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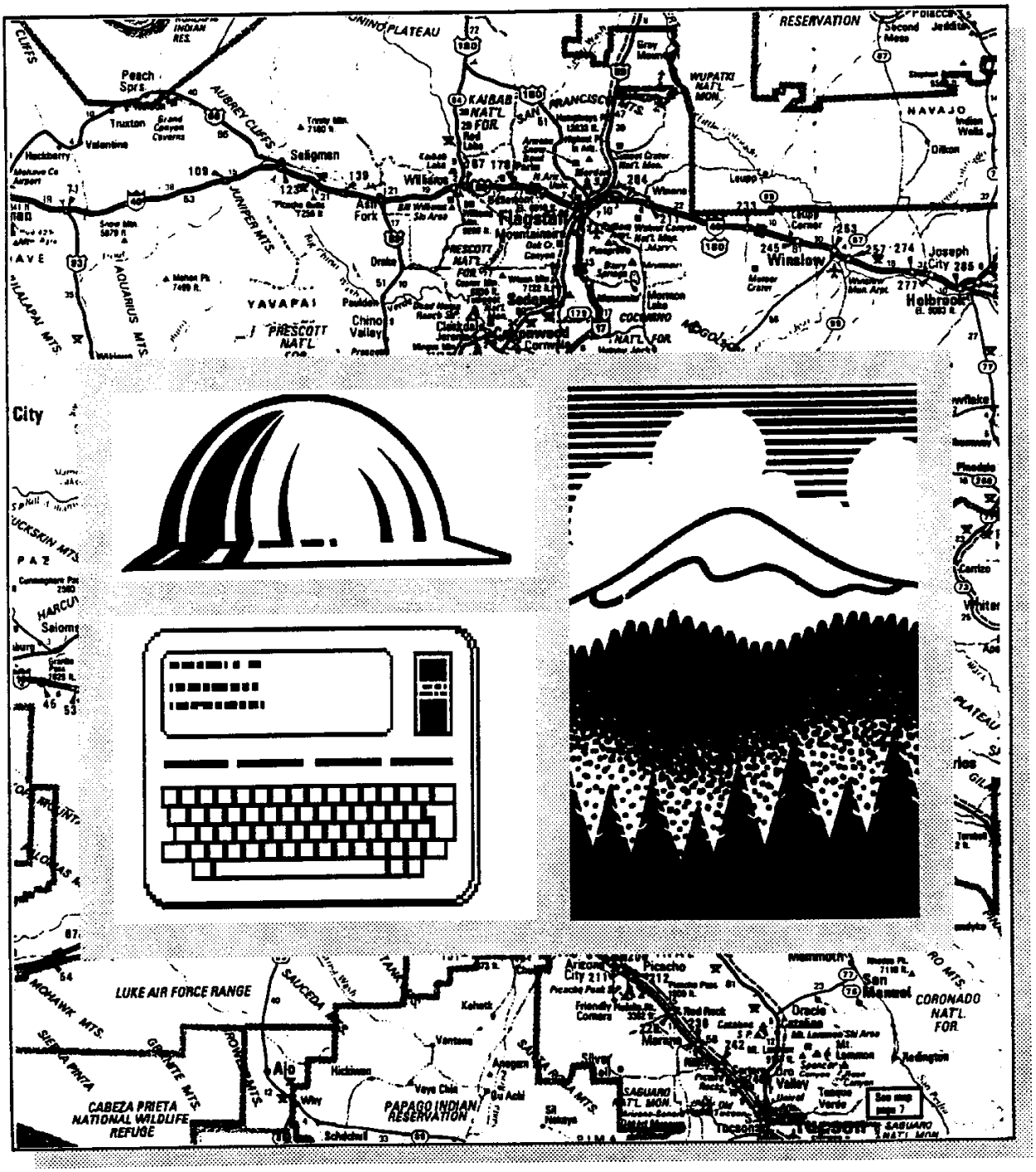
# Forest Service Resource Inventories : An Overview



# FOREST SERVICE RESOURCE INVENTORIES: AN OVERVIEW


Forest Inventory, Economics, and

Recreation Research Staff

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## INTRODUCTION

Forest and related resource inventories are conducted by the U.S. Forest Service to provide the quantitative base necessary for making sound management, conservation, and stewardship decisions affecting these valuable resources. Inventory information has guided the management of 191 million acres (77.3 million ha) of publicly-owned National Forest land. Forest inventories on private and public lands have helped guide industrial expansion into the most suitable and opportune locations. They have identified problems already created or developing in the timber supply. They have provided key forest resource information for planners and policy makers. Our inventory experts have advised and assisted myriad groups, organizations, and countries in solving complex resource questions. They are motivated to continually improve the reliability and usefulness of forest resource statistics and analyses of resource conditions. Collecting, displaying, and analyzing spatial and temporal resource data using geographical information systems; investigating practical and novel uses of remote sensing including satellite imagery; monitoring the environmental health of U.S. forests; and identifying the extent and condition of forests in our urban areas are but a few of the new frontiers that Forest Service inventories are beginning to explore. Any changes, expansion, or shifts in program emphasis, however, are made with utmost care to insure that all information is based on adequately tested procedures and research and that links to invaluable historical records are maintained.

This report provides an overview of the major forest and related resource inventories conducted by the U.S. Forest Service. Attention focuses on legislative and administrative mandates, the Forest Inventory and Analysis (FIA) program, National Forest System resource inventories, linkages among Forest Service inventories, and major partnerships and cooperators.

## LEGISLATIVE AND ADMINISTRATIVE MANDATES FOR RESOURCE INVENTORIES

As with any Federal agency, it takes an act of Congress to provide broad guidance and direction for its various programs. So it is with the inventory activities of the Forest Service.

### *Founding Legislation*

At the close of the 19th century, Congress acknowledged the need for information about the supply and condition of the nation's natural resources. The Organic Administration Act of 1897, which established the National Forests, included provisions for the inventory and management of these lands. In 1928 hallmark legislation, the McSweeney-McNary Forest Research Act (P.L. 70-466), directed the Secretary of Agriculture to make "a comprehensive survey of the present and prospective requirements for timber and other forest products in the United States, and of timber supplies...and of such other facts as may be necessary in the determination of ways and means to balance the timber budget of the United States" (Doig 1976).

### *The Resources Planning and Research Acts*

The Forest and Rangeland Renewable Resources Planning Act (RPA) of 1974 (P.L. 93-378) amended the earlier research act and directed the Secretary of Agriculture 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 range lands of the United States..." This act further directed the Secretary "as part of the Assessment effort... to develop and maintain on a continuing basis a comprehensive and appropriately detailed inventory of all National Forest Systems land and resources." This important legislation broadened the Forest Service mandate to include the non-timber forest resources, such as wildlife habitat, recreation opportunities, soil, and water.

The Forest and Rangeland Renewable Resources Research Act of 1978 (P.L. 95-307), which replaced the earlier forestry research legislation, repeats the amendment contained in the RPA and is the current agency mandate for conducting broad-scale resource inventories. In Section 3(a) of this act, the Secretary of Agriculture is authorized "...to obtain, analyze, develop, demonstrate, and disseminate scientific information about protecting, managing, and utilizing forest and rangeland renewable resources in rural, suburban, and urban areas." Forest Service inventory activities are a crucial component of this authority.

### *The NFMA*

The National Forest Management Act (NFMA) of 1976 (P.L. 94-588) states that, "to serve the national interest, the renewable resources program must be based on a comprehensive assessment of present and anticipated uses, demand for, and supply of renewable resources for, and supply of renewable resources from the Nation's public and private forest and rangelands..." This legislation considerably broadened the provisions of the Organic Act of 1897, and most directly impacts inventories on National Forest System lands.

NFMA regulations established a planning process that is problem solving. National goals are prorated to each National Forest or Grassland. Local issues and concerns are addressed within the context of those assigned goals and objectives. As the planning progresses, assessment information is used as a basis for the NFS portion of the national Assessment and Program.

The NFMA regulations (CFR 219.12(d)) "Inventory data and information collection" require that: "Each Forest Supervisor shall obtain and keep current inventory data appropriate for planning and managing the resources under his or her administrative jurisdiction. The supervisor will assure that the interdisciplinary team has access to the best available data. This may require that special inventories or studies be prepared."

The national assessment for National Forest System lands based on forest planning is broadly addressed in CFR 219.12(e), "Analysis of the management situation." This section describes five broad capability and suitability requirements about an analysis of the management situation. These include:

(1) Benchmark analyses to define the range within which alternatives can be constructed. These include a minimum level, a maximum physical and biological production potential level, and a monetary maximization level.

(2) Current and future level of goods and services expected if current management direction continues.

(3) Projections of demand using best available techniques and both price and nonprice information.

(4) A determination of the potential to resolve public issues and management concerns.

(5) Based on the data and findings, a determination of the need to establish or change management direction.

The first requirement is an estimate of the sustained yield levels for each resource (independently) and the levels of combined resources that may be produced under differing management intensities (or funding levels). These provide an assessment of levels possible under "natural" physical and biological conditions and those that might occur under various levels of management.

Determining what management can, should, and will apply to these areas is a function of the planning process. An interdisciplinary team assesses the potential capability to produce various levels of resource goods and services. The team formulates alternatives that are consistent with national goals and objectives, addresses local issues and concerns, and provides management direction for areas within the National Forests or Grasslands. That management direction determines the location, scheduling of activities, and proposed funding requests.

### *Other Legislation*

Other legislation directed toward non-natural resource inventory subjects nevertheless include sections relevant to Forest Service inventories. The Forest Ecosystems and Atmospheric Pollution Research Act of 1988 (P.L. 100-521) directs the Secretary of Agriculture to "increase the frequency of forest inventories in matters that relate to atmospheric pollution and conduct such surveys as are necessary to monitor long-term trends in the health and productivity of domestic forest ecosystems." The Food, Agriculture, Conservation, and Trade Act of 1990 (P.L. 101-624), also known as the Farm Bill, contains a subsection that encourages the Secretary of Agriculture to develop and implement improved methods of gathering and analyzing forest inventory information to help solve resource management problems created by increasing human settlement in forests adjacent to urban areas. Such legislation is leading the Forest Service into inventories of urban forest resources of the U.S.

### *Administrative Mandates*

As outgrowths of these legislative mandates, the Forest Service has developed a series of administrative mandates to guide the inventory work of the agency. These formalized directives are incorporated into the Forest Service Manual (FSM) and Forest Service Handbook (FSH) system. The manual provides broad policy-level guidance while the handbook is intended to supplement the policy direction with more specific details on how to approach a given task. Another important aspect of the directive system is to provide standards for the Forest Service Regions and/or Experiment Stations to follow. In a decentralized agency, such standardization is important, especially when inventory data from different organizational sources are aggregated for national compilations. Appendix I is a list of all the various manual chapters and handbooks that pertain to resource inventories conducted by the Forest Service.

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## THE FOREST INVENTORY AND ANALYSIS PROGRAM

In response to the McSweeney-McNary Act of 1928, the Forest Service organized regional Forest Survey projects in the Division of Forest Economics Research. In 1930, the initial inventory efforts were begun in the West. In most regions, the inventories were conducted on a state-by-state basis. As a state was completed, statistical-analytical resource reports were prepared and published. These reports contained descriptive information on forest acreage and timber volume, growth, and removals along with analysis of the impacts of these relationships on the current and future timber supply. By the 1960s, inventories were completed for all of the 48 conterminous states, and many of the more heavily-forested states had been re-inventoried at least once.

During the first 25 years, an organization was developed, accuracy standards and definitions of terms were established, and several compilations of resource statistics for the nation were prepared. All of these efforts concentrated on the timber aspects of the forest resource, and most of the inventory output was presented as forest area or volume data on the timber resource of most states and regions.

