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Minnesota's Forest Resources in 1999

Thomas L. Schmidt

ABSTRACT.—The North Central Research Station's Forest Inventory and Analysis Program began fieldwork for the sixth Forest Inventory of Minnesota in 1999. This inventory initiates a new annual inventory system. This Research Note contains preliminary estimates of Minnesota's forest resources prepared from data gathered during the first year of the inventory.

KEY WORDS: Annual inventory, forestland, forest type, growing-stock volume, Minnesota.

BACKGROUND

The North Central Research Station's Forest Inventory and Analysis Program (NCFIA) began fieldwork for the sixth forest inventory of Minnesota in 1999, in cooperation with the Minnesota Department of Natural Resources. This inventory initiates a new annual inventory system. Under this new system, one-fifth of the field plots in the State are measured each year. As a result, the current inventory of Minnesota's forest resources will not be completed until 2004. However, because each year's sample is a systematic sample of the State's forests and because timely information is needed about Minnesota's forest resources, preliminary estimates of Minnesota's forest resources have been prepared from data gathered during the first year of the inventory. **Due to the limited number of field plots measured, future estimates using data in this report are subject to change when ensuing annual inventories are completed and data compiled.** The results presented are estimates based on sampling techniques. As additional annual inventories are completed, the precision of the estimates will increase and additional data will be released.

Reports of previous inventories of Minnesota are dated 1936, 1953, 1962, 1977, and 1990. Data from new 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 efficiency and reliability of the inventory, several changes in procedures and definitions have occurred since the last Minnesota inventory in 1990. Some of these changes make it inappropriate to directly compare portions of the 1999 data with those published for 1990. When comparisons are made or estimates presented from past inventories in this report, data from previous inventories are recomputed using current methods to ensure that comparisons are valid.

RESULTS

Results of the 1999 inventory show that the area of timberland in Minnesota has continued to increase, maintaining a trend that began in the early 1980's. Before that, from initial European settlement to the 1970's, the area of timberland in Minnesota had declined. The decrease in timberland was primarily due to agricultural expansion as forests were cleared for crops and pastures. Since the 1970's, however, some of the agriculture and other land-use practices have changed in Minnesota, which has allowed for the expansion of timberland.

Before European settlement in Minnesota, the southern, southwestern, and far western areas of the State were primarily prairie due to wildfires and/or a drier climate. Native Americans used fire as a tool to attract and/or herd

THOMAS L. SCHMIDT is a Research Forester with the North Central Research Station, St. Paul, MN.

wildlife, which helped to maintain the area in prairie. This limited trees to mainly along streams and rivers where they were somewhat protected from wildfires. As Europeans settled the area, the number of wildfires decreased but the area dedicated to agriculture increased, which continued to limit the extent of forests in these regions. If disturbances are limited, trees can grow in almost all locations across Minnesota.

The remaining area of Minnesota was more heavily forested before European settlement. Fires also occurred in this region but not with the same frequency and severity as in the prairie portions of the State. The different fire regime, combined with different topography and soils, allowed this portion of Minnesota's vegetation to be oriented toward trees rather than grasses.

In all these areas, agricultural practices have changed. Some marginal croplands have been allowed to convert back to forest, and some domestic livestock grazing methods have changed as more operations switch from open grazing to confinement systems. These changes, combined with effective wildfire control, have allowed trees to become established on formerly forested sites and to expand into new areas. In the historically forested regions of Minnesota, the recovery of the resource from the initial large-scale disturbances associated with early settlement and logging at the turn of the century has continued, resulting in an increase in area of timberland. The recovery has occurred through natural regeneration as well as through plantations.

The first inventory of Minnesota's forests in 1936 estimated that the area of timberland represented about 35 percent of the total land area in the State. The second inventory in 1953 of Minnesota estimated that the area of timberland had decreased by 4 percent to 17.3 million acres. This trend of declining area of timberland continued with the third inventory of Minnesota in 1962 when 17.1 million acres of timberland were reported. Between the 1962 and 1977 inventories, the area of timberland declined to 13.6 million acres, a 20-percent decrease over just 15 years. However, between 1977 and 1990, area of timberland increased by 8 percent in Minnesota, to 14.7 million acres (Miles *et al.* 1995).

