The Role of Strategic Forest Inventories in Aiding Land Management Decision Making: Examples From the U.S. Forest Inventory and Analysis Program

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Abstract—A major challenge for today's resource managers is the linking of stand- and landscape-scale dynamics. The U.S. Forest Service has made major investments in programs at both the stand- (national forest project) and landscape/regional (Forest Inventory and Analysis [FIA] program) levels. FIA produces the only comprehensive and consistent statistical information on the status, changes, and trends in the condition and health of all forest ecosystems in the USA. Intended to be a strategic inventory, FIA data have not been used very much for small area inventory, planning, and analysis due to the high variation associated with the estimates. Yet, trends observed over landscape and regional scales can help managers making decisions at the local level. FIA data can be used to assist with project-level decision making, adding scientifically defensible data and framing local management in a larger context. FIA data are helpful in understanding stocking and density limitations and inter-species interactions. They also can provide insight into future growth and yield. FIA data provide opportunities to conduct scale-independent analyses to examine relationships between stand characteristics and forest health and invasive species, as well as methods for establishing ecological benchmarks and prioritizing restoration opportunities.

This paper explains how FIA data can be used at three different levels of analysis. At the project level, FIA data can be used for Forest Plan revision, monitoring conditions and trends at mid- to broad spatial scales over time, and setting the context for proposed projects. One step beyond management decision making, FIA data can provide input for stocking guides and other quantitative tools that aid silvicultural planning. Finally, FIA data can help detect and analyze patterns across broader geographic areas that reveal (or illustrate) relationships and processes that can be applied at the local level or provide policy guidelines that can guide prioritization and allocation of scarce management resources.

Introduction

The original objective of the Forest Inventory and Analysis Program was to estimate resource availability at the strategic or state-level as an aid to understanding trends in resource utilization potential. Early inventories were referred to as "Forest Survey" and focused on growing stock volume and productive timberland area, both reflecting an emphasis on the potential for wood utilization. With the evolution of our nation's attitudes toward the environment and the role of forest resources in providing ecosystem services, the purview of the "Forest Survey" has expanded to include not only productive and accessible timberland, but also (protected) forest land reserved from timber harvest and forest land that may not be considered productive enough to grow crops of timber. Additionally, selected

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criteria and indicators of ecological sustainability, such as estimates of coarse woody debris, understory vegetation, and lichens, are now incorporated into the sample design. A robust forest inventory requires a large network of sample plots measured consistently over time. Over the past decade, the USDA Forest Service, Forest Inventory and Analysis (FIA) program has implemented an inventory system that seeks to achieve national and international consistency[4]. This system utilizes three phases of inventory designed to make estimates of forest extent, composition, structure, health, and sustainability: Phase 1 – remote sensing, Phase 2 – the actual on-the-ground sampling in a systematic grid, and Phase 3 – a subset of Phase 2 that examines certain variables that are considered to be indicators of forest health (McRoberts 1999). The design of the FIA program gives greater certitude to estimates across larger geographic extents. While FIA does publish estimates of county-level attributes, the uncertainty at such scales often is high, especially in sparsely-forested locales. The paucity of plots for small geographic areas and elements of stratification by ownership or forest type can limit usefulness at the local level. Nonetheless, FIA data can still provide great information value to forest managers.

The potential benefits of FIA data for forest resource managers exist at three levels that are loosely represented by their distance from the project-level, on-the-ground decision-making process. At the most immediate level is the use of FIA data for formulating or updating land management plans for large tracts, monitoring forest conditions and trends at the broad level over time, and setting the context for proposed projects. We present three examples: monitoring trends of target species or forest types, managing snag habitat, and estimating the extent of old-growth forest.

Further removed from the management decision, FIA data provide input for stocking guides and other quantitative tools that aid silvicultural planning. In the past, many of these tools were developed using limited data, and they were regional in scope. As a result, some tools have been used in areas outside those for which they were developed, perhaps without local validation. The fact that FIA data are geographically unbiased and represent a range of conditions that exist within a given forest type in proportion to the abundance of those conditions on the landscape permits regional comparisons of modeling results and geographically appropriate application of silvicultural tools. In addition, the data permit analysis and generalizations of stand dynamics and growth-growing stock relationships that are not possible or appropriate with more limited data sets. To illustrate this point, we provide an example of using FIA data to develop density management diagrams.

Finally, FIA data can detect and analyze patterns at large geographic extents that reveal relationships and processes that can be applied at the local level. The data also can inform policy guidelines for prioritizing and allocating scarce management resources. We present two examples of this capability, one that provides guidance in prioritizing restoration activities by comparing FIA data to historic estimates of structure and abundance, and the other that examines the extent of non-native invasive plants in forest land and the factors that appear to influence their presence. At all three scales, decision makers will find FIA data to be a valuable information resource.

[4] Complete documentation of the plot design and all measurements is at http://socrates.lv-hrc.nevada.edu/fia/dab/databandindex.html.

Use of FIA Data for Project Level Planning

Statistically sound estimates of the current condition and trends of vegetation and associated attributes are fundamental to developing forest plan components, monitoring in relation to forest plan standards, guidelines, and desired conditions, and managing wildlife habitat, including cumulative effects analysis for project-level planning. Furthermore, statistically reliable data are needed to address controversial management issues, such as climate change effects and carbon accounting.