The 1960s and 1970s were decades of change and rapid expansion in natural resource inventory. The 1974 Resources Planning Act (RPA) emphasized the need for FIA to provide information about the various resources occurring on forests and rangelands--forage, timber, water, wildlife habitat, recreation. At the same time, data users were requesting additional information at more frequent intervals, and for more localized areas. Meeting these additional demands is the challenge of the present under the purview of the 1978 Resources Research Act.

High standards set in its early days and maintained over the years by FIA have established a tradition for full, unbiased, and factual presentation of forest resource information. Since its beginning, Forest Inventory and Analysis has played an integral role in the orderly inventory of the nation's forest and related resources, which is required for the development of effective management scenarios. It has helped guide industrial expansion into the most suitable and opportune locations. FIA has acted as watchdog in identifying problems already created or developing in the supply of timber and other forest outputs. It has provided key forest resource information for planners and policy makers, and has provided expert advice and assistance in solving complex resource questions. In keeping with this tradition, all change, expansion, or shifts in program emphasis are made with utmost care to insure that all information produced is based on adequately tested procedures and sound research and that new data will be comparable to historical information.

The Forest Inventory and Analysis mission is to improve the understanding and management of our nation's forests by maintaining a comprehensive inventory of the status and trends of the country's diverse forest ecosystems, their use, and their health. FIA staff in the Washington Office is under the administrative direction of the Deputy Chief for Research and, in turn, the direction of the Forest Inventory, Economics and Recreation Research (FIERR) Staff (Fig. 1). FIA inventories provide the necessary foundation for building a program of land stewardship and serving the people by providing unbiased, accurate, current, and relevant forest resource information that meets their diverse needs. As part of Research's foundation program, FIA develops basic statistics that are needed as background for many research proposals and problem analyses. Although much of the FIA program focuses on gathering data and reporting statistics, the program includes a dedicated and capable cadre of scientists who evaluate forest resource trends, develop techniques, and adapt the latest technology. Throughout its existence, Forest Inventory and Analysis has been recognized internationally as a premier inventory organization.

Six research units located at Forest Experiment Stations are responsible for translating the various inventory needs into action programs at the regional and state levels. Figure 2 shows the distribution of these units and their areas of inventory/analysis responsibility. Because of the increasing complexity and enlarged scope of research activities, personnel, and budgets (average per unit of $2.5 million for fiscal year 1992), many of the FIA units are in the process of changing from research work units to research programs. A seventh unit conducts multiresource inventory techniques research at the Rocky Mountain Forest and Range Experiment Station. FIA contacts and addresses are listed in Appendix II.

### *Forest Resources Inventories and Analyses*

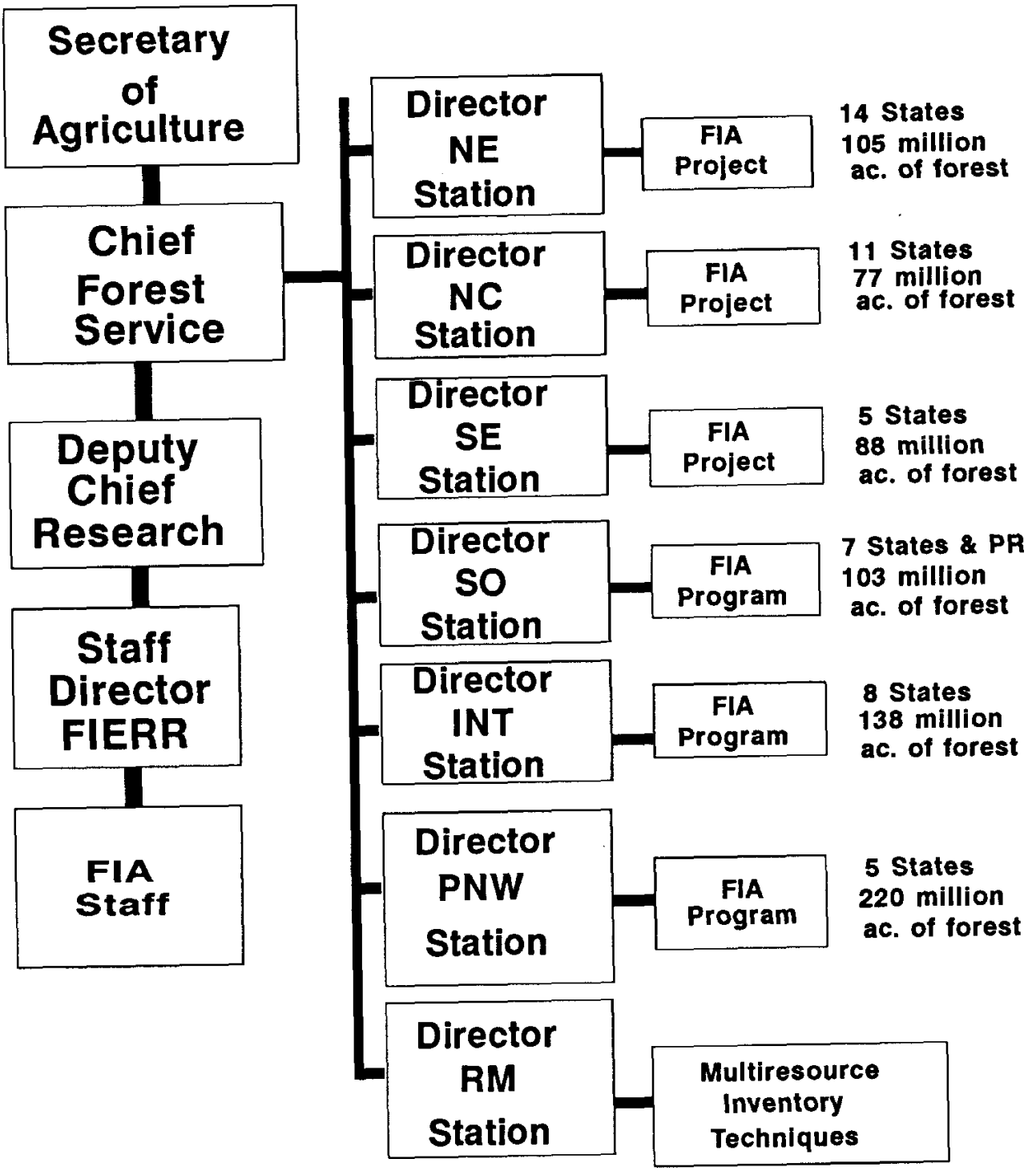
The FIA inventory effort serves a diverse group of resource managers, planners, and other interested data users (see section **MAJOR PARTNERSHIPS AND COOPERATORS** for some examples). The initial planning of an inventory includes contacting these parties to determine their particular information needs and analysis considerations. Where a particular need would require data collection or data processing in excess of the funded program, specific clients will often contribute funds, manpower, or equipment to obtain the information.

#### *Defining the Information Needs*

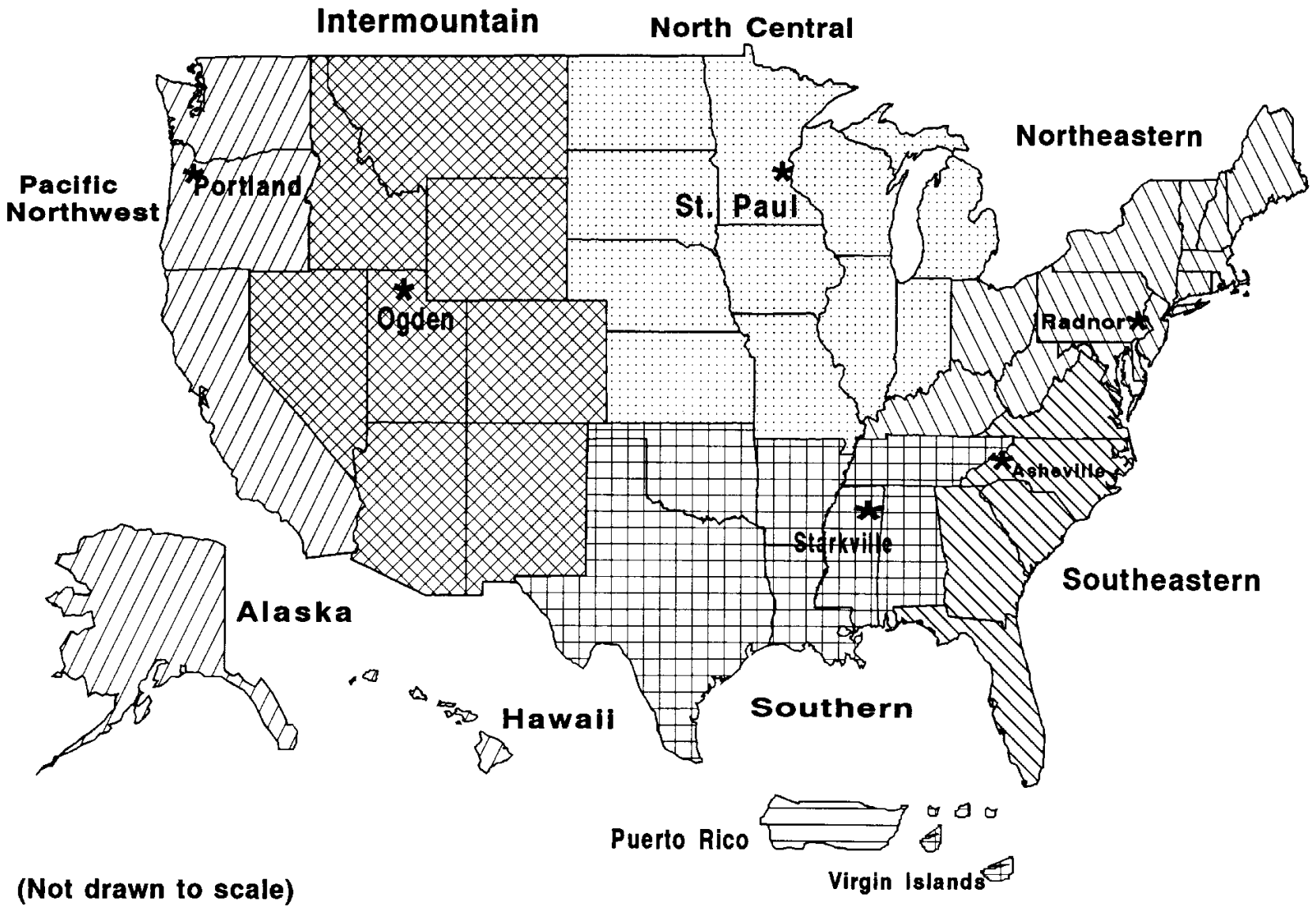
As mandated responsibilities grow and the client base becomes more diverse, FIA must become more responsive to the public's information needs. One approach to identifying these needs is to look at what are the important issues and trends facing the use or management of our forests.

Four long-term issues stand out as being related to renewable natural resources that will directly affect the FIA program. The first, increasing pollution, includes such topics as acid precipitation, the effects of global climate change, deterioration of forest health, and lower forest productivity. The second, dwindling resources, encompasses lack of regeneration, overharvesting, desertification, loss of biological diversity, dwindling old-growth forests, and forest and ownership fragmentation. Increasing population is the third major, long-term issue. It is closely linked to urbanization, land clearing, and increased pressure on remaining forest systems to supply necessary goods and services. The fourth, proliferation of information, concerns the need for accurate, timely resource information and easy access to data. Consistency and comparability of resource estimates among geographic regions and across time (i.e., from one survey to the next) are related concerns.

# Figure 1.--Organization of Forest Inventory and Analysis



# Figure 2.--Forest Inventory and Analysis Research Zones of Responsibility



While these long-term issues and trends will assist FIA in defining information needs for the next century, there are some major trends for the 1990s that FIA must be aware of and must anticipate.

