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September 2001
Research Bulletin 1194
Ohio Agricultural Research and Development Center

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Salaries and research support were provided by state and federal funds appropriated to the Ohio Agricultural Research and Development Center and Ohio State University Extension of The Ohio State University's College of Food, Agricultural, and Environmental Sciences. Additional grant support was provided by the organizations and companies listed in the individual research reports.

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Abstract

Remote sensing and Geographic Information Systems technology were successfully used to inventory white pine resources in a 21-county area in eastern Ohio. The inventory required less labor and time than traditional forest inventory techniques and produced acreage and volume estimates with standard errors substantially below those of existing inventories. Conifer stands within the 21-county study area were identified on 1994 Landstat 5 Thematic Mapper images using a maximum likelihood classification algorithm in ERDAS IMAGINE. The validity of the conifer classification; the proportion of white pine; and the area, volume, and other stand

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The authors thank D. Barr, C. Dygert, M. Griffith, and C. Vrotney for assistance during the study. This research was supported by the Ohio Agricultural Research and Development Center and a United States Department of Agriculture Forest Service grant from the Rural Development Through Forestry Fund.

characteristics were evaluated by surveys. Within the 21-county study area, 36,454 acres of conifers were identified, 24,147 acres of which were white pine containing 570.5 million board-feet volume. White pine stands in the study area averaged 9.8 acres in size; 37 years in age; 11.7 inches average diameter at breast height; 162 square feet basal area; 23,625 board feet of volume; and had a 35-year white pine site index of 76 feet. These results indicate that Ohio's white pine resource is considerably larger and may have substantially greater economic development potential than previous inventories suggested.

Introduction

Since the early 1900s, forest inventory has been used in the United States to estimate stand parameters and conditions to facilitate the development of short- and long-term management strategies. Large-area forest inventory has gradually evolved away from a labor-intensive and time-consuming process with slow data collection and processing and difficult forest stand delineation.

Today, remote sensing and Geographic Information System (GIS) technology are increasingly used by forest resource managers and users to support planning initiatives. These tools allow forest inventories to be completed in a much more timely manner with greater accuracy and provide a database for storing, manipulating, and displaying spatial data often missing in more traditional inventories.

This study evaluates the application of remote sensing and GIS technology to inventory eastern white pine *(Pinus strobus* L.) over a 21-county area in eastern Ohio. Because of its potential for rapid growth on a wide variety of sites, white pine has been planted extensively on abandoned farmland and strip mines in Ohio since the 1920s. Despite this, white pine has remained an underdeveloped, essentially unrecognized, resource in the state. Certainly a major contributing reason for this is a lack of information on the amount, age, size, and distribution of the resource.

Currently, the only information on the extent and distribution of white pine in Ohio is the Forest Inventory and Analysis (FIA) conducted by the U.S. Forest Service in 1991. According to the FIA, an estimated 61,000 acres of white pine are distributed throughout the state, with nearly 70 percent of the total volume concentrated in 18 counties located in the East-Central and Southeastern Units (Griffith *et al.*, 1993). However, the sampling error associated with these volume estimates is 57.9% in the Southeastern Unit and 34.5% in the East-Central Unit.

A more precise and reliable inventory is required before the economic potential of Ohio's white pine can be evaluated and suitable management and utilization strategies developed. An inventory that utilizes traditional techniques would be time consuming and expensive, requiring extensive field sampling and exhaustive hours studying aerial photographs and conducting ground surveys. However, the use of remote sensing and GIS technology should be ideally suited to complete such an inventory more rapidly and with improved sampling error. The primary objectives of this study were, therefore, to:

- Utilize current remote sensing and GIS technologies to conduct an inventory of the white pine resource in eastern Ohio with sampling errors lower than previous studies.
- Evaluate the accuracy of the methodology used.
- Provide a database for future research to define eastern white pine's spectral signature.

Methods

Study Area

The 21 counties chosen for this study were located in eastern Ohio and distributed across the Northeastern, East-Central, and Southeastern Units as defined by the U.S. Forest Service (Figure 1). Counties included were Ashland, Athens, Belmont, Carroll, Columbiana, Coshocton, Guernsey, Harrison, Hocking, Holmes, Jefferson, Meigs, Monroe, Morgan, Muskingum, Noble, Perry, Tuscarawas, Vinton, Washington, and Wayne.