FIA data allow for regional monitoring based on an unbiased, representative sample of forest lands that are remeasured regularly. Many attributes of trees and the site are collected on an FIA plot. The FIA sampling frame uniformly covers all forested lands, regardless of ownership status or management emphasis; thus, wilderness and roadless areas, as well as more intensively managed lands, have equivalent sampling probabilities. As a result, spatial data sets can be intersected with FIA plot locations to describe vegetation characteristics within various map strata. This section contains 3 examples that incorporate these capabilities.

Example 1 — Identifying Target Species in Silvicultural Prescriptions

Within a national forest's planning area, FIA data can be used to assess current condition. Since plots are remeasured on a 5- to 10-year cycle (depending upon geographic area), progress towards desired condition or compliance with achievement standards can be monitored. Furthermore, comparing current condition to future condition allows prioritizing project-level vegetation treatments needed to achieve management objectives. For example, FIA data can be used to compare current estimates to desired conditions for the historically most-common forest types found on the Idaho Panhandle National Forests (IPNF) in the Northern Region (Region 1, which covers Montana and parts of Idaho and North Dakota). The comparison suggests that projects that encourage restoration and regeneration of specific forest types, such as white pine, western larch, and ponderosa pine, should take priority other forest types.

Example 2 — Managing Snag Habitat

In another example, the Northern Region analyzed snag densities for planning development of project-level snag retention and recruitment options. FIA data were used to assess the density and distribution of snags within and outside of wilderness/roadless areas and categorized by vegetation classifications, such as habitat type groups and seral stages (table 1). This analysis took into consideration recent findings on the effects that timber harvest and human access have on snag density, how snag density relates to stand succession and disturbances, and the spatial pattern of snags. After obtaining these results, all national forests in the Northern Region began to monitor snag densities over time at the broad level and use the data to adaptively manage at the project-level.

Example 3 — Managing Old Growth

Additionally, the Northern Region uses FIA data to estimate and monitor forest plan standards such as the percentage of a national forest in old growth status (table 2). The Region has a documented definition of old growth based on geographic area, old growth forest type, and habitat type groups that are applied to FIA inventory data. Using FIA data, one can estimate that 9.4 percent of the Clearwater National Forest (CNF) is in an old growth condition; an estimate with a

Table 1—Mean snag densities per acre with 90% confidence interval, by diameter classes, inside and outside of wilderness/roadless areas for all northern Idaho Forests and for each Forest.

Area	Wilderness/ Roadless	Snags per acre 10"+			Snags per acre 15"+			Snags per acre 20"+			Total Number PSUs	Number Forester PSUs
		Mean	90% CI - Lower bound	90% CI - Upper bound	Mean	90% CI - Lower bound	90% CI - Upper bound	Mean	90% CI - Lower bound	90% CI - Upper bound		
North Idaho Forests	IN	10.3	9.3	11.4	3.9	3.4	4.4	1.6	1.4	1.9	514	514
Idaho Panhandle		10.4	8.4	12.6	3.7	2.8	4.7	1.6	1.1	2.1	133	133
Clearwater		8.9	7.3	10.5	3.7	2.9	4.5	1.6	1.2	2.1	189	189
Nez Perce		11.7	9.9	13.7	4.2	3.3	5.2	1.7	1.3	2.1	192	192
North Idaho Forests	OUT	11.7	10.5	12.9	4.3	3.7	4.9	1.6	1.4	1.9	478	478
Idaho Panhandle		12.7	11.1	14.5	4.2	3.5	4.9	1.4	1.1	1.7	260	260
Clearwater		9.6	7.5	11.9	4.4	3.3	5.7	2.1	1.4	2.8	106	106
Nez Perce		11.2	8.6	14.0	4.3	3.0	5.9	1.8	1.2	2.4	112	112

Table 2—Northern Region and individual National Forest estimates of percent of old growth and 90%-confidence intervals.

Unit	Percent old growth estimate	90 percent confidence interval— Lower bound	90 percent confidence interval— Upper bound	Total number of PSUs	Number of forested PSUs
Northern Region	13.7	12.9	14.4	3883	3423
Beaverhead—Deerlodge	22.9	20.5	25.4	547	442
Bitterroot	12.8	10.1	15.6	252	226
Idaho Panhandle	11.8	9.6	14.0	413	397
Clearwater	9.4	7.3	11.8	305	300

90 percent confidence interval and a lower bound of 7.3 percent. The CNF's Forest Plan Standard is to retain at least 10 percent old growth forest-wide. Currently, the CNF is not proposing any treatments that impact old growth stands or stands approaching old-growth status. When FIA annual data show an increase in the amount of old growth on the Forest, the Forest will reconsider its current position.

FIA data can be associated with various map products to describe and explore various map strata. For example, FIA inventory data were analyzed to determine whether or not the Region's old growth criteria were met. Forests collapse their existing vegetation layers into several cover types. The percentage of plots within each cover type, which meet old growth criteria can then be extracted and compared (fig. 1).

