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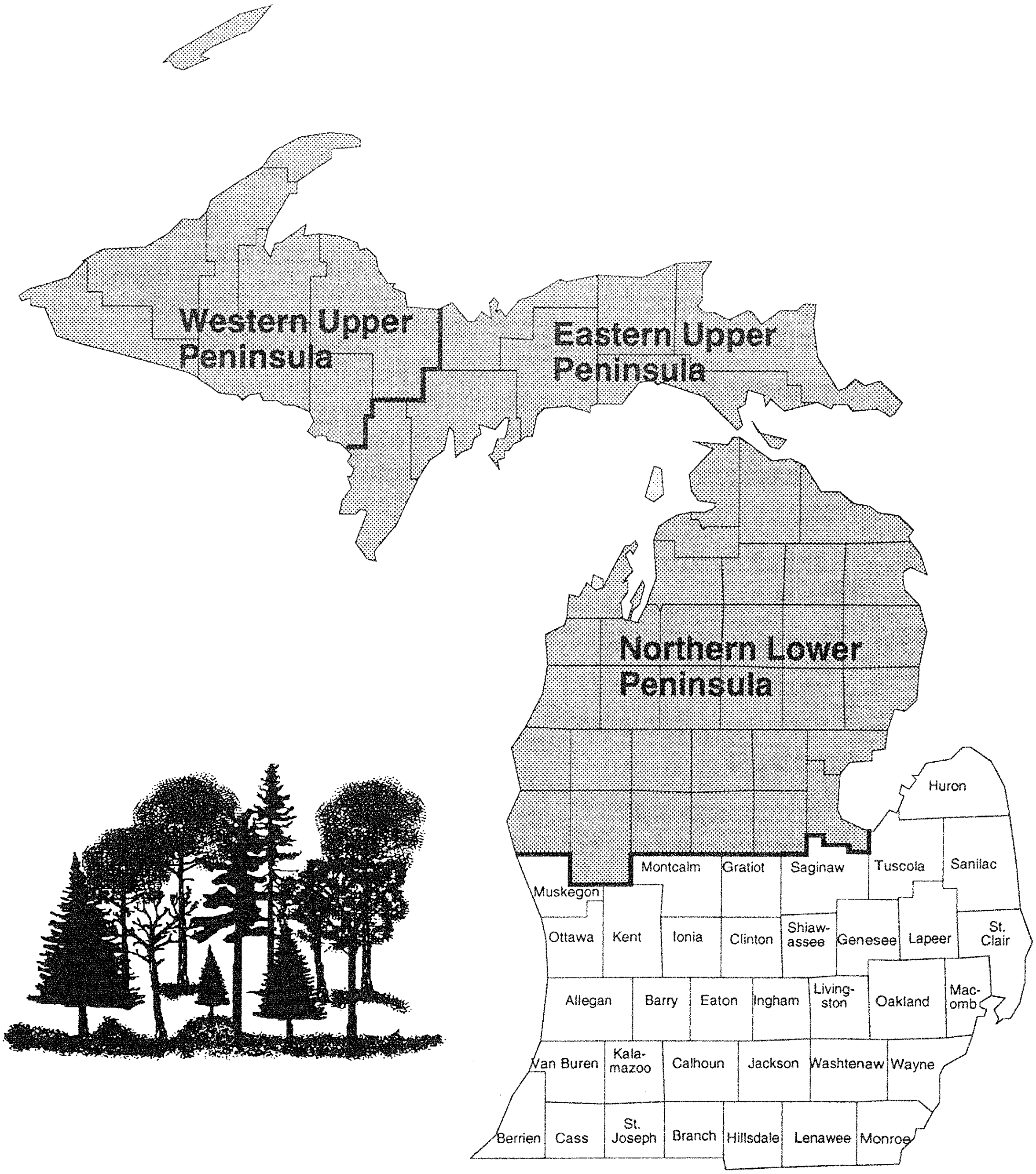
Forest Statistics for Michigan's Southern Lower Peninsula Unit, 1993

Thomas L. Schmidt



This report includes the most commonly used U.S. Department of Agriculture, Forest Service, Forest Inventory and Analysis (FIA) statistics. Additional forest resource data can be provided to interested users. Persons requesting additional information from the raw inventory data are expected to pay the retrieval costs. These costs range from less than $100 for a relatively simple request to more than $2,000 for a complex retrieval involving the services of a Forest Inventory and Analysis computer programmer. Requests will be filled so as to minimize the impact on the Forest Inventory and Analysis Work Unit.

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FOREWORD

Forest Inventory and Analysis (FIA) is a continuing endeavor as mandated by the Renewable Resources Research Act of 1978. Prior inventories were mandated by the McSweeney-McNary Forest Research Act of 1928. The objective of FIA is to periodically inventory the Nation's forest land to determine its extent, condition, and volume of timber, growth, and removals. Up-to-date resource information is essential to frame forest policies and programs. USDA Forest Service regional experiment stations are responsible for conducting these inventories and publishing summary reports for individual States. The North Central Forest Experiment Station is responsible for forest inventory and analysis in Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, and Wisconsin.

Fieldwork for the fifth forest inventory of Michigan's Southern Lower Peninsula Unit was begun in September of 1992 and completed in August of 1993. Reports of the four previous inventories of Michigan's timber resource are dated 1935, 1955, 1966, and 1980.

