Coordination, Cooperation, and Collaboration between FIA and NRI

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Abstract.—The USDA Forest Service conducts a detailed survey of the Nation's forests through the Forest Inventory and Analysis (FIA) program. The USDA Natural Resources Service conducts an entirely separate survey, the National Resources Inventory (NRI), to monitor status and trends in the Nation's soil and other natural resources. Blue Ribbon Panels for both FIA and NRI have recommended better cooperation and collaboration. In response, a joint venture among the State of Minnesota, the U.S. Geological Survey, NRI, and FIA searched for potential synergies by fusing FIA and NRI plot data with Landsat imagery and a statewide geographic information system. FIA and NRI plot data did prove useful as training data for classifying land cover, and as supplemental labeling data for detecting changes with multi-date Landsat imagery.

The U.S. Department of Agriculture (USDA) conducts three statistical surveys of the Nation's natural resources:

1. The USDA National Agricultural Statistics Service (NASS) estimates annual production and supplies of food and fiber, prices paid and received by farmers, farm labor and wages, and farm aspects of the agricultural industry (e.g., pesticide use). The annual NASS budget is approximately $100 million.
2. The National Resources Inventory (NRI) is conducted by the USDA Natural Resources Conservation Service (NRCS) on all non-Federal lands. NRI estimates the extent of different kinds of land cover and land use in the USA; indicators of soil condition and erosion; and the extent and changes in land management; wetlands; and other natural resources. For example, NRI estimates area of cropland, pastureland, rangeland, land enrolled in the Conservation Reserve Program, other rural land, builtup and urban land, water bodies, and forestland (including nonstocked and 22 broad categories of forest type).
3. The Forest Inventory and Analysis (FIA) program is conducted by the USDA Forest Service. FIA estimates tree, site, and stand conditions of the Nation's forests. For example, FIA estimates the area of forestlands by many detailed categories of stand conditions. The FIA budget was $49 million in 2001, with an additional $8 million in State funds (USDA 2002).

Each of these USDA surveys is well designed to implement a different congressional mandate that relates to the inventory of natural resources. Each mandate serves a distinct group of customers, each with its own unique blend of natural resource issues. Each survey uses its own sampling designs,

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protocols, and definitions that are designed to best serve its own mission.

Unfortunately, differences among USDA surveys create discrepancies among a few important variables that overlap surveys, such as area of forestland. For example, NRI estimates for acres of forest can differ from FIA estimates by over 30 percent (fig. 1). Why? FIA and NRI define urban and builtup lands differently. They can use different sources and dates of administrative data to develop area expansion factors. While both FIA and NRI define forest to be at least 10 percent stocked, this definition is applied with different protocols. NRI classifies some land with forest cover as Conservation Reserve Program (CRP), while FIA classifies the same lands as forest. In Minnesota, NRI often classifies as forest the tall shrubland within the transition zone between forest and inland marshes and swamps, while FIA classifies the same areas as nonforest. FIA classifies vast areas of oak, pinyon, and juniper woodland as forest in the interior west, while NRI often classifies the same areas as shrubland or rangeland.

In 1998, a team of senior scientists from the FIA, NRI, NASS, U.S. Geological Survey (USGS), Bureau of Land Management, and Environmental Protection Agency demonstrated the feasibility of combining FIA and NRI surveys while preserving critical historic information (House *et al.* 1998, USDA 1998b). They formulated a framework for estimating the extent of forest and rangeland that explains the discrepancies between FIA and NRI estimates. This framework envisioned a joint USDA inventory and monitoring effort for terrestrial natural resources that links the FIA and NRI surveys through a co-located subset of sample plots and a shared database.

