ESTIMATION BASED ON THE FIRST CYCLE OF THE ANNUAL FOREST INVENTORY SYSTEM: METHODS, PRELIMINARY RESULTS, AND OBSERVATIONS[1]

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Abstract—The first year of annual FIA data collection in the North Central region was completed for 1999 in Indiana, Iowa, Minnesota, and Missouri. Estimates of timberland area, total growing-stock volume and growing-stock volume per acre are presented. These estimates are based on data from 1 year, collected at the base Federal inventory intensity, a lower intensity sample than previous periodic inventories conducted in these States. In the North Central region, plots are measured on a 5-year cycle (20 percent of the plots measured each year) at a base intensity of one plot per 5,937 ac. These first-year estimates, obtained from the 20 percent sample, are based on a sample intensity of one plot per 29,685 ac and, thus, have greater sampling variability than previous periodic inventories conducted by FIA.

INTRODUCTION

The Forest Inventory and Analysis (FIA) program at North Central Research Station, USDA Forest Service, has completed the first year of statewide annual forest inventories in four States: Indiana (IN), Iowa (IA), Minnesota (MN), and Missouri (MO). Ground plot measurements and quality control checks were made by a combination of NCFIA field personnel, cooperating State employees, and private forestry consultants under contract to cooperating state agencies. Plots in these states were measured between September 1998, and April 2000.

These first year plot data, together with a thematic GIS layer based on a classification of Landsat TM data for stratification purposes (Vogelmann and others 1998), were used to produce estimates and sampling errors for standard forest resources variables. This paper presents results from the inventory, compares those results to estimates from previous periodic inventories, and discusses implications of these comparisons.

DATA AND ESTIMATION

NCFIA sampled a total of 5,240 systematic plot locations in the four-State study area using the National FIA plot design, a cluster of four 1/24th ac fixed area subplots. Of these 5,240 plot locations, 1,467 were found to contain some forest land. Table 1 compares the number of plots observed in each state under the first year of the annual inventory system to the number of plots in the most recent periodic inventory. It is important to keep in mind that there was a change in plot design in IA, MN, and MO between the last periodic inventory and 1999. Under the old plot design, a plot was tallied as a forest plot only if a forest condition existed at plot center. Under the new plot design, a plot is tallied as a forest plot if any portion of the plot falls in a forest condition. This change in plot design increases the percentage of forest plots in the total sample without a change in total forest area, especially in areas with a great deal of forest/nonforest interface such as IA and MO.

Table 1—Number of plots observed in the first year (1999) of the annual inventory and number of plots observed in the most recent periodic inventory in the North Central Region

	Number of observed plots				Date of most recent periodic inventory
	1999 annual inventory		Most recent periodic inventory		
	Total	Forest	Total	Forest	
Iowa	1,202	110	12,767	713	1998
Indiana	769	174	6,402	1,605	1990
Minnesota	1,801	578	43,955	13,507	1990
Missouri	1,468	605	17,259	5,072	1989
All States	5,240	1,467	80,383	20,897	

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The intensity of the plots from a single year of the annual inventory is lower than any periodic inventory conducted by NCFIA. This first year sample comprises 20 percent of the base sampling intensity of the full 5-year inventory. When the complete 5-year cycle of plots has been measured, estimates will be based on all the plots measured over the 5-year cycle (five times the number available for this first year). In addition, some states have provided resources to intensify the inventory by measuring additional plots. In this first year, we have not included any intensified plots in the analyses.

The ground plot locations sampled in the first year are a combination of plot locations from the previous periodic inventory and plots in new locations. The hexagon/panel system (Brand and others 2000) determined the plot locations that were measured. This system divides the entire conterminous 48 States into 5,937-ac hexagons and selects a measurement location within each hexagon. When one or more locations from the previous inventory exist within a hexagon, one is selected for remeasurement, otherwise a new location is selected. In three States (IN, MN, and MO) the previous periodic inventory used a sample design in which the status of some plots that were determined to be undisturbed between the two previous inventories were updated using models (Miner and others 1988) rather than a field and remeasurement. For example, when the 1990 MN inventory was conducted, all plots measured in the 1977 inventory plots were examined using aerial photography. The conditions on a portion of the plots that were found to be undisturbed were projected forward to 1990 using a forest growth model (adjusted using information from actual remeasured data), and the resulting projected plot data were used as observations in the estimation process. In the plot location selection procedures for the annual inventory system, both the remeasured and projected plot locations were candidates for measurement. Thus, three kinds of plots were measured in the 1999 annual inventory:

1. New plots at locations never previously measured,
2. Remeasured plots from the previous periodic inventory, and
3. Remeasured plots that were not measured in the immediate previous periodic inventory.