To aid in determining current timber removals, the Michigan Department of Natural Resources (MiDNR) surveyed primary wood-using plants in the State. Aerial photographs used were black and white, infrared taken in 1986 at a scale of 1:15,840 (nominal). These photographs were purchased by MiDNR and loaned to the USDA Forest Service.

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HIGHLIGHTS

NOTE: Data from new forest inventories are often compared with data from earlier inventories to determine trends in forest resources. However, for the comparisons to be valid, the procedures used in the two inventories must be similar. As a result of our ongoing efforts to improve the inventory's efficiency and reliability, we have made several changes in procedures and definitions since the last Michigan inventory in 1980. Because some of these changes make it inappropriate to directly compare the 1993 data with those published for 1980, data from the 1980 inventory have been re-processed using the current procedures. Forest inventories completed before 1980 have not been adjusted to reflect current FIA inventory methodology and techniques. Comparisons between inventories should be general and used solely for analyzing trends.

All area and volume data and tables were based on what existed as of January 1, 1993, in the Southern Lower Peninsula of Michigan. The time period used for growth, mortality, and removals was January 1, 1980, to December 31, 1992. The area of census water recorded for this unit increased from 198,400 acres in 1980 to 4,603,400 acres in 1993 as major portions of the Great Lakes were allocated to the total area for this unit by the U.S. Bureau of the Census. ***The data in this report are subject to change when inventory data for the entire State have been compiled. It is expected, however, that any such changes will be minor.***

General

Michigan's Southern Lower Peninsula Unit (fig. 1) is comprised of 35 counties and is the most heavily populated unit in the State. The region is bounded by Lake Michigan, Lake Huron, and Lake Erie, which provide international access for a multitude of products from this region, including a wide array of forest based products.

Agriculture and urban/industrial development dominate land-use and economic activity in southern Michigan. However, forest land represented 21 percent of all land in the Survey Unit in 1993, and provided economic, ecological, scenic, and recreational diversity for the region.

As with most forest land in this region of the United States, the forests in the Southern Lower Peninsula were subjected to intensive harvesting during early European settlement. In addition, widespread slash burning and wildfire, unleashed because of the lack of adequate fire control, contributed to the understocking and poor condition of most of the forest lands by the turn of the 19th century. However, that trend reversed during the early 1900's as regrowth of the forest resource began, in conjunction with organized wildfire control and active forest management. From 1935 through 1955, most of the regenerated forest reached sapling to poletimber sizes (Chase and Pfeifer 1970). These trees have continued to grow into larger diameter classes. Now, the current forest resource is well stocked with a wide range of diameter classes. The following are a few major highlights from the 1993 inventory of the Southern Lower Peninsula Survey Unit.

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Figure 1.—*Southern Lower Peninsula Survey Unit, 1993.*

Area

- Forest land accounted for more than 3,053,700 acres in 1993, 21 percent of the total land area (excluding water). Of this total, timberland occupied 3,000,700 acres, and reserved forest land occupied 53,000 acres.

- Timberland increased in area by 20 percent, adding more than 524,000 acres from 1980 to 1993. This represents an average increase of 40,000 acres each year. Most of the increase came from abandoned cropland and pasture on which trees became established through either planting or natural succession between 1980 and 1993.

- In 1993, the 3 million acres of timberland represented the highest level of total timberland area since forest inventories began in this Survey Unit (fig. 2). This increase occurred as new forest stands were established on land previously used in other ways, while existing stands continued to grow and move into the larger stand-size classes.

- More than 738,000 acres of land were classed as nonforest with trees in 1993, an increase of more than 570,000 acres since 1980. These lands have the potential to become forest land if the existing trees are allowed to grow, and if additional tree invasion occurs.

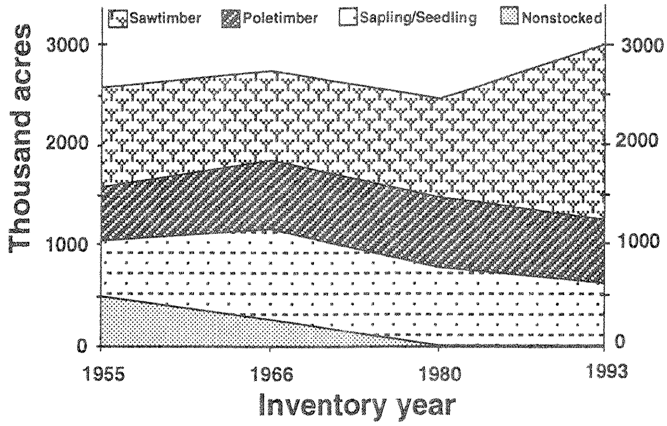

Figure 2.—*Timberland area by stand-size class from forest inventories of the Southern Lower Peninsula in 1955, 1966, 1980, and 1993.*

- Area of wooded strips decreased between inventories. In 1980, there were more than 183,000 acres in wooded strips compared to 110,000 acres in 1993. About half of this decline was due to reclassification of some wooded strips that had expanded to more than 120 feet in width, putting them into the forest land category. The other half of the decline was due to the removal of other wooded strips. Where the decline occurred due to physical removal, it represents an important loss because wooded strips provide: water quality improvement by filtering sediments and other pollutants; shading for rivers and streams, which helps to lower the water temperature and improves fish habitat; wildlife habitat and escape cover; soil erosion protection; and aesthetics.

