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Missouri's Forest Resources in 1999

Thomas L. Schmidt

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

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

BACKGROUND

The North Central Research Station's Forest Inventory and Analysis Program (NCFIA) began fieldwork for the fifth forest inventory of Missouri in 1999, in cooperation with the Missouri Department of Conservation. 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 Missouri's forest resources will not be completed until 2004. However, because each year's sample is a systematic sample of the State's forest and because timely information is needed about Missouri's forest resources, preliminary estimates of Missouri'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.

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

Reports of previous inventories of Missouri are dated 1947, 1959, 1972, and 1989. 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 Missouri inventory in 1989. Some of these changes make it inappropriate to directly compare portions of the 1999 data with those published for 1989. 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

Before European settlement, forests occupied an estimated 70 percent of the total land area in Missouri (King *et al.* 1949). Between initial European settlement and the first inventory of Missouri's forests in 1947, area of forestland declined to about 35 percent of the State. The second inventory in 1959 of Missouri's forestlands estimated that about 3 out of every 10 acres were forested. The trend of declining area of forestland continued with the third inventory of Missouri's forests in 1972. Between the 1959 and 1972 inventory, the area of forestland declined by more than a million acres. The decrease in forestland was primarily due to agricultural expansion as forests were cleared for crops and pastures. However, the 1989 inventory showed a reversal in the declining trend in area of forestland in Missouri because of land-use practices and wildfire control. Between 1972 and 1989, area of forestland increased by 8 percent in Missouri.

The Missouri River marks the southern terminus of glacial expansion, which had a profound effect on topography, soils, drainage systems, and resulting vegetation. Before European settlement in Missouri, the area north of the Missouri River was primarily prairie with a mix of woodlands along rivers and streams. Northern Missouri has historically been dominated by grassland ecosystems due to frequent wildfires. Native Americans commonly used fire as a tool to attract and/or herd buffalo and other wildlife. This limited trees in northern Missouri to being mainly along streams and rivers where they were somewhat protected from wildfires. As Europeans settled the area, the number of wildfires decreased in northern Missouri but the area dedicated to agricultural practices increased, which continued to limit the extent of forests in the region. If disturbances are limited, trees can grow in almost all locations across northern Missouri.

The area south of the Missouri River was more heavily forested before European settlement than the area north of the Missouri River. Fires also occurred in southern Missouri but not with the same frequency and severity as in northern Missouri. The combination of a different fire regime with different topography and soils allowed southern Missouri's vegetation to be predominately forest.

In both regions, agricultural practices have changed. Marginal croplands have been allowed to convert back to grasslands or forests. 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 forests to become established on formerly forested sites in southern Missouri and to expand into new areas in northern Missouri.

Results of the 1999 inventory of Missouri show a slight increase in the area of forestland. While forestland area continues to increase, the rate of conversion from other land uses to forestland has slowed. It appears that in the 10 years between inventories (1989 to 1999), the area of forestland increased by approximately 5 percent. Timberland, a subset of forestland, has followed the same trend in Missouri. Timberland is forestland that is capable of growing trees at a minimum level (20 cubic feet per acre per year) and that is not restricted from harvesting. Currently, it appears that the area of timberland in Missouri may have reached or exceeded the 1959 level (fig. 1).

Missouri is well known for its oak-hickory forests. Every inventory conducted in the State has shown this to be the dominant forest type. The 1999 inventory estimates almost three-fourths of the timberland in Missouri is oak-hickory and associated species (fig. 2).

The area of publicly owned forestland in Missouri increased between 1989 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. On average, these public forests also