These counties were selected because the 1991 FIA concluded that this area contained more than 70 percent of the state's white pine volume (Griffith *et al.*, 1993). Further, this region is geographically well situated to supply white pine to Ohio's forest industries.

Land Classification

White pine stands were identified using four Landsat 5 Thematic Mapper images. The images utilized were as follows:

- Path 18 Row 32 taken October 15, 1994
- Path 18 Row 33 taken September 13, 1994
- Path 19 Row 32 taken September 20, 1994
- Path 19 Row 33 taken September 20, 1994.

All images were georeferenced to Universal Transverse Mercator Zone 17 coordinates with the North American Datum of 1927 as the reference. The spatial or ground resolution of the Landsat Thematic (TM) data was 30 meters by 30 meters and was not resampled.

The areas classified as "wooded" by the 1994 Ohio Land Cover Inventory (DREALM-ODNR, 1994) were used to extract the multispectral data for woodland from the TM image data. This multispectral data was computer processed to develop spectral signatures for deciduous and coniferous species. A clustering program was used to group the data into unique spectral signatures that typically define land covers. The resulting signature set was reviewed, and signatures with high variability, which corresponded to multiple land covers, were removed.

A spectral distance or separability measure was computed on remaining signature pairs. If the spectral distance between two signatures was not significant, one of the signatures was not distinct enough to aid in a successful classification and the signature was deleted. The resulting signature set was used in a maximum likelihood classification program.

Each 30 meter by 30 meter pixel in the TM data was assigned into the spectral cluster it most closely fit statistically. The resulting classification was compared against ancillary data to assign each spectral cluster into an informational land-cover category, deciduous wooded or coniferous wooded. The data used to do the assignments included Landsat TM data from the spring of 1986, spring of 1987, and early summer 1988; aerial photo interpreted land-use/land-cover data from the Ohio Capabilities Analysis Program (OCAP); and National Aerial Photography Program (NAPP) 1994 photographs.

Clusters that were classified as mixed deciduous and coniferous were extracted again from the TM data, and new spectral signatures were produced and reviewed with a new classification produced for these mixed areas. All classified data were combined to produce a final "conifer" classification. A contiguity analysis of this final classification was performed to identify conifer stands three acres or larger for the 21-county study area.

Stand Data Collection and Analysis

Two stratified random samples of identified conifer stands in the study area were selected. The first was used to determine what proportion of the stands identified as conifers were white pine; the second was used to estimate white pine volume per acre and site quality.

To ensure that stands sampled would best reflect the entire geographic region, the 21-county study area was stratified into seven three-county regions (Figure 1). The proportion of stratified random samples drawn from each geographic region was determined based on the proportion of the total conifer acreage in the study area contained in that region as indicated by the spectral classification. Seventy-two conifer stands were selected to determine what percentage of the conifer stands identified by the classification scheme were white pine. Species composition of the selected stands was determined by site visit.

Forty-one white-pine stands were selected for the purpose of estimating volume per acre and site quality. To minimize any potential effect of stand size, the distribution of stands sampled within each region was also stratified based on stand size, with the proportion of stands sampled in each size class reflecting the frequency of that size class in the region. Stand size classes used in the stratification were 0–4 acres, 5–9 acres, 10–19 acres, 20–39 acres, 40–79 acres, and 80+ acres. The geographic distribution of the stands selected within the study area is shown in Figure 1.

Stand volume and site quality were estimated on a 0.2-acre plot randomly located within each of the 41 stands. On each plot, the diameter at breast height (dbh) of each tree, the total height of the first tree measured in each two-inch diameter class beginning at eight inches