- As in 1980, the group that owned the largest area of timberland was the farmer/miscellaneous private individuals group, with 2.4 million acres in 1993. Miscellaneous private corporations were the second largest owner group in 1993, accounting for almost 260 thousand acres. In 1993, about 89 percent of all timberland in the Unit was privately owned (fig. 3).

- The largest public timberland owner in 1993 was the State, which added substantially to its timberland ownership between inventories, increasing from 150,000 acres in 1980 to 238,000 acres in 1993. In 1993, the State of Michigan owned timberland in 22 of the 35 counties in this Survey Unit.

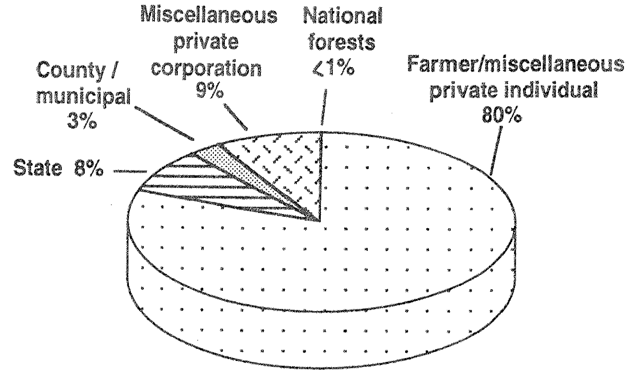

Figure 3.—*Ownership of timberland in the Southern Lower Peninsula in 1993.*

- Maple-birch was the dominant forest type with more than 1.3 million acres in 1993. The oak-hickory and elm-ash-soft maple forest types were second and third, respectively. These three forest types accounted for 90 percent of the total area of timberland in 1993 (fig. 4).

- All hardwood forest types except aspen increased in area of timberland between 1980 and 1993 (fig. 4). Aspen declined by one-third in timberland area, falling from 181 thousand acres in 1980 to 121 thousand acres by 1993. The loss of aspen was probably due to succession as the intolerant shorter lived aspen succumbed to old age and was replaced by longer lived, shade tolerant hardwoods that had been present in the understory of undisturbed stands.

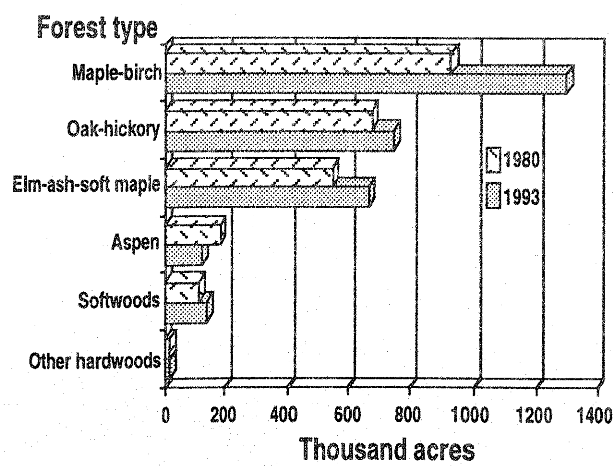

Figure 4.—*Area of timberland by forest types, Southern Lower Peninsula, 1993.*

- Area of nonstocked timberland has steadily decreased from a high of almost 20 percent of all timberland in 1955 to less than 1 percent in 1993 (fig. 2). From 1955 through 1993, the area of poletimber-sized stands remained relatively stable. The major gains in area of timberland by stand-size class since 1955 have occurred with the sawtimber-size class. By 1993, sawtimber stands accounted for 58 percent of all timberland. Poletimber and sapling/seedling stands represented 22 percent and 20 percent, respectively, of all timberland.

Volume

- Total volume of growing stock increased from 2.6 billion cubic feet in 1980 to 4.2 billion in 1993, an increase of more than 60 percent between inventories. Growing stock increased an average of more than 126 million cubic feet each year.

- The hard hardwood species group accounted for 50 percent of the total growing-stock volume in 1993, with more than 2.1 billion cubic feet. Soft hardwoods contributed an additional 1.8 billion cubic feet, 44 percent of the total growing-stock volume in 1993 (fig. 5).

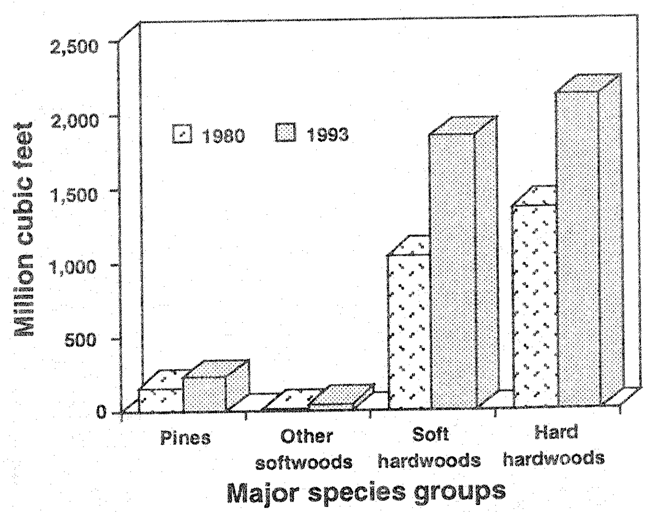

Figure 5.—*Growing-stock volume for major species groups in the Southern Lower Peninsula, 1980 and 1993.*

- Most forest types increased in growing-stock volume between 1980 and 1993 (fig. 6). The greatest increase occurred in the maple-birch forest type, as more than 800 million cubic feet were added during the 13 years between inventories.

