Application of Forest Inventory and Analysis (FIA) Data to Estimate the Amount of Old Growth Forest and Snag Density in the Northern Region of the National Forest System

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Introduction

This report discusses valid use of data produced by the Forest Service's Forest Inventory and Analysis (FIA) program and used by the Northern Region of the National Forest System to analyze the compliance of individual National Forests with their Standards and Guidelines. It emphasizes use of FIA data on snag density and the percentage of forest area that meets the definition of old growth. This report does not give the results of such analyses. Rather, it gives the rationale for use of FIA data for such analyses.

Description of the national Forest Inventory and Analysis Program

Since 1930, the Research and Development Deputy Area of the USDA Forest Service has been responsible for conducting the FIA program. The Research and Development Deputy Area is directly accountable to the Chief of the Forest Service, which makes it administratively independent from the National Forest System. By design, FIA is conducted by the Research and Development Deputy Area to assure impartiality and scientific credibility.

FIA is the only congressionally mandated, comprehensive, field-based forest inventory for each of the 50 States, Puerto Rico, and Trust Territories. The McSweeney-McNary Forest Research Act of 1928 defines the FIA mission[3] as to "*Make and keep current a comprehensive inventory and analysis of the present and prospective conditions of and requirements for the renewable resources of the forest and rangelands of the United States*."

FIA is the nation's "census" of its public and private forestlands[3]. In a study commissioned by the White House Office of Science and Technology Policy, the RAND Corporation found that "FIA is the nation's most ambitious forest monitoring program[4]." FIA produces statistical reports and analytical information on status and trends in forest area and location; species, size, and health of trees; total tree growth, mortality, and

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[1] USDA Forest Service; Research and Development Deputy Area; Rocky Mountain Research Station; Natural Resource Assessment, Ecology, and Management Science Research, Research Work Unit RMRS-4852; 2150 Centre Ave. Bldg. A., Fort Collins, CO 80526. 970-295-5945. http://www.fs.fed.us/rm/main/labs/ftcollins/rmrs4852.html
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[3] See http://fia.fs.fed.us/about.htm for an overview of the FIA program.
[4] Peterson, D.J.; Resetar, Susan; Brower, Jennifer; and Diver, Ron. 1999. *Forest Monitoring and Remote Sensing: A Survey of Accomplishments and Opportunities for the Future*. MR-1111.0-OSTP. Arlington, VA. Science and Technology Policy Institute, RAND Corporation. 90 p. http://www.rand.org/publications/MR/MR1111.0/

removals by harvest; wood production and utilization rates for various products; and forest land ownership.[5] FIA information is used in analyses that impact public policies and private sector decisions; examples include assessments of sustainable forestry at the national and state levels; better management planning and assessments of land management practices on large tracts of forestland; investigations of changes in forest ecosystems; formulation of business plans in the private sector that are financially and ecologically sustainable; and information to inform the public about the health and sustainability of the nation's forests.

Users of FIA data come from diverse groups, including State and Federal forestry agencies, private industry, academia, environmental organizations, and members of the public who want reliable information about the Nation's forests. FIA data serve many internal needs within the Forest Service, such as status reports on international Criteria and Indicators of Sustainable Development, and special assessments, such as the United Nation's Food and Agriculture Organization (FAO) global Forest Resource Assessment. The Forest and Rangeland Renewable Resources Planning Act of 1974, P.L. 93-378, as amended, directed the Secretary of Agriculture to prepare a Renewable Resources Assessment every 10 years. These assessments include "an analysis of present and anticipated uses, demand for, and supply of the renewable resources, with consideration of the international resource situation, and an emphasis of pertinent supply, demand and price relationships trends." FIA data provides the foundation for many of the analyses used in each decadal assessment.

Except for a few data elements whose release is restricted by Public Law[31], FIA data[6] are freely available to the public through publications and the internet.[7] Forest Service Research Stations maintain lists that contain mailing information for any individual who has expressed interest in receiving FIA publications (Forest Service Manual FSM 1633.22). FIA publications are available from the Publications Section at each Research Station at no direct cost to the public. They are also available at a large number of university libraries.