Figure 1.—*Differences between NRI and FIA in estimated number of acres of forest. Discrepancies are primarily caused by differences in measurement protocols and definitions for land cover v. land use.*

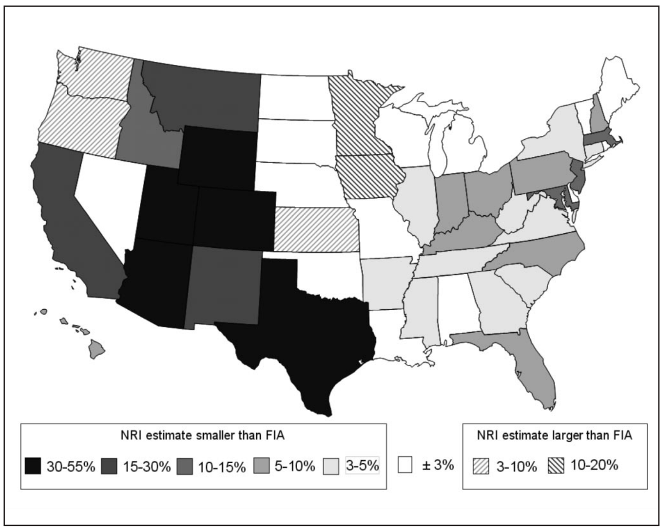
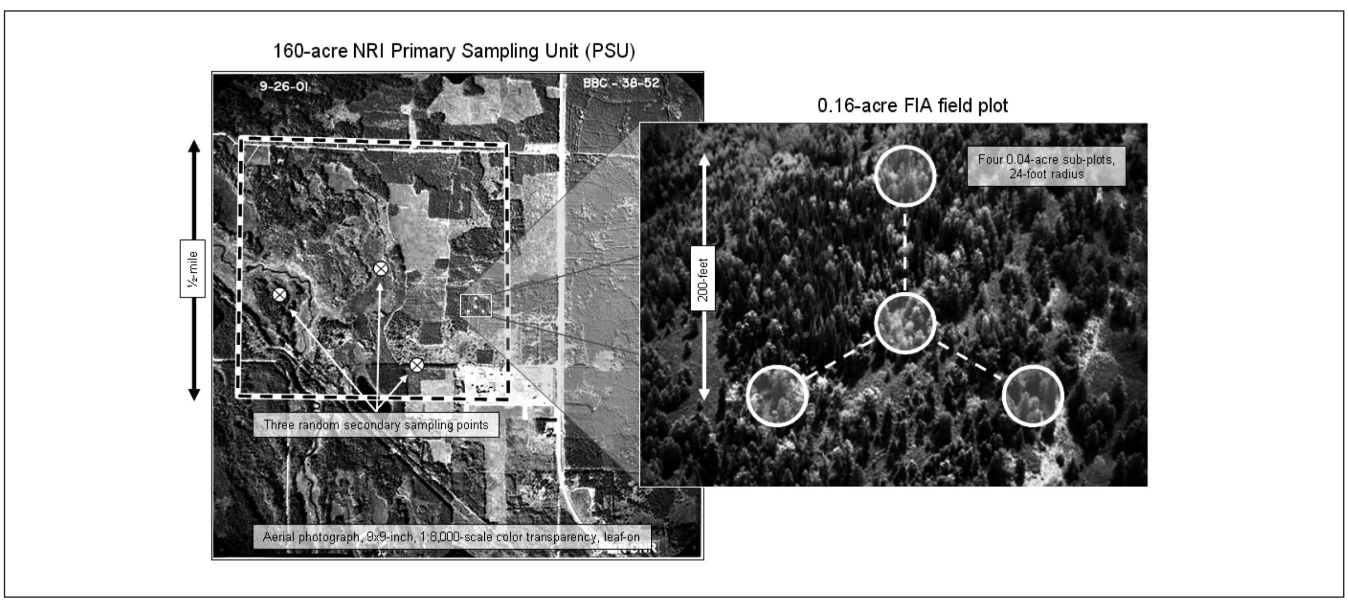


Figure 2.—*Comparison of a 160-acre NRI Primary Sampling Unit with a FIA 1-acre field plot. The NRI 1:8,000-scale aerial photographs encompass approximately 5 percent of the landscape; therefore, only about 5 percent of FIA field plots are imaged within NRI sample photographs. These are demonstration plots, and they are not part of the FIA or NRI sampling frames.*



Beginning the following year, a second team of scientists investigated a fusion of the independent databases produced by FIA and NRI within a geographic information system (GIS), without a shared subset of co-located sample plots. This paper briefly summarizes the results of these latter experiments and suggests future experiments to improve collaboration between FIA and NRI.