Use of FIA Data for Development of Silvicultural Tools

Although the FIA inventory system was designed to estimate population characteristics and trends across broad geographic areas, plot-level FIA data are increasingly being used to describe and model stand growth and structural characteristics. This use of FIA data is partly driven by the fact that FIA reporting, by design, requires wall-to-wall coverage (i.e., all forest types in all ownerships

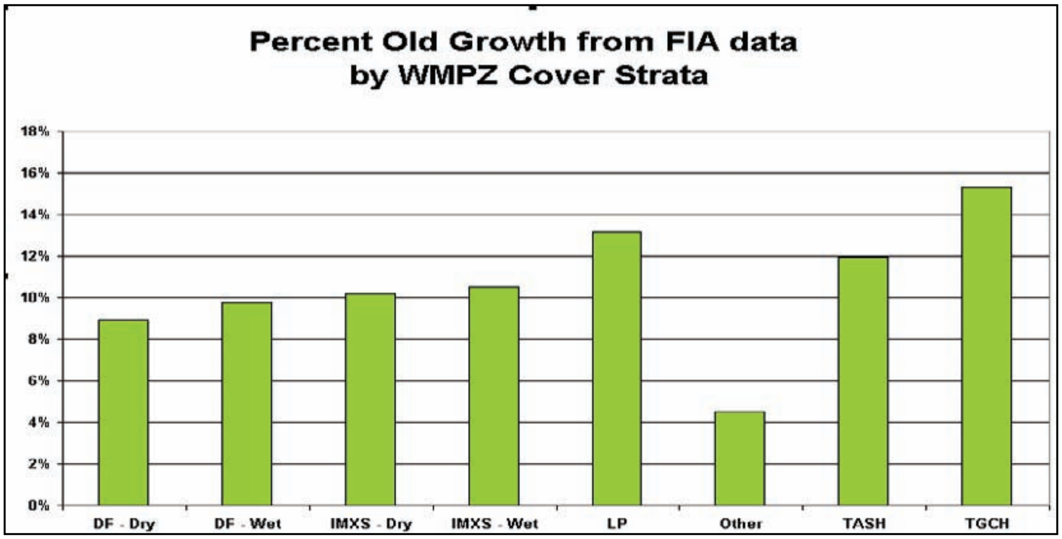

Figure 1—Percent of old growth, based on FIA data, by Western Montana Planning Zone (WPMZ) Cover Strata.

under all management scenarios). Unfortunately, some of the most basic tools and models, such as stocking charts, yield equations, and site index curves, have been developed locally using relatively small data sets. Often, the geographic extent is not well documented. Because of the extensive demand for these tools, the FIA program applies these models over geographic areas that may be greater than appropriate for the scope of the original research. This extrapolation may occur without substantial validation, because the process for adopting models typically relies on expert opinion of model developers, or in some cases, model users.

Because of this situation, the FIA program has relied largely on third parties (such as non-FIA Forest Service and university-based researchers) to develop the tools and models underlying many FIA variables. Problems arise where there are large knowledge gaps, such as for species that are less studied because they are not commercially important in all or part of their range. These gaps tend to persist for a long time because there has generally been no systematic mechanism available to fill them. Until recently, the FIA program had little capacity to develop new models and so used the "best available" tools and models, based on limited testing and expert opinion. As a result, many "surrogate" models persist in the FIA computation system.

However, with the advent of the current, nationally consistent, mapped-plot design, the FIA program began compiling data that can be used to validate existing tools and models or to develop new ones from scratch. Plot-level FIA data can be compiled to describe characteristics and conditions, such as stand structure and composition, individual tree- and stand-level growth, and mortality rates. In comparison to the studies that produced many models and tools in use today, data developed on FIA plots offer several potential advantages.

First, many older studies were geographically limited, or one species may have been represented by multiple studies across its range, with differing experimental procedures and analysis being used among studies. FIA data cover the entire ranges of species, or at least their range within the boundaries of the United States, and sample all parts of the range with one core protocol. As a result, the data are consistent across large geographic areas. Sub-regions of a species' range can be compared without the introduction of noise from varying methods.

Second, older studies were frequently based on relatively small sample sizes, usually confined to one geographic area, and with unknown geographic bias. For common species and forest types, FIA plots available for analysis typically number in the thousands, depending on the criteria imposed by the research question. FIA data are geographically unbiased because FIA uses a systematic sampling design.

Finally, many older studies relied on temporary plot data. FIA data from the legacy periodic inventories and initial measurement of annual inventory plots are also treated as temporary plot data for many current analyses. However, annual inventory plots are permanent and will be remeasured on a 5- to 10-year cycle, depending on the state (Bechtold and Patterson 2005). The annual inventories eventually will yield long-term data on growth, mortality, successional change, and other tree- and stand-level characteristics. These data can serve as validation data for existing models, or time-series data for the development of new models.

Although the points above are broad generalities, they highlight some of the potential advantages of using plot-level FIA data in a variety of analyses. Of course, the data collected on FIA plots cannot satisfy every research question, so the need for "experimentally based" research will always exist. What the FIA program offers is a well documented, statistically sound sample design that produces the kind of data used in many observational studies, without the pitfalls associated with ad-hoc selection of plots. In the longer term, FIA data will produce valuable time-series data with unparalleled geographic scope.