The Agricultural Research, Extension, and Education Reform Act of 1998 (P.L. 105-185) mandates that FIA data be consistently collected and summarized across all land ownerships, including public lands managed by the National Forest System, with reports for each State produced at five year intervals.[8,9]

As an example of its scientific stature, FIA maintains a bibliographic database[10] of over 1,400 reports and scholarly papers dealing with FIA field surveys for the United States and its territories for the period 1975 through July 2001. These citations include

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[5] http://www.fs.fed.us/research/

[6] Applies only to those data that have been fully processed under the FIA quality assurance procedures (see p. 8)

[7] http://fia.fs.fed.us/dbrs_setup.htm

[8] Gillespie, Andrew J. R. and W. Brad Smith. 2000. Introduction to the Forest Inventory and Analysis Program. USDA Forest Service, National FIA Program Staff, Washington, DC http://fia.fs.fed.us/library/fia_for_nfs.rtf

[9] 1999 FIA Strategic Plan for Forest Inventory and Monitoring, http://fia.fs.fed.us/library/strategy.pdf

[10] *A Quarter Century of Multipurpose Forest Inventories in the United States*, Victor Rudis, http://www.msstate.edu/dept/forestry/biblio.html

integrated assessments and multi-disciplinary surveys, representative citations associated with timber resource assessments, and all known M.S. theses and Ph.D. dissertations associated with FIA data since 1975, regardless of topic.

FIA is a large, national program in USDA Forest Service. In Fiscal Year 2002[11], total funds available to FIA were $55,919,830, with a federal staffing of 400.8 full-time equivalents. In 2002, FIA measured 14,827 forested sample locations (field plots) in the USA, which is 12.4% of the total. The Interior West FIA Research Work Unit[12], which is responsible for covering the Northern Region of the National Forest System, measured 1,651 sample locations in 2002, which represents about 4% of the total FIA sample locations maintained by this Unit.

Data quality assurance and quality control

Quality Assurance encompasses the plans, specifications, and policies affecting the collection, processing, and reporting of data, and is covered under FSM 4070, Research Program Formulation and Documentation. The responsible officials are as follows. The Washington Office Staff Directors in Research and Development are responsible for providing advice to the Deputy Chief and Station Directors on program development and budgeting, technical support, and oversight for Forest Service research programs.[13] Station Directors are responsible for planning, conducting, coordinating, and evaluating research programs, and for ensuring the documentation of research results in published articles and agency reports. Assistant Station Directors for Research are responsible for administering, planning, overseeing, and evaluating the research program of individual FIA Research Work Units. FIA Program Managers are responsible for directing, evaluating and documenting the FIA program.[14]

Quality Assurance within the FIA Program also includes a total integrated program for ensuring that the magnitude of uncertainties inherent in FIA data are known and do not exceed acceptable magnitudes, within a stated level of confidence.[15,16] This system of activities is designed to provide independent assurance that total system quality control is being effectively implemented. These activities include setting measurement quality objectives[17] and assessing data quality relative to those objectives.

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[11] http://fia.fs.fed.us/library/FIA_Annual_Report_2002.pdf
[12] http://www.fs.fed.us/rm/ogden/index.html
[13] FMS 1235
[14] FSM 4072.6
[15] http://fia.fs.fed.us/library.htm#Manuals, http://fia.fs.fed.us/library.htm#factsheets, http://fia.fs.fed.us/library.htm#Business
[16] http://socrates.lv-hrc.nevada.edu/fia/imb/imbandindex.html#_FIA_Glossary_Documentation
[17] Describes the acceptable tolerance for each data element, which is based on the data user's estimate of the precision, bias, and completeness of data necessary to satisfy a prescribed application. Included is a statement of the tolerance and a percentage of time when the collected data are required to be within tolerance. Measurement quality objectives can only be assigned where standard methods of sampling or field measurements exist, or where experience has established upper or lower bounds on precision or bias. Measurement quality objectives can be set for measured data elements, observed data elements, and derived data elements.[15]

Quality Control is defined by the FIA programs as the routine application of prescribed field and laboratory procedures (e.g., random check cruising, periodic calibration, instrument maintenance, use of certified standards, etc.) in order to reduce random and systematic errors and ensure that data are generated within known and acceptable performance limits.[16] Quality control also ensures the use of qualified personnel; reliable equipment and supplies; training of personnel; good field and laboratory practices; and strict adherence to standard operating procedures. The FIA Program has documented its supplemental guidance on quality control.[45]

The Research & Development branch of the Forest Service, which includes the FIA program, has a formal Code of Scientific Ethics that guides conduct of all FIA personnel.[18] The Code commits FIA personnel to fairness, honesty, accuracy, and integrity, all of which are placed ahead of allegiance to individuals or organizations. FIA data and analyses may not support a predetermined conclusion, nor may FIA personnel be compromised by conflicts of interest. A competent, credible and well documented peer-review process for FIA information is an important component of ethical conduct. The Code includes procedures for investigating allegations of misconduct and imposing penalties when appropriate.[19]

Sigma Xi, The Scientific Research Society, provides the following ethical guidance to government scientists[20]: "(O)ne challenge the government researcher faces (is) to insist on an accurate description of what is known and what is not, to include uncertainty in the estimates, and to be clear just how far the science can take you. … It is always the researcher's responsibility to give the decision-maker a frank, understandable description of the science. … The government researcher may disagree with the decision, but that disagreement may be more a policy issue than a scientific issue. The researcher should not confuse the two and particularly should avoid confusing the public."