***A Changing Forest Land Base*** - The ability of our forests to supply timber products is declining in response to growing pressures to supply a broad spectrum of commodities and nonmarket goods and services. To keep pace with dynamic land-use change, the inventory remeasurement cycles should be shortened and appropriate variables should be collected to adequately characterize other resources values.

***Rising Noncommodity Uses*** - The extent and condition of forest resources, on which these uses depend, needs to be thoroughly documented. In-depth analyses are needed to estimate outdoor recreation demand and potential increases in use, wildlife habitat suitability and extent, watershed conditions, grazing use, and biological diversity. To get a complete picture of these resources, all forest land, including wilderness areas and parks, should be included in forest resource inventories and featured in reports.

***Environmental Health Change*** - Forest health and productivity are affected by a large number of interacting factors. Air quality problems and the potential for anthropogenic climate change have increased the need for timely information on the health and productivity of the nation's forests. Addressing these issues requires efforts from many disciplines to provide new kinds of monitoring data. A key role will be the establishment of a baseline set of field locations that can be monitored to detect changes in the health and condition of major forest ecosystems over time.

While taking these long- and short-term issues into account, the inventory designer must identify a particular set of data requirements, specify them as a statement of objectives, and through sampling technology, define optimum solutions based on time, needs, and funding constraints.

Another way of defining information needs came through the American Forest Council's Blue Ribbon Panel on FIA, which generated several findings and recommendations to the Chief of the Forest Service. These include: 1) improve and expand information on ecosystems and noncommodity values, 2) recognize and identify ownership, regulatory, and social value impacts on forest productivity, 3) produce the most current resource data possible, 4) implement a uniform approach on all ownerships, 5) increase consistency and compatibility among FIA units, and 6) enhance coordination between FIA and public agencies.

Experience with forest inventories has shown that data needs can be segregated into one of five classes: (1) forest area, (2) current inventory, (3) forest tree and vegetation growth, mortality and removals, (4) management opportunities, and (5) future supply. Forest area questions relate to productivity, ownership, present condition, forest type, stand size, availability, and the direction of change in land base. Inventory, growth, mortality, and removals are often described in relation to tree species, stand conditions, damage-causing agents, product uses, utilization, and impact on future supply. Forest condition questions require the interaction of stand data with silvicultural/management prescription tools or guidelines. Future supply information needs are related to past trends, prospective technological and management changes, and economic considerations.

### *Developing the Information*

Forest resource inventories have been guided by national standards and definitions for the required information but encourage efficient sampling designs tailored to each particular inventory situation. The size, condition, and variability of the forest resource across the nation favor such an approach.

*Periodicity of Sampling*

Statewide inventory information has been collected continuously for over 50 years. In most regions of the United States, the third inventory cycle has been completed and some areas have been inventoried as many as six times. Each year, over 60 million acres (24.3 million ha) of forest land are inventoried in the United States by FIA. Currently, this rate of coverage translates into an average inventory cycle of 10 years for the nation.

*Sampling Design and Intensity*

Data collection is normally based upon a common sampling approach -- double sampling for stratification. This includes the interpretation of sample points on aerial photographs and subsampling a portion of the points to obtain additional data on the ground. For additional information on the sampling methods and the design refer to Appendix III.

The extensive renewable resource inventories conducted by Forest Inventory and Analysis field units meet most state, regional, and national information needs. In most cases, the first phase, photo sample, covers all land classes at a uniform level. FIA nationwide uses data from approximately 6.5 million photo samples to conduct their inventories.

Depending upon the extent to which remote sensing is used, the intensity of the second phase, ground sample, ranges from one plot per 3,000 acres to one per 10,000 (1,214 to 4,047 ha). In some cases, with additional funding support from cooperators, the number of samples is increased to make the information more useful at the sub-state level. FIA is currently using data from approximately 130,600 forested ground plots and 279,000 non-forested ground plots to develop resource estimates. Inventory costs average about 25 cents per forested acre (10 cents per hectare).

*Plot Procedures and Data Collected*

A common ground sample plot consists of a cluster of 5-10 subplots spaced in such a way to cover one acre (0.4 ha). Area attributes and vegetation data are collected at each subplot. Trees and other vegetation are sampled according to specific rules related to plant size. Sampling rules vary from region to region depending on forest stand conditions. The standard FIA subplot samples trees less than 5.0-inches (12.7-cm) dbh on a fixed area plot and larger trees using a variable-radius plot.

Some Forest Inventory and Analysis field units have used plot designs other than the one described above, such as a fixed area sample for the trees 5.0-inches (12.7-cm) dbh and larger and the imposition of imaginary, fixed-diameter cylinders over points to quantify the volume and vertical location of all the biomass. Most of these changes are related to special regional information needs, while others enable the evaluation of silvicultural treatment opportunities or wildlife habitat and forest biomass values.

The aerial photo interpretation phase of the inventory yields information about land use, timber volume classes, and general forest type categories. In addition, ground plots yield specific information about area, the plot, individual trees, and other vegetation. Computer processing generates more data from the field tally. An example of FIA resource data is shown in Table 1. Nearly all FIA units employ portable data recorders in the field to collect and perform cursory edit checks on resource data.

*Displaying the Solutions*

Forest resource information is published in two kinds of reports: (1) comprehensive statistical and/or analytical reports of inventories, and (2) special topic reports. The six Forest Inventory and Analysis work units prepare comprehensive statistical/analytical reports for geographic units, states, or regions which describe the forest area, resource supply, components of changes (i.e., growth, removals, and mortality), treatment

**Table 1.--Kinds of Resource Data Available from FIA**

**Example using FIA's Eastwide Data Base (Hansen et al. 1992)**

*County-level Data*

1. State
2. Geographic survey unit
3. County
4. Inventory cycle number
5. Date of inventory

*Plot-level Data*

1. Ownership
2. Current forest type
3. Old forest type
4. Stand age
5. Stand size class
6. Current stand origin
7. Old stand origin
8. Site productivity class
9. Site index
10. Site index base age
11. Administrative forest
12. Current land use class
13. Old land use class
14. Basal area
15. Slope
16. Aspect
17. Physiographic class
18. Treatment opportunity class
19. Percent inhibiting vegetation
20. Percent nonstocked
21. Growing-stock stocking
22. All live stocking
23. Remeasurement period
24. Area expansion factor
25. Volume expansion factor
26. Growth expansion factor
27. Mortality expansion factor
28. Removals expansion factor
29. Longitude
30. Latitude
31. Measurement date

*Tree-level Data*

1. Point number
2. Tree number
3. Tree status (or history)
4. Species
5. Species group
6. Current diameter
7. Old diameter
8. Tree grade
9. Tree class
10. Crown ratio
11. Crown class
12. Damage
13. Volume expansion factor
14. Mortality expansion factor
15. Removals expansion factor
16. Net cubic foot volume
17. Net cubic foot volume in sawlog
18. Net board foot volume in sawlog
19. Net cubic foot growth
20. Net board foot growth
21. Total gross biomass
22. Merchantable biomass

opportunities, resource use, and analyze future prospects for the resource. An example of a statistical report is Forest Statistics for New Jersey--1987 (DiGiovanni and Scott 1990), and an analytical report example is Forest Resources of Tennessee (May 1991).

Special reports delve into a particular facet of the resource in more detail or highlight a particular analysis or technique. They are produced at various levels. A national-level publication is The Forest Biomass Resource of the United States (Cost et al. 1990). Regional examples include Timber Volume Distribution Maps for the Eastern United States (Beltz et al. 1992) and A Method for Estimating Operability and Location of the Timber Resource (Spencer et al. 1986). Examples of state-level special reports are Growth Prediction for Azizona's Mesquite (*Prosopis velutina*) Woodlands (Chojnacky 1991) and Changing Stand Structure and Regional Growth Reductions in Georgia's Natural Pine Stands (Bechtold et al. 1991).

The Forest Inventory and Analysis work units devote considerable time and effort responding to information requests. While most requests can be satisfied by statistics from the forest resource reports, some work units have developed special computer capabilities to answer unique requests. For the more sophisticated data user who wishes to do his/her own data manipulations and analyses, the FIA units provide data computer tapes for a charge or make arrangements for the user to pay for an interactive account on the host computer.

Results of inventory techniques research--a continuing activity of the work units--are reported at periodic in-service workshops or national and international professional conferences. Research products are tested during ongoing inventories and are integrated into future inventory procedures if they prove to lower costs, save time, or increase efficiency.

### *Forest Products and Related Studies*

Forest products play an important role in the U.S. economy. Construction, manufacturing, and transportation all require an enormous amount of wood as raw material. Also, there are strong indications that as energy costs increase, wood will become even more important to the nation. Wood use is also likely to increase as nonrenewable resources become increasingly scarce and costly. Monitoring the characteristics of the forest products industry requires several types of studies. The data obtained in these studies are incorporated with the renewable resource inventory data to enable a more complete analysis of the resource supply.

Timber products and industry studies are conducted by FIA work units using questionnaire surveys. Industry surveys generate statewide statistics on timber product output while product surveys generate regional output statistics for a single product, such as sawlogs, pulpwood, or veneer logs. Primary wood-using mills are contacted by mail or personal interview to determine their roundwood receipts for a specific year. In addition, species information and source of roundwood are determined along with the disposition of their manufacturing residues. Often the data are collected in cooperation with state forestry organizations. Interstate roundwood shipments are traced by contacting wood manufacturers in adjoining states or regions. Roundwood exports are estimated from canvasing exporters, railroads, and Department of Commerce log export data.

Timber utilization studies are closely related to timber product output studies because they make it possible to estimate the volume of timber inventory necessary to produce a specific quantity of timber products. Tree measurements are taken on active logging operations immediately before and after sample trees are harvested. Standing tree measurements are taken and recorded according to timber inventory standards as if the trees were standing on inventory plots. After felling, tree sections are scaled and classified as being (1) used for products, or (2) left in woods as residue. Growing-stock sections of sample trees as well as nongrowing stock material used for products are measured. Nongrowing stock includes cull trees, topwood and limbwood, saplings, dead trees, and trees on nonforest land.

Studies on utilization and timber products output provide information needed to determine how much timber is removed annually. Timber removals are the net volume of products and residues from growing-stock trees removed from the inventory by harvesting; cultural operations, such as timber stand improvement; land clearing; or changes in land use or classification. The components of removals can be estimated in several ways. First, if timber utilization factors are applied to timber products output statistics, growing stock output can be determined. Second, growing-stock output can be determined by counting tree stumps on remeasured forest inventory plots. Tree volumes can be assigned by relating stump dimensions to height and dbh of the original tree. Third, timber volume on remeasurement plots can be estimated by simulation methods when the forest land has been cleared or where land use has been reclassified between surveys. Finally, statistics that show forest land area cleared for urban development, right-of-way expansions, and road construction or forest land acreage reserved for parks, wilderness, and outdoor recreation can be multiplied by representative per acre plot volumes to estimate other removal components.

### *Research Focus on Forest Values Besides Timber*

With the passage of the Resources Planning Act of 1974 (RPA) the mission of Forest Inventory and Analysis research broadened considerably beyond the traditional timber surveys to encompass the many other renewable resources that our nation's forests can and do provide. Inventories of these important aspects of our nation's forest ecosystems provide valuable information for diverse user groups.

To meet the additional data needs of RPA, data collection activities have expanded to include information on forest vegetation and the non-commodity aspects of the forest ecosystems. Table 2 presents some of the information collected by the FIA units related to forest values besides timber.

FIA units across the country have been conducting a variety of research studies and analyses of forest resources using data from an extensive sampling design of permanent plots. As these plots are revisited in subsequent surveys, data describing changes in tree populations, forest communities, and landscape patterns will provide an invaluable historical record and explanation of large-scale forest dynamics. FIA data can feed into a variety of research studies, such as those relating to biological diversity and global change.