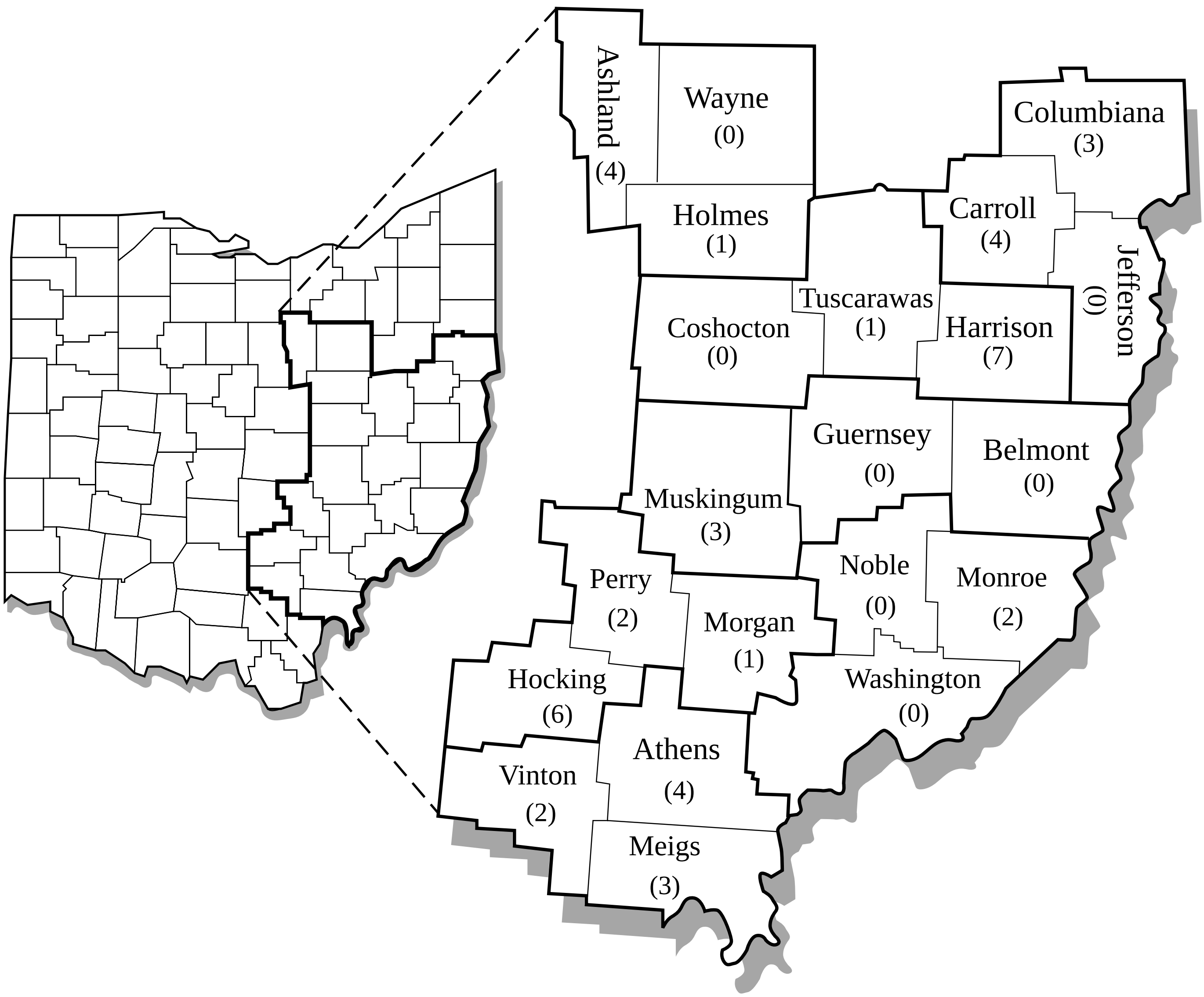

Figure 1. The 21-county study area in eastern Ohio. These counties were selected because FIA information concluded that this area contained more than 70 percent of the state's white pine volume. The number of stands sampled for individual stand characteristics in each county is indicated in parentheses.

dbh, the total age of the stand, and the five-year height intercept beginning three years above dbh for three dominant or codominant trees were recorded. White pine volume per acre was estimated using an equation developed by Dale *et al.* (1989) for white pine in southern Ohio. For each plot, height and average dbh were used to assign board-foot volumes (International 1/4-Inch volume to a 6.0-inch diameter top inside bark) to trees in each diameter class. Site quality was estimated by calculating the 35-year site index based on height intercept equations developed in Ohio by Brown and Stires (1981).

Results

Within the study area, the classification algorithm identified 4,441 stands three acres and larger as conifer (Figure 2). The classification was completely successful in identifying conifer stands. All 113 stands visited that were classified as conifer were, in fact, conifer. The 4,441 stands totaled 36,454 acres and represented 0.56 percent of the 6,498,465 acres within the study area.