To ensure the objectivity of scientific research information developed and disseminated by USDA, the Forest Service and the FIA program require a clear statement of the research objectives and a description of the approaches and methods used in conducting the research; subjects proposed research projects to a high quality and objective review; provides appropriate oversight to ensure that sound scientific practices are followed; and adheres to the Research Misconduct Policy developed by the Office of Science and Technology Policy[21]. Research misconduct includes falsifying data or results, manipulating research processes, or changing or omitting data or results such that the research is not accurately represented. Appropriate administrative penalties are enforced if research misconduct is found in response to allegations.

FIA publications are reviewed and approved in compliance with Forest Service Manual (FSM) 1630[22] and Forest Service Handbook (FSH) 1609.11[23]. The Research Station

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[18] http://www.fs.fed.us/research/pdf/fs_code_of%20_scientific_ethics.pdf
[19] Cases of alleged scientific misconduct use processes developed for Administrative Misconduct (see Federal Register 5 CFR 752)[18]
[20] *The Responsible Researcher: Paths and Pitfalls*. Sigma Xi, The Scientific Research Society. 64pp. http://www.sigmaxi.org/programs/ethics/ResResearcher.pdf
[21] Federal Register (65 FR 76260, December 6, 2001) http://www.ostp.gov/html/misconduct.html.
[22] http://fsweb.wo.fs.fed.us/directives/fsm/1600/1630.doc
[23] http://fsweb.wo.fs.fed.us/directives/fsh/1609.11/1609.11,10_contents.rtf

Director[39] is responsible for the overall review process.[24] The Assistant Station Director for Research and Development is responsible for assuring integrity of the formal review of each FIA publication.[25] The FIA Program Managers supervise the writing of planned manuscripts and ensure an objective and competent review of each FIA.[26] The author of each FIA publication is responsible for preparing factually accurate reports and obtaining adequate reviews.[27] FIA Program Managers ensure that authors of FIA publications solicit written comments from at least two independent peers who are competent in the subject matter; solicit statistical review when appropriate; and supply the final revised manuscript to the Assistant Director for Research, along with review comments and reasons for any rejection of review comments.[28]

The Data Quality Act[29] of 2001 provides "policy and procedural guidance … for ensuring and maximizing the quality, objectivity, utility, and integrity of information (including statistical information)" disseminated by FIA. The Act establishes administrative mechanisms that allow affected persons to seek and obtain correction of information that does not comply with guidelines. In 2003, the USDA published guidelines[30] that cover FIA data along with many other types of USDA information. The information disseminated by FIA must be substantively accurate, reliable, and unbiased. This requires use of sound statistical methods or generally accepted professional standards, with data collected by accepted or best available methods. FIA must report on any reservations or limitations on the use of these data. Higher standards apply to FIA statistical data whenever they have the potential to have a clear and substantial impact on important public policies or private sector decisions. Also, especially rigorous checks might be expected because public access to FIA sample locations is restricted by Public Law[31], which impacts reproducibility.

At the request of FIA, the Society of American Foresters[32] regularly convenes a national Blue Ribbon Panel on FIA.[33,34] The panel has representatives of FIA partners and external customers from the Forest Service, other federal agencies, universities, states, industry, trade associations, environmental organizations, and professional societies. The

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[24] FSM 1630.42a
[25] FSM 1630.42b
[26] FSM 1630.42c
[27] FSM 1630.43
[28] FSM 1631.15; FSH 1611.14.2
[29] Treasury and General Government Appropriation Act for Fiscal Year 2001, Pub. L. No. 106-554, § 515 Appendix C, 114 Stat. 2763A-153 (2000)
[30] http://www.ocio.usda.gov/irm/qi_guide/index.html
[31] FIA cannot release exact coordinates for FIA sample locations because of the Fiscal Year 2000 Consolidated Appropriations Bill (PL 106-113), which included language that modified the Food Security Act of 1985 (7 U.S.C. 2276(d)) to include FIA plot locations. This protects the privacy of landowners who grant FIA access to their lands, as well as to protect the long term integrity of the FIA sample plots.
[32] The Society of American Foresters (SAF) is the national scientific and educational organization representing the forestry profession in the United States. See http://www.safnet.org/
[33] Reports of the Blue Ribbon Panel on FIA are available at http://fia.fs.fed.us/library.htm#Business.
[34] The Blue Ribbon documents have been published by the American Forest and Paper Association, and the 1992 and 1998 Panels were convened by the same Association. The 2001 and 2004 Panels are convened by the Society of American Foresters. In all cases, the Panels include a diverse membership drawn from prominent leaders from the full forestry community.[33]

Panel reviews FIA performance and results, and has reported its major findings in 1992, 1998 and 2001.[33]