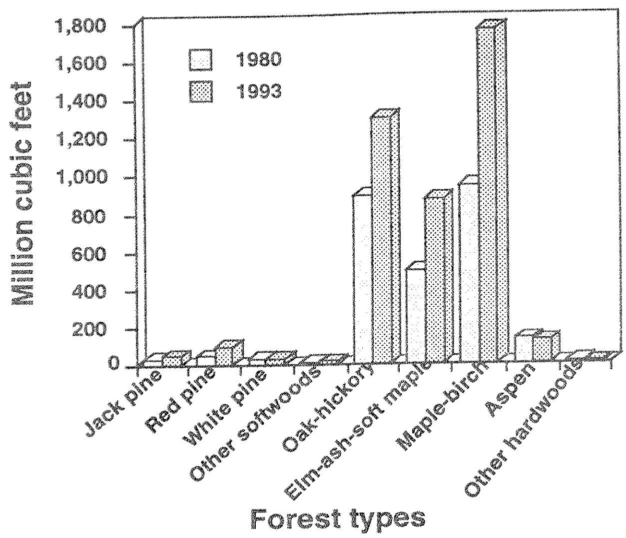

Figure 6.—*Growing-stock volume by forest type, Southern Lower Peninsula, 1980 and 1993.*

- Timberland averaged more than 1,400 cubic feet of growing-stock volume per acre in 1993, compared to about 1,000 cubic feet per acre in 1980. Timberland is becoming better stocked with larger trees as the forests that regenerated in the early 1900's mature.

- Growing-stock volume accounted for 90 percent of the total volume of all live trees in 1993. The remaining 10 percent consisted of short-log, rough, and rotten trees that were classified as live but did not meet the standards for growing stock.

- The soft maple species group represented the largest volume of sawtimber with more than 2.3 billion board feet in 1993. Select red oak and select white oak species groups were second and third in total sawtimber volume, respectively, with both having about 1.7 billion board feet in 1993.

Growth

- Total gross growing-stock average annual growth (net growth plus mortality) between 1980 and 1992 was more than 169 million cubic feet in the Southern Lower Peninsula. In comparison, the average annual net growth (total gross growth less mortality) for growing stock was 148 million cubic feet.

- From 1980 through 1992, average annual net growth for all species on timberland was nearly 50 cubic feet of growing stock per acre. This average annual net growth rate represented 3.5 percent of the growing-stock inventory in the Southern Lower Peninsula.

- Current (1992) net growth for all species on timberland was nearly 157 million cubic feet, 9 million cubic feet more than the 13-year average annual net growth between inventories.

- Soft hardwoods led all major species groups with an average of more than 70 million cubic feet of growing-stock growth per year from 1980 through 1992 (fig. 7). In addition, hard hardwoods contributed more than 65 million cubic feet of growing-stock growth annually between inventories.

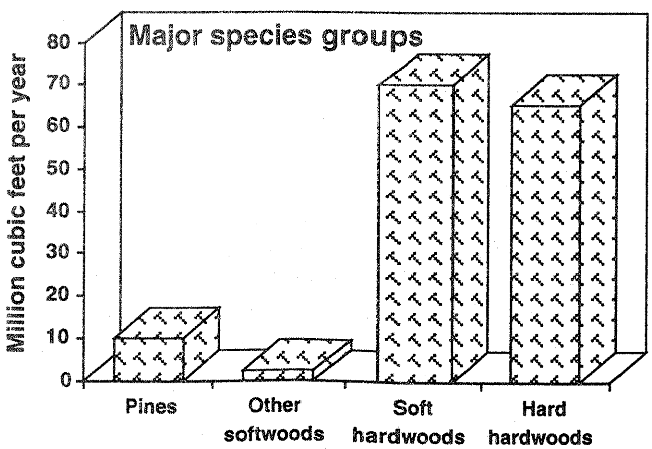

Figure 7.—*Average annual net growth of growing stock for major species groups in the Southern Lower Peninsula, 1980-1992.*

- Within hardwood species groups, soft maple, select red oak, and white/green ash all averaged more than 15 million cubic feet of growing stock net growth per year between 1980 and 1992 (fig. 8).

- Within softwood species groups, red pine and white pine averaged more than 4 million cubic feet of growing-stock net growth per year between 1980 and 1992 (fig. 9).

- Soft maple led all hardwood species groups in average sawtimber growth, with almost 90 million board feet per year from 1980 through 1992. White and green ash, select red oaks, and select white oaks averaged more than 40 million board feet of sawtimber growth each year.