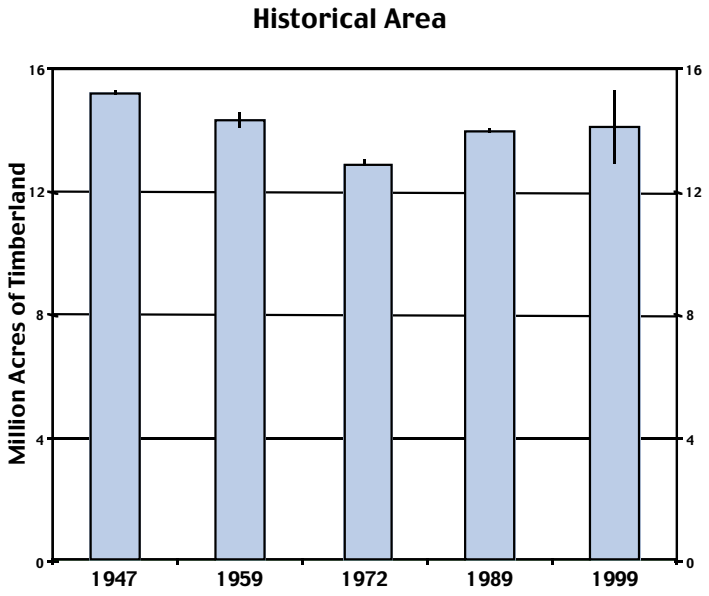

Figure 1.—*Area of timberland in Missouri by inventory year (Note: sampling errors associated with each inventory are represented by the vertical lines at the top of each bar).*

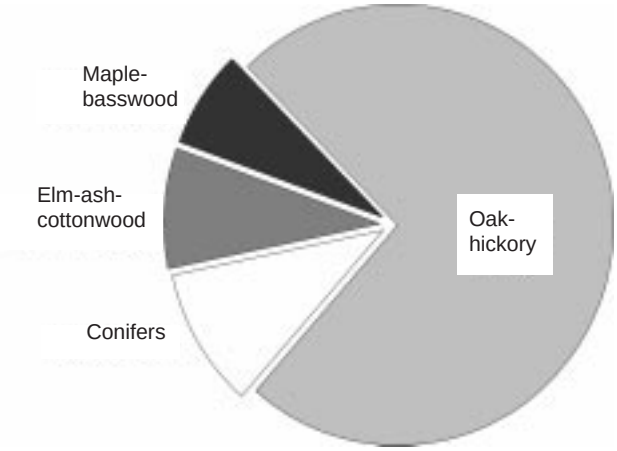

Figure 2.—*Area of timberland in Missouri by forest type, 1999.*

currently appear to have better stocking rates (stocking is a measure of the density of tree cover) and more volume per acre than most privately owned timberlands in Missouri.

Missouri's timberlands continue to mature, resulting in increases in the number of acres classified as sawtimber and poletimber and decreases in the area of sapling-seedling-size stands (fig. 3). Forests have been maturing due to a lack of natural or human disturbances. As mentioned, the number of disturbances from fire has declined in Missouri over time. Historically, harvesting methods in Missouri ranged from clearcutting to individual tree selection (individual trees were selected for harvest but the entire stand was not removed). However, harvesting methods in Missouri are now undergoing some changes, which may influence the future distribution among the three classifications of stand size.

With the increase in average stand-size class, growing-stock volume has also increased. 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. As trees increase in diameter and as the timberlands increase their stocking rate, the volume of wood also correspondingly increases. Both hardwood and conifer growing-stock volumes have increased between every inventory of Missouri's timberlands (figs. 4, 5). The increase in growing-stock volume is a reflection of both increased stocking and tree size. Another factor in the increase of growing-stock volume between inventories is the conversion of some non-growing stock (primarily either having rough form or having rotten portions of the live tree) to growing stock because of improved quality.

In 1999, the majority of the growing-stock volume in Missouri was in oak species. The second greatest volumes were in hickory species, followed by maples, black walnut, hackberry, sycamore, and ash. Hardwoods dominate in Missouri, representing more than 90 percent of the total growing-stock volume.

In summary, it appears from the initial annual inventory of Missouri completed in 1999 that area, stand-size class, stocking, growing-stock volume, and most other measures related to forestland and timberland continue to increase. This is a positive note for the condition of the State's forests as we await further implementation and completion of additional annual inventories in Missouri.