However, only 40 of the 72 conifer stands visited to evaluate the amount of white pine identified by the algorithm were white pine. Thus, the number of white pine stands three acres or larger within the study area was estimated as 2,469 with a standard error of 31 stands, based on the normal approximation to the binomial probability distribution. (Ott, 1977). The average size of those 40 stands was 9.78 acres (standard error = 1.27 acres).

Combining these estimates, the total white-pine acreage within the study area in stands three acres and larger was estimated to be 24,147 acres, with a 95% probability that the acreage of white pine within the study area was between 17,972 and 30,321 acres.

Table 1 summarizes characteristics of the 41 white-pine stands inventoried. The average stand was 36.7 years old; was moderately well stocked with a basal area per acre of 162.4 square feet and mean dbh of 11.7 inches (Lancaster and Leach, 1978); was growing on a site of above-average productivity with a 35-year site index of 76.3 feet (Doolittle and Vimmerstedt, 1960; Frothingham, 1914); and contained 23,625 board feet of volume per acre (International 1/4-Inch Rule) measured to a 6.0-inch top diameter inside bark. While the ranges of the stand characteristics shown in Table 1 indicate that wide variation existed among the stands in measured parameters, the relatively small standard errors suggest that there was less variation among the stands than the ranges imply.

The total volume of white pine in the study area was determined by combining the estimated number of acres of white pine in the study area with the estimated average volume per acre. Appropriate confidence bounds were calculated using a pooled standard error (Meyer 1963). Total white-pine volume in the 21-county study area was estimated to be 570,468,623 board feet with a 95% probability that the total volume was between 411,217,295 and 729,719,950 board feet.