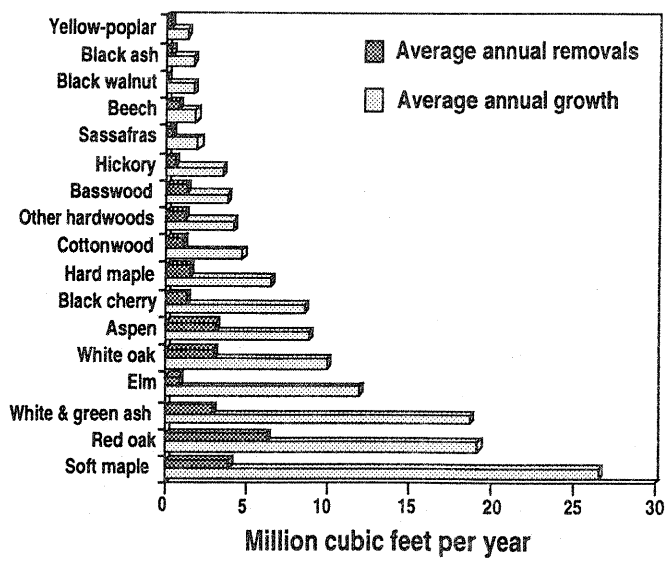

Figure 8.—*Comparison of average annual hardwood growing-stock growth with removals, by species group, Southern Lower Peninsula, 1980-1992.*

- Softwood sawtimber averaged more than 59 million board feet of net growth per year between 1980 and 1992. White pine, with more than 23 million board feet, and red pine, with nearly 20 million board feet, accounted for 73 percent of all softwood sawtimber growth between inventories.

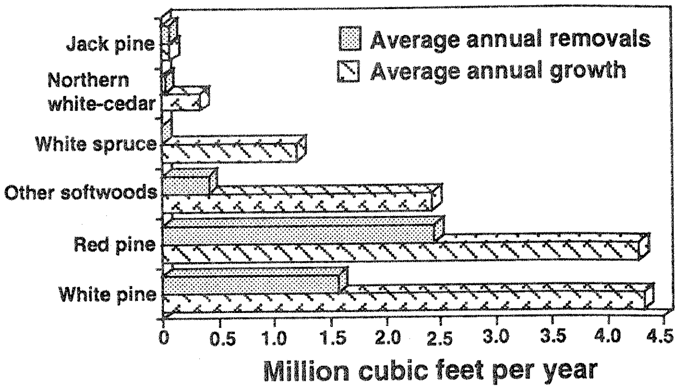

Figure 9.—*Comparison of softwood growing-stock growth with removals, by species group in the Southern Lower Peninsula, 1980-1992.*

Removals

- Annual growing-stock removals averaged less than 1 percent of total growing-stock volume and about 22 percent of the annual net growth volume between 1980 and 1992. During this period, removals averaged more than 33 million cubic feet per year.

- Current growing-stock removals were 20.3 million cubic feet in 1990 (1990 is the most recent mill survey for the Southern Lower Peninsula), which was about 12.8 million cubic feet less than the 13-year average between inventories.

- Average annual removals of hardwood growing stock represented 21 percent of hardwood average annual growth from 1980 through 1992 (fig. 8).

- Removals of hardwood growing-stock occurred primarily in the select and other red oaks, soft maple, select white oak, white and green ash, and aspen species groups. These species groups accounted for 67 percent of all hardwood growing-stock removals each year from 1980 through 1992.

- Average annual removals of softwood growing stock represented 36 percent of softwood average annual growth from 1980 through 1992 (fig. 9). Removals of softwood growing stock were primarily in red pine and white pine.

- Average annual hardwood sawtimber removals were 21 percent of average annual sawtimber growth from 1980 through 1992. Most sawtimber removals occurred in the select red oak, soft maple, and select white oak species groups, with more than 10 million board feet removed annually from each of these species groups.

Mortality

- Annually, growing-stock mortality averaged 21.5 million cubic feet between inventories. Sawtimber mortality averaged 45.8 million board feet during this time period. These totals represent annual losses of less than 1 percent of both volumes.

- Current growing-stock mortality (1992) was 20.6 million cubic feet and current sawtimber mortality (1992) was 46.9 million board feet in the Southern Lower Peninsula. Both current mortality levels were nearly identical to the 13-year average.

- Dutch elm disease continued to ravage the elm species group. From 1980 through 1992, elm represented almost 20 percent of all growing-stock mortality, but accounted for less than 5 percent of the total volume.

- Soft maple, elm, red oak, aspen, and white and green ash species groups recorded more than 60 percent of all sawtimber mortality from 1980 through 1993. Mortality of these species groups averaged more than 3 million board feet of sawtimber each year.

ACCURACY OF THE SURVEY

Forest Inventory and Analysis (FIA) information is based on a sampling procedure designed to provide reliable statistics at the State and Survey Unit levels. Consequently, the reported figures are estimates only. A measure of reliability of these figures is given by sampling errors. The level of sampling error used by FIA means the chances are two out of three that if a 100-percent inventory had been taken, using the same methods, the results would have been within the limits indicated.

For example, the estimated growing-stock volume in the Southern Lower Peninsula Unit in Michigan in 1993, 4,238.5 thousand cubic feet, has a sampling error of ± 2.19 percent (± 92.8 thousand cubic feet). Based on this sampling error, growing-stock volume from a 100-percent inventory would be expected to fall between 4,145.7 and 4,331.3 thousand cubic feet (4,238.5 ± 92.8), there being a one in three chance that this is not the case. The following tabulation shows the sampling errors for Michigan's Southern Lower Peninsula Forest Inventory:

Item	Unit totals	Sampling error
Growing stock	(Million cubic feet)	(Percent)
Volume (1993)	4,238.5	2.19
Average annual growth (1980-1992)	148.1	2.40
Average annual removals (1980-1992)	33.4	11.85
Sawtimber	(Million board feet)	
Volume (1993)	13,044.5	2.89
Average annual growth (1980-1992)	516.4	2.90
Average annual removals (1980-1992)	116.0	13.06
Timberland	(Thousand acres)	
area (1993)	3,000.7	1.29