The American Forest & Paper Association (AF&PA) has a research subcommittee on FIA that conducts an ongoing users' review process[35]. This national-level panel consists of industry and academic specialists in inventory and biometrics, and it works with FIA Research Work Units on the continuous improvement of FIA sampling designs, data and analyses.[35]

FIA has a national Executive Team and a separate national Management Team. By Charter[36], both teams are jointly responsible for appropriate actions that maintain and protect the scientific integrity and quality of the FIA program.[37] The FIA Management Team is chaired by the National FIA Program Leader, and it is composed of the five Program Managers responsible for the FIA Research Work Units, two representatives from the Forest Service State and Private Forestry Deputy Area, two representatives from the National Forest System Deputy Area; and a representative of State Foresters from each of the Northeastern, Southern, and Western Associations of State Foresters (appointed by the Chair of the of the National Association of State Foresters).[38] The FIA Executive Team is chaired by the Washington Office Staff Director for Science Policy, Planning, Inventory, and Information in the Research and Development Deputy Area[39]; other members include the five Directors of those Research Stations[39] that supervise FIA Research Work Units, two Regional Foresters from the National Forest System[40], a State Forester from each of the Northeastern, Southern, and Western Associations of State Foresters (also appointed by the Chair of the of the National Association of State Foresters[38], a Washington Office Staff Director from the National Forest System, and a Washington Office Staff Director from the State and Private Forestry (SPF) Deputy Area.

The FIA Management Team commissions technical teams[41] that help FIA deliver a consistent, efficient, and complete core national program. There are currently six teams[42] that address the following subjects: Data Acquisition; Analysis and Reporting; Information Management and Compilation; Remote Sensing, Statistics, and Indicator Advisors. Each technical team is composed of representatives from the five FIA Research Work Units; one representative from a State Forester agency in each of three regions of the USA (south, north, and west); two representatives from the National Forest System; one representative from the State and Private Forestry Deputy Area; and a non-voting liaison member from the FIA Management Team. Other scientists and technical specialists from universities or public agencies may participate on a temporary or permanent basis.

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[35] see http://fia.fs.fed.us/library/brp2.htm
[36] ftp://socrates.lv-hrc.nevada.edu/fia/mteam/etcharter.rtf and ftp://socrates.lv-hrc.nevada.edu/fia/mteam/etcharter.rtf
[37] ftp://socrates.lv-hrc.nevada.edu/fia/mteam/
[38] http://www.stateforesters.org/
[39] http://www.fs.fed.us/research/
[40] http://www.fs.fed.us/contactus/regions.shtml
[41] http://fhm-server.lv-hrc.nevada.edu/fia/band_overview.htm
[42] http://socrates.lv-hrc.nevada.edu/fia/band_links.htm

The *Data Acquisition* team develops tests, and documents standard approaches to collecting core FIA data collected in the field. This includes documentation, training programs, and quality assurance approaches[45], as well as identifying problems for analysts or Indicator Advisors (p. 7) to address. The current national FIA field manual for national core variables has undergone external peer review[43].

The *Information Management and Compilation* team develops and maintains data base management systems for core FIA data, including systems for data editing and validation, internal and external databases, and web applications for allowing outside users to access and analyze FIA data.

The *Statistics* team develops and documents national standards for the statistical techniques, conceptual details, and technical specifics of collecting and analyzing FIA core data. The FIA statistical documentation, entitled *The Enhanced Forest Inventory and Analysis Program—National Sampling Design and Estimation Procedures*, has been reviewed by an independent and external panel of experts.[44] This is in the process of being published as a Forest Service General Technical Report, which is subject to the quality assurance directives of the Forest Service[22, 23] and the Department of Agriculture.[29, 30]

The *Remote Sensing* team focuses on modeling the remote sensing business requirements for FIA operations, and explores ways in which remote sensing can enhance FIA program delivery, including development of new information products.

The *Analysis and Reporting* team develops statistically defensible approaches to summarizing core FIA data, including identification of new variables needed by FIA customers.

The *Indicator Advisors* team focuses on developing the processes for implementing FIA indicators of forest health and condition, from documentation and training through analysis and reporting. Members of each team are technically competent in the applicable subject area.

These teams identify any weaknesses in the FIA approach to core technical issues, and they recommend solutions to the FIA Management Team.[41] The teams also review FIA documentation, quality assurance plans and procedures, and they participate in the continuous improvement of the FIA program.[45]

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[43] U.S. Department of Agriculture, Forest Service. 2003. Forest inventory and analysis national core field guide, volume 1: field data collection procedures for phase 2 plots, version 1.7. U.S. Department of Agriculture, Forest Service, Washington Office. Internal report. On file with: U.S. Department of Agriculture, Forest Service, Forest Inventory and Analysis, 201 14th St., Washington, D.C., 20250. see http://fia.fs.fed.us/library.htm#Manuals

[44] Review team included nine professionals and scientists from government, industry, and the environmental community across the U.S. and overseas. The team has expertise in survey design, conduct analysis and usage with a diversity of backgrounds. Team was chaired by Dr. Alan R. Ek, Professor and Head, Department of Forest Resources, University of Minnesota. See October 15, 2004 letter from Dr. Ek to Mr. Jim Alegria, USDA Forest Service, Portland OR.