In 1989 a workshop, "Integrating Multiple Value Surveys Into Timber Survey," was held in Syracuse, NY as part of a symposium on "State of the Art Methodology in Forest Inventory". The proceedings (LaBau and Cunia 1990) provide an important overview of several techniques that have been successfully applied to broaden and round out large-scale forest inventories.

A compendium of more than 400 citations of literature published between 1979 and 1990 on wildlife habitat, range, recreation, hydrology, and related research was assembled by Rudis (1991). This report demonstrates the breadth and extent of how the Forest Inventory and Analysis program nationwide has responded to the challenge issued in the the RPA legislation. Since then other reports have been published (e.g., Ohmann 1992) as this important aspect of FIA research continues.

While the process is ongoing, such investigations have already generated new perspectives, analytical techniques, multiple-value forest inventories, support groups, and attitudes within the FIA program. The focus has shifted toward measurement of physical, human, and other biological components of forest ecosystems and away from a strictly timber perspective. Scientists from social, biological, and environmental disciplines, in addition to traditional silviculture and biometrics, are involved in FIA research. Data on trees and board feet of merchantable timber are still important but are now joined by information on a host of other forest attributes and values.

**Table 2.--Forest Vegetation and Multi-resource information collected by FIA.**

| Information Category and Data Collected | FIA Unit | | | | | |
|---|---|---|---|---|---|---|
| | Pacific Coast | Interior West | North Central | Mid-South | North-east | South-east |
| Non-tree Vegetation | | | | | | |
| Species abundance | X | X | X | X | X | X |
| Vegetation profile | X | X | | | | X |
| Biomass | X | X | X | X | X | X |
| Wildlife Habitat | | | | | | |
| Edge | X | | | | | X |
| Animal use, browsing | X | X | X | | X | |
| Snags | X | X | | X | X | X |
| Down, woody material | X | X | | | | |
| Cover, shelter | X | X | X | | X | X |
| Suitability | X | | | X | | |
| Forested Range for Livestock | | | | | | |
| Grazing | | X | X | X | | X |
| Recreation | | | | | | |
| Opportunity assessment | X | | | X | X | X |
| Use | | X | | X | X | X |
| Soils | | | | | | |
| Landscape context | X | X | X | X | X | X |
| Physical characteristics | X | X | | | X | X |
| Water | | | | | | |
| Type | X | X | X | X | X | X |
| Proximity to plot | X | X | X | X | X | X |
| Other Data | | | | | | |
| Logging operability | | | X | X | | X |
| Spatial coordinates | X | X | X | X | X | X |
| Residential fuelwood | X | | X | | X | |
| Fire fuel quantities | X | | | | | |
| Woodland assessment | X | X | | | | X |
| Resource zone | X | | | | | |

Note--similar data are often collected on NFS lands during the course of management inventories.

### *Inventory Techniques Research*

Forest resource inventory in the United States is based on statistical sampling methods. Sampling technology is an indispensable part of the process. Consequently, forest sampling for timber resource inventory relies on perhaps the largest body of technical estimation procedures among the natural resources disciplines. Future requirements for integrated renewable resources information call for the expansion of this body of technical skills into many areas.

Resource analyses require information that describes the stocks of, condition of, and interactions among all of the renewable resources of the forest including timber, range forage, wildlife habitat, and water. Although the principles of multiresource inventory are emerging, specific tools and techniques of integration are lacking. During the last two decades, analyses have recognized restraints on timber growing and future timber supply from other forest uses, but the Resources Planning Act gave clear direction to incorporate the nontimber resources as an integral part of FIA assessment activities.

#### *Regional Work Units*

Techniques research has always been a part of the regular work activity at each FIA unit. Techniques studies are aimed at improving the efficiency and utility of the resource data being gathered. Four general areas of investigation are involved: (1) sampling design efficiencies, (2) data collection, processing, and mensurational techniques, (3) measurement of non-commodity resources, and (4) multiresource inventory techniques.

As an example, the North Central FIA work unit and cooperators are researching an annual forest inventory system (AFIS) that integrates current data base techniques, satellite imagery, annual design-based sampling, and model predictions. AFIS features a computerized data base of plot data that is updated annually. Satellite imagery is used for determining area and for detecting major changes in plot characteristics.

An example of the remote sensing application research conducted by FIA units is the development of a forest cover type map of the U.S. by the unit at Starkville, MS. Advanced Very High Resolution Radiometer (AVHRR) data collected from a weather satellite were used. The AVHRR sensor collects 5 channels of data, ranging from the visible and reflected infrared to the emitted (thermal) infrared portions of the electromagnetic spectrum. From these channels another type of data, maximum normalized difference vegetation index (NDVI) is derived. This index is effective for vegetation classification because it is highly correlated to the amount of vegetation (chlorophyll and leaf reflectance) present and it is relatively independent of solar and sensor scan angles. This project used nine separate data sets collected throughout the 1991 so as to represent the entire range of vegetation phenological development. Each data set was composited over a 2-week period so as to be cloud-free and was geo-referenced to a common base projection. Unsupervised classification of forest land into the broad FIA forest type groups was calibrated and verified in several ways: 1) Landsat Thematic Mapper data, 2) aerial photographs, 3) various ancillary data such as information on regional ecological and climatic divisions, vegetation types, elevation data, and FIA and RPA data, and 4) review of draft products by regional experts and others doing vegetation mapping.

Besides remote sensing research, the FIA projects are continually exploring the latest technology for applications in improving the accuracy and efficiency of our resource inventories. Each unit has a geographic information system (GIS) and is working on various aspects of integrating sample-based inventories with spatial, in-place inventories. The FIA unit in Asheville, NC uses a GIS to access large forest inventory data files of sample plots that are distributed throughout the five southeast states. When combined with accurate representations of spatial features such as county boundaries, roads, and streams, these forest resource data can be displayed in a number of ways to describe regional resource distributions, answer user-specific resource questions, and conduct proximity analyses. Other technologies being investigated include relational data base management systems, laser field equipment, global positioning systems (GPS), portable data recorders, and videography.

*Multiresource Inventory Techniques Project*

The mission of the FIA national multiresource inventory techniques research work unit at the Rocky Mountain Forest and Range Experiment Station, Ft. Collins, Colorado, is to provide techniques and knowledge that will improve the efficiency and utility of inventories of renewable natural resources associated with forest and rangelands.

To meet the needs for multiresource inventory and evaluation, the work unit's activities are directed toward modifying and expanding existing techniques and developing new resource data acquisition, estimation, and analysis techniques. These include sample designs; ground based measurement procedures; and a combination of model predictions and remotely sensed estimates with field data for application in national renewable resource assessments.

One research focus of the Ft. Collins work unit is to provide techniques and knowledge of optimum multiresource sampling strategies for incorporating various sources of data to assess and monitor renewable resource stocks. In addition, a second area of research deals with the development of consistent change estimation and projection techniques with accompanying measures of precision and determination of the potential underlying causes of change. This work unit is also involved in researching certain aspects of forest health monitoring (see section under **MAJOR PARTNERSHIPS AND COOPERATORS**), especially the area of forest health indicator testing and development.

***Other FIA Research and Analyses***

Besides exploring various techniques for improving the way inventories are conducted, the FIA program is also actively involved in many other research problems related to assessing and analyzing the status, condition, and trends of the nation's forests. Here is but a sample of activities.

*Ownership Studies*

Forest-land ownership studies have been completed in fourteen northeastern states, three North Central states, and portions of the Pacific Northwest, and an update of the national ownership pattern is underway. Such studies are designed to complement the data collected on the inventory plots. Objectives of the ownership studies are to provide a description of typical private forest land owners, and to determine their motive for ownership and attitudes toward timber harvesting, forest management, and the public's use of their lands for recreation. Data are collected from questionnaires mailed to the owners of forested field plots. A field follow-up of nonrespondents is undertaken. Landowner studies help public agencies plan and organize programs targeted for private owners, aid forest industries in determining the availability of timber, and assist researchers in identifying the motivations and objectives of forest land ownership.

*Landscape Characterization*

In the Southeast, rapidly increasing populations in many areas have resulted in increasing amounts of timberland being cleared for nonforest uses. Many other samples remain in forest but are greatly affected by the buildup in population and/or land uses surrounding the sample location. For these affected samples, the character of the landscape surrounding the area may have a direct bearing on timber supply. In order to describe the general area surrounding each forest sample, a circular 450-acre (182-ha) area is observed on aerial photography. For each sample a series of codes are used to separate the categories with the highest-density residential and recreational areas from those with the least potential for conflicts.

*Biomass on Nonforest Lands*

Traditionally, statewide forest inventories have been designed to estimate the volume of wood from a 1-foot (0.3-m) stump to a 4.0-inch (10.2-cm) top diameter outside bark (dob) for trees 5.0-inches (12.7-cm) dbh and larger on forest land. Starting in Florida in 1978, a subsample of nonforest plots based on a crown closure stratification were visited on the ground. At each sample location the number of trees 1.0-inch (2.54-cm) dbh and larger that are associated with nonforest uses are recorded on a 1-acre (0.4-ha) circular plot. These sample counts are expanded to represent total population of trees on land classified as nonforest. This enables the FIA project to estimate biomass in strips or stringers, along highway medians, riparian zones, isolated trees in pastures or trees in city parks.

*Pacific Yew Inventory*

Taxol, a chemical extracted from Pacific yew (*Taxus brevifolia*), has proven to be an extremely effective anti-cancer drug. But clinical trials have been limited due to the extremely small supply of taxol raw material--yew bark. Extracting taxol from yew needles shows promise, but approvals to use compounds derived from yew needles on humans will take 3 to 5 years. To date, attempts to produce taxol synthetically have had limited success.

Current and historic inventory data for yew on private lands in California, Oregon, and Washington have been compiled by the Forest Inventory and Analysis unit at Portland, OR. FIA is working closely with the National Forest System and Bureau of Land Management inventory specialists to develop accurate Pacific yew assessments for public lands as well.

*Lake States Forest Resources Assessment*

This project of the Lake States Forestry Alliance (a three-state coalition) and the North Central FIA unit, was designed to examine trends and identify opportunities presented by the rich resources and values of the forests of Michigan, Minnesota, and Wisconsin. It will establish the foundation for policies and programs for the sustainable use of resources to achieve social, economic, and environmental objectives. These three Lake States have more than 52 million acres (21 million ha) of forest land. Of this, six million acres (2.4 million ha) are in parks and designated wilderness, while more than 46 million acres (18.6 million ha) are available for a wider range of management activities. The assessment will consider all uses of the forests, project supply and demand for resources to the year 2020, provide objective baseline data on resources and trends, and improve on existing data and analyses. Funded by a consortium of State and Federal agencies, the assessment will result in a comprehensive picture of the Lake States' forests.

***FIA's Program for the 1990s***

In early 1992 the FIA staff was challenged to envision its program as the last decade of the century unfolded. The resulting document, "A Blueprint for Forest Inventory and Analysis Research and Vision for the Future," laid out some ambitious direction and goals. These were organized into five general research areas.

The first was comprehensive inventories of the forest ecosystems of the United States. The focus will be on the efficient collection and compilation of forest resources data required for periodic national assessments and statewide resource evaluations. Research and analysis of past, current, and prospective trends in the renewable forest resources as they relate to the nation's overall economic and social needs will identify the value and importance of all of the forest resources, note the interactions among various management activities, and identify opportunities for altering prospective trends. Timely, accurate, and comprehensive data for the forest ecosystems in the nation are essential for the formulation of sound forest management policies and programs. Some specific actions include:

- Identify new kinds of information that better describe the forest resources, and the landowners that control them
- Obtain baseline data on forested wetlands and old-growth forests across the nation and develop analytical methods for assessing the condition of this ecologically important resource
- Undertake the inventory of woodland and reserved forest lands of the nation
- Improve techniques and procedures for measuring biomass on forested and other land and estimate amount of carbon stored in forest ecosystems
- Develop procedures to quantify landscape features when addressing fragmentation and other issues pertinent to contemporary management concerns.