Example 4 — FIA Data and Development of Density Management Diagrams

An example of the broad applicability of FIA data is the development of density management diagrams for ponderosa and longleaf pines (Long and Shaw 2005; Shaw and Long 2007). Density management diagrams relate yield and density and allow forest managers to use current stand density to project what the future stand would look like (Kershaw and Fischer 1991). Both of these species are commercially and ecologically important, and many aspects of their ecology and associated silvicultural practices have been studied. Density management diagrams, which are graphic models of stand structure and development (Jack and Long 1996; Newton 1997), are commonly used in the western U.S. and much of Canada. They are less commonly used in eastern states, but availability and use there is gradually increasing.

The lack of a density management diagram (DMD) for ponderosa pine represented a major knowledge gap for that species. Even the maximum relative density of ponderosa pine, expressed as stand density index (Reineke 1933), was not well understood across the species' range. The need for a ponderosa pine DMD and the availability of FIA data presented an opportunity to create a "test case." One aspect of this test would be the use of "off-the-shelf" FIA data — i.e., the data that are freely available to the public through the FIA Datamart (http://fiatools.fs.fed.us/fiadb-downloads/datamart.html). Given this approach, it would be possible for users of the DMD to independently reproduce the results of the research using publicly available data and the methods described by Long and Shaw (2005). This feature would add a level of transparency to the study that is relatively rare in research today.

The number of plots needed to construct a DMD is about 300 (J.N. Long, pers. comm.). FIA data provided 766 plots (out of 8,183 plots with ponderosa pine) for development of the ponderosa pine DMD based on compositional and structural criteria. The DMD appeared to be robust across several sub-regions of the range of ponderosa pine, suggesting that the tool can be used over a large geographic area without concern for local bias (Long and Shaw 2005). Although the data used in construction of the diagram were necessarily treated as temporary plot data, many of the plots used in the original analysis will be remeasured in the future, providing data that can be used for periodic validation of the stand dynamics represented in the DMD.

From a management perspective, the lack of a DMD for longleaf pine did not represent as great an unmet need as did the lack of a DMD for ponderosa pine. However, two issues related to longleaf pine could be addressed with the development of a DMD. The first was an apparent fall-off in the relative density of mature stands that resulted in gross over-prediction of potential basal area and volume when a full-stocking scenario was extended beyond a certain limit. The second was the need for tools that would assist silviculturists in the development of treatments for the benefit of the endangered Red-cockaded Woodpecker (RCW *Picoides borealis*). Although management goals for the RCW were well established by recovery guidelines (U.S. Fish and Wildlife Service 2003), the fall-off issue in mature stands was not well understood. Were the apparent limits of relative density that were derived from local data universal for the longleaf forest type or were they only local?

Again, the broad-ranging availability of FIA data was able to provide a defensible answer. The FIA database yielded 5,222 plots with longleaf pine present, leaving 343 available for development of the DMD after applying somewhat stricter compositional and structural evaluation criteria than were used in the case of ponderosa pine. A somewhat larger pool of plots was used to characterize the "fall-off" phenomenon, which appeared to be common to the longleaf forest type throughout its range. As a result, the longleaf pine DMD was published with the inclusion of a "mature stand boundary" (fig. 2) that represented the practical upper limit of stand-level management in size-density space (Shaw and Long 2007). Finally, FIA data were used to analyze the relationships among mean stand diameter, stand basal area, and cumulative basal area by diameter class. These relationships were used to translate stand structural characteristics specified in the RCW recovery guidelines (U.S. Fish and Wildlife Service 2003) into a "suitable habitat zone" on the DMD (fig. 2). Addition of the mature stand boundary and the RCW habitat suitability zone considerably enhance the utility of the basic longleaf pine DMD.

Although the construction of density management diagrams has been used to illustrate the usefulness of FIA data for development of new tools, the list of potential applications is long. There are many species and forest types for which DMDs are in demand; DMDs for the Sierra mixed conifer and aspen forest types are under development using FIA data, and several more are planned. In addition, FIA data are being brought to bear on a variety of questions related to forest growth and yield and stand dynamics. In contrast to past studies that may have been limited in scope and developed from data collected at one point in time, it will be possible to establish a cycle of development, validation, and revision as the flow of annual FIA data continues.

Use of FIA Data at the Landscape Level

Because of the extent of the FIA inventory design, at least 1 plot per 6,000 acres, patterns and trends that are not obvious at a project level might reveal themselves at a larger scale. Some of the questions are explicitly a function of this landscape view, like the restoration example below. Others merely need a large number of data points to examine specific cause-and-effect relationships, like the invasive plant example that follows.