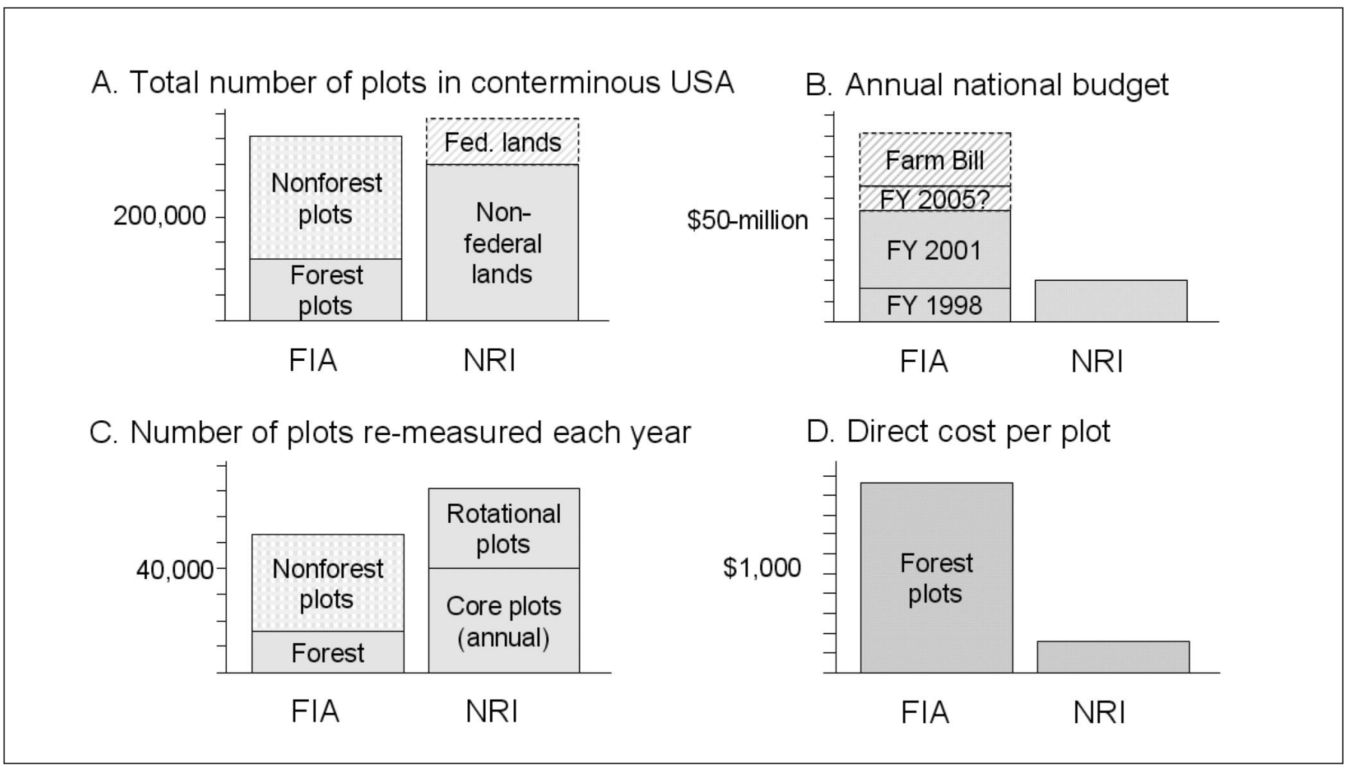
Comparison of FIA and NRI Surveys

FIA maintains one field plot for every 6,000 acres, regardless of land ownership or presence of forest cover. FIA uses a systematic sampling grid and equal selection probabilities for each plot. NRI uses one plot per 8,000 acres of non-Federal lands, with more intensive sampling where land use and resource patterns are more heterogeneous. These unequal selection probabilities increase statistical efficiency and accommodate special analyses. NRI does not currently measure plots on Federal lands.