[45] FIA Fact Sheet Series: Quality Assurance http://fia.fs.fed.us/library/Factsheets/QA.doc

FIA has an integral quality assurance program for planning, method documentation, training for data collectors, checks of data quality, evaluation of uncertainty in survey data, peer review of analysis products, and continuous feedback[45]. Quality assurance plans are reviewed by FIA technical teams (p. 6) and approved by FIA Program Managers. The FIA program produces extensive documentation of methods for all phases of its operations. FIA inspects field work through independent re-measurement of a sub-sample of FIA field locations. FIA has developed a national information management system that implements in a consistent manner all nationally recognized equations and processing algorithms. Referential integrity is maintained through a list of acceptable codes enforced by the database system. Exhaustive editing algorithms check for potential errors in data that are collected by field crews. FIA analysts closely evaluate FIA statistical information before dissemination. Quality assurance data are evaluated for regional and temporal differences, and compliance with national measurement quality objectives. Continuous improvement is promoted through internal feedback procedures with the FIA technical teams (p. 6) and the FIA field crews and their supervisors.

The integrity of FIA sample locations is protected to assure that they remain representative of unsampled locations. In compliance with Public Law[31], FIA closely restricts disclosure of exact coordinates for all FIA sample locations, including those on public lands[46]. This protects FIA sample locations from unauthorized access and unintentional impacts or improper tampering. Any person who publicly releases restricted information without proper authorization may be fined not more than $10,000 or imprisoned for not more than 1 year, or both[46].

FIA Sampling, Measurement and Estimation Techniques

FIA currently uses a standardized configuration for its sample locations in the field. This configuration is designed to measure a diverse spectrum of forest conditions, ranging from seedling/sapling stands to mature stands, in tropical, temperate and boreal forests, and within public and private ownerships. The National Forest System applies its definition of old growth forest using data collected according to FIA standards and maintained in the FIA database.

It is not feasible to measure every acre within the 747-million acres of forestland in the USA[47,48,49], which contain trillions of individual trees.[50] Therefore, FIA draws a

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[46] FIA has always had a policy of not releasing exact coordinates for FIA sample locations, both to protect the privacy of landowners who grant us access to their lands, as well as to protect the long term integrity of the FIA sample plots. This policy was incorporated into law through the Fiscal Year 2000 Consolidated Appropriations Bill (PL 106-113), where Congress included language that modified the Food Security Act of 1985 (7 U.S.C. 2276(d)) to add FIA data collection to a list of items requiring confidential treatment. See http://fia.fs.fed.us/privacy

[47] USDA Forest Service, 2000 RPA Assessment of Forest and Range Lands. FS-687. Washington, DC. USDA, Forest Service. 78 p. http://www.fs.fed.us/pl/rpa/rpaasses.pdf

[48] Approximated 33% of these forestlands are management by federal agencies.[47]

[49] *U.S. Forest Facts and Historical Trends*. USDA Forest Service, Washington, DC. April 2001. http://fia.fs.fed.us/library/ForestFacts.pdf

[50] FIA does measure a sample of 1.5 million trees[49], and maintains a database that tracks each individual sample tree over time.

representative sample of field locations, and uses data from those sample locations to estimate or infer the condition of all 747-million acres of forestlands. FIA uses a probability sample,[51] which by design allows FIA to quantify the uncertainty in its estimates that are caused by random sampling.

FIA maintains a base federal sample of about 360,000 sample locations in the United States, which is approximately one sample location for every 6,000 acres[52]. Of these sample locations, about 125,000 have forest cover.[49] The same survey protocols and uniform systematic sampling frame are used in all of the nation's forests regardless of public or private ownership (**Figure 1**).

Each FIA sample location is located at randomized point within a regular, systematic cell in a standardized grid[53] across the entire United States. By design, this provides a representative sampling frame for the nation[54]. Each FIA sample location is currently a cluster of field sub-plots that collectively cover an area that is nominally one acre in size, and FIA measures a probability sub-sample of trees at each sub-plot within this cluster. Over 100 characteristics are measured at each sample location.[49] Each forested sample location is typically measured in the course of a single day by a two-person field crew. Field measurement protocols are reviewed, documented, and updated annually, and a sub-set of FIA sample locations is independently re-measured according to an approved quality assurance plan.[45]

Each National Forest is covered by the same FIA sampling frame that exists on all other public and private lands. For example, The Lolo National Forest is covered by 347 of these 360,000 FIA sample locations (Figure 2). The FIA sampling grid provides an equal-probability sample of each National Forest. This sampling grid uniformly covers Wilderness Areas and roadless areas as well as lands managed for other purposes, regardless of their suitably for timber production. Therefore, the FIA sampling frame is appropriate to make scientifically defensible and reliable inferences regarding the condition of forests within sufficiently large areas[8], regardless of their management regime. These inferences include estimation of snag density and the proportion of all forested areas in a National Forest that meets its definition of old growth forest.