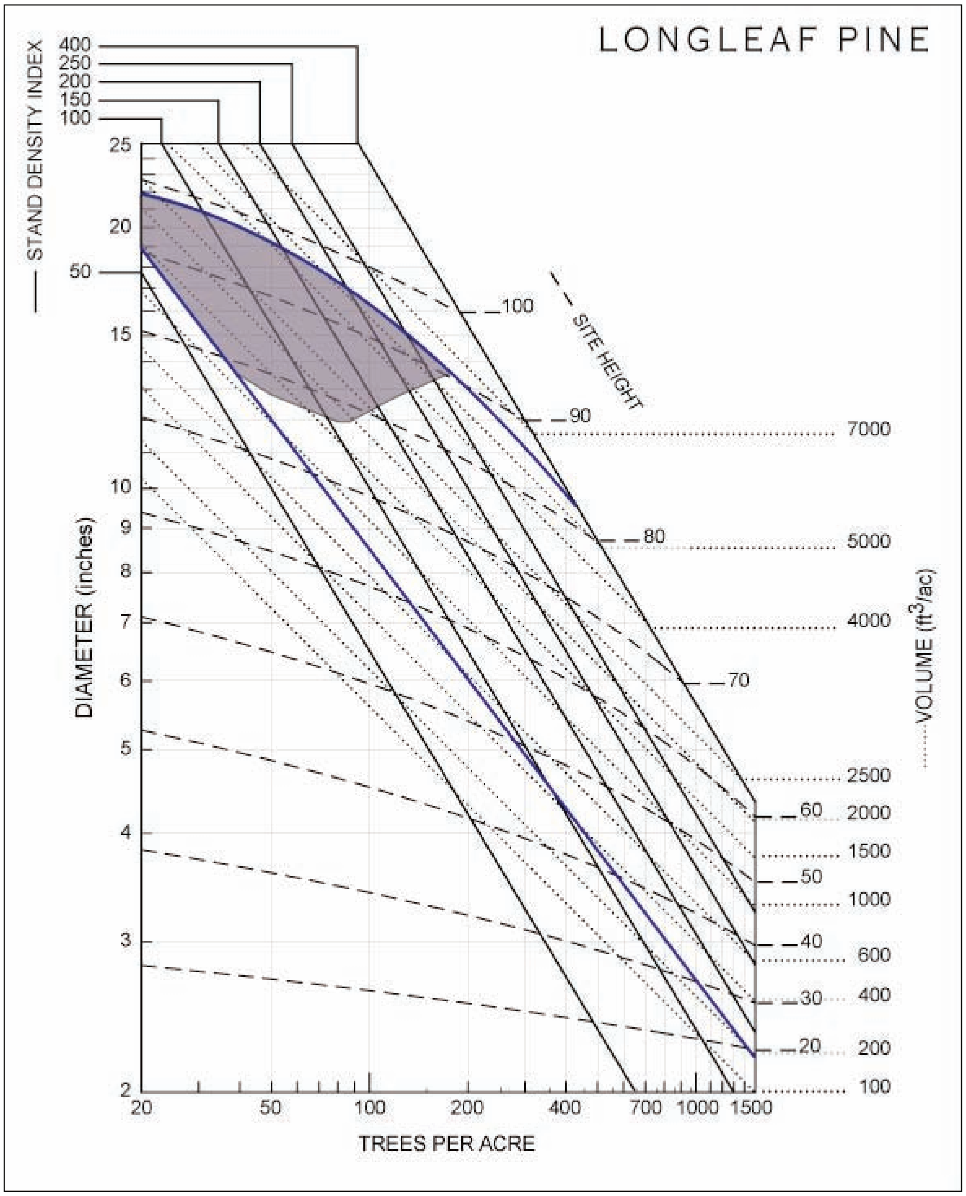

Figure 2—Density management diagram for longleaf pine, with the mature stand boundary (in blue) and zone of Red-cockaded Woodpecker habitat suitability (shaded polygon) (based on Shaw and Long 2007).

Example 5 — Restoration Ecology

As a counterpoint to the highly altered landscapes of today, some ecologists and resource professionals trying to establish criteria for sustainability have pointed to the pre-Euro-American-settlement landscape as a benchmark for restoration efforts (Bragg 2003; Foti 2004; Landres and others 1999; Swetnam and others 1999). To prioritize restoration efforts, a robust method for comparing current and historical landscapes would be extremely useful. In the western two-thirds of the United States, public land managers are fortunate to have an historical inventory in the Public Land Survey (PLS) and the FIA Program's inventory of current forest conditions.

The U.S. government's General Land Office (GLO) conducted public land surveys (PLS) across most of the country during the 19th century. Most of the lands west of the 13 original colonies were subject to the GLO surveys. These public records are an excellent source of historical landscape conditions when properly interpreted. The PLS is a rectangular, rule-based system that divided the landscape into a series of townships and ranges associated with a point of origin and a series of meridians and baselines (usually by state). These north-south and east-west running demarcations divided the land into nominal 36 mi^2 townships, which were then further subdivided into 36 640-acre sections (National Atlas 2006). These townships were replicated across the landscape. Along this hierarchical grid, survey markers (posts) were set at 1/2 mile and 1 mile intervals. At these locations, information such as species, estimated diameter, and distance were collected on two to four trees near the posts and recorded in survey notebooks. Despite significant deficiencies (e.g., a not particularly intensive sampling regime, and numerous biases, ambiguities, and inconsistencies [Bourdo 1956; Bragg 2004; Mladenoff and others 2002; Nelson 1997; Schulte and Mladenoff 2001]), the PLS records still provide landscape-to-regional information on the vegetation of the period due to their detail, wide extent, and resolution.