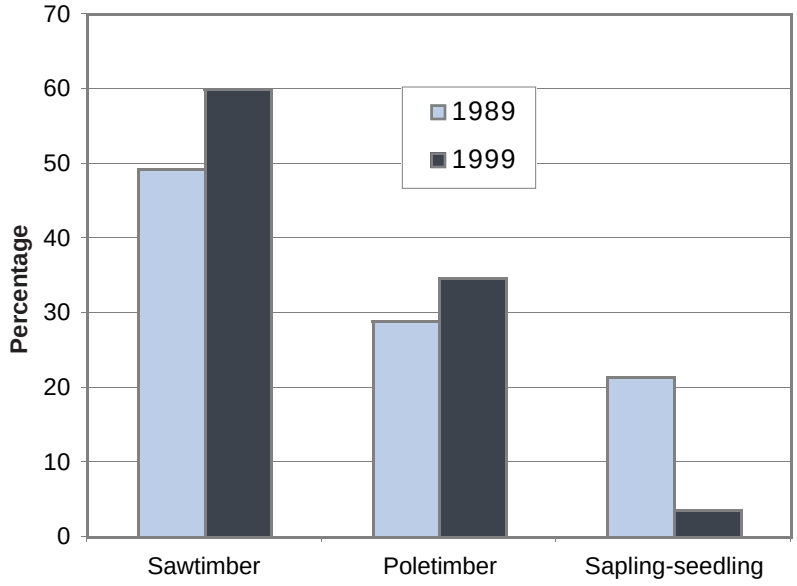

Figure 3.—*Stand-size classification as a percentage of total timberland area in Missouri, 1989 and 1999.*

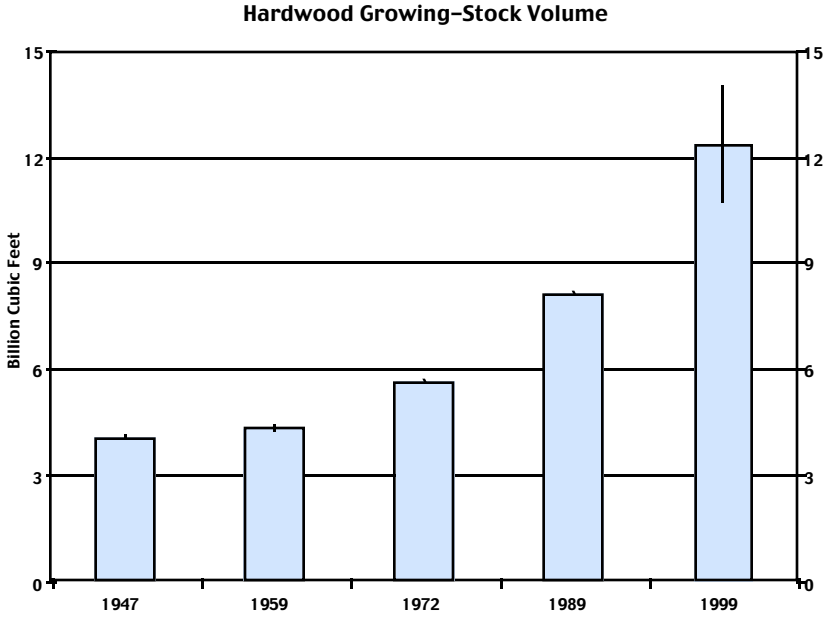

Figure 4.—*Hardwood growing-stock volume in Missouri by inventory year (Note: sampling errors associated with each inventory are represented by the vertical lines at the top of each bar).*