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[51] The Northeast FIA program is an exception. Selection probabilities are unknown because of complex and non-standard procedures used to re-stratify permanent plots established between 1950 and 1999. These sample data are analyzed as though they came from a simple random sample. FIA assumes the resulting estimates have no significant bias, although that assumption is can not be verified.

[52] See http://fia.fs.fed.us/library.htm#factsheets

[53] See http://fia.fs.fed.us/

[54] This has been a standard practice in forest inventories for over 50 years. See Osborne, J. G. 1942. Sampling errors for systematic and random surveys of cover type areas. *Journal of the American Statistical* Association. 37:256-264; and Bickford, C. Allen. 1952. The sampling design used in the forest survey of the Northeast. *Journal of Forestry* 50:290-293.

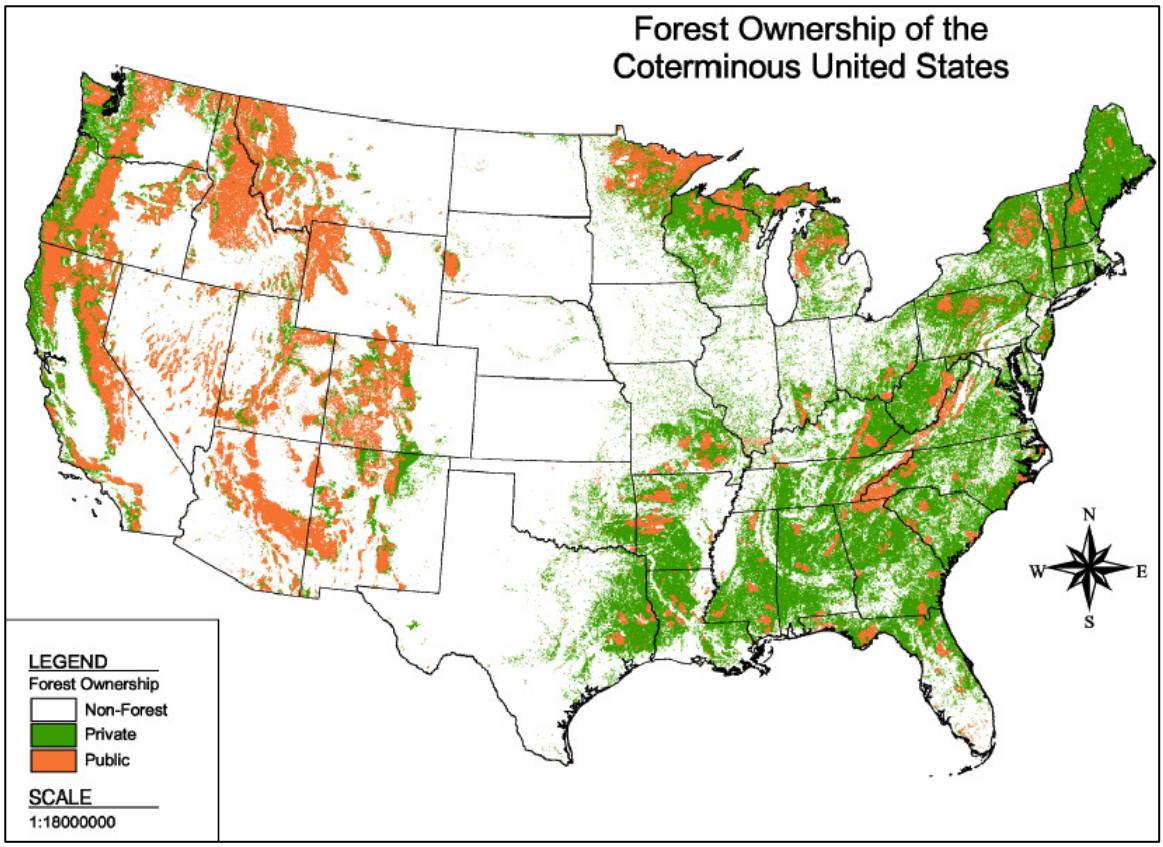

Figure 1 The FIA program surveys the all of the 431-million acres of our nation's private forests, and all 317-million acres of its public forests[49], with a nationally consistent sample of 360,000 forested sample locations, each nominally 1-acre in size. An average National Forest of 1.2-million acres can be expected to have approximately 200 of these 360,000 FIA sample locations, and FIA sample data can provide estimates for geographic areas as small as 0.2-million acres[8], although the reliability depends on the required estimation precision. (Illustration courtesy of Brad Smith, FIA Washington Office staff.)