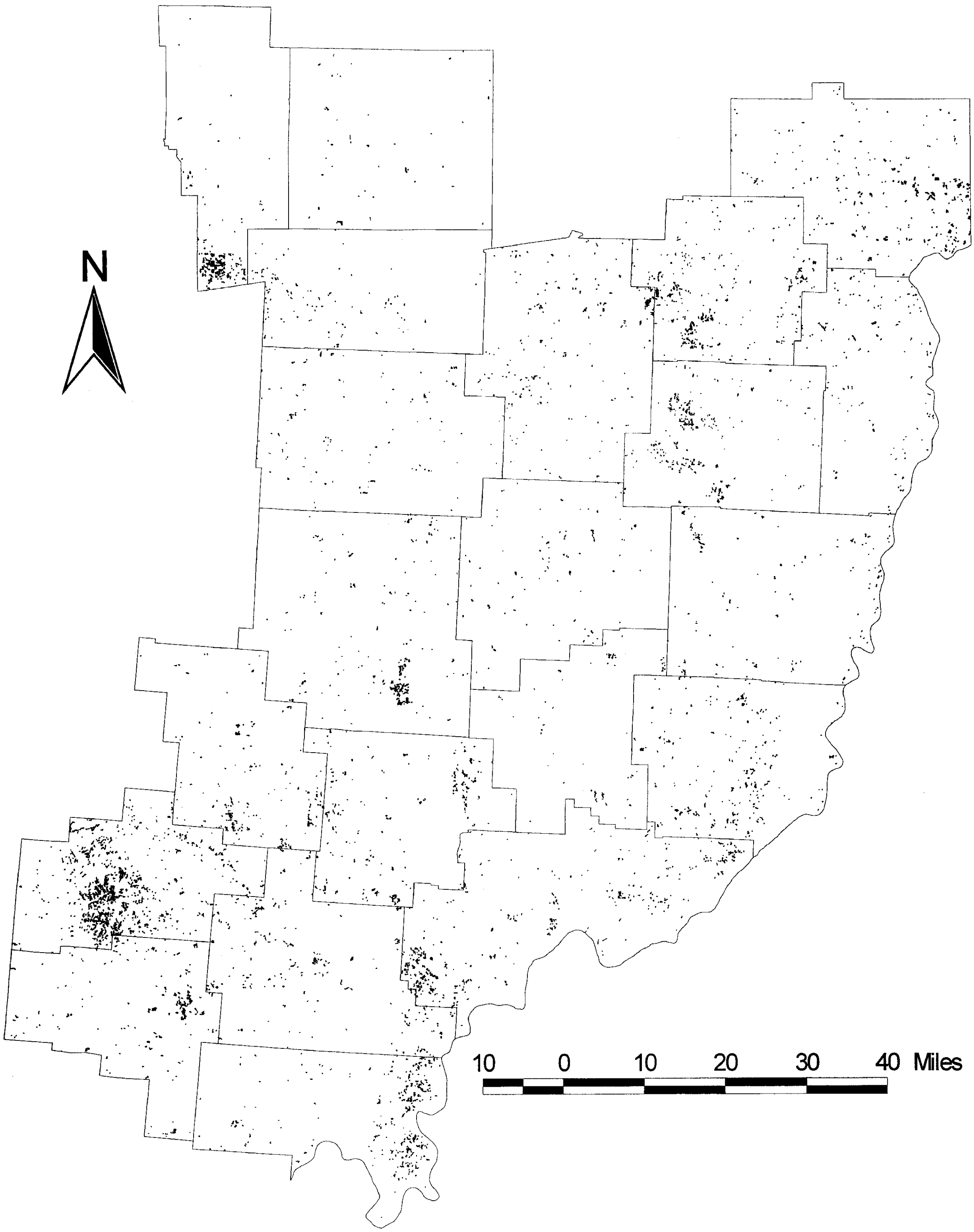

Figure 2. Distribution of conifer stands three acres and larger in the 21-county study area. Remote Sensing/GIS White Pine Inventory.

Table 1. Characteristics of Average White Pine Stand Sampled Within Study Area.

Parameter	Mean	Range	SE
Age (years)	36.7	12 to 55	1.4
Dbh (in)	11.7	6 to 26	0.1
Basal area (ft^2/ac)	162.4	80 to 230	5.8
Site index (ft) (base age 35)	76.3	66 to 88	1.0
Volume (Int. 1/4 Inch bd.ft./A)	23,625	0 to 46,933	1,350

Discussion

This first application in Ohio of remote sensing and GIS technology to inventory a forest species for forest management and utilization purposes was successful, providing useful information and forming the foundation for further refinements of the technology. The spectral signature for conifers produced a 100% accuracy rule in identifying the conifer stands that were visited.

This initial classification of land area into conifer or non-conifer saved much time compared to working with aerial photographs and performing the field work that would have been required with more traditional inventory methods. No attempt was made in this initial study to use spectral signature to distinguish among the various conifer species found in Ohio.

Fifty-six percent of the conifer stands identified were white pine. The other 44 percent were a variety of conifers found in natural stands and plantations throughout the study area. These species include Norway spruce *(Picea abies* L.), red pine *(Pinus resinosa* Ait.), Virginia pine *(Pinus virginiana),* pitch pine *(Pinus rigida* Mill.), scotch pine *(Pinus sylvestris* L.), and shortleaf pine *(Pinus echinata* Mill.).

A more efficient and accurate inventory of the white-pine resource in Ohio could be obtained with a spectral classification scheme refined to identify only white pine. Karteris (1990) used a six-band combination of Landsat TM data to achieve classification accuracies for individual stands of conifers ranging from 79.7 percent for Scotch pine *(Pinus sylvestris* L.) to 88.7 percent for Jack pine *(Pinus banksiana* Lamb.).

Information and data from our study can provide an important foundation for future efforts with white pine. This study estimated the white-pine resource for the 21-county study area in eastern Ohio as 24,147 acres containing 570.5 million board feet of volume (International 1/4-Inch Log Rule), with standard errors of 3,150 acres (13.05%) and 81.3 million board feet (14.24%), respectively.

These estimates differed substantially from those released in the 1991 Ohio Forest Inventory and Analysis (Griffith *etal.,* 1993) which reported more than 51 thousand acres of white pine containing nearly 335 million board feet for the same geographic area. Standard errors for acreage and volume estimates in the Forest Inventory and Analysis, most of which were calculated on geographic subunits of the study area, all exceeded 34%.

Differences in results and precision between this study and the 1991 Ohio Forest Inventory and Analysis may be partially explained by temporal changes and differences in sampling methods. At the time of this study, the average stand age within the study area was 37 years; at the time of the Forest Inventory, average stand age was 28 years. White-pine volume per acre can be expected to increase dramatically during this nine-year age period (Leak *et. al.,* 1970).

This study was specifically designed to sample a single species within a specific geographic region; the Ohio Forest Inventory and Analysis examined all species and forest types over the entire state. Statistically, as one examines smaller and smaller parts of a larger, broader study, precision is generally reduced and standard errors increase. This is true with the Forest Inventory and Analysis data. While standard errors statewide were exemplary — 1.2 percent for total forest acreage and 2.4 percent for total volume, for example — standard errors for smaller geographic areas or individual species or groups of species were much greater, often ranging up to 100 percent.