Table 2 summarizes the numbers of these various kinds of plots for each State.

In addition, various ground plot designs were used in different States so that not every remeasurement consists of the remeasurement of the same plot design. IN used the current standard FIA plot design for its previous inventory, however, the other States used a 10-point cluster of variable radius plots. The change in plot design and the mix of new and remeasurement plots limits our ability to estimate the components of change attributes requiring actual plot remeasurements (e.g. growth, removals, and mortality) and also increases the sampling error associated with estimates of total change (e.g. change in forest area and change in total growing-stock volume). Only after 10 years under the annual inventory system will all the plots used to produce estimates be remeasurement plots with observations 5 years apart using a standard plot design, assuming we maintain this system and plot design.

The stratified random sampling estimator, with stratification after the selection of the sample (post-stratification), was used to produce all resource estimates. This estimator is a special case of the double sampling for stratification

Table 2—Number of plot locations by plot type and State

	Number of observed plots			
States	New plots	Plots remeasured from the previous periodic inventory	Plots remeasured from and older periodic inventory	All plot types
	All plots (includes forest and nonforest plot locations			
Iowa	240	962	0	1,202
Indiana	42	296	431	769
Minnesota	103	928	770	1,801
Missouri	160	920	388	1,468
All States	545	3,106	1,589	5,240
	Forest plot locations only			
Iowa	19	91	0	110
Indiana	13	97	64	174
Minnesota	84	382	112	578
Missouri	87	427	91	605
All States	203	997	267	1,467

estimator that has been used in NCFIA estimation for over 30 years. With the use of satellite imagery and computer classification in place of photo plot sampling and human interpretation, we obtained known strata areas (rather than estimates of strata areas), eliminating one source of sampling error in our estimates. National Land Cover Data (NLCD) available from the Multi-Resolution Land Characteristics Consortium (MRLC) (http://www.epa.gov/mrlc/) are used to obtain strata areas. This classification was conducted without any knowledge of the location, classification or other characteristics of FIA ground plots and is truly independent of the ground sample. Independence of the strata area estimates and the ground plot classification (assumed in previous inventories that used double sampling for stratification) came into question when both the strata area estimates and classification of plot locations into strata was done by the same photo interpreters. Some bias that could not be corrected was likely introduced into estimates under that system. Details of the procedures used to produce these estimates are presented in another paper in this report (Hansen 2001).

RESULTS

Estimates of timberland area, total growing-stock volume and average growing-stock volume on timberland for each state are shown in figures 1 through 3. Estimates from the first year of the annual inventory and those from all periodic statewide inventories since 1965 are shown for comparison. In these figures, the solid lines indicate the estimates and the dashed lines indicate the estimates plus or minus one standard error and thus delineate a 67 percent confidence interval around those estimates.

Estimates of timberland area increased in three of the four States (MO, IA, and MN) from the estimates made at the time of the previous inventories: 1989 for MO, 1990 for IA, and 1990 for MN. Data for these inventories were collected over several years and the aerial photography used for stratification was taken prior to the field work, usually several years prior. The date (year) of a periodic inventory is a reporting date assigned to the entire inventory and reflects the year when the last of the field plot measurements were taken, although the measurements are usually made over several years. Based on the inventory date, the estimated annual change in timberland area between inventories was 0.54 percent in MO, 0.32 percent in MN, and 0.37 percent in IA. These increases continue trends that were observed between the prior two inventories in these three States.