The second general research area was the identification of non-commodity variables needed for the nation's Resource Planning Act assessments. Starting in 1976, particular attention was given to link variables indicative of more than one forest condition or attribute. Classifications and measurements made at sample locations focused on special information needs for evaluating wildlife habitat, recreation use, range suitability, water quality, erosion hazards related to forestry practices, and the use-interaction relationships associated with the numerous forest conditions. As this research proceeds some specific actions that FIA will focus on include:

- Developing closer alliances with diverse multiresource data users
- Assisting NFS in developing definitions, field procedures, and analytical methods for portraying old-growth forest ecosystems
- Developing data requirements, definitions, and analytical methods to assist in evaluating wildlife habitat condition and extent, measuring biological diversity, and tracking threatened and endangered species
- Expanding the basic inventory of trees to include all vegetation for the purpose of establishing a long-term, statistically valid sample of condition of the entire forest ecosystem.

The third area, forest industry and timber production analyses, will explore timber use and its relationship to inventory volume, and estimate the amount of logging residues and other removals associated with cultural practices and changes in land use. Timber recovery studies and forest products and timber industry production information provide the necessary input for maximizing investment returns. Specific actions include:

- Conduct thorough analyses of change between successive inventories, examining gross growth, mortality, and removals
- Estimate and analyze changes in timber utilization
- Conduct studies of total roundwood removals from all lands
- Conduct analyses of biomass/energy potentials and their impact on traditional timber uses.

The fourth research area involves the continued implementation of the forest health monitoring (FHM) program (see section under **MAJOR PARTNERSHIPS AND COOPERATORS**). As FHM moves into new forest ecosystems and as successive measurements allow analyses of deviations from baseline information, the program will become more visible and valuable. Research in this uncharted area will include:

- Investigating forest sampling strategies that are best suited to forest health monitoring
- During analyses, determining how to link forest health data collected in the field, remotely sensed data, and other data (e.g. climate parameters and pollution loadings)

- Identifying key environmental health indicators which directly, or indirectly, reflect forest ecosystem condition. Determine if forest indicators discriminate between forest stands of known "good" and "bad" health
- Determining how to monitor and track long-term trends in the health and productivity of the forest ecosystems
- Identifying the field data measurements required to adequately assess both human-induced and natural environmental stresses
- Developing sound mensurational and data processing procedures applicable to forest health monitoring
- Conducting studies to determine the kinds of information that can be acquired from remote sensing.

The final area, urban forest inventory research, is relatively new to FIA but has the potential to be a major component of the program. The 1990 census found that for the first time in our nation's history over 75 percent of the population lives in urban areas. Backyard forests and single or groups of trees in urban/suburban settings are receiving increasing attention as a source of wildlife habitat, specifically for songbirds and small mammals in predominantly urban or suburban areas. Small forested tracts, that do not meet FIA's definition of forest land, are being used as inner-city environmental education centers. Greenways are increasingly used by city dwellers as a focal point for recreation, exercise, and other leisure activities. In addition, research is currently being conducted to identify the tree species that are best suited for planting as windbreaks, noise barriers, to abate hydrocarbon emissions, and as potential for summer shade to reduce energy costs in cities and suburbs. A baseline estimate of tree biomass in urban settings is necessary to be able to monitor the effectiveness of urban tree planting programs and to identify the size and species distribution of trees. To meet the inventory challenges of this resource where three-fourths of us find our habitat, FIA plans to:

- Develop a methodology for delineating and stratifying "Urban Forest Land"
- Test, and if necessary, modify existing procedures of land classification and estimation in order to conduct forest/tree inventories in densely populated areas
- Evaluate the extent of forest urbanization at present, track changes in "urbanized forest land", and evaluate the effects of urbanization on levels of forest management and ecosystem retention
- Design appropriate sampling procedures to study ecological systems along urban-rural gradients and to examine remnant forest patches, species composition, and vertical and horizontal vegetative structure
- Investigate new ways of describing the urban forest, such as leaf area indices or foliar volume
- Develop total tree biomass equations for urban trees by evaluating crown structure and relating canopy biomass to stem diameter for trees in urban settings. Determine the current extent and distribution of tree biomass, by species and size
- Identify the level of use and the extent of management for recreation and wildlife habitat associated with urban land uses, such as backyard forests, land supporting trees and shrubs but less than 1 acre (0.4 ha) in size, and strips of isolated trees along fences and streams in agricultural settings
- Evaluate the current levels of removals and mortality of trees in urban land uses and develop trend data by species and land-use classes
- Assess the impacts of urban expansion and other developments on the forest resources. Provide information on the forest area and tree volume found in close proximity to areas developed for permanent or seasonal homes, campgrounds, recreational resorts, and industrial complexes.

This direction will build upon the solid foundation that FIA has achieved since those first timber inventory plots were established in the 1930s, and will chart a course into the future that meets the needs of a much larger and more diverse public.

## THE NATIONAL FOREST SYSTEM INVENTORIES

The National Forest System (NFS) is the largest branch of the Forest Service. It is charged with the conservation and management of 191 million acres (77.3 million ha) of National Forests and Grasslands, which is an area roughly the size of North Dakota, South Dakota, Nebraska, and Kansas combined (about 9 percent the nation's total area). National Forests and Grasslands are found in 43 states and the territory of Puerto Rico. The Forest Service administers these lands through nine Regional Offices (Fig. 3), 156 Forest Supervisor's Offices and over 850 Ranger Districts. The lands and vegetation vary from ice caps and boreal rain forests in Alaska to sub-tropical forests of Puerto Rico, and from the eastern hardwood forests of the northeast to the chaparral and desert areas of the southwest.

Periodic information is required for all lands in the National Forest System including data on soil, timber, forage, water, air, fish and wildlife, recreation, wilderness, and energy and mineral resources for forest planning and national assessments.

Resource inventories and analyses have been conducted on the NFS lands since their creation by Congress--some over 100 years ago. Historically these inventories have been functional in nature, but are changing due to the nature and requirements of the integrated ecological approach to management required by forest plans. An integrated ecological approach to management results from an interdisciplinary team utilizing integrated data and information on all components of the ecosystem to produce integrated plans, prescriptions and management activities. The degree of integration of inventories to produce these data and information varies considerably from Region to Region and from Forest to Forest.

Under the National Forest Management Act of 1976, each National Forest must prepare a land and resource management plan. These plans require inventory data on the various forest and related resources as well as additional information and data about the interactions of the component parts of the ecosystem. Some regions have designed integrated inventories which are providing core information and supplementing it with additional functional inventory to satisfy functional needs. Still other regions are continuing with their functional inventories and supplementing them with additional inventories on other ecosystem components and with additional functional inventories. The trend toward integration of functional inventories will be covered in more depth later. Since there are so many diverse inventories on the National Forests, the best individual contact to inquire about information for a particular Forest or Region is the Deputy Regional Forester for Resources (see Appendix IV for addresses).

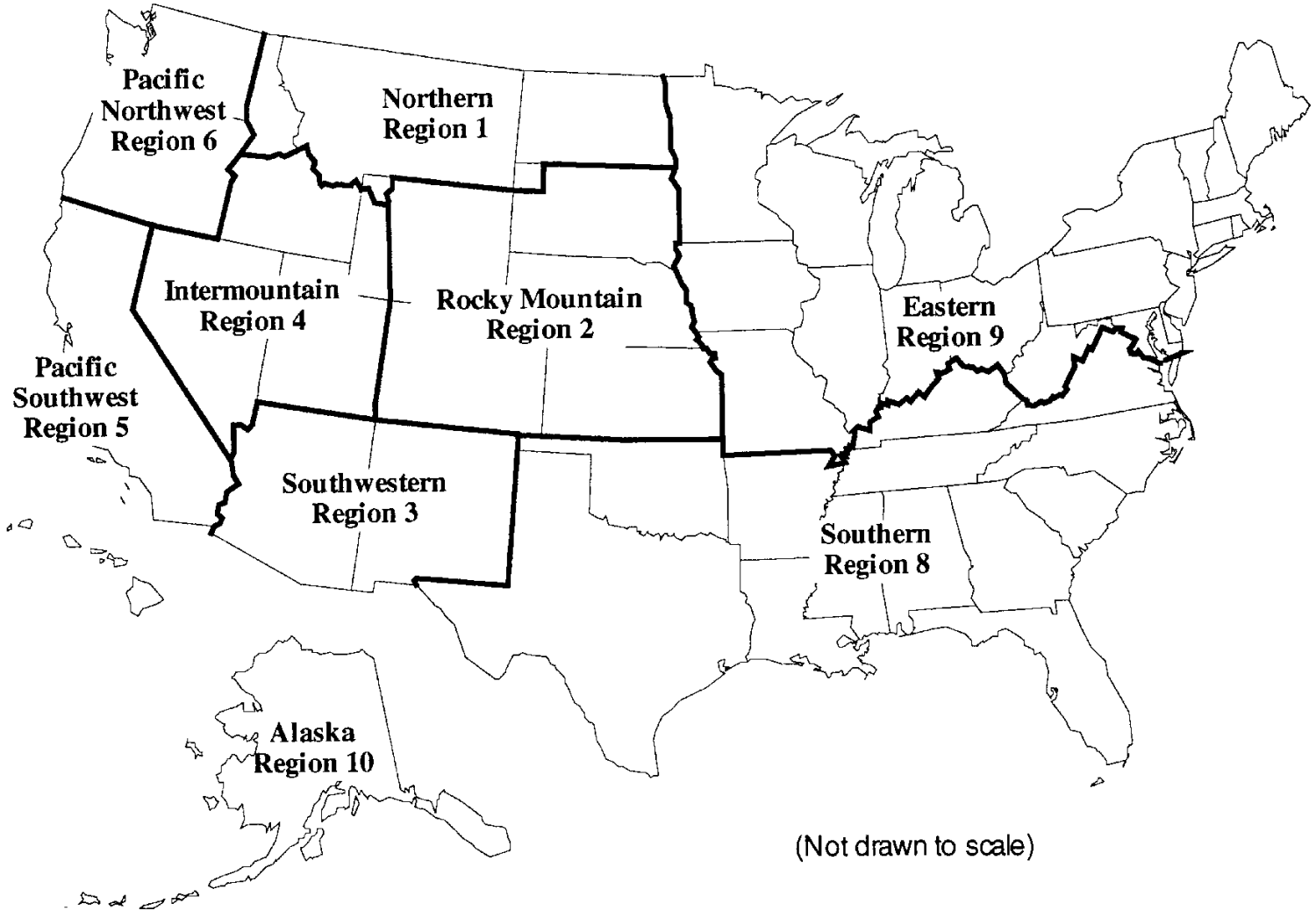
Inventories include range, timber, soils and geology, natural water occurrences (including quality and quantity), wetlands and flood plains, existing plant and animal life (including threatened and endangered species), habitat conditions for selected vertebrate or invertebrate species, quantitative data for determining species and community diversity, and cultural resources.

### *Range Inventory*

Range inventories began in the Southwest in 1911 on the Coconino National Forest to determine how much livestock the range could carry. Since then, almost all National Forest System rangeland has been inventoried in various ways and for a number of purposes, but primarily for on-site management of range allotments.

Methodology for sampling and collection of information has constantly improved, particularly with the assistance of Forest Service Research personnel, since the late 1920s. A classification of standard range types was pioneered by the Forest Service in the early thirties in cooperation with other government agencies.