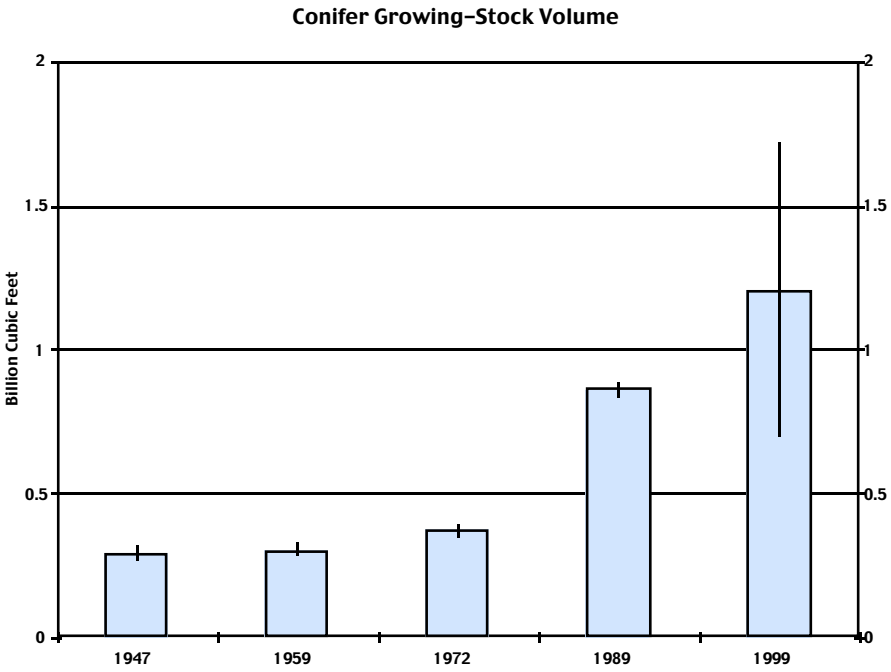

Figure 5.—*Conifer growing-stock volume in Missouri by inventory year (Note: sampling errors associated with each inventory are represented by the vertical lines at the top of each bar).*

INVENTORY METHODS

Changes Between Inventories

Since the 1989 inventory of Missouri, several changes have been made in NCFIA inventory methods to improve the quality of the inventory as well as 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. Missouri 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 in any one year. After 5 years, the entire inventory will be completed. After the first 5 years, NCFIA will report and analyze results as a moving 5-year

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 all field plots have been measured. Sampling error estimates for the 1999 inventory results are 8.43 percent for timberland area and 12.7 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 expand.

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 1989 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.

The new volume equations, developed by USDA Forest Service research scientists and other cooperating researchers, more accurately estimate the true growing-stock and sawtimber volumes. As additional annual inventories are implemented and comparisons between the current inventory and previous inventories become possible, FIA will update the 1989 inventory using the new volume tables.

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 1989 inventory when it is updated. 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.

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 Missouri survey used a two-phase sample for stratification that included remeasuring inventory plots from the 1989 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 Missouri (about 2 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 forest/nonforest strata. Pixels within 60 m of the boundary on the nonforest side were classified into nonforest/forest strata. An overlay of all National Forest land ownership was used to identify all lands owned by the Mark Twain National Forest. 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. In the National Forest stratum, forest and forest/nonforest strata were combined because there were fewer than five ground plots in one of these strata. 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 1989 inventory, aerial photographs were assembled into township mosaics, and a systematic grid of 121 one-acre photo plots (each plot representing approximately 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 1989 ground plots formed the basis for the remeasured ground plots in the 1999 inventory. Additional information related to procedures for the 1989 inventory can be found in Spencer *et al.* (1992).

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 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 Missouri. 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 Missouri is funded by the Federal government.

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; 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 Missouri the complete 5-year annual inventory will involve about 150 phase-three plots. On the remaining plots, only variables that can be measured throughout the entire year are collected. In Missouri, the complete 5-year annual inventory is expected to involve about 2,350 phase-two forested plots and about 500 phase-two straddler plots.

The new national FIA 4-point cluster plot design was used for data collection (fig. 6) 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 (1989) location. In addition, the first five subplots of the old 10-point (subplot) cluster plot were also 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 1989 and current annual inventories for characteristics such as average annual net growth, mortality, and removals. Thus, until a complete cycle of annual inventories for Missouri 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 Missouri, 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, the full range of change variables will be available.

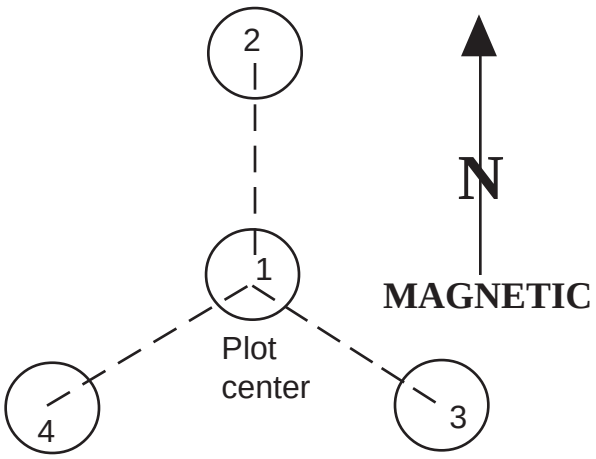

Figure 6.—*Current NCFIA field plot design.*

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
Missouri Department of Conservation
2901 West Truman Blvd.
P.O. Box 180
Jefferson City, MO 65102

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