FIA relies primarily on re-measurement of field plots. While expensive, field measurements are required for accurate estimates of tree- and site-characteristics. However, FIA uses remote sensing to improve precision of statistical estimates[8] of forest area using low-resolution aerial photography or Landsat satellite imagery. NRI primarily uses high-resolution aerial photography to measure status and changes in land cover, land use, and land management practices. These changes are especially important in NRI erosion estimates. NRI uses a limited amount of fieldwork to measure features they believe do not often change over time, or cannot be accurately obtained with aerial photography.

The FIA field plot has four subplots that together encompass about 0.17-acres (fig. 2). The NRI plot, referred to as the Primary Sampling Unit, or PSU, is typically 160-acres (fig. 2). Most NRI plots have three secondary sampling points, at which detailed photointerpreted measurements are made. In recent years, NRI has made these measurements with custom 1:8,000-scale aerial photos. These sample photographs pro-

Figure 3.—*Comparison of FIA and NRI based on number of plots and cost (USDA 1999, 2002).*



[8] FIA uses post-stratification, double sampling for stratification, or double sampling for regression to reduce variance for estimates of forest area. This also reduces variance for estimates of population totals, such as volume.

vide unusually high resolution for interpretation of forest cover and land use. For example, resolution at this scale is sufficient to detect single-family houses under a tree canopy and individual tree mortality.

There are about 360,000 permanent FIA field plots in the U.S. (fig. 3A), located on both private and public land. About 120,000 of those are forested and are intensively measured by field crews. The remaining 240,000 are nonforested and are not measured in significant detail. NRI has about 300,000 NRI plots in the U.S., all of which are measured regardless of their land use. However, NRI does not measure Federal lands; an additional 75,000 NRI plots would be required to cover this land (fig. 3A). Most NRI plots include three secondary sampling points (fig. 2).

Since 1999, both FIA and NRI have adopted different forms of annualized systems for re-measuring permanent plots. The 1998 Farm Bill required FIA to change from re-measuring all FIA plots in an entire State once every 10 to 20 years, to re-measuring 10 percent to 15 percent of all FIA plots in every State every year. FIA plots are separated into five groups, called panels, which are uniformly distributed over the landscape. With current funding, all FIA plots in a single panel are re-measured within a 12- to 24-month period. Then, fieldwork restarts on the next panel. When partial implementation of the 1998 Farm Bill is fully funded, it will take about 7 years to re-measure all FIA plots in the Eastern United States, and about 10 years in the Western U.S. (USDA 2002). On the other hand, NRI plots are divided into two groups: "Core" plots are re-measured every year; NRI "Rotational" plots are re-measured at variable intervals, depending on analysis issues and funding. FIA currently re-measures over 50,000 of its 360,000 field plots each year (USDA 2002); about 19,000 of these field plots contain trees and the remaining 31,000 have no forest cover (fig. 3C). NRI re-measures all 42,000 Core plots and 32,000 of its 258,000 Rotational plots each year (fig. 3C); it acquires and processes over 74,000 aerial photographs (fig. 2) each year.

Detailed tree- and site-conditions on an FIA plot can be accurately measured only in the field. On average, a two-person field crew can re-measure one 0.17-acre forested FIA plot each day. The average cost is $1,800 per plot (fig. 3D), although cost varies by geographic area. NRI statistics are more sensitive to changes in land cover and land use, which can be reliably measured with photointerpretation (fig. 2). The average direct cost for re-measuring a 160-acre NRI plot is about $150 (fig. 3D), of which half is for procurement of the 1:8,000-scale aerial photograph and the remaining half is for labor costs.[9]

Search for Synergy

The experiments reported here evaluated the advantages of fusing the FIA and NRI plot databases with remotely sensed data and statewide GIS database.[10] We hypothesized that this combined database would yield synergies during important analyses. We tested this hypothesis by analyzing land cover and changes in land use with NRI data from 1987 and 1997; FIA data from 1977, 1990, and 1996; and Landsat satellite data from 1986 and 1996.

The most time-consuming portion of these experiments was assembly and harmonization of data from disparate sources. This included combining similar but different FIA and NRI classification systems into a single system. The FIA classification system has detailed categories for stand-level forest conditions but little detail for nonforest conditions, while the NRI system focuses on agricultural uses and land cover on non-Federal lands, with but little detail on forest conditions. A cross-walk was developed that reclassified FIA and NRI categories into five common categories: forest, crops, urban, herbaceous cover, and other land uses (Rack *et al.* 2002). However, some differences between FIA and NRI could not be fully reconciled in the database; these imperfections impact our results to some unknown degree.