Results of the 1999 inventory of Minnesota show a slight increase in the area of timberland. While timberland area continues to increase, the rate of land conversion from other land uses to forest has slowed. It appears that in the 10 years between inventories (1990 to 1999), the area of timberland increased by about 3 percent (fig. 1). Currently, it appears that the area of timberland in Minnesota is recovering to levels of the late 1960's.

Minnesota is well known for its hardwood and conifer forests. Aspen-birch continues to dominate the State in terms of area by forest type (fig. 2). The other three main hardwood

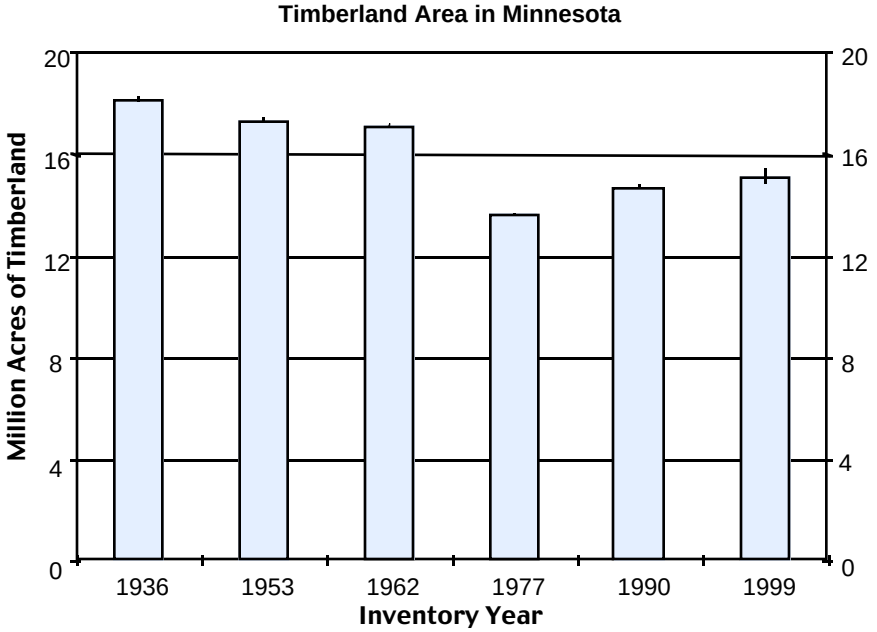

Figure 1.—*Area of timberland in Minnesota by inventory year (Note: sampling errors associated with each inventory are represented by the vertical lines at the top of each bar).*