To test the effectiveness of a system comparing PLS to FIA data, Moser and others (2006a) compared historic and current data covering the southeast Missouri Ozarks. Missouri was surveyed by General Land Office surveyors from 1816 through 1855. FIA data have been collected annually in Missouri since 1999. Moser and others (2006a) used data from the 1999-2003 FIA inventory of the State of Missouri to depict current forest conditions. The two datasets – historic (PLS) and current (FIA) — had to be reduced to a common data structure to compare species and structures and determine potential for restoration.

During a review in 2002 of current forest management technical specifications by the Missouri Department of Conservation, a team produced a table of current and potential hardwood forest type groups with the suitability (and, by implication, the ease) of conversion based on site index. This table (updated to include pine forest types) became the basis for comparing the PLS data to the FIA data to determine how easy it might be to "convert" current forest types to historic ones.

In order to create common variables of structure and composition between the historic and current data, Moser and others (2006a) used a simple moving window to classify each pixel in the study area to a structure and forest type, using data from land survey plot corners (PLS) and inventory plots (FIA). The moving window centers on a target pixel and then looks at all points within a specified distance (window) of the target pixel. It assigns the value of most of the points in the window to the target pixel and moves to the next pixel. The size of the moving window was adjusted to reflect the spacing of the data points, using a smaller window for the PLS data and a larger window for the FIA data.

After the moving window maps were combined with the forest conversion table, a restoration difficulty/suitability map was created. While there were combinations of past/present that had no information, a substantial amount of acreage was classified into restoration categories: Low Effort, Medium Effort, High Effort, Maximum Effort, and Not Possible.

A map that identifies the effort required to restore a landscape to pre-settlement condition (fig. 3) was produced by combining PLS and FIA data.

Of the 3 million acres in the study area, 14 percent was classified as low-effort sites, 17 percent as medium-effort sites, 11 percent as high-effort sites, 21 percent as non-forest, and 11 percent as not possible (table 3). The remaining 25 percent was classified as no information.

Available funds and time are usually not sufficient to restore all deserving sites, so choices must be made. Resource managers can use this methodology

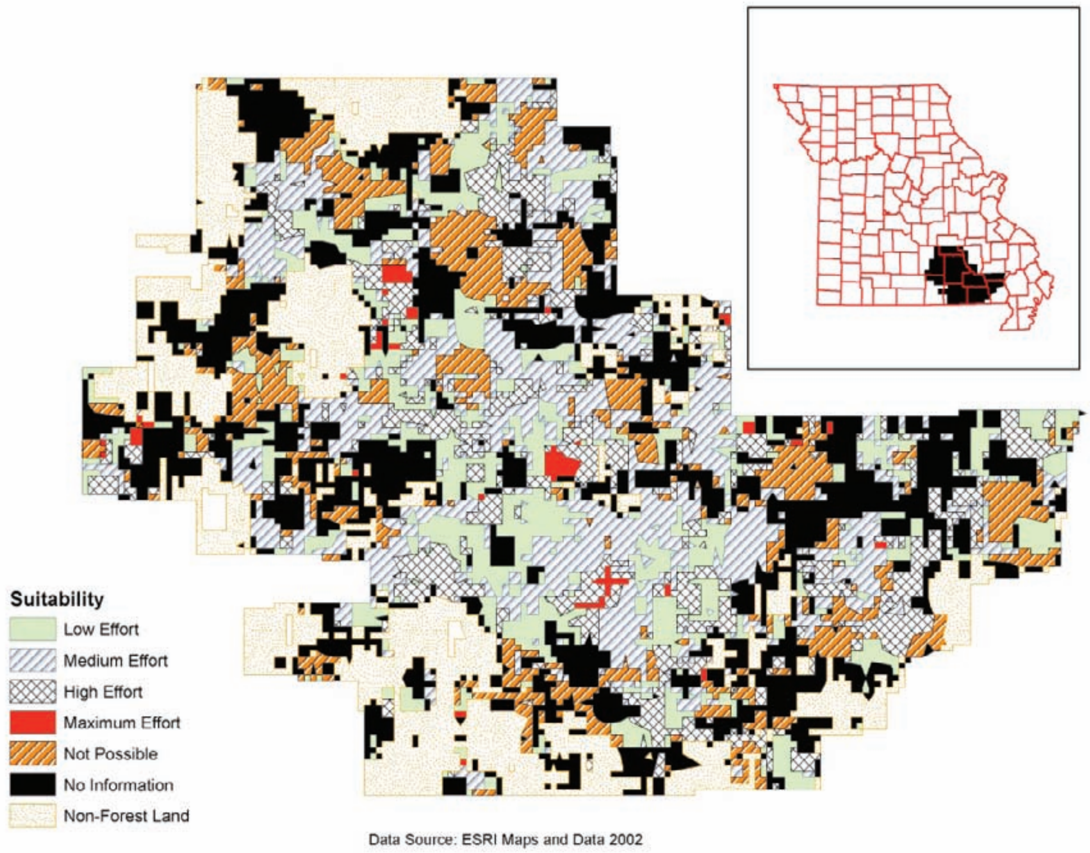

Figure 3—Map of categories of restoration suitability and effort. Suitability is inversely related to effort, e.g., high suitability for restoration is assumed to equal low effort required to do so. The "Not possible" category" represents those binary combinations that were deemed highly unsuitable. "No information" represents those pairs of current and historic forest types that were not considered.