# Figure 3.--NATIONAL FOREST SYSTEM (NFS) REGIONS



The original 18 standard range types are now being replaced by a classification based upon ecosystem concepts.

Current management plans are available on only 30 percent of 9,800 allotments which encompass 104 million acres (56.7 million ha) of National Forest System lands. Extensive revision of other out-of-date existing plans is underway to make them consistent with forest plan requirements. Inventories are being conducted within the framework of ecological unit inventories to determine lands suitable for livestock grazing, the kind of plant communities present, the ecological status of those communities, livestock forage conditions, the status of soil cover and soil stability, the trends in ecological status and soil stability, the capability of the lands to produce suitable food and cover for wildlife, and the effects of grazing.

The responsibility to develop specific standards and guidelines for range inventory are delegated to the Regional Foresters who establish handbooks which define acceptable inventory techniques and procedures. Variation between Regions is permitted to accommodate the natural variation between range ecosystems and to better serve local administrative and management needs.

### *Timber Inventory*

Timber resource inventories evolved in a similar manner, and are used mainly for planning, controlling, and monitoring the results of management of National Forest Systems lands. In most Regions, these inventories are in the third cycle and some areas have been inventoried five times.

Four types of inventories are employed by Forest Supervisors in managing the timber resource: forest-wide surveys; silivcultural stand examination; timber cruises; and regeneration examinations.

#### *Forest-wide Surveys*

The Forest-wide inventories are conducted at a 10-year intervals or as planning needs dictate. These surveys, which cover all forested land, are used to support land management planning efforts and the RPA Assessment and Program. All include some form of mapping the forest vegetation and some field sampling. Most inventories at this level are designed to provide data on vegetation for wildlife habitat as well as timber. The timber information includes tree volume, growth, and mortality. The eastern National Forest Regions contract for cooperative inventories with the local Forest Inventory and Analysis units. The National Forests provide the area statistics from stand maps, and FIA gathers the volume, growth, and mortality data.

Most western National Forest Regions use mapped stands as primary sampling units. Some Regions select a random sample of stands when establishing field measurement locations while others use a grid to locate field sample locations. Region 5 uses Landsat imagery to form mapping and sampling strata and SPOT imagery to update treatment areas. Region 6 uses Landsat-TM to classify and map vegetation condition classes. In most cases the maps become the sampling frame for ground samples.

*Silvicultural Examinations*

Silvicultural examinations are conducted generally on forest lands that will have some type of vegetation treatment applied. The treatment may be to increase timber production, improve wildlife habitat, increase snow accumulation, etc. Silvicultural prescriptions are developed using variable radius or fixed-area plots located throughout the stands. These examinations are made before stand treatment to determine need or after stand treatment to verify the treatment results. In addition to stand condition, some regions also gather habitat type, fuel loading, and wildlife use information. Results may presented in tabular or map format. Regions are moving towards tying the silvicultural examination and the forest-wide inventory into one integrated data collection system.

*Timber Cruises*

Before selling timber, or before land is exchanged or acquired, a timber cruise is essential for determining timber volume and value. Cruise design and intensity can vary from a probability-proportional-to-prediction (3P) sample to a 100-percent tally depending on the timber value and stand characteristics. The results are usually available at the Forest level.

*Regeneration Examinations*

These examinations are conducted within a sale area to determine if natural reproduction is adequate or if planted seedling survival is acceptable. The exams can entail establishment of fixed-area plots or line transects; usually within 5 years of the final harvest. The results are usually available at the Forest level.

### *Soil Inventory*

Soil resource inventories were initiated on National Forest System lands in the mid 1950s. These inventories are conducted at several different levels of intensity and provide information on soil capabilities and suitabilities. This information is used in the development of Forest and resource project plans. To date more than 90 percent of the National Forest System lands have some level of soil resource inventory information. Soil resource inventories are conducted using the standards of the National Cooperative Soil Survey. Soils are described and classified according to widely accepted soil taxonomy standards (Soil Survey Staff 1975).

### *Minerals Information*

Management issues involving minerals activities on public lands regularly arise, in part because many mineral related activities conflict with other proposed land uses. However, public lands are a major repository of energy and nonenergy resources essential to economic health and defense of the country. As a result, increasing attention and effort is being placed on identifying areas with a high likelihood for exploration, extraction and reclamation activity. To do so requires information regarding the location, extent and economic viability of mineral deposits.

Mineral resources are classified on the basis of geologic certainty of tonnage and quality. These range from occurrences whose existence and nature are well established by engineering measurements (identified resources) to those whose presence is implied by geochemical, geophysical or statistical data (undiscovered resources). In addition, they range economically from highly profitable to highly unprofitable.

Historically the Forest Service has not been responsible for developing national mineral resource inventories. These subsurface resources have largely fallen within the domain of three other Federal agencies. The U.S. Geological Survey has been and continues to be responsible for broad scale geologic mapping, including the identification of areas of high potential mineralization and estimation of oil and gas reserves. The Bureau of Mines estimates and reports production and reserves for nonenergy minerals. The Bureau of

Land Management is responsible for mineral lease and claim administration, as well as subsurface resource management.

In January of 1987 an Interagency Agreement among the Bureau of Mines, U.S. Geological Survey and U.S. Forest Service was signed instituting a program to appraise selected areas within the NFS for mineral resource potential. Areas of high potential mineralization are identified and the probabilities of mineral exploration and development assessed. This program is ongoing, with at least five Forests studied each year. In addition, mineral potential is estimated for all proposed land withdrawals, such as wilderness areas, and for areas undergoing NEPA review prior to oil and gas leasing.

The Forest Service estimates production of mineral commodities from NFS lands. Leasable mineral production (oil, gas, coal) is estimated from data reported by the Minerals Management Service. Production data for common variety minerals (sand, gravel) are collected by the Forests. Locatable mineral production is estimated by the Bureau of Mines, but is not available on a site by site basis. Nonetheless, Regional Minerals Staff personnel do estimate NFS based production from the available information.

On a broader scale, the Forest Service is undertaking an assessment of the mineral supply and demand situation nationwide. This report will include the mineral resource and reserve estimates, and production data, mentioned above. These data will be compared with consumption and import/export projections in an attempt to identify those minerals likely to face increased exploration and development pressures. In addition, the information will be combined with maps of high mineralization areas, and background information on potential resource conflicts and environmental degradation to present an overall picture of the minerals management issues facing the NFS.

### *Water Information*

Water was a prime consideration in the establishment of National Forests. The Organic Act of 1897 included a purpose of securing favorable conditions of water flow. The Weeks Act of 1911 recommended purchase of watersheds to regulate flows of navigable streams.

Some of the earliest forestry-related water data collections were in Colorado in 1910-1917 and New Hampshire in 1911-1912. The New Hampshire results documented the affect of forests on flow regulation and validated the assumptions of the Weeks Act. The Colorado results documented the beneficial affects of forest management on water yield.

Water resource information currently used in National Forest management includes information on surface and ground waters as well as climatic information. There are many legal requirements which necessitate water resource information. Securing favorable flows involves knowledge of runoff and channel conditions. Meeting the goals of the Clean Water Act requires information on resource condition, capability, and the cumulative effects of management. Reducing damages from flood loss requires information on flooding and flood plains.

Much of the data used for NFS management are collected by other agencies including the National Weather Service, U.S. Geological Survey, Soil Conservation Service, and State agencies. Because National Forests are important water source areas, many groups are involved in collecting water related information on National Forests. These groups are currently collecting information ranging from stream flow and snow pack to evaluating the affects of acid rain on remote lakes.

### *Fish and Wildlife Inventory*

Fish and Wildlife surveys and inventories are oriented more toward specific problems or needs. Each Region has conducted lake and stream habitat surveys, and participated in surveys for selected species, such as the bald eagle and osprey. Increasing attention to threatened and endangered species habitat has

emphasized the need for more data and information and a standard national approach to determine inventory needs for each specific species. To meet this need each Region has developed a regional data base which is part of the National Wildlife and Fisheries Habitat Relationships System (WFHRS). The data bases are necessary to accomplish wildlife and fisheries planning and to implement and monitor wildlife and fish habitats within the regions.

### *Other Information*

Other inventories needed for management include those for cultural and visual resources, recreation opportunities, facilities, and improvements, such as roads and trails. These are maintained at the Forest or Regional level.

### *Trend Toward Integrating NFS Inventories*

Single resource inventories no longer suffice to serve an increasingly sophisticated public that no longer views what the Forest Service does in functional terms. One approach to integrating diverse inventories is the development of standards for ecosystem classification and mapping. National direction was finalized in 1991 to provide an ecologically sound basis for resource management that integrates landscape components of soil, vegetation, landform, geologic material, topographic features, and climate. Ecological types are classified and used to design ecological inventories that stratify land into map units. The map units are categories of land that have a unique combination of vegetation, soil, landscape features, etc., and differ from other categories in ability to produce vegetation and respond to management. Interpretations are made for production capability, biological diversity, and to predict ecosystem responses to various management practices.

This effort led, in 1992, to a Service-wide workshop in Salt Lake City, UT, where the agency embraced the concept of ecosystem management, which calls for inventories that will eventually transcend specific resource or value boundaries and will provide a holistic assessment of the composition and function of our National Forests and Grasslands. The Forest Service has recognized that integrated management is critical to performing the mission and business of the organization. To be responsive to today's needs requires the creation of an integrated data/information environment throughout the agency. The Forest Service has embarked up an aggressive program to adopt standards that will allow it to facilitate that process.

One major trend that shows great potential to assist the agency is the increasing emphasis on spatial data and analyses. The Forest Service is in the midst of planning and implementing a nationwide computer-based geographic information system that will revolutionize the production and use of spatial data within the agency. By using a common structure for organizing geographic information into themes and features (Computer Sciences and Technology 1991), the functional barriers between traditional inventories can be substantially reduced. As mentioned later in discussing major partnerships (see section ***Forest Service and Other Federal Agencies***), the agency is active in three cooperative efforts involving spatial data. By creating and using data standards and sharing information, duplication of effort and waste of personnel and funding resources can be minimized.

## LINKAGES AMONG FOREST SERVICE INVENTORIES

In a highly decentralized agency with so many different types of inventories and so many different inventory organizational units, the concept of aggregating and compiling data for regional or national summaries appears problematic. But while admitting that there is considerable work yet to do in this area, the Forest Service does have several procedures, mechanisms, and relationships in place to accomplish this formidable task.

The Washington Office staffs provide valuable coordination assistance to their respective field units. Having a national perspective, they are in position to provide "side boards" within which regional inventories may operate to meet local needs while also serving national clientele. These "side boards" are normally a minimum set of national standards or requirements (usually issued as manual or handbook direction as in Appendix I) that each field unit should be able to produce. Beyond this minimum set, the field units are free to collect other data and analyze them as they see fit to meet the demands of local user groups. WO staffs also organize meetings, conferences, and workshops of inventory specialists to discuss issues and develop solutions to problems of common concern.

### *Linking FIA Inventories*

With only six FIA units conducting inventories that are generally more uniform than those of NFS, there is a shared concern and a common interest in working together to provide consistent, high-quality inter-regional data and information.

Since FIA inventory results are routinely reported in tabular form, one useful approach to standardizing has been to agree to a common set of basic tables. During a review of the FIA program in November 1983, and again in a followup review in October 1985, an important recommendation was that consistent data were needed among Forest Service Experiment Stations. With the help of the American Pulpwood Association's Southwide Forest Survey Task Force, the Southern Industrial Forestry Research Council, and the assistance of many reviewers from forest industry, the universities, and state and other public agencies, a set of 25 core tables were adopted by the Experiment Stations in the East in 1986. This commonality of information was extended to the western FIA units in 1990 and 22 tables have been adopted that will accommodate the general needs of a large segment of western clients. Nine of the western core tables are identical in content to the eastern core tables. With these core tables it is now much easier for a user to compare the forest resources of areas in different states and to assess the total resource of an area that crosses state and/or region boundaries.