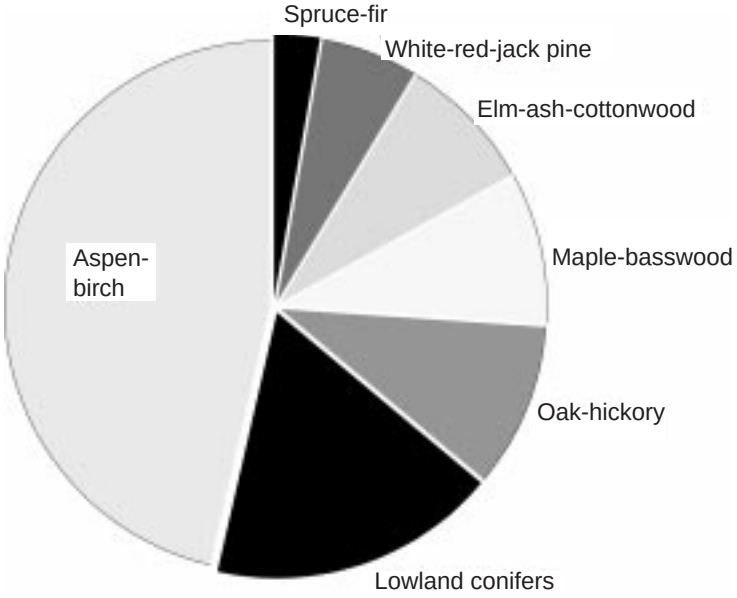

Figure 2.—*Area of timberland in Minnesota by forest type, 1999.*

forest types—oak-hickory, elm-ash-cottonwood, and maple-basswood—are currently represented in about equal amounts. Swamp conifer forest types such as black spruce, tamarack, and northern white-cedar represented about two-thirds of the total area of conifers in Minnesota in 1999.

The area of publicly owned timberland in Minnesota increased between 1990 and 1999. Publicly owned timberlands are a critical component of the landscape because they are major sources of wildlife habitat, outdoor recreation, and other social and environmental benefits. The three Upper Lake States (Minnesota, Michigan, and Wisconsin) lead the Nation in terms of area of timberland owned by counties and local governments. Nationally, this public ownership group accounts for about 6 percent of all timberland, but in the Upper Great Lakes, counties and local governments own about 25 percent of the timberland resource.

On average, these public forests also currently appear to have slightly better stocking rates (stocking is a measure of the density of tree cover) than most privately owned timberlands in Minnesota (70 percent of all public timberlands in Minnesota are moderately or better stocked while 65 percent of all private lands fall into those categories). Stocking is the degree of occupancy of the land by trees and is a good measure of how well the timberlands are utilizing a site for wood production.

Results of the 1999 inventory show that Minnesota's timberlands continue to mature, resulting in an increase in area of timberland classified as sawtimber and decreases in the area of sapling-seedling size stands. Forests have been maturing due to a lack of natural or human disturbance. As mentioned, the number of disturbances from fire has declined in Minnesota over time. Historically, timber harvesting in Minnesota has varied from using clearcuts, where entire stands are removed, to using selective methods where individual trees are selected for harvest but the entire stand is not removed. Clearcuts generally result in a new stand-size classification, but selective harvesting generally results in the stand maintaining its overall stand-size classification. However, harvesting methods in Minnesota are now undergoing some changes; the impact of these changes might affect future stand-size classifications (Puettmann *et al.* 1998).

Total growing-stock volume in Minnesota slightly decreased between 1990 and 1999 (figs. 3, 4). Growing-stock volume is the amount of solid wood in trees 5 inches d.b.h. and over, from 1 foot above ground to a minimum 4-inch top diameter. The decrease in total growing-stock volume was due to a slight decrease in both hardwoods and conifers. In addition to the growing-stock volume in Minnesota, significant volumes are found in short-log trees, rough trees, and rotten trees. These tree classifications are grouped into what is

