aug 26 18:59:25 UTC 2022. National Woodland Owner Survey Table Maker web-application version 2.0. Amherst, MA: U.S. Department of Agriculture, Forest Service, Northern Research Station. [Available only on internet: https://apps.fs.usda.gov/nwos/tablemaker.jsp]

- *NWOS Table Maker Ver 2.0 web application that allows users to create customized NWOS summary tables*

Climate Change Resource Center. (n.d.). *Forest Vegetation Simulator (FVS) | Climate Change Resource Center.* Www.fs.usda.gov; USDA FS Climate Change Resource Center.

- *User-friendly resource on Forest Vegetation Simulator (FVS) features fast facts, important links and resources, and overviews FVS's use and applications, its history, inputs and outputs, and restrictions and limitations*

National Council for Air and Stream Improvement, Inc, & USDA Forest Service, Northern Research Station. (n.d.). COLE Carbon On Line Estimator ~ Flexible Web-based Tool for Forest Carbon Analysis. U.S. Department of Agriculture, Forest Service, Northern Research Station.

- *One-page handout overviewing Carbon On-Line Estimator (COLE) tool*

Oswalt, S. N. (2020, September 11). *NWOS Dashboard: Interactive Results from the National Woodland Owner Survey Showcasing Family Forest Owner Survey Responses.* Tableau Public.

- *Interactive visualization tool for NWOS family forest owner response results*

SQLite. (2019). *SQLite Home Page*. Sqlite.org.

- *SQLite's main webpage, contains information on and links to download the SQLite C-language library*

Stanke, H. (n.d.). *rFIA: Unlocking the FIA Database in R*. RFIA.
- *Main rFIA webpage includes information on rFIA, links to install rFIA packages, usage examples, and publications*

USDA Forest Service. *FIA DataMart FIADB_1.8.0.03 :: SQLiteDB*. U.S. Department of Agriculture, Forest Service.
- *SQLite database containing all of the FIADB tables and FVS-ready tables for a State*

USDA Forest Service. *Forest Vegetation Simulator (FVS)*. U.S. Department of Agriculture, Forest Service.
- *FVS website with links to downloadable software, documentation, training resources, and tool support*

USDA Forest Service, Davey Tree Expert Company, The Arbor Day Foundation, Society of Municipal Arborists, International Society of Arboriculture, & Casey Trees. (n.d.). *i-Tree Tools*. ITree.
- *iTree website with links to all iTree tools, including tools used for assessing individual trees and tree canopy area assessment tools*

USDA Forest Service, Forest Inventory and Analysis Program. *EVALIDator API Documentation and Examples:: Home*. U.S. Department of Agriculture, Forest Service.
- *Webpage featuring documentation on FIADB application programming, EVALIDator source code examples, as well as information and links to examples for running the EVALIDator using the fullreport API GET request, and batch EVALIDator reports using MS-Excel and fullreport GET API*

USDA Forest Service, Forest Inventory and Analysis Program. *FIA DataMart FIADB_1.9.0 :: Home*. St. Paul, MN: U.S. Department of Agriculture, Forest Service, Northern Research Station.
- *FIADB file hub, featuring links to FIA State report PDFs, HTML of the most recent FIA data by State, XLS workbooks, SQLite3 State databases, CSV files, and a link to the API for EVALIDator*

USDA Forest Service, Forest Inventory and Analysis Program. *Forest Inventory EVALIDator web-application Version 2.0.3*. St. Paul, MN: U.S. Department of Agriculture, Forest Service, Northern Research Station.
- *Latest version of USFS EVALIDator tool*

USDA Forest Service, Forest Inventory and Analysis Program. *National Woodland Owner Survey*. U.S. Department of Agriculture, Forest Service.
- *NWOS results page, featuring links to the 2013 & 2006 NWOS Table Makers, special products, and publications including summary documentation for multiple NWOS data years and fact sheets*

USDA Forest Service, Forest Inventory and Analysis Program. *National Woodland Owner Survey Dashboard (NWOS-DASH)*. NWOS Dashboard.
- *The FIA program's National Woodland Owner Survey Dashboard (NWOS-DASH) web application and results viewer*

USDA Forest Service, Forest Inventory and Analysis Program. *Timber Products Output (TPO)*. U.S. Department of Agriculture, Forest Service.
- *TPO Toolkit webpage, featuring one-click fact sheets, an interactive reporting tool, a data download tool, and a reporting tool for legacy data*

USDA Forest Service, Forest Inventory and Analysis Program. *Urban Datamart*. The Forest Inventory & Analysis DataMart.
- *FIA's Urban Datamart features an interactive map with completed and in-progress urban inventories, as well as information and downloadable data for cities with a complete inventory*

USDA Forest Service, Northern Research Station. (n.d.). *Consistent Standard Estimates of Carbon in Forest Ecosystems and Harvested Wood*. U.S. Department of Agriculture, Forest Service, Northern Research Station.
- *One-page handout overviewing GTR-343, including basic background information and various applications and methods of use*

USDA Forest Service, Northern Research Station. (n.d.). *Stand Level Carbon Reporting Using the Forest Vegetation Simulator (FVS)*. U.S. Department of Agriculture, Forest Service, Northern Research Station.
- *One-page handout overviewing how FVS users can produce carbon reports along with traditional FVS output*

USDA Forest Service Resource Information Group. (n.d.). *Design and Analysis Toolkit for Inventory and Monitoring (DATIM)*. U.S. Department of Agriculture, Forest Service.
- *DATIM webpage including a link to launch the app, user guides, data source information, training materials, FAQs, and more*