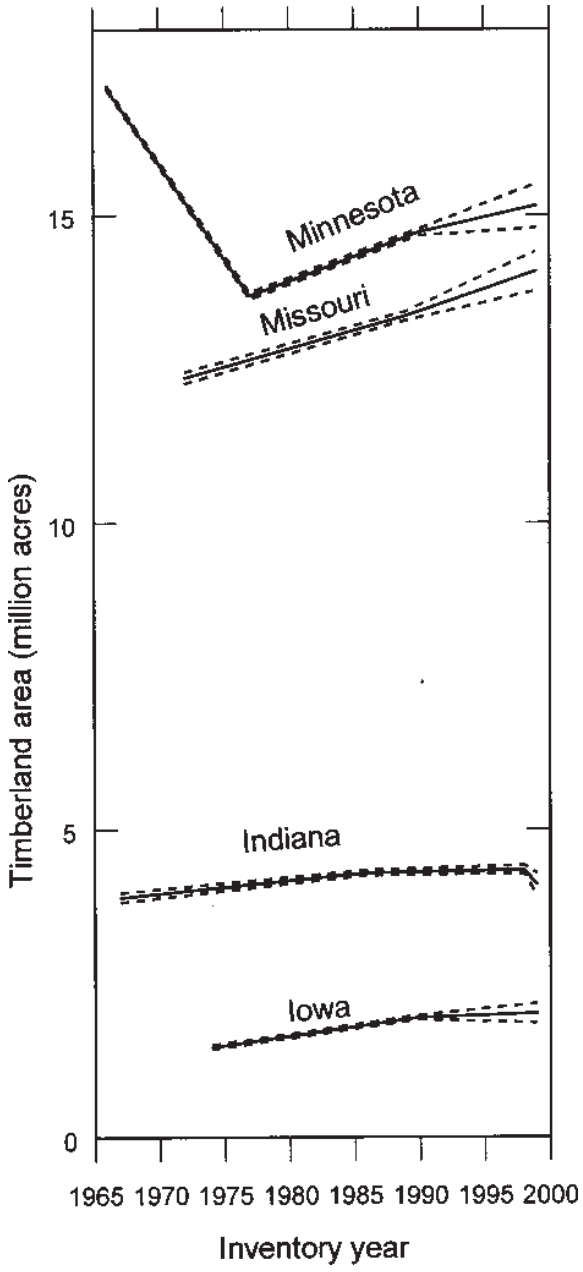

Figure 1—Timberland area estimates for four states, 1965 to 1999. Solid lines indicate the estimates and the dashed lines indicate the estimates plus or minus one standard error.

The estimates for IN are contrary to the trends that were seen in the past and show a decrease in timberland area. The last periodic inventory in IN was 1998, just one year prior to the first year of the annual inventory. An estimated 5.65 percent decrease in timberland area is indicated between that inventory and the first year of the annual inventory system. The sampling error on the 1999 estimate of the timberland in IN is fairly high (4.56 percent), and the sampling error on the 1998 estimate is considerably less (1.59 percent). As mentioned previously, the 1998 inventory was based on considerably more observations, and the 1999 estimate is based on a remeasurement of only 11 percent of these plots (727 of the 6,402 plots measured in 1998) plus the addition of 42 new plots. Also, the 1998 estimate was based on a different classified image for stratification. In detailed analysis of the data, only 3 of 727 (0.41 percent) remeasurement plots in the 1999 annual data indicated an observed change from timberland to another condition from the 1998 periodic inventory. One of these three plots was measured in 1998 and observed to be timberland at that time. When this plot was remeasured in 1999, the area had been cleared of most trees and construction of a park was underway. The other two were field visited in the 1986 inventory and found to be timberland, classified undisturbed in 1998 (based on aerial photo interpretation), and not remeasured in 1998. In 1999, when these two plots were remeasured, they were observed to have changed to a nonforest land classification. One plot