As survey data are broken down into sections smaller than Survey Unit totals, the sampling error increases. For example, the sampling error for timberland area in a particular county is higher than that for total timberland area in the Unit. This tabulation shows the sampling errors for Unit totals. To estimate sampling error for data smaller than Unit totals, use the following formula:

$$E = \frac{(SE)\ \sqrt{\text{(Unit total area or volume)}}}{\sqrt{\text{(Volume or area smaller than Unit total)}}}$$

where:

E = sampling error in percent
SE= Unit total error for area or volume

For example, to compute the error on the area of timberland in the maple-birch type for the Unit:

1. Total area of timberland in the maple-birch forest type from table 3 = 1,300,900 acres;

2. Total area of all timberland in the Unit from table 3 = 3,000,700 acres;

3. Unit total error for timberland area from the above tabulation = 1.29 percent.

Using the above formula:

$$E = \frac{(1.29)\ \sqrt{(3{,}000{,}700)}}{\sqrt{(1{,}300{,}900)}} = \pm\ 1.96 \text{ percent.}$$

County Data

A standard FIA inventory is designed to provide sampling errors of no more than 3 percent per million acres of timberland. Thus, this Unit's 3,000.7 thousand acres of timberland required a sampling error of 1.73 percent to meet national FIA standards. Because the 35 counties in the Southern Lower Peninsula were inventoried at a single level of intensity, sampling errors will increase if data from this inventory effort are utilized below the unit level. Caution must be used accordingly. The sampling error within an individual county depends on county size and total area of timberland.

COMPARING THE FIFTH INVENTORY OF THE SOUTHERN LOWER PENINSULA WITH THE FOURTH INVENTORY

A new volume estimation procedure has been developed for the Lake States since the last survey conducted in 1980. We used this procedure to compute the 1993 volumes and to re-compute the 1980 volume for growth calculations. Although the adjustment will differ by species, the re-computed 1980 volumes will generally be greater than those shown in the original 1980 report.

Past surveys used only growing-stock trees to determine stand-size class. Current survey procedures require that stand-size class be determined on the basis of all live trees. Therefore, direct comparisons of current inventory data to old inventory data by stand-size class may be misleading.

The basic building block for estimating forest area and timber volume has been changed from the Survey Unit (as utilized during the 1980 inventory) to the county (current methodology). In the past, statistics were developed at the Unit level and prorated back to the county on the basis of photo-interpretation results. Direct development of county-level data helps users interested in more precise local data, but can make the outcome of comparisons with past estimates uncertain.

SURVEY PROCEDURES

The 1993 survey of Michigan's Southern Lower Peninsula used a growth model enhanced, two-phase sample design. Using this sampling scheme and associated estimators is similar to sampling with partial replacement, in that a set of randomly located plots is available for remeasurement and a random set of new plots is established and measured. A significant feature of the new design is stratification for disturbance on the old sample and use of a growth model to improve regression estimates made on old undisturbed forest plots (fig. 10). Detailed descriptions of the sampling and estimation procedures are presented by Hansen (1990). The growth model used was the Lake States Stand and Tree Evaluation and Modeling System (STEMS) (Belcher *et al.* 1982).

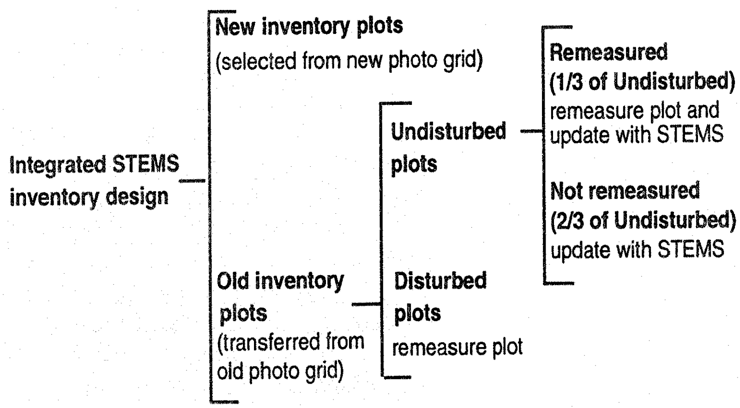

Figure 10.—*Overview of the sample design for the Southern Lower Peninsula's 1993 survey.*

Major Steps in the New Survey Design

1. Aerial photography (Phase 1)

In this phase, two sets of random points were located on current aerial photographs. The first set was new photo plots, and the second set was relocated, old ground plot locations from the 1980 inventory. Locations of the plots used in the 1980 inventory were transferred to the new photographs. The photographs were then assembled into township mosaics, and a systematic grid of 121 one-acre photo plots (each plot representing approximately 190.4 acres) was overlaid on each township mosaic. Each photo plot was examined by aerial photogrammetrists and classified stereoscopically as to its land use. If trees were present, forest type and stand-size/density classes were recorded. All of the 1980 ground plot locations were also examined for disturbance (logging, fire, catastrophic mortality, etc.). After this examination, all the old "disturbed" sample locations and one-third of the old "undisturbed" forested plots were sent to the field for survey crews to verify the photo classification and to take further measurements. All photo plot locations for the 1993 inventory were examined and classified as shown in the following tabulation.

Photo land class	Photo plots
Timberland	15,955
Reserved forest land	314
Other forest land	0
Questionable	552
Nonforest with trees	4,357
Nonforest without trees	55,822
Water	978
All classes	77,978

2. Plot measurements (Phase 2)

On plots classified as timberland, wooded pasture, or windbreak (at least 120 feet wide), a ground plot was established, remeasured, or modeled. Old plots sent to the field for remeasurement that could not be relocated were replaced with a new plot at the approximate location of the old one. Each ground plot consisted of a 10-point cluster covering 1 acre. At each point, trees 5.0 inches or more d.b.h. were sampled on a 37.5 basal area factor variable-radius plot, and trees less than 5.0 inches d.b.h. were sampled on a 1/300-acre fixed-radius plot. The measurement procedure for both the new and old sample locations was as follows:

a. New inventory plots

A random sample of the new photo plots was selected for field measurement. Ground plots were established, and measures of current classification such as land use, forest type, and ownership, as well as size and condition of all trees on the plot, were recorded. These locations were monumented for future remeasurement.

b. Old inventory plots

These plots were originally established, monumented, and measured as part of the 1980 field inventory. Procedures for these old plots were different from those for the new plots. Old plots were classed as "undisturbed" or "disturbed" in the aerial photo phase of the sampling process. All disturbed plots and a one-third sample of the undisturbed forested plots were remeasured to obtain estimates of current condition and changes since the last inventory. All trees measured on these plots in 1980 were remeasured or otherwise accounted for, and all new trees were identified and measured.

All sample plots that were forested at the time of the 1980 inventory and determined to be undisturbed until the 1993 inventory were projected to the current time (1993) using STEMS. This procedure gives projected estimates of current volume and growth for undisturbed plots. Comparison of the projected and observed values on the one-third sample of the undisturbed forest plots that were remeasured provided local calibration data to adjust the projected values of the undisturbed plots that were not remeasured. The adjustment procedure is a modified version of the method described by Smith (1983).

Undisturbed forested plots that were not remeasured played a crucial role in the new survey design. These plots, after careful comparison of past and current aerial photography, were determined to be undisturbed and had conditions that could be simulated by

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STEMS. The STEMS growth model was used to "grow" the old plot and tree data to produce an estimate of current data. Thus, these plots were treated as ground plots, even though they were never visited. The plot record for each modeled plot was sent to the field for verification of current ownership information.

All old plots classified as disturbed were sent to the field for remeasurement to assess and verify changes since the last inventory. Disturbance referred to any change on a plot that was detected on aerial photos and that the STEMS growth processor could not predict, such as catastrophic mortality, cutting, seedling stands, and/or land use change.

The estimation procedure for computing statistics from this sampling design was more complicated than the simple two-phase estimation procedure used in the past. In fact, this procedure yielded two independent samples, one coming from the new photo points and the other from the old photo points that were remeasured or modeled. The following tabulation summarizes the distribution of all ground plots for the new inventory design by type of plot:

3. Area estimates

Area estimates were made using two-phase estimation methods. In this type of estimation, a preliminary estimate of area by land use is made from the aerial photographs (Phase 1) and corrected by the plot measurements (Phase 2). A complete description of this estimation method is presented by Loetsch and Haller (1964). All area estimates were based on what existed as of January 1, 1993, in the Southern Lower Peninsula of Michigan.

4. Volume estimates

Estimates of volume per acre were made from the trees measured or modeled on the 10-point plots. Estimates of volume per acre were multiplied by the area estimates to obtain estimates of total volume. Volume estimates were based on what existed as of January 1, 1993, in the Southern Lower Peninsula of Michigan. Net cubic foot volumes were based on a modification of the method presented by Hahn (1984) for use in the Lake States. For the Southern Lower Peninsula inventory, the merchantable height equation presented was used in conjunction with Hahn's board foot volume equation (adapted from Stone's equation—Hahn 1984) to estimate gross volume.

Ground land use class	Old plots remeasured	Old plots updated	New plots	Total plots
Timberland	506	233	165	904
Reserved forest land	6	0	47	53
Nonforest with trees	137	64	58	259
Nonforest without trees	1,543	1,455	606	3,604
Water	40	33	43	116
Total	2,232	1,785	919	4,936

This estimate was then corrected by species for variation in bark and cull volume to yield an estimate of net volume (Hahn 1984).

The Forest Service reports all board foot volume in International 1/4-inch rule. In Michigan, the Scribner log rule is commonly used. Scribner log rule conversion factors were derived from full tree measurements taken throughout the Lake States (Michigan, Wisconsin, and Minnesota) and an equation developed by Wiant and Castenaeda (1977). Factors, or multipliers, that can be used to convert board foot International volumes to the Scribner rule are shown in the following tabulation:

D.b.h. (inches)	Scribner rule conversion factor Softwoods	Hardwoods
9.0-10.9	0.7830	—
11.0-12.9	.8287	0.8317
13.0-14.9	.8577	.8611
15.0-16.9	.8784	.8827
17.0-18.9	.8945	.8999
19.0-20.9	.9079	.9132
21.0-22.9	.9168	.9239
23.0-24.9	.9240	.9325
25.0-26.9	.9299	.9396
27.0-28.9	.9321	.9454
29.0+	.9357	.9544

5. Growth and mortality estimates

On remeasured plots, estimates of growth and mortality per acre come from the remeasured diameters of trees and from observation of trees that died between inventories. Growth reported as the average net annual growth between the two inventories (1980 and 1992) was computed from data on remeasurement plots and modeled plots using methods presented by VanDeusen *et al.* (1986). Mortality was also reported as average annual for the remeasurement period. On new plots, where trees were not remeasured, estimates of growth and mortality were obtained by using STEMS to project the growth and mortality of trees for 1 year. Growth and mortality estimates for old undisturbed plots that were updated were derived in the same manner as remeasured plots. The STEMS growth model was adjusted to meet local conditions, using data from the undisturbed remeasurement plots. As with volume, total growth and mortality estimates were obtained by multiplying the per acre estimates by area estimates.