Table 3—Summary of categories of conversion suitability, in 1000s of acres.

Suitability	Acres (1000s)	Percentage of total
Low Effort	406	14
Medium Effort	503	17
High Effort	333	11
Maximum Effort	25	1
Non-Forest	609	21
Not Possible	334	11
No Information	752	25
Grand Total	2,962	

to prioritize restoration opportunities as part of a larger management plan. This methodology is limited by the spatial distribution of past and present species groups and the simplification of a fairly complex vegetation pattern into a more manageable number of categories. Nested within these broad geographic categories will be individual, stand-level decisions that will be based on site conditions and the local manager's individual knowledge and expertise.

Example 6 — Invasive Plants

Non-native invasive plants (NNIP)[5] are expanding across the U.S. Once established, NNIP threaten the sustainability of native forest composition, structure, function, and resource productivity (Moser and others 2009; Webster and others 2006). Factors influencing exotic plants' invasion of forests include: disturbance, competitive release, resource availability, and competitive pressure (Richardson and Pyšek 2006). Moser and others (2008) analyzed FIA plot data with three objectives in mind: 1) document the distribution of species, 2) compare invasive presence to site characteristics, and 3) determine the role of disturbance in invasive species presence and coverage in Missouri. This study was more a snapshot than a trend analysis, as the full extent of NNIP had not previously been documented statewide on FIA plots in Missouri.

Located at the juncture of several ecoregions, Missouri's pre-settlement landscape ranged from upland forest in the Ozarks to bottomland ecosystems of the Mississippi Embayment in the southeast of the state to savannas and prairies in the north and west. The fertile soils of northern Missouri were ideal for farming and settlers quickly cleared the land for agriculture and grazing. In the heavily timbered areas of southern Missouri, commercial harvesting exploited the magnificent stands of shortleaf pine and other species (Beilmann and Brenner 1951). The combination of clearing, settlement, and timber harvesting resulted in a highly fragmented landscape, creating many opportunities for non-native invasive plants to become established in forests.

During 2005-2006, Phase 2 FIA plots were assessed for presence and cover of any of 25 non-native invasive woody, vine, grass, and herbaceous species of interest[6] (table 4). Moser and others (2008) used these NNIP data, along with a geographic information system and geospatial data about road location (ESRI, Redlands, CA, 2006 version) and density and summaries of forest fragmentation data from the Conservation Biology Institute (Heilmann and others 2001), to look for relationships among evidence of human disturbance, forest structure and composition, and invasive species presence.

Of the 25 NNIP species sampled for in the 2005 and 2006 annual inventory panels, only 13 were observed in Missouri and only three—multiflora rose (*Rosa multiflora* Thunb.), non-native bush honeysuckles (*Lonicera* spp.), and Japanese honeysuckle *Lonicera japonica* Thunb.)—were recorded in substantial number. Of the 1,264 plots sampled in this study, 42 percent had at least one invasive species of interest. Multiflora rose was the most frequently recorded species, being observed on 36 percent of the plots (fig. 4). Woody invasive species were especially prominent.

Like all plants, NNIPs benefit from higher site productivity. FIA measures elements of site productivity in three ways: 1) site index, based on representative trees near the plot, 2) aspect, based on measurements taken by the field crews, and 3) physiographic class code, a determination made by field crews based on their assessment of land form, topographic position, and soil type.

[5] This paper will also refer to NNIP as "exotics" or "invasives."

[6] This list was not exhaustive but represented those species likely to have a significant impact somewhere in the 11-state Upper Midwest.

Table 4—Non-native invasive plants surveyed on FIA plots in the Upper Midwest of the U.S., 2005-2006.

Common name	Scientific name
Woody species	
Multiflora rose	*Rosa multiflora*
Japanese barberry	*Berberis thunbergii*
Common buckthorn	*Rhamnus cathartica*
Glossy buckthorn	*Frangula alnus*
Autumn olive	*Elaeagnus umbellata*
Non-native bush honeysuckles	*Lonicera* spp.
European privet	*Ligustrum vulgare*
Vines	
Kudzu	*Pueraria montana*
Porcelain berry	*Ampelopsis brevipendunculata*
Asian bittersweet	*Celastrus orbiculatus*
Japanese honeysuckle	*Lonicera japonica*
Chinese yam	*Dioscorea oppositifolia*
Black swallowwort	*Cynanchum louiseae*
Wintercreeper	*Euonymus fortunei*
Grasses	
Reed canary grass	*Phalaris arundiacea*
Phragmites, Common reed	*Phragmites australis*
Nepalese browntop, Japanese stiltgrass	*Microstegium vimineum*
Herbaceous	
Garlic mustard	*Alliaria petiolata*
Leafy spurge	*Euphorbia esula*
Spotted knapweed	*Centaurea bierbersteinii*
Dame's rocket	*Hesperis matronalis*
Mile-a-minute weed, Asiatic tearthumb	*Polygonum perfoliatum*
Common burdock	*Arctium minus*
Japanese knotweed	*Polygonum cuspidatum*
Marsh thistle	*Cirsium palustre*