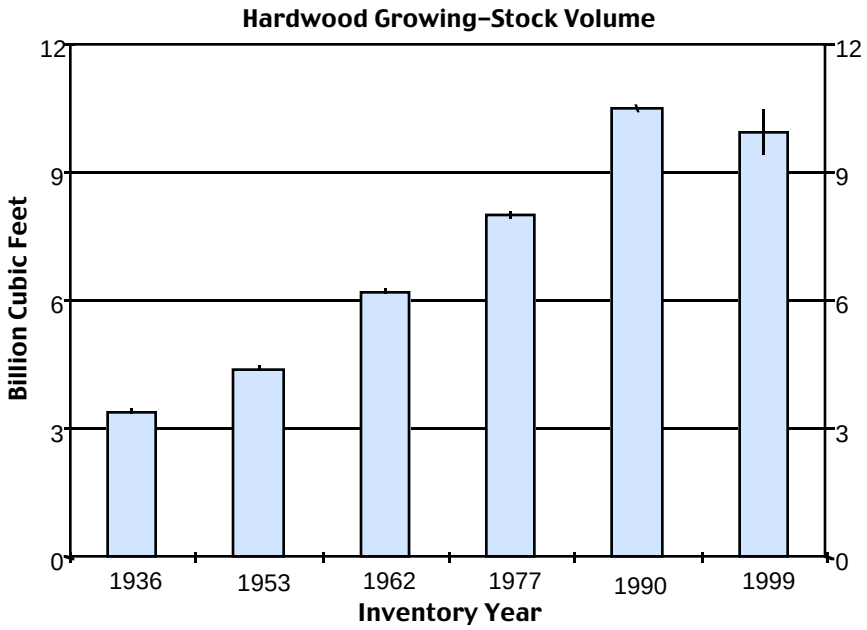

Figure 3.—*Hardwood growing-stock volume in Minnesota by inventory year (Note: sampling errors associated with each inventory are represented by the vertical lines at the top of each bar).*

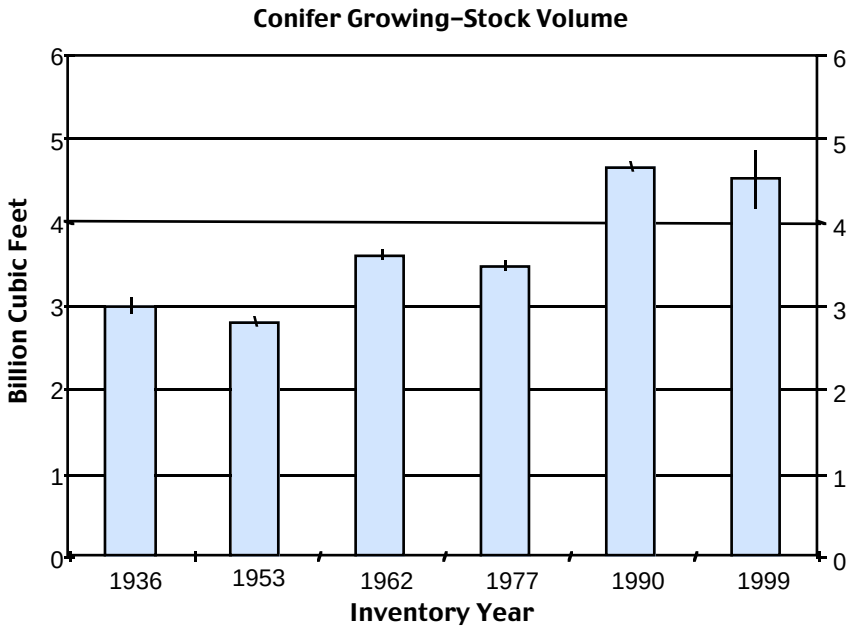

Figure 4.—*Conifer growing-stock volume in Minnesota by inventory year (Note: sampling errors associated with each inventory are represented by the vertical lines at the top of each bar).*

termed non-growing-stock trees. Non-growing-stock trees can be used for a wide variety of forest products such as pulpwood, firewood, and are excellent sources of wildlife habitat and other nontimber forest values. The volume in short-log trees appears to have increased between inventories while the volume in rough and rotten trees has slightly decreased.

Hardwoods dominate in Minnesota, representing more than 75 percent of the total growing-stock volume. In 1999, the majority of the growing-stock volume in Minnesota was in aspen-birch species. Aspen-birch species alone accounted for about 45 percent of the total growing-stock volume in the State in 1999. The second greatest hardwood volumes were in oak species, followed by maples, ash, and basswood. Each of these species had more than 700 million cubic feet of growing-stock volume in Minnesota in 1999.

Dominant conifer species in Minnesota in 1999, in terms of total growing-stock volume, were northern white-cedar, black spruce, balsam fir, and red pine. All of these species had more than 600 million cubic feet of growing-stock volume in Minnesota in 1999.

In summary, it appears from the initial annual inventory of Minnesota completed in 1999 that most measures related to timberland continue to increase. This is an exciting, positive note for the State as we await further implementation and completion of additional annual inventories in Minnesota.