FIA and NRI classification systems are based on "land use," which is more difficult to apply with digital classification of satellite data than is "land cover." For example, urban land can include forest, grass, and shrub cover, categories easily confused with those same types of cover in nonurban landscapes. A photointerpreter can use landscape patterns, and the

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[10] Standard GIS maintained by the State of Minnesota, http://www.dnr.state.mn.us/maps/index.html.

higher resolution available in an aerial photograph, to better deduce land use than can digital classification of satellite data. However, there are inevitable differences among interpreters, and some apparent changes in land cover are likely caused by photointerpretation inconsistencies. Except for classification of forested FIA plots, photointerpretation is used by both FIA and NRI to classify land use.

Spatial Patterns of Land Use Change among FIA and NRI Plots

The first experiment attempted to better understand changes in land use between 1977 and 1997 by analyzing the spatial patterns among changes on sample plots (Rack *et al.* 2002). The union of FIA and NRI plots increased the available observations. Those plots that changed were displayed on a map. Kriging produced no discernible relationship to patterns that were visually apparent in the map display. There were obvious clusters of change: near Minneapolis and St. Paul, where forest and agriculture were changed into urban; along the Mesabi Iron Range, where pits and overburden re-vegetated into forest; and near Park Rapids, where forestlands changed to cropland to serve a food processing plant constructed in the 1980s. However, these changes were previously well known, and no new insights were provided through spatial displays of changed FIA and NRI plots.

There were problems in matching locations of nonforested FIA plots on the aerial photographs used for different surveys; some apparent changes from urban to forest were likely caused by registration errors rather than actual changes in land use. Furthermore, differences between FIA and NRI classification systems for land use and land cover made use of the combined data set difficult. Finally, there were unlikely and unexplainable differences occurring at some county boundaries; these were likely caused by inconsistencies in photointerpretation methods for nonforested FIA plots during the 1977 survey. Therefore, the remaining experiments evaluated FIA and NRI plot-level data in combination with remotely sensed data.

Mapping Changes in Land Use

Several experiments evaluated FIA and NRI plots for mapping changes in land use with Landsat data from 1986 and 1996. The test area included one Landsat scene that covered the Minneapolis/St. Paul area. One experiment used supervised classification, which requires large amounts of training data. The results were disappointing (Rack *et al.* 2002). There were too few FIA and NRI plots that had changed within a single Landsat scene, especially those associated with urban development. Another experiment used unsupervised classification of temporal differences in the Kauth-Thomas transformation, which is more orthodox for digital change detection. The resulting clusters were primarily labeled through image-interpretation; however, FIA and NRI plots provided helpful examples of sites that had changed. The resulting 30-m resolution map of changes in land use is a valuable complement to the traditional FIA and NRI statistics on rates of change. However, map accuracy is unknown because there are no independent reference data available. Rack *et al.* (2002) describe this complex operation in more detail.

Supervised Mapping of Land Cover

Another experiment evaluated FIA and NRI plots as training data for supervised classification of land cover with multiple Landsat scenes for northeastern Minnesota.[11] The remote sensing procedures were designed for the National Land Cover Data (NLCD-2001) Program[12] (Homer *et al.* 2002). NLCD is a consortium of Federal agencies that is building a national Multi-Resolution Land Characterization (MRLC 2001) database of Landsat 7 ETM+ imagery, nominally from the year 2001. The database includes three dates of imagery per Landsat scene: early season, peak greenness, and late season. Radiometric calibration of the Landsat imagery improves consistency of mosaics that include multiple Landsat scenes. NLCD-2001[13] will be a 30-m resolution geospatial database for the entire U.S., including seamless, Web-based delivery of standardized Landsat data (multi-season, Normalized Tasseled Cap transformation); independent ancillary data layers (30-m resolution slope, aspect and elevation); independent, Landsat-

[11] NRLC-2001 Map Zone 41 (http://landcover.usgs.gov/pdf/homer.pdf).