A more recent effort to provide FIA data consistent throughout the east has been the creation of the Eastwide Data Base (EWDB) for FIA inventory data. The idea of the EWDB was for each project to produce a set of data files for the most recent inventory of each state in its area of responsibility (Fig. 1). All the files are in the same format and contain all data items needed to produce the core tables. Additional data items common to all four projects are also included (see Table 1). The EWDB data file can be produced for a state as soon as the regular data processing of an inventory is completed. An outside user can then obtain a copy of this file for a flat fee per state and use it to do analysis suited to their individual needs (Hansen et al. 1992). The data base is typically used for regional analyses of timber resources (e.g., volume, growth, removals, and mortality) for area ranging in size from a few counties to a number of states. The data base offers a major advantage over core tables in that there is considerably more flexibility to produce whatever table is desired.

### *Linking FIA and NFS*

National Forest Systems administrators are major land managers and are responsible for intensive management-level inventories on National Forest lands. In the East, where the majority of the FIA program is located, FIA conducts extensive inventories on both public and private land. The two inventory activities are complementary. Land management questions can best be answered by map-based NFS inventories, while questions that are regional in nature and that effect all forest land ownerships can best be answered by the FIA sample-based inventories. As the Forest Health Monitoring program (see section under **MAJOR PARTNERSHIPS AND COOPERATORS**) is implemented, FIA will be establishing and maintaining these field-plots at FIA photo- or field-plot locations on all forest land ownerships and thus will have opportunities to strengthen its partnership with NFS.

The most basic and fundamental linkages between FIA and NFS occurs at the field locations. Each FIA work unit has NFS cooperators for its geographic region. Personnel from each Forest Service branch work together in diverse ways depending on the region and the issue at hand.

In the East the four FIA projects (Fig. 1) work directly with the two NFS regions (Fig. 3). During the initial phase of each statewide inventory with NFS lands, the FIA personnel meet with each affected National Forest. They explain the kinds of data FIA collects and how they will be available upon completion of the survey. In many cases, FIA publishes a separate statistical report of the forest resources of individual National Forests. During these planning meetings, the Forest staff has opportunity to request additional data, and negotiations and agreements are pursued for mutual benefit. The Forests often provide assistance during the data collection phase, such as necessary road access, office and/or lodging facilities, and sometimes actual assistance in plot establishment and sample tally. The FIA unit and the Regions sign cooperative agreements and arrange for NFS funds to cover FIA costs for the inventory of National Forests.

In the West, where the area administered by NFS is so large, cooperation takes a different form. The FIA units rely on the NFS Regions and Forests to supply them with data from their NFS inventories so that FIA may report on the forest resources of entire states, regardless of ownership. NFS inventory plans are reviewed and approved by the corresponding FIA unit to assure that all required data are provided.

While such arrangements do avoid costly duplication of effort, it is still a time consuming and often tedious job for NFS inventories to be satisfactorily blended into the FIA unit's system and data bases. New arrangements are being explored between FIA and NFS to improve this situation. One promising example is the current inventory of Utah where FIA crews are measuring plots "wall-to-wall" across the state no matter what the ownership of the plot. Region 4 and the Intermountain FIA unit are trying this out as a test case with the option of expanding it to other states if it is successful. The Pacific Northwest FIA unit and Region 6 are working jointly on a strategic plan for inventory in the Northwest to insure that the combined efforts meet all inventory needs and objectives for all lands.

On a national level, the primary way that inventories from FIA and NFS are linked is through the RPA Assessment process. The Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA) as amended by the National Forest Management Act of 1976 is intended to help guide Forest Service planning and management activities on National Forest land. These statutes direct that an assessment of all renewable resources be made every 10 years. For the 1990 RPA Assessment, the Assessment Management Group (AMG) established a permanent national data base that contained plot, stand, or stratum level data from the 9 Regions and 6 FIA units across the nation. Each of these individual data bases had a common data structure (with identical codes and data formats) and was stored in a central location. In the intervening years many new inventories have been conducted in National Forests and States. There was the perception that significant changes had occurred in several regions of the country. In order to substantiate this and to provide current data for the many users of this information, the AMG decided to update the data base and forest statistics. This effort is called the 1993 RPA Assessment Update. If it meets expectations, this 5-year updating period may replace the 10-year standard.

These RPA Assessments are the latest in a series of comprehensive reports at the national level that have appeared periodically throughout this century. Working back in time, here are some national timber reports that the Forest Service has prepared or contributed towards:

| *Year* | *Report* |
|---|---|
| 1987 | Forest Statistics of the United States, 1987 (Waddell et al. 1989) |
| 1977 | An Analysis of the Timber Situation in the United States 1952-2030 (U.S. Forest Service 1982) |
| 1970 | The Outlook for Timber in the United States (U.S. Forest Service 1974) |
| 1962 | Timber Trends in the United States (U.S. Forest Service 1965) |
| 1952 | Timber Resources for America's Future (U.S. Forest Service 1958) |
| 1945 | Reappraisal Report (U.S. Forest Service 1948) |
| 1938 | Forest Lands of the United States (U.S. Congress 1941) |
| 1930 | Copeland Report (U.S. Forest Service 1933) |
| 1920 | Capper Report (U.S. Forest Service 1920) |

These reports provide insight into national and regional trends in forest area and timber resource use, condition, and development. An important function of national reports is the forecasting of future timber supply. Elements of change can be analyzed in relation to economic indicators to strengthen our forecasting capabilities. Such forecasts influence policy decisions of the legislative and executive branches of the Federal government, state organizations, and many of the forest industries. National reports have served a key role in bringing the various inventories conducted by the Forest Service together and demonstrating their utility to our society.

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## MAJOR PARTNERSHIPS AND COOPERATORS

Cooperation and coordination of Forest Service inventory efforts with other interested parties to obtain maximum efficiency and effectiveness are continuing goals. Because analyses need to encompass the myriad resources of forest and rangelands, the opportunities for added cooperation are more important than ever. New disciplines within the natural resources field are being contacted and made aware of our inventories. Experience to date has revealed a wealth of untapped information that can be included in statewide resource analysis. Budget constraints provide additional incentive to forge beneficial partnerships.

### *International Cooperation*

International cooperation between Forest Service inventory specialists and foreign counterparts has been steadily increasing. Here are some examples of the diverse nature of these relationships:

- Various Forest Service personnel were detailed to the United Nations Food and Agriculture Organization (FAO) in Rome to assist the 1990 Global Assessment team by providing statistical and analytical support
- Forest Service personnel provided a review of planning documents dealing with standards, definitions, and procedures for monitoring tropical deforestation in developing countries--both for current and future assessments

- A Rocky Mountain Station scientist developed statistical procedures for pilot tests of land use change in Brazil and Mexico. These satellite and ground verification procedures can be applied to tropical forests world-wide
- The Southern Station Forest Inventory and Analysis unit is training Mexican cooperators on the basics of remote sensing and is demonstrating remote sensing capabilities through development of a land cover map of Mexico
- In the Pacific Rim region, the Pacific Northwest and Intermountain FIA units worked with Taiwan in setting up an inventory system and organization. The Pacific Northwest and Southwest Research Stations have also worked with the Federated States of Micronesia on inventories and assessments
- Forest Service personnel are assisting the International Union of Forestry Research Organizations in developing guides for world forest monitoring.

growth of the new International Forestry Deputy area of the Forest Service and the addition of a full-time international inventory expert to the Washington Office Forest Inventory and Analysis staff indicate the expanded role of the agency in working with diverse organizations and cultures on challenging resource inventory problems and opportunities.

*Forest Service and Other Federal Agencies*

Legislation such as the Federal Land Policy and Management Act of 1976 (P.L. 94-597) and the Soil and Water Resources Conservation Act of 1977 (P.L. 95-192), while not directed toward the Forest Service, do share common themes with the Forest Service legislative mandates. These acts direct the Bureau of Land Management and Soil Conservation Service, respectively, to (1) prepare and maintain continuous resource inventories, (2) coordinate and cooperate with resource agencies and organizations to avoid duplication of inventory and planning efforts, (3) determine the changes in status and condition, both current and potential, of the resource base, (4) determine resources interactions and management alternatives, and (5) submit periodic assessment reports for the natural resources under their jurisdiction. The importance of cooperation and coordination between the Forest Service and other agencies is highlighted during natural resource inventories for national planning purposes.

The Soil Conservation Service and the Forest Service, both U.S. agencies, have a special relationship. A signed, formal agreement states that the "Forest Service will be responsible for forest resource inventories" and "FS and SCS will work together on inventory...to identify data needs, avoid duplication of efforts, and assure that data collected by each agency are mutually useable." It further states, that SCS and the FS will "...develop common methodology and standards, and broaden opportunities for sharing information." In recent years, cooperation during several statewide inventories has resulted in the verification and upgrading of SCS soils maps and the addition of soils information when evaluating forest productivity. Joint research studies were conducted in Arkansas and Florida to identify similarities and differences in inventory results. A major cooperative effort is underway to use the best features of each agency's inventory approach to efficiently assess the relatively sparse forest resource of Kansas, Nebraska, South Dakota, and North Dakota. Each agency has inventory responsibilities, and they plan to cooperate closely during current and future SCS National Resources Inventories and FS Resource Planning Act Assessments.

The Forest Service recognizes that it is not the only agency dealing with spatial (i.e., geographically referenced) data. Efforts to minimize duplication are focused in three major interagency efforts.

The first is a massive undertaking in cooperation with dozens of Federal agencies. In October 1990 the Office of Management and Budget (OMB) issued the revised OMB Circular A-16, "Coordination of Surveying, Mapping, and Related Spatial Data Activities." This revision established the Federal Geographic Data Committee (FGDC) to promote the coordinated development, use, sharing, and dissemination of surveys, maps, and related spatial data. The work of the FGDC is accomplished by several subcommittees with the Forest Service

having lead responsibility for the Vegetation Subcommittee. Membership of this committee represents 14 different agencies with responsibilities involving spatial vegetation data.

The second interagency effort is the U.S. Geographic Information System Work Group, which was established in 1989 by the Assistant Secretary U.S., serving as the Chairman, Natural Resources and Environment Committee. The Forest Service and Soil Conservation Service were appointed to co-chair the work group. The primary objectives are 1) to promote coordination of GIS activities within the Department and awareness of emerging GIS issues, 2) to promote the development of Agency-wide, Department-wide, and/or Government-wide standards for digital data bases that support comprehensive GIS use, and 3) to promote cooperation and data exchange with state and local government agencies that are developing and using GIS technology.

The third cooperative effort is the Spatial Data Management Committee (SDMC), which consists of the Geological Survey, the Forest Service, and the Bureau of Land Management. All have major programs which deal with the production, management, and dissemination of digital data. In order to better coordinate activities, an Interagency Agreement was signed by the three agency heads November 1988. The objective of the agreement is to initiate cooperative activities to eliminate duplication of effort and assure consistency of digital data. Under the agreement, the relationships and linkages between major systems being developed by each organization in support of their own missions are being identified and appropriate interagency coordination mechanisms are being established. In addition, the agreement is addressing coordination of certain specific digital data collection activities for base category, Public Land Survey System (PLSS), and other thematic or resource data which potentially may be shared between agencies.