INVENTORY METHODS

Changes Between Inventories

Since the 1990 inventory of Minnesota, several changes have been made in NCFIA inventory methods to improve the quality of the inventory as well as to meet increasing demands for timely forest resource information. The most significant difference between inventories was the change from periodic inventories to annual inventories. Historically, NCFIA periodically inventoried each State on a cycle that averaged about 15 years. However, the need for timely and consistent data across large geographical regions, combined with national legislative mandates, resulted in NCFIA's implementation of an annual inventory system. Minnesota was one of the first States in the North Central region, and one of the first States in the Nation, to be inventoried with this new system, beginning with the 1999 inventory.

With an annual inventory system, about one-fifth of all field plots are measured each year. After 5 years, the entire inventory will be completed. After the first 5 years, NCFIA will report and analyze results as a 5-year moving average. For example, NCFIA will be able to generate a report based on inventory results for 1999 through 2004 or for 2001 through 2006. While there are great advantages for an annual inventory, one difficulty is reporting on results in the first 4 years. With the 1999 inventory, only 20 percent of the field plots have been measured. Sampling error estimates for the 1999 inventory results are 2 percent for timberland area and 4.3 percent for growing-stock volume. Thus, caution should be used when drawing conclusions based on this limited data set. As ensuing measurements are completed, we will have additional confidence in our results due to the increased number of field plots measured. As each measurement year is completed, the quantity and quality of results will increase.

Remote Sensing Techniques

Other significant changes between inventories include the implementation of new remote sensing technology, implementation of a new field plot design, development of new volume equations, and gathering of additional remotely sensed and field data. The advent of remote sensing technology since the previous inventory in 1990 allowed NCFIA to use computer-assisted classifications of Multi-Resolution Land Characterization (MRLC) data and other available remote sensing products to stratify the total area of the State and to improve estimates. Previous inventories used manual interpretation of aerial photos to stratify the sample.

New Volume Equations

The new volume equations, developed by USDA Forest Service research scientists and other cooperating researchers, more accurately estimate growing-stock and sawtimber volumes. As additional annual inventories are implemented and comparisons between the current inventory and previous inventories become possible, FIA will produce new estimates from the 1990 inventory using the new volume tables to provide a comparison for the 1999 inventory results.

Forest Type and Stand Size

New algorithms were used in 1999 to assign forest type and stand-size class to each condition observed on a plot. These algorithms are being used nationwide by FIA to provide consistency from State to State and will be used to reassign the forest type and stand-size class of every plot measured in the 1990 inventory. This will be done so that changes in forest type and stand-size class will reflect actual changes in the forest and not changes due to a change in algorithms. The list of recognized forest types, grouping of these forest types for reporting purposes, equations used to assign stocking values to individual trees, definition of nonstocked (stands with a stocking value of less than 10 percent for all live trees), and names given to the forest types changed with the new algorithms.

Plot Location

Another change with the current inventory is the determination of the exact plot location of every ground plot in the inventory. For plots that are visited in the field, this is done using a geographic positioning system (GPS) device at plot center. For plots not visited in the field, the plot location is determined by transferring the old plot location from the aerial photography to an unclassified, geo-corrected remotely sensed image. Both procedures provide an accurate location that is used to link the ground plots to the classified remotely sensed data used for stratification.

PROCEDURES

The 1999 Minnesota survey used a two-phase sample for stratification that included remeasuring inventory plots from the 1990 inventory and new field plots. Two-phase sampling, also called double sampling, consists of a phase-one sample used to estimate area by strata and a phase-two sample to estimate the average value of parameters of interest within these strata. The estimated population total is the sum across all strata of each stratum's estimated area multiplied by its estimated mean per unit area.

The only land that could not be sampled was private land where field personnel could not obtain permission from the owner to measure a phase-two field plot. These denied access plots were somewhat rare in Minnesota (less than 1 percent of the total forest plots statewide) and the methods used in the preparation of this report make the necessary adjustments to account for sites where access was denied.

