USDA United States Department of Agriculture

Forest Service

North Central Research Station

Research Note NC-389
2005

Change in the Minneapolis/St. Paul Metropolitan Area Oak Forests from 1991 to 1998

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ABSTRACT.—Based on classifications of Landsat TM imagery, the total area of oak forests in the Minneapolis/St. Paul, Minnesota, metropolitan area decreased by 5.6 percent between 1991 and 1998, and oak forest losses ranged from 12 to 1,229 ha in six of seven ecological subsections. Maps and spatial data layers are provided.

KEY WORDS: *Quercus*, remote sensing, Landsat, urban planning.

The Minneapolis/St. Paul, Minnesota, metropolitan area (the Metro) is a rapidly urbanizing portion of the Upper Midwest. Virtually all aspects of the physical and social landscapes in the region have been characterized by change over the past two decades (USDA Forest Service 2004). The human population in the seven counties of the Metro grew by an average of 10 percent between 1991 and 1998; in three of those counties, increases of 28 to 30 percent occurred (Land Management Information Center 2003). The population is growing in previously undeveloped areas outside the urban core. Development associated with this growth is leading to fragmentation and loss of wooded areas (Mouelle 2000). Oaks (*Quercus* spp.) are a collection of tree species that are abundant throughout the Metro. Widespread development is occurring in many of the Metro oak-dominated woodlands. Removal of oaks for development varies by land use class with the greatest losses occurring in the Medium Density Residential and Commercial-Retail-Office classes, and the smallest losses in the Rural Residential and Undeveloped classes (Loeffelholz 2003). In addition, the health of the remaining trees can be negatively affected by development activities. Rapid decline and death of oak trees often follows abrupt conversion of woodlands to other land use classes. Oak decline and death can result from construction activities such as clearing, thinning, soil removal, and soil compaction, which destroy the fine roots necessary for absorption of oxygen, nutrients, and water (Ware 1982). Oak wilt can also be introduced to newly developed sites via insect transmission of the oak wilt fungus to oaks wounded during construction (Juzwik and Schmidt 2000, Roberts 2001).

The negative effects of development on oaks can be mitigated by urban planning (Mouelle 2000). But such planning efforts require baseline data about the amount and distribution of the natural resources in the area. Because the recent change in amount of the Metro oak acreage is not known, we conducted a study to quantify the amount of oak forest in 1991 and 1998, and to spatially determine how it has changed over time.

MATERIALS AND METHODS

Landsat Thematic Mapper (TM) satellite imagery is useful for delineating and characterizing land use and land cover over large areas because of its relatively wide coverage, low costs, and the spectral range of its sensors, which were developed specifically to distinguish among vegetation types. TM data have been used extensively for forest cover type mapping (Lillesand *et al.* 1998, Reese *et