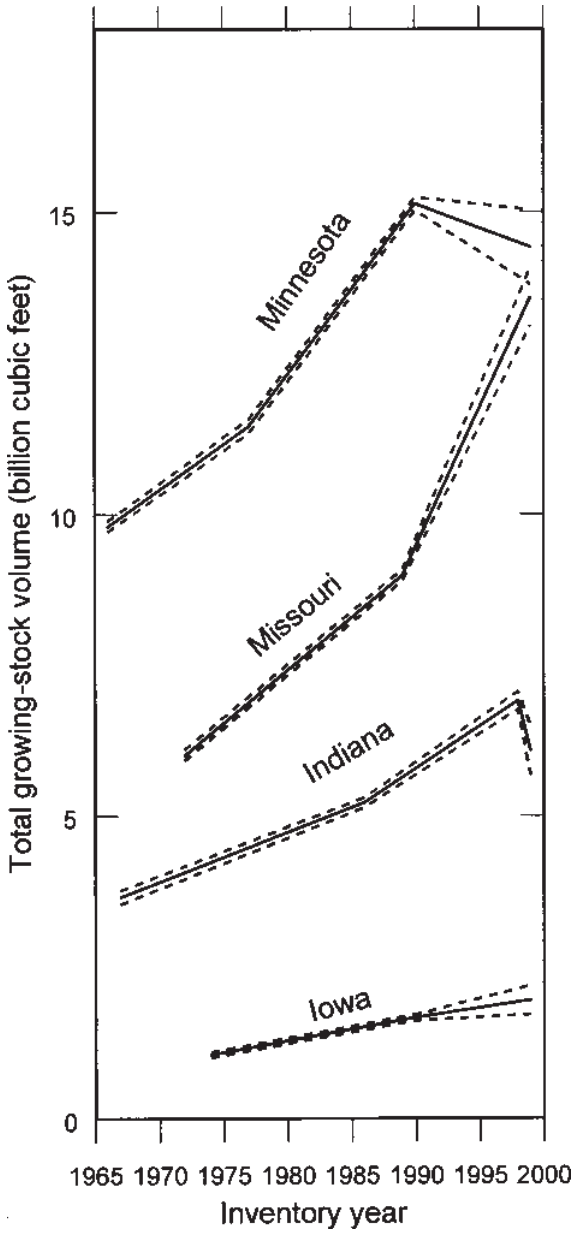

Figure 2—Total growing stock volume estimates for four States, 1965 to 1999. Solid lines indicate the estimates and the dashed lines indicate the estimates plus or minus one standard error.