Phase One

Phase-one and phase-two plots were placed systematically across the entire State without regard to specific land characteristics. All lands have the same probability of being sampled under this inventory system. The 1999 inventory used a computer-assisted classification of satellite imagery for classification. FIA used the imagery to form two initial strata—forest and nonforest. Pixels within 60 m (2 pixel widths) of a forest/nonforest edge formed two additional strata—forest/nonforest and nonforest/forest. Forest pixels within 60 m on the forest side of a forest-nonforest boundary were classified into a forest/nonforest stratum. Pixels within 60 m of the boundary on the nonforest side were classified into a nonforest/forest stratum. An overlay of all National Forest land ownership was used to identify all lands owned by the Superior and Chippewa National Forests. These National Forest lands were treated separately but were also stratified into one of the above four strata. Stratification and estimation were conducted at the State level for National Forest Lands and at the unit level for other lands. Final estimation of area by stratum was based on these five strata—National Forest, forest, forest/nonforest, nonforest/forest, and nonforest for all lands.

In the 1990 inventory, aerial photographs were assembled into township mosaics, and a systematic grid of 121 one-acre photo plots (each plot representing 190.4 acres on the ground) was overlaid on each township mosaic. Each of these photo plots was stereoscopically examined by aerial photo interpretation specialists and classified based on land use, forest type, and stand-size density. From these photo plots, a systematic sample of plots (without regard to their aerial photo classification) was selected as ground plots and further examined by survey crews to verify the classification and to take further measurements. These 1990 ground plots formed the basis for the remeasured ground plots in the 1999 inventory. Additional information related to procedures for the 1990 inventory can be found in Miles *et al.* (1995).

The move to satellite imagery changed NCFIA's phase-one sample from being based on one photo plot every 190.4 acres to a sample based on a classified pixel every 0.22 acres. The increased intensity of the phase-one sample greatly improved the precision of estimates of the area with each stratum, particularly at the county level. Also, because classification was conducted using a computer-assisted algorithm across the entire State, biases in the photo plot sampling method that resulted from differences in photo quality, age of photography, and experience of the photo interpreter were eliminated and classification was consistent across the entire State.

Phase Two

Phase two of the inventory consisted of the measurement of an annual sample of field plots in Minnesota. Current FIA precision

standards for annual inventories require a sampling intensity of one plot for every 5,937 acres. To satisfy this requirement, the geographical hexagons established for the Forest Health Monitoring (FHM) program were divided into 27 smaller NCFIA hexagons, each of which contained 5,937 acres (McRoberts 1999). A grid of field plots was established by selecting one plot from each smaller hexagon based on the following rules: (1) if an FHM plot fell within a hexagon, it was selected as the grid plot; (2) if no FHM plot fell within a hexagon, the existing NCFIA plot from the 1989 inventory nearest the hexagon center was selected as the grid plot; and (3) if neither FHM nor existing NCFIA plots fell within the hexagon, a new NCFIA plot established at the hexagon center was selected as the grid plot (McRoberts 1999). This grid of plots is designated the Federal base sample and is considered an equal probability sample; its measurement in Minnesota is funded by the Federal government. The State of Minnesota and the Chippewa and Superior National Forests supplemented the base Federal sample with a doubling of the field sample plots across the State except for the major reserved tracts found in the Boundary Waters Canoe Wilderness Area and Voyageurs National Park.

The total Federal base sample of hexagonal grid plots was systematically divided into five interpenetrating, non-overlapping subsamples or panels. Each year the plots in a single panel are measured with panels selected on a 5-year, rotating basis (McRoberts 1999). For estimation purposes, the measurement of each panel of plots may be considered an independent random sample of all land in a State. Field crews measured vegetation on plots in the forested and straddler (nonforest/forest and forest/nonforest) categories, and a sample of plots classified as non-forested were checked to ensure correct classification.