Finally, the average stand volume of 23,625 board feet per acre provided a suitable estimate on which to base the estimate of total white-pine volume in the 21-county study area.

However, additional detailed information on age distribution by acreage would be invaluable in assessing the availability of the resource over time under alternative utilization and management scenarios. This would more definitively answer questions concerning the amount and types of industry and harvesting the resource could support long-term. Obtaining such data using the remote sensing techniques and GIS technology utilized in this study would require developing separate spectral signatures for individual white-pine age classes.

Summary

The white pine resources of 21 counties in eastern and southeastern Ohio were successfully inventoried using remote sensing and Geographic Information System technology. The inventory required less labor and time than traditional forest inventory techniques and produced acreage and volume estimates with standard errors substantially below those of existing inventories.

Within the 21-county study area, 36,454 acres of conifers were identified, 24,147 acres of which were estimated to be white pine containing 570.5 million board feet of timber (International 1/4-Inch Rule). White-pine stands in the study area averaged 9.8 acres; 37 years of age; 11.7 inches average diameter at breast height; 162 square feet basal area; 23,625 board feet of volume; and had a 35-year white-pine site index of 76 feet.

These results indicate that Ohio’s white pine resource is considerably larger and may have substantially greater economic development potential than previous inventories suggested. An accurate inventory of the white-pine resources of the entire state is needed to evaluate this potential. The methodology evaluated in

this study, utilizing remote sensing and Geographic Information System (GIS) technology, offers an efficient and accurate method of obtaining this information.

The efficiency of a comprehensive inventory could be increased by refining the spectral classification scheme to identify only white pine. Further, its usefulness in evaluating the types of industry and harvesting that the resource could support long-term and the availability of the resource over time under alternative utilization and management scenarios could be substantially improved with acreage and age distribution information. Results and data from our study could be used to refine spectral signatures and to evaluate the potential for identifying different white-pine age classes.

Literature Cited

Brown, James H. and James L. Stires. 1981. *Growth Intercept Methods for Predicting Site Index in White Pine Plantations.* Wooster, Ohio: Ohio Agricultural Research and Development Center. Research Circular 265. 14 pp.

Dale, Martin E., David E. Lutz, and Herman J. Bailey. 1989. Yield of White Pine Plantations in Ohio. *Northern Journal of Applied Forestry* 6:51-56.

Division of Real Estate and Land Management, Ohio Department of Natural Resources. 1994. *1994 Ohio Land Cover Inventory.*

Doolittle, Warren T. and John P. Vimmerstedt. 1960. *Site Index Curves for Natural Stands of White Pine in the Southern Appalachians.* Res. Note 141. USDA, Forest Service, Southeastern Forest Experiment Station.

Frothingham, E. H. 1914. *White Pine Under Forest Management.* USDA, Bull. 13. 70 pp.

Griffith, D., D. Digiovanni, T. Witzel, and E. Wharton. 1993. *Forest Statistics for Ohio, 1991.* Resource Bulletin NE-128. USDA, Forest Service, Northeast Forest Experiment Station. Radnor, Pa. 169 pp.

Karteris, Michael A. 1990. The Utility of Thematic Mapper Data for Natural Resources Classification. *International Journal of Remote Sensing* 11(9):1589-1598.

Lancaster, Kenneth F. and William B. Leak. 1978. *A Silvicultural Guide for White Pine in the Northeast.* USDA, Forest Service, Gen. Tech. Rept. NE-41. 13 pp.

Leak, W. B., P. H. Allen, J. P. Barrett, F. K. Beyer, D. L. Mader, J. C. Mawson, and R.K. W ilson. 1970. *Yields of Eastern White Pine in New England Related to Age, Site, and Stocking.* USDA, Forest Service, Res. Pap. NE-176. 15 pp.

Meyer, W. H. 1963. Some Comments on the Error of the Total Volume Estimate. *Journal of Forestry* 61:503-507.

Ott, Lyman. 1977. The Binomial Distribution and the Normal Approximation to the Binomial. Chap. 10 in: *An Introduction to Statistical Methods and Data Analysis.* Belmont, Calif.: Wadsworth Publishing Company, Inc.