The FIA Sample Covering the National Forests in Region One

The forest inventories for the Northern Region in the FIA database had used a sample location (field plot) composed of five variable-radius sub-plots, each with a Basal Area Factor of 40. This plot configuration was the standard protocol at that time in the Interior West. Each of the five FIA sub-plots in the FIA cluster matches the plot configuration used to develop the definition of old growth forest[55]; therefore, the scale and extent of each FIA sub-plot is well suited to apply the definition of old growth forest used throughout the Northern Region of the National Forest System. FIA currently uses a cluster of four sub-plots, each encompassing 1/24th of an acre, and cumulatively covering 1/6th of an acre. These four sub-plots are uniformly distributed within a nominal area of 1-acre.

[55] Green, P.; J. Joy; D. Sirucek; W. Hann; A. Zack; and B. Naumann. 1992. Old Growth Forest Types of the Northern Region. Missoula, MT. United States Department of Agriculture, Forest Service, Northern Region. 61 p

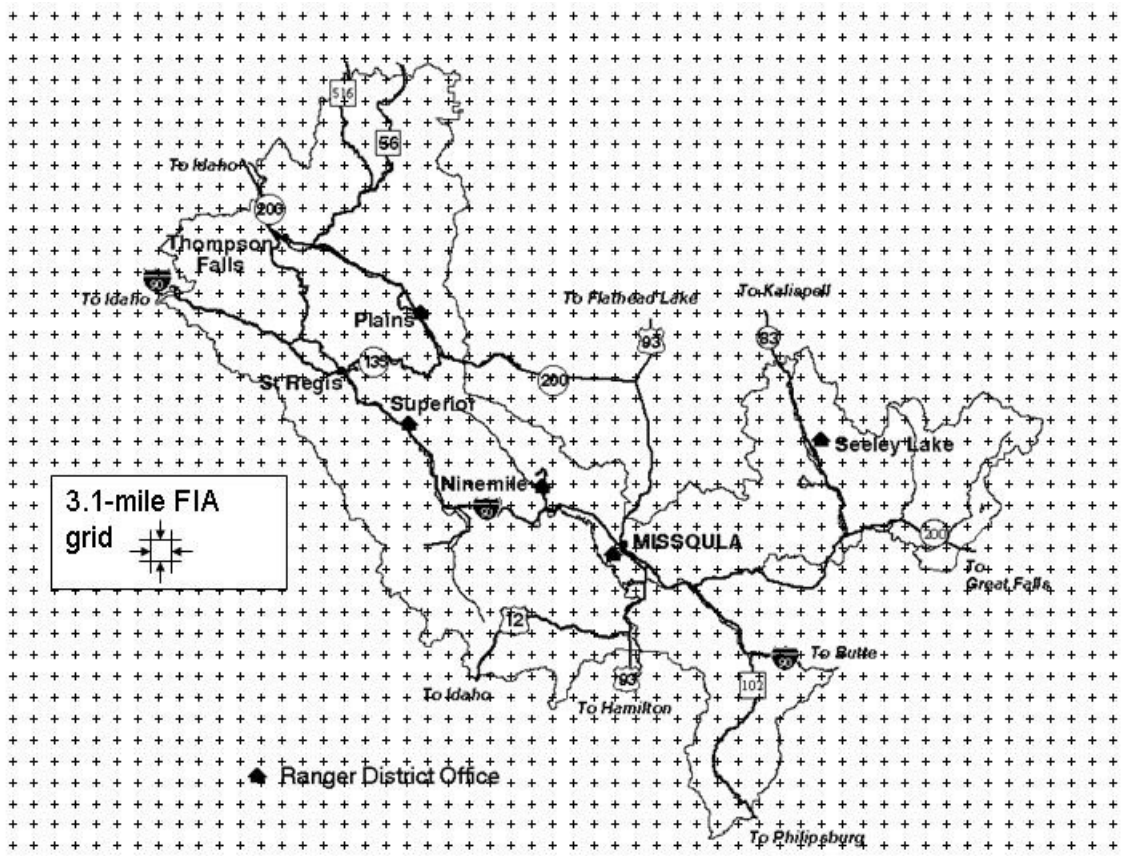

Figure 2 Representative map (to scale) of FIA sampling grid in the vicinity of the Lolo National Forest. An FIA sample location is systematically located with a sampling intensity indicated by the cross marks.[56] In the 1995-1996 inventory of lands managed by the Lolo National Forest, there were 347 FIA sample locations, of which 327 locations were classified as forested, 17 locations were classified as either non-forest or water, and 3 locations were inaccessible.