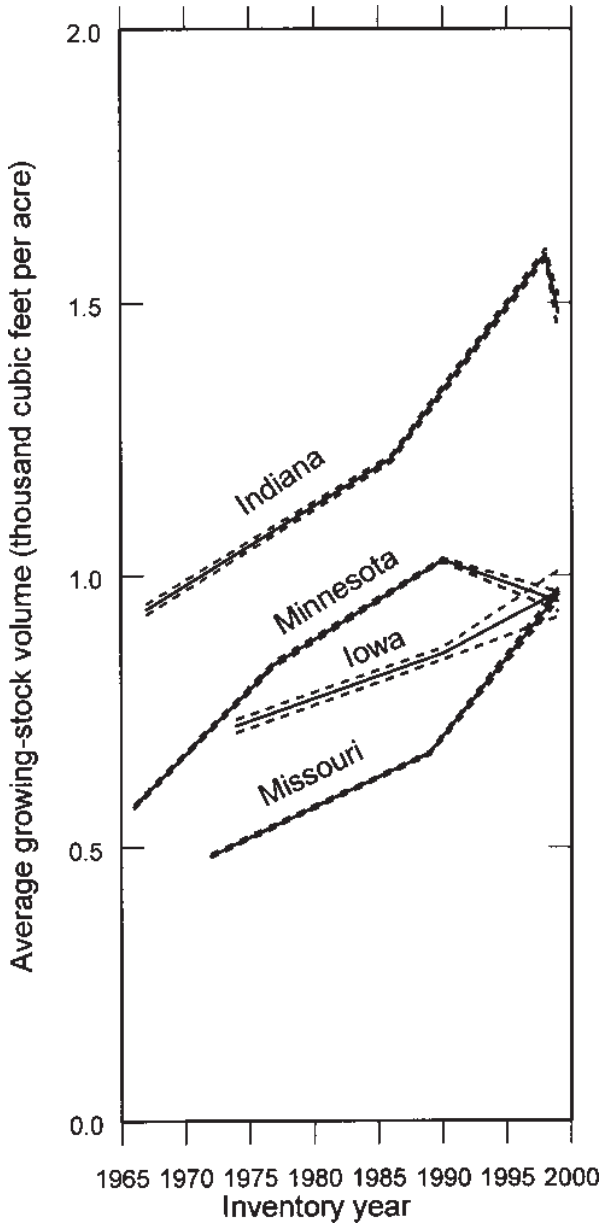

Figure 3—Average growing stock volume per acre estimates for four states, 1965 to 1999. Solid lines indicate the estimates and the dashed lines indicate the estimates plus or minus one standard error.

was in a lowland area where flooding associated with beaver activity had killed the trees, and the other was a farm woodlot where tree mortality associated with cattle grazing resulted in a reclassification of the plot to nonforest. In both of these cases it is unclear when the change to nonforest occurred. This analysis of the IN remeasurement plots indicates that the decrease in estimated timberland area in IN in 1999 from that reported in the 1998 periodic inventory may be a result of the high sampling error associated with the 1999 estimates rather than a loss of timberland between the two inventories.

The total growing-stock volume estimates presented in figure 2 show a large increase in MO from 1989 (over 5 percent per year), a smaller increase in IA from 1990 (slightly less than 2 percent per year) and net decreases in MN (0.5 percent per year) and IN (12 percent per year). Total growing-stock volume estimates are dependent on estimates of timberland area and volume per acre, of which both have associated sampling errors. When combined, the sampling errors for total growing-stock volumes are fairly high. Figure 3 shows the growing-stock volume per acre estimates for each State. As with the timberland area estimates in IN, there is a decrease in the estimated growing-stock volume per acre (6.7 percent from 1998 to 1999). This decrease, combined with the estimated decrease in timberland area results in a large decrease in estimated total volume. Again, high sampling errors most

likely account for a part of this estimated decrease. As additional data become available, the precision of these estimates will improve; and it will be possible to associate changes in volume to the various factors that can cause these changes (growth, mortality, harvesting, and land-use change). Although sampling errors are fairly high, it does appear that the trend of increasing growing-stock volumes in MN and IN that have been observed over the past two periodic inventories may have ended. Additional analysis and data are needed to confirm these findings and to study the causes and impacts of these changes.

Other publications are available that present more detailed estimates for individual States (Schmidt 2000a, 2000b). Additional analysis of the data is being conducted and will be presented in future publications. Also, data will be made available via the internet at http://www.fs.fed.us/research/databases.htm.

DISCUSSION

One purpose of this paper was to demonstrate that estimates from the first year of the annual forest inventory could be made shortly after the completion of data collection. FIA has made a commitment to complete inventories on an annual basis and make final data and estimates from these inventories available when sufficient data is available for detailed analysis. Estimates from the first four states inventoried under this new system were presented at a symposium within six months of the final field measurements. As we gain more experience and improve data collection and processing systems the time to produce and report estimates will decrease. As the speed of reporting increases, the amount of detailed analysis that we can provide with the estimates decreases. To date, results are reported with a minimum of analysis. As annual inventories are implemented and replace periodic inventories as the source of the best available information on the forest resources of a state, users will find it possible and necessary to perform more of the detailed data analysis themselves.

During the transition period to annual inventories, sampling errors for estimates are high and detailed breakdowns of the estimates are questionable. Our plans for making raw data and estimates available to our users over the next few years will be determined by the number of years of annual inventory data collected in a state. Following the first year, state-level estimates such as those presented here will be published. After 2 years, nine State-level tables of area, volume, and number of trees will be published. Following the third year the full suite of 24 standard FIA core tables will be published. After 4 years, the core tables will be revised and web access to the plot data and the FIA table generation program will be available. Following the fifth year of data collection, a full analytical report will be prepared. Periodic analysis of the data will be conducted once the system is in full operation. Over the transition some States will have few remeasurement plots (Kansas, Nebraska, North Dakota, and South Dakota) and estimates of change will not be produced until sufficient remeasurement data is available. In these States tables related to current conditions will be produced following this schedule.

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