

DEMONSTRATING A PROGRESSIVE FIA THROUGH FIESTA: A BRIDGE BETWEEN SCIENCE AND PRODUCTION

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Abstract

FIESTA (Forest Inventory ESTimation and Analysis) is an open-source, R estimation package designed for analysts who work with sample-based vegetation inventory data from the USDA Forest Service, Forest Inventory and Analysis (FIA) Program. With today's complex questions and fast-evolving technologies, an adaptive tool is needed to efficiently process and translate multi-scale resource data into information. FIESTA was developed to augment currently available FIA tools by providing a flexible platform to accommodate unique research questions, including on-the-fly estimations from user-defined polygons as well as enabling the use of auxiliary data from a wide variety of remote sensing instruments. It also incorporates statistical advances in areas such as model-assisted, model-based, and small area estimation. FIESTA's flexible, open-source strategy allows for accessibility, adaptability, and integration with other R packages and other software platforms—helping bridge the gap between science and FIA's production-level operations.

The Forest Inventory and Analysis (FIA) Program of the U.S. Department of Agriculture, Forest Service was established in 1928, with primary responsibility to collect, analyze, and report on the status and trends of America's forests (<https://www.fia.fs.fed.us/>). Through the years, a publicly available national database of forest resources was developed to house a comprehensive collection of field inventory data, along with auxiliary information needed to generate State-wide population estimates in support of a standard FIA estimation procedure (Bechtold and Patterson, 2005). Publicly available tools have been created to access this database and compile, analyze, and report estimates of forest resources by State and inventory cycle (<https://apps.fs.usda.gov/fia/datamart/datamart.html>).

While these standard estimates continue to serve an important function, information needs continue to evolve, including estimates to accommodate unique geographic areas and time scales, non-forested lands, and small areas having minimal inventory data. FIA scientists have been taking advantage of advancements in computing capacity, statistical techniques, and availability of remotely-sensed data to develop new estimation strategies for meeting these needs. Unfortunately,

no national FIA tools are available for scientists to access customized datasets to facilitate development and testing of new estimation and analysis strategies, nor are there national FIA tools available for implementing new estimation techniques or non-standard analysis routines. FIESTA emerged to “bridge” this gap between science and production for FIA, demonstrating a progressive solution for using FIA data.

FIESTA is an open-source, R estimation package designed for scientists who work with sample-based vegetation inventory data, like that from the FIA Program. FIESTA was developed to augment the capabilities of currently available FIA estimation tools, such as DATIM or EVALIDator (<https://www.fia.fs.fed.us/tools-data/index.php>). It provides a flexible platform to accommodate unique research questions such as on-the-fly estimations from user-defined polygons, and enables the use of auxiliary data from a wide variety of remote sensing instruments. It also allows FIA to make use of statistical advances in areas such as model-assisted, model-based, and small area estimation. The package contains a collection of functions that can access publicly available FIA databases, summarize and explore inventory data, compile spatial data, generate

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estimates with associated sampling errors, and automate reports and analyses. FIESTA's flexible, open-source strategy allows for accessibility, adaptability, and integration with other R packages and software platforms.

FIESTA's functions are organized into three categories: (1) Core functions; (2) Estimation modules; and (3) Analysis functions. The Core functions provide assistance for data compilation, including: database functions (DB*) for querying FIA databases; data functions (dat*) for data summarizing; and spatial functions (sp*) for spatial data manipulation. FIESTA's Estimation modules use compiled data and either programmed estimators or estimators from other R packages to generate population estimates of inventory attributes. FIESTA's current estimation modules include: Green-Book (GB*), Photo-Based (PB), Model-assisted (MA), and Small-Area (SA). The Green-Book module contains FIA's standard estimators from Bechtold and Patterson (2005) for semi-systematic annual sample design, with capability for on-the-fly estimation for a given area of interest. The Photo-Based module contains estimators from Patterson (2012), using the infinite sampling paradigm with a support region for image-based, point sample designs. The Model-Assisted module reaches out to the *mase* R package (McConville and others 2018) for use of alternative model-assisted survey estimators, such as post-stratification and generalized regression estimators. The Small-Area module also integrates other R packages including *JoSAE* (Breidenbach 2018) and *sae* (Molina and Marhuenda 2015) for generating estimates using different area- and unit-level small area estimation techniques. FIESTA's Analysis functions are wrapper functions, or subroutines, to streamline customized estimation routines.

FIESTA can serve as a “bridge” from FIA database production to FIA data users. Acquiring and compiling FIA inventory and auxiliary data for development and analysis purposes requires an extensive amount of knowledge, preparation, and time. FIESTA's *Core functions* provide a mechanism or “bridge” for securing data in appropriate formats, thereby empowering FIA data users to extract and explore different

datasets, allowing more time for analysis, research, and development. FIESTA's open-source R-based design provides a platform for users to share and improve methods, while also having access to an extensive library of other open-source tools. FIESTA can also “bridge” FIA research and development to production-level operations. FIA's current operational estimation strategy was designed for mandated State-level reporting. This strategy is fast, efficient, and easy to use and includes reproducible web-based functionality. Unfortunately, the strategy was not designed to handle special studies with unique populations, customized attributes, or different auxiliary information. FIESTA's *Estimation modules* provide a mechanism or “bridge” for implementing new, on-the-fly estimation strategies developed for situations not standard to FIA, such as unique populations, small areas, and supplementary photo-based inventories. In addition, FIESTA's *Analysis functions* provide a venue for investigators to develop analytical templates that can be quickly applied to any geographic region or timeframe. FIESTA's single-platform strategy allows interaction with other software platforms, thus allowing FIESTA interoperability with FIA's current estimation production-level system.

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