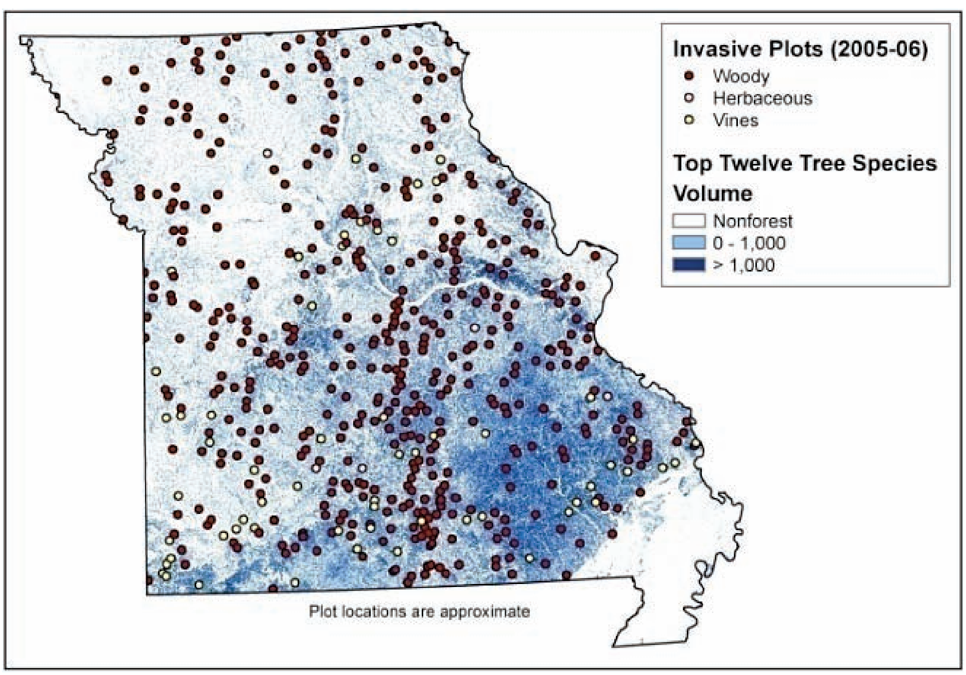

Figure 4—Distribution of plots containing non-native invasive plants in Missouri in 2005-2006 inventory years.

Moser and others (2008) reported the following significant relationships:

- site index and the presence of multiflora rose and non-native bush honeysuckles,
- level aspects and multiflora rose and Japanese honeysuckle, and
- mesic physiographic class and multiflora rose and Japanese honeysuckle.

Like young tree seedlings, ground flora—both native and exotic—are influenced by the presence of trees in the overstory. Not only is the presence of a particular basal area an indicator of the likely microenvironment below the canopy, but in addition it is likely the result of past disturbance events that may also have facilitated the establishment of NNIP. Of the three most prominent invasive plants that Moser and others (2008) reported in Missouri, only multiflora rose appeared to benefit from reduced basal area.

Analysis of the presence and cover of invasive species at a single point in time does not usually provide enough data to evaluate trends in regeneration, expansion, or growth (Rejmánek 1989). The FIA database can elicit evidence of disturbances and/or management activities, but only in the interval since the previous inventory. Non-native invasive plant sampling has only recently been initiated in certain parts of the country; remeasurements of these plots will provide information about the extent and trends of these unwanted guests.

Summary

Strategic forest inventories—such as FIA in the United States—have traditionally focused on estimating the total number of trees or the total tree volume in a state, and they have performed that task well. Such inventories can also be valuable to land managers working at smaller scales, such as management projects on national forests. However, the increased level of statistical variation when using FIA data for small area estimation tends to dissuade people from considering its usefulness altogether at the local level. Yet, the unbiased statistical design of FIA can provide valuable information to support planning and decision making at the project, landscape, and regional levels. To provide useful and defensible information at the local and regional levels, the analysis must be focused and take into account both the opportunities and limitations of the data.

In this paper, we presented examples of how FIA data aids managers at the project level (target tree species, snag management, old-growth estimation), the planning level (density management diagrams), and the landscape level (forest restoration prioritization and factors influencing the presence of exotic plants). While the examples we presented were not explicitly linked across scales, it is quite possible to use the same subset of FIA data to aid decision-making at each of these levels.

The FIA program is designed to estimate resource availability and forest health trends at broad scales. National estimates of carbon storage, forest health indicators, and wood product utilization potential depend on these data. But FIA data also have great potential to assist in achieving management objectives at the local level, while still satisfying broad-level, long-term goals.

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The content of this paper reflects the views of the authors, who are responsible for the facts and accuracy of the information presented herein.