*Forest Health Monitoring*

Recognizing that pollution, insects, diseases, fires, and other disturbances were increasingly stressing our forest resources and that the public and Congress (e.g., Forest Ecosystems and Atmospheric Pollution Research Act of 1988) were demanding answers relating to ecosystem health, the Forest Service has developed a national forest health monitoring program (FHM). The program employs remote sensing in combination with annual visits to permanent sample plots to (1) detect and describe symptoms of changes in forest health, (2) evaluate the role of stress factors in forest health, and (3) understand and predict consequences in order to respond with appropriate management. Monitoring occurs at three tiers: (1) detection, (2) evaluation, and (3) intensive-site ecosystem. The FIA role is primarily in the detection phase: answering questions of what, where, and when by recording the condition of forest ecosystems, estimating baseline conditions, and detecting changes from the baseline. Evaluation monitoring is the primary responsibility of the Forest Pest Management Staff of State and Private Forestry. They assist in detecting changes and take the process one step further by determining the causes of the detected changes. When cause is identified, then corrective actions can be identified and implemented. The third tier involves long-term studies at major research sites across the country, and its focus is on ecological processes and mechanisms. FHM began with detection monitoring in New England in 1990 and is gradually being implemented throughout the nation. Close cooperation has been established with the State forestry agencies, and as implementation expands the National Forest System will take a more active role.

The Environmental Protection Agency (EPA) also supports a monitoring program, Environmental Monitoring and Assessment Program (EMAP). This program is also designed to respond to the growing demand for information characterizing the condition of the nation's ecological resources and the type and location of changes in these resources. EMAP focuses on 6 major systems: forests, wetlands, surface waters, near coastal ecosystems, agroecosystems, and arid ecosystems (EPA 1990). Because of obvious overlap of interests and concerns, the Forest Service and EPA have developed close cooperative ties, especially between FHM and EMAP-Forests. This partnership involves joint planning; budgeting; quality control and quality assurance; indicator development; pilot testing; field procedures, data collection, processing and compiling; analyses; and publication of results. EMAP-Forests will also provide ancillary data that will help in interpretation of detection monitoring results.

*Other Major Partners and Cooperators*

States have a long tradition, both directly and through the National Association of State Foresters, of providing cooperative assistance to Forest Service inventories, especially Forest Inventory and Analysis. Individuals within State agencies serve on important forest inventory advisory committees. During periodic reinventories, states may provide financial support to increase the sample intensity. State personnel provide training to field crews in insect and disease detection, manpower, field equipment, vehicles, and aerial photography for both forest inventory and forest health monitoring activities. State Forestry staffs also assist in gathering commodity drain and forest landowner data at specified intervals, and they review forest resources reports and assist in disseminating results to the clients and data users.

Forest industry has long been an active cooperator with and supporter of the FIA program. Industry is a major user of resource inventory data, and is the primary advocate for keeping resource data current through shortened inventory cycles. They participate with FIA through the Research Committee of the American Forest Council to provide review and advice on technical inventory matters. In 1991, this committee chartered a Blue Ribbon Panel to evaluate the current FIA program, determine future demands of all user groups, identify how FIA could better serve its users, develop public recognition that FIA data are basic and are needed by society as a whole, and to generate Congressional and Administration funding support for FIA programs.

In recent years, conservation groups, including the Wilderness Society, Friends of the Earth, Audubon Society, and the Sierra Club, have made increasing use of Forest Service multi-resource inventory data and analyses. With increased recognition of the value and uses of this information, these groups and others are becoming more active supporters and cooperators. These groups provide useful guidance on how to inventory and assess forest resources more effectively.

Universities participate actively in recruitment of students for both seasonal and permanent Forest Service inventory positions. In addition, researchers at universities are involved in formal cooperative agreements with FIA research units for research and analysis using resource inventory data. Forestry extension activities at universities are an important means for transferring inventory findings and technology.

Last, but not least, national Forest Service inventories would not be possible without the permission and cooperation of the thousands of individuals, organizations, and companies who own the land where Forest Service inventory plots are located. Access to these sample areas are critical to successful and accurate reporting of forest resources, so these landowners, as a collective group, are indeed major partners and cooperators.

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## APPENDIX I. FOREST SERVICE DIRECTIVES PERTAINING TO INVENTORIES

| *Reference* | *Caption* |
|---|---|
| | **Series 1000 - Organization and Management** |
| FSM 1390 | Information Management |
| FSH 1309.14 | Information Requirements Handbook |
| FSH 1909.12 | Land and Resource Management Planning Handbook |
| FSH 1909.14 | Resource Inventory Handbook |
| | **Series 2000 - National Forest Resource Management** |
| FSM 2060 | Ecosystem Classification, Interpretation, and Application |
| FSM 2070 | Biological Diversity |
| FSH 2090.11 | Ecological Classification and Inventory Handbook |
| FSM 2210 | Range Management Planning |
| FSM 2270 | Range Information Management and Reports |
| FSH 2209.14 | Service-Wide Range Analysis and Management Handbook |
| *Recreation, Wilderness, and Related Resource Management* | |
| FSM 2310 | Planning and Data Management |
| FSM 2320 | Wilderness Management |
| FSH 2309.11 | Recreation Information Management Handbook |
| *Timber Management* | |
| FSM 2410 | Timber Resource Management Planning |
| FSM 2440 | Designating, Cruising, Scaling, and Accountability |
| FSM 2490 | Timber Management Information System |
| FSH 2409.11 | National Forest Log Scaling Handbook |
| FSH 2409.11a | Cubic Scaling Handbook |
| FSH 2409.12 | Timber Cruising Handbook |
| FSH 2409.13 | Timber Resource Planning Handbook |
| FSH 2409.13a | Timber Permanent Plot Handbook |
| FSH 2409.14 | Timber Management Information System Handbook |
| FSH 2409.15 | Timber Sale Administration Handbook |
| *Watershed and Air Management* | |
| FSM 2510 | Watershed Planning |
| FSM 2520 | Watershed Protection and Management |
| FSM 2530 | Water Resource Management |
| FSM 2550 | Soil Management |
| FSM 2580 | Air Resource Management |
| FSH 2509.16 | Water Resource Inventory Handbook |
| FSH 2509.17 | Water Information Management System Handbook |
| FSH 2509.18 | Soil Management Handbook |

| *Reference* | *Caption* |
|---|---|
| *Wildlife, Fish, and Sensitive Plant Habitat Management* | |
| FSM 2620 | Habitat Planning and Evaluation |
| FSM 2630 | Management of Wildlife and Fish Habitat |
| FSM 2650 | Animal Damage Management |
| FSM 2670 | Threatened, Endangered and Sensitive Plants and Animals |
| FSH 2609.13 | Wildlife and Fisheries Program Management Handbook |
| *Minerals and Geology* | |
| FSM 2880 | Geologic Resources and Services |
| **Series 3000 - State and Private Forestry** | |
| *Rural and Urban Forestry Assistance* | |
| FSM 3250 | Forest Soil and Water Management |
| *Forest Pest Management* | |
| FSM 3410 | Pest Detection |
| FSH 3409.11 | Forest Pest Management Handbook |
| *Cooperative Watershed Management* | |
| FSM 3570 | Hydrologic Surveys and Analyses |
| **Series 4000 - Research** | |
| FSM 4810 | Forest Inventory and Analysis |
| FSH 4809.11 | Forest Survey Handbook |
| **Series 5000 - Protection and Development** | |
| *Fire Management* | |
| FSM 5150 | Fuel Management |
| FSH 5109.19 | Fire Management Analysis and Planning Handbook |
| **Series 7000 - Engineering** | |
| FSH 7109.13b | Cartographic Specifications and Symbols Handbook |

## APPENDIX II. FIA CONTACTS

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## APPENDIX III. FIA SAMPLING APPROACHES

*PNW (Pacific Coast) FIA Unit*

Two approaches are used. In Alaska, the sample populations are first identified by broad vegetation classification based on satellite digital data. Within these populations, the primary sample consists of a random selection of satellite pixels transferred to aerial photographs. Items classified on the primary photo samples include land class, ownership, forest type, and timber volume class. Secondary samples for ground examination are selected from the primary samples. All strata are sampled but the sampling intensity on nonforest strata is less than in forested strata. In other Pacific Coast states, the primary sample is defined by a systematic grid of permanent, mapped points. At each grid point, aerial photos are used to classify the land into strata similar to those used for Alaska. Secondary samples for ground examination are selected systematically from the primary sample locations. Secondary sample intensity can be varied to meet special objectives for individual sampling units.

*Intermountain (Interior West) FIA Unit*

The general approach is a stratified double-sampling design. The primary sample is defined by points on a systematic 1,000-meter grid. Each grid point is located on an aerial photograph for interpretation. Items identified for stratification include ownership, land class, and forest type group. The interpreted items are used to define sampling strata. The secondary ground sample is a subset of the primary sample at 5,000-meter intervals. A supplemental 5,000-meter field grid is available for sampling intensification as required by cooperators, and additional samples can be selected from the 1,000-meter primary grid.

*North Central FIA Unit*

Using a systematic grid of 121 plots per township (36 square miles or 9,324 hectares) on aerial photographs, each photo plot is classified steroscopically based on land use, forest type, size, and density. Areas are allocated to ground locations, which are a systematic subsample of the photo plots using random allocation. The total number of ground plots sampled in an inventory is a function of the expected variability of the resource, the expected accuracy of the aerial photo interpretation, and the desired sampling errors.

*Southern (Mid-South) FIA Unit*

Estimates of timberland area are based on forest-nonforest interpretation of plots on aerial photographs. These plots represent approximately 230 acres (93 ha). The land use interpretations are checked in the field at sample locations representing approximately 3,840 acres (1,554 ha). After using these checks to adjust the photo interpretations, an estimate of the proportion of forest to nonforest area is then made for each county,. The proportion of forest area is combined with U.S. census land area data to derive county-level forest area statistics.

Descriptive forest resource statistics are derived from measurements at permanent sample plots located at the intersections of a 3- by 3-mile (4.8 x 4.8 km) grid; each plot represents, on average, 5,760 acres (2,331 ha). The sample plots are remeasured each survey to allow assessment of change (i.e., growth, removals, and mortality estimates) and of current resource status.

At each forested sample plot on the 3-mile (4.8 km) grid, trees are measured on a cluster of ten sample points. Trees at least 5.0-inches (12.7-cm) diameter at breast (dbh) are selected using a 37.5-factor prism; each sample tree thus represents 3.75 square feet (0.35 square meters) of basal area. Trees smaller the 5.0-inches (12.7-cm) dbh are sampled on a 1/275-acre (0.0015 ha) circular plot at the first three points of the ten-point cluster. Using several tree measurements, volumes are computed using Smalian's forumla.

*Northeastern FIA Unit*

A primary sample is obtained from a grid of photo points overlaid on aerial photographs of the inventory area. Interpretation of each photo point is for land use and timber volume class stratification. A secondary sample is taken for on-the-ground examination; samples include all ground plots measured at the last occasion and new ground plots that are added to make the ground sample proportional to the primary sample. Data from all plots, new and remeasured, are combined to calculate a combined estimate of current volume.

*Southeastern FIA Unit*

In the first phase (of a two-phase design), a large number of 16-point cluster samples are interpreted from aerial photographs for forest, nonforest, and non-census water land use. In phase 2, a smaller set of 16-point cluster samples are centered over each permanent ground sample and classified in the same manner as described above and then checked on the ground. The 16-point clusters checked on the ground are used to adjust the area estimates from the photo sample. A linear regression is fitted to develop a relationship between the photo and ground classification of the sub-sample. The entire photo estimate in phase 1 is adjusted for change in land use since the date of photography and for misclassifications.

The inventory volume design consists of all the permanent sample points that fall on timberland. These are used for volume-per-acre estimates, number of trees, and stand attributes. Each permanent forest inventory sample that is relocated and remeasured is used to estimate growth, removals, and mortality.

## APPENDIX IV. NATIONAL FOREST SYSTEM CONTACTS

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Deputy Regional Forester for Resources
U.S. Forest Service Intermountain Region (R-4)
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