Uncertainty in Estimates from a Forest Inventory

Like any forest inventory of a large geographic area, FIA uses sampling, and there is some uncertainty in estimates for an entire population that are based upon a sample of that population. The role of the forest survey scientist is to make defensible estimates and characterize the degree of this uncertainty[20]. The role of the decision-maker is to use those estimates to help make an informed decision in the presence of uncertainty.

It is possible to quantify the degree of uncertainty for any scientifically rigorous probability sample. One common metric is the "confidence interval." Sampling in forest inventory has some similarities to sampling in the familiar opinion poll. Assume a scientific poll estimates the proportion of the sampled population who are in favor of a

[56] Because release of the exact coordinates of FIA sample locations is restricted by Public Law, the locations in this figure are hypothetical, although the figure accurately portrays but the true situation. The purpose of this figure is only to illustrate the FIA sampling design and sampling intensity.

proposition is "53% with a margin of error of ±3%." The "±3%" is an example of a confidence interval. The lower limit is 53%-3%=50%, and the upper limit is 53%+3%=56%. Assume that the "confidence level" is 90%. Some might explain this as a 90% probability that the true proportion is between 50% and 56%. However, a more precise explanation follows. If independently replicated 100 times, the procedure used in this opinion poll, which allows us to state that the true proportion lies between 50% and 56%, is expected to result in a correct statement for 90 out of 100 polls, on the average.[57] If we state that the true proportion is less than the lower limit of the confidence interval, *i.e.,* 50%, then we will be correct for 5 out of 100 polls; and if we accept that the true proportion exceeds 56%, then we will be correct in another 5 out of 100 polls, on average

Estimates for a National Forest in the Northern Region

FIA sample locations[43] that are located on a National Forest can be used to estimate the proportion of old growth forest and the average number of snags per acre within that National Forest. Any FIA sample location in which wildfire and harvest have occurred since the latest FIA inventory can be coded to: (1) does not meet the old growth definition; and (2) represent that there are no snags remaining at these sample locations. This inexpensive protocol might underestimate the quantities of old growth and snags that remain at these sample locations.

Using measurements of sample locations made by FIA crews, the definition of old-growth[55] can be applied by the Forest Service Regional Office in Missoula, MT to classify the old growth status for each FIA sub-plot. These classifications are sent to the Forest Service Inventory and Monitoring Institute in Fort Collins, CO, where a standard statistical estimator is applied.[58] The confidence intervals can be computed with the bootstrap method[59], which is a robust technique that is well suited for complex sampling designs. [60] This application was developed under the direction of Dr. Hans T. Schreuder[61]. These procedures can produce a scientifically defensible estimate of the proportion of forest within a National Forest that meets the Northern Region's definition of old-growth. Similarly, these procedures can produce a scientifically defensible estimate of the number of snags within a National Forest.

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[57] Steel, Robert G.D. and James H. Torrie. 1960. *Principles and Procedures of Statistics*. McGraw-Hill, New York. 480p.

[58] Schreuder, H.T., T.G. Gregoire and G.B. Wood. 1993. *Sampling Methods for Multiresource Forest Inventory*. John Wiley & Sons, Inc. New York. 446 pp.

[59] DiCiccio, T.J. and B. Efron, B. 1996. Bootstrap confidence intervals. *Statistical Science* 11:189-228.

[60] Schreuder, H.T. and M.S. Williams. 2000. Reliability of Confidence Intervals Calculated by Bootstrap and Classical Methods using the FIA 1-Ha plot design. General Technical Report RMRS-GTR-57. Fort Collins, CO. United States Department of Agriculture, Forest Service, Rocky Mountain Research Station. 6 p.

[61] Dr. Hans T. Schreuder (retired) had been the senior mathematical statistician with the Forest Inventory and Monitoring Environmetrics Research Work Unit RMRS-4804 at the Forest Service Rocky Mountain Research Station in Fort Collins, CO. Since 1968, Dr. Schreuder has been author or coauthor of 136 scientific works, most of which deal with the mathematical statistics of forest inventories. Dr. Schreuder is lead author for a seminal reference on sampling methods for forest inventories[58], and he has published an assessment of the bootstrap confidence interval.[60]

Summary

FIA data are collected with a probability sample that objectively characterizes forest resources over large geographic areas, including a measure of the uncertainty of this characterization caused by sampling. Of the 360,000 FIA sample locations that systematically cover the United States, several hundreds of sample locations will fall within the lands managed by any single National Forest. FIA provides a representative sample of all forest conditions within a National Forest, regardless of their old growth classification. FIA sample locations cover lands both suitable and not suitable for timber production, Wilderness Areas and roadless areas. FIA sample data provide a scientifically valid basis to estimate snag density and apply the Forest Service definition of old growth forest.