Current annual growth for 1992 was computed by using the adjusted STEMS model to grow all current inventory plots for 1 year. All growth and mortality estimates were based on growth and mortality through December 31, 1992, in the Southern Lower Peninsula of Michigan.

6. Average annual removals estimates

Average annual growing-stock and sawtimber removals (1980 to 1992) were estimated only from the remeasured plots; new plots were not used to estimate removals. These estimates are obtained from trees measured in the last survey and cut or otherwise removed from the timberland base. All removal estimates were based on removals through December 31, 1992, in the Southern Lower Peninsula of Michigan. Because remeasurement plots make up about one-half of the total ground plots, average annual removals estimates have greater sampling errors than volume and growth estimates.

Tree and Log Grades

On approximately one-third of the sample plots in Michigan's Southern Lower Peninsula, all sawtimber sample trees were graded for quality and assigned either a tree grade (hardwoods) or a log grade (softwoods). Tree and log grades were based on the evaluation of external characteristics as indicators of quality. The volume yield by grade for this sample was used to distribute the volume of the ungraded sample trees by species group. Hardwood sawtimber trees were graded according to "Hardwood tree grades for factory lumber" (Hanks 1976). The best 12-foot section of the lowest 16-foot hardwood log was used for grading. Hardwood sawtimber trees that did not meet minimum tree grade specifications for grades 1 through 3 were assigned grade 4 according to Forest Service standard specifications for hardwood construction logs described in "A guide to hardwood log grading" (Rast *et al.* 1973). Red pine and jack pine sawtimber trees were graded based on specifications described in "Forest Service log grades for southern pines" (Campbell 1964). White pine and other softwood sawtimber trees were graded according to specifications described in "Sawlog grades for eastern white pine (Ostrander and Brisbin 1971). For all softwoods, the first merchantable 16-foot log, or shorter lengths down to 12 feet, was used for grading.

Hardwood Tree Grades for Factory Lumber[a]

Grade factor	Tree grade 1	Tree grade 2	Tree grade 3
Length of grading zone (feet)	Butt 16	Butt 16	Butt 16
Length of grading section [b] (feet)	Best 12	Best 12	Best 12
D.b.h., minimum (inches)	16[c]	13	11
Diameter, minimum inside bark at top of grading section (inches)	13[c] 16 20	11[d] 12	8
Clear cuttings (on the three best faces)[e] Length, minimum (feet) Number on face (maximum) Yield in face length (minimum)	 7 5 3 2 5/6	 3 3 2 3 4/6	 2 ([f]) 3/6
Cull deduction (including crook and sweep, but excluding shake) maximum within grading section (percent)	9	9[g]	50

[a] *(Hanks 1976).*

[b] *Whenever a 14- or 16-foot section of the butt 16-foot log is better than the best 12-foot section, the grade of the longer section will become the grade of the tree. This longer section, when used, is the basis for determining the grading factors.*

[c] *In basswood and ash, diameter inside bark (d.i.b.) at top of grading section must be 12 inches and d.b.h. must be 15 inches.*

[d] *Grade 2 trees can be 10 inches d.i.b. at top of grading section if otherwise meeting surface requirements for small grade 1's.*

[e] *A clear cutting is a portion of a face free of defects, extending the width of the face. A face is one-fourth of the surface of the grading section as divided lengthwise.*

[f] *Unlimited.*

[g] *Fifteen percent crook and sweep or 40 percent total cull deduction are permitted in grade 2, if size and surface of grading section qualify as grade 1. If rot shortens the required clear cuttings to the extent of dropping the butt log to grade 2, do not drop the tree's grade to 3 unless the cull deduction for rot is greater than 40 percent.*

Forest Service Standard Specifications for Hardwood Construction Logs (Tie and Timber logs)[a,b]

Position in tree	Butts and uppers
Minimum diameter, small end	8 inches +
Minimum length without trim	8 feet +
Clear cuttings	No requirements
Sweep allowance	One-fourth small end d.i.b. for each 8 feet of length. One-half d.i.b. for logs 16 feet long.
Sound surface defects:	
Single knots	Any number, if no knot has an average diameter above the callus in excess of one-third of the log diameter at point of occurrence.
Whorled knots	Any number, if the sum of knot diameters above the callus does not exceed one-third of the log diameter at point of occurrence.
Unsound defects:	
Surface	Same requirements as for sound defects if they extend into included timber. No limit if they do not.
Interior	None permitted except one shake not more than one-third the width of contained tie or timber, and one split, not over 5 inches.

a *These specifications are minimum for the class. If, from a group of logs, factory logs are selected first, thus leaving only nonfactory logs from which to select construction logs, then the quality range of the construction logs so selected is limited, and the class may be considered a grade. If selection for construction logs is given first priority, it may be necessary to subdivide the class into grades.*

b *(Rast* et al. *1973).*