NCFIA has two categories of field plot measurements—phase-three plots (FHM plots) and phase-two field plots to optimize our ability to collect data when available for measurement. It is imperative that each type of plot be uniformly distributed both geographically and temporally. Phase-three plots are measured with the full array of FHM vegetative and health variables collected (Mangold 1998). Phase-three plots must be measured between June 1 and August 30 to accommodate measurement of non-woody understory vegetation, ground cover, soils, and other variables. We anticipate that in Minnesota the complete 5-year annual inventory will involve about 175 phase-three plots. On the remaining plots, only variables that can be measured throughout the entire year are collected. In Minnesota, the complete 5-year annual inventory is expected to involve about 2,800 phase-two forested plots and about 560 phase-two straddler plots. With intensification, the number of field plots will be doubled.

The new national FIA 4-point cluster plot design was used for data collection (fig. 5) in 1999 and will be used in subsequent years. The old NCFIA 10-point cluster plot design will be phased out over the next 5 years. For all remeasured field plots in the Federal base sample, the new 4-point cluster plot was established and measured at the old plot (1990) location. In addition, the first five subplots of the old 10-point (subplot) cluster plot were remeasured in 1999 to estimate change. All trees previously measured on these plots were remeasured or otherwise accounted for on these five subplots. These measurements form the basis for change estimates between the 1990 and current annual inventories for characteristics such as average annual net growth, mortality, and removals. Thus, until a complete cycle of annual inventories for Minnesota has been accomplished, both the new 4-point cluster plots and part of the old 10-point cluster plots will be measured. If the anticipated 20 percent of the State is sampled each year, by the sixth year of annual inventories in Minnesota, the new 4-point cluster plots will begin to be remeasured and the former plot design will be abandoned. The national plot design also requires mapping forest conditions on each plot. Due to the small sample size (20 percent) each year, precision associated with change factors such as mortality will be relatively low. Consequently, change estimates will not be reported until at least three annual inventories are completed, and even then we anticipate that estimates of change will be limited in detail. When the complete annual inventory has been implemented in 2004, estimates for the full range of change variables will be available.

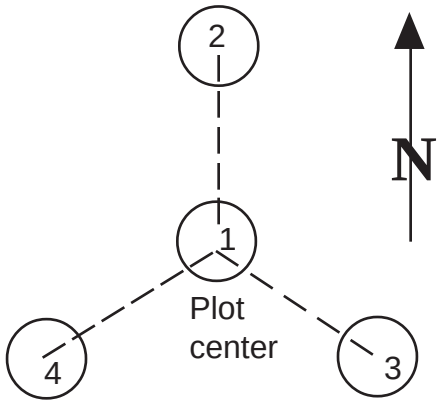

Figure 5.—*Current NCFIA field plot design.*

The overall plot layout for the new design consists of four subplots spaced 120 feet apart in a triangular arrangement. Subplots 2, 3, and 4 are spaced 120 degrees apart. The center of the new plot is located at the same point as the center of the previous plot if a previous plot existed within the sample unit. All trees less than 5 inches in diameter at breast height (d.b.h., or 4.5 feet above ground level) are measured on a 6.8-foot-radius ($1/300^{th}$ acre) circular microplot located at the center of each of the four subplots. Trees with diameters 5 inches and larger are measured on a 24-foot-radius ($1/24^{th}$ acre) circular subplot. The forest condition of each subplot is recorded. Factors that can determine a change in condition from subplot one are changes in forest type, stand-size class, land use, ownership, and density. Each condition that occurs anywhere on one of the subplots is identified, described, and mapped if the condition in total meets or exceeds one acre in size (the one acre minimum size for a condition to be identified could include land off the subplot). Each condition is assigned a condition number and condition information is recorded.

Field plot measurements are combined with phase-one estimates in the compilation process and table production. The number of tables generated from a single year's data is limited, but as additional annual inventories are completed the number of tables will increase until year 5, when all statewide inventory summary tables will be available in both printed and electronic format. If additional information is desired, requests may be directed to:

Program Manager
Forest Inventory and Analysis
North Central Research Station
1992 Folwell Ave.
St. Paul, MN 55108

or

State Forester
Minnesota Department of Natural Resources
Forestry Division
P.O. Box 44, 500 Lafayette Road
St. Paul, MN 55155

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