[12] The MRLC and NLCD consortia are led by the USGS EROS Data Center. See www.mrlc.gov.

[13] http://www.mrlc.gov.

based estimates of percent of imperviousness surfaces and tree canopy density; and supervised classification of land cover with these Landsat and ancillary data. FIA and NRI sample plots provided sufficient training data for supervised classification. FIA and NRI plot data helped increase map accuracy (Huang *et al.* 2002) and agreement of the map with FIA and NRI measurement protocols. If FIA and NRI join NLCD-2001, their customers will have a more accurate and user-friendly, nationally consistent, interagency geospatial database for national and regional assessments.

Software for Managing Aerial Photography

An early experiment looked at cooperation in the development of software that benefited all partners (Rack *et al.* 2002). "*Plotview*" is a user-friendly, secure, intranet graphical system that displays FIA and NRI plot locations, associated aerial photography, and proximate data from a statewide GIS system. *Plotview* facilitated use of FIA and NRI plot data and rapid handling of associated aerial photography and GIS data during classification of Landsat imagery. *Plotview* was a useful demonstration that led to similar developments in the FIA and NRI programs.

Future Directions

The experiments described above produced useful results, but they did not achieve any stunning synergies. Several additional experiments are being considered.

The discrepancy between FIA and NRI estimates of total forestland area is a pervasive problem (fig. 1). Many discrepancies are caused by differences between FIA and NRI classification systems for land use. Some of these differences have already been reconciled during the construction of the database described above. Perhaps there are additional ways to better align the classification systems and protocols used by FIA and NRI; separation of classifications systems into land use and land cover holds promise.

Assessments of forest resources with FIA data can benefit from information on soils from NRCS,[14] and assessments of forest soils with NRCS data can benefit from information about forest conditions from FIA. Such assessments could be enhanced by adding the corresponding NRCS code for soil group to each FIA plot. The average characteristics of that soil group could be associated with each FIA plot. This would support analyses, such as those for soil carbon described by Prisley[15] (personal communication). Likewise, FIA attributes, such as tree productivity and biomass density, could be summarized across all FIA plots for each soil group, and those mean FIA values stored in the NRCS national soils database as representative descriptors. Since assembly of disparate databases can be the single largest task in multi-resource assessments, cross-referencing FIA and NRC databases could reduce these costs to external customers. Some soil groups are rare, and association of a plot with a rare soil group could inadvertently compromise the privacy of the landowner. Additional experiments are being considered to test the value of linking certain attributes in the FIA and NRI databases while protecting privacy of landowners.

The cost of implementing the FIA Federal base program mandated by the 1998 Farm Bill, with its requirement for more current data and re-measurement of 20 percent of all plots each year, is estimated at $90 million per year for full implementation (USDA 1999, adjusted to 2002 dollars), or $68 million for partial implementation (USDA 2002, fig. 3B). In response to the FIA Strategic Plan (USDA 1999), the FIA annual budget has nearly tripled, from $18 million in 1997 to $49 million in 2001 (USDA 2002). However, these funds are not yet adequate for even partial implementation of the Federal base program. The current FIA strategy (USDA 1999) transforms traditional FIA periodic surveys into annual surveys by changing the plot re-measurement schedule. Alternatively, combination of FIA and NRI statistical estimates might achieve the 1998 Farm Bill mandate with current FIA funding. The direct cost of re-measuring an NRI plot is about one-tenth the direct cost of re-measuring an FIA plot (fig. 3D) The cost of the current FIA strategy might be reduced if the NRI system could frequently monitor changes in forest area, which can be rapid in many areas during 5 years, and the FIA system could less frequently re-measure tree- and site-conditions within undisturbed forest stands, which usually change more slowly (Smith *et al.* 2001).

[14] http://nasis.nrcs.usda.gov/index.html.

[15] Prisley, Stephen. Personal communication, Virginia Polytechnic Institute and State University, Blacksburg, VA: November 20, 2002.

Assume NRI estimates of forest area could be subdivided into the following categories through photointerpretation: nonstocked stands, clearcuts, partial cuts; seedling/sapling stands, poletimber stands, deciduous sawtimber stands, coniferous sawtimber stands, and mixed sawtimber stands. Further assume that these NRI estimates could be statistically calibrated for photointerpretation errors and differences between the FIA and NRI classification systems. FIA field data could estimate volume per forested acre for each of these stand conditions. The product: (forest acres) x (volume per forested acre) = (total volume). Other FIA estimates of population totals could be similarly estimated. This approach might have little impact on current operations within FIA and NRI, while producing high-quality statistical estimates under current funding levels. Additional experiments will test these assumptions and conjectures in Minnesota.

Summary

Agencies can work together at three levels:[16] coordination, cooperation, and collaboration. Coordination is communication among agencies involved, but each separately conducts its own work. The next higher level is cooperation, which occurs when agencies work together because it would directly benefit each one's mission. Collaboration emerges as agencies work together to develop synergies. While coordination is the easiest to implement, it brings the least benefits. Collaboration takes considerable time, effort, and perseverance, but it can be the most beneficial to participating agencies, their customers, and the public. Future experiments in the integration of FIA and NRI products will examine how to better achieve true collaboration.

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Literature Cited

Homer, Colin G.; Huang, L. Yang; Wylie, B. 2002. Development of a circa 2000 landcover database for the United States. In: Proceedings, American Society for Photogrammetry and Remote Sensing; 2002 April 19–26; Washington, DC (CDROM).

House, Carol C.; Goebel, J. Jeffery; Schreuder, Hans T.; *et al.,* 1998. Prototyping a vision for inter-agency terrestrial inventory and monitoring: a statistical perspective. Environmental Monitoring and Assessment. 51(1-2): 451–463.

Huang, Chengquan; Yang, Limin; Homer, Collin; *et al*. 2002. Synergistic use of FIA plot data and Landsat 7 ETM+Images for large area forest mapping. In: 3d Annual Forest Inventory and Analysis Symposium, 2001 October 17–19; Traverse City, MI. Gen. Tech. Rep. NC–230. St. Paul, MN; U.S. Department of Agriculture, Forest Service, North Central Research station: 50–55 (http://landcover.usgs.gov/pdf/synergistic.pdf).

Rack, Jim.; Boss, Ken; Aunan, Timothy; *et al.* 2002. Annualized integrated inventory and monitoring initiative: final report. Grand Rapids, MN: State of Minnesota, Department of Natural Resources, Resources Assessment Unit. 55 p.

Smith, W. Brad; Vissage, John S.; Darr, David R.; Sheffield, Raymond M. 2001. Forest resources of the United States, 1997. Gen. Tech. Rep. NC-219. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. 190 p.

[16] Dr. Richard Guldin, Director of Science, Policy, Planning, Inventory and Information; U.S. Department of Agriculture, Forest Service, Washington, DC 20090. Phone: 703–605–4177; e-mail: rguldin@fs.fed.us.

USDA. 1992. Report of the Blue Ribbon Panel on forest inventory and analysis. Washington, DC: U.S. Department of Agriculture, Forest Service. 10 p. (http://fia.fs.fed.us/library.htm#Business).

USDA. 1995. A report to the Chief of the Natural Resources Conservation Service by the Blue Ribbon Panel on natural resource inventory and performance measurement. Data rich and information poor. Washington, DC: U.S. Department of Agriculture, Natural Resources Conservation Service.

USDA. 1998a. Report of the Second Blue Ribbon Panel on forest inventory and analysis. Washington, DC: U.S. Department of Agriculture, Forest Service. 17 p. (http://fia.fs.fed.us/library.htm#Business).

USDA. 1998b. Integrating surveys of terrestrial natural resources: the Oregon Demonstration Project. Inv. Monitor. Rep. 2. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Forest Service Inventory and Monitoring Institute. 20 p. (http://www.pwrc.usgs.gov/brd/odp/odp.htm).

USDA. 1999. Strategic plan for forest inventory and monitoring. Washington, DC: U.S. Department of Agriculture, Forest Service. 48 p. (http://fia.fs.fed.us/library.htm#Business).

USDA. 2002. Forest inventory and analysis fiscal year 2001 business report. FS-747. Washington, DC: U.S. Department of Agriculture, Forest Service. 31 p. (http://fia.fs.fed.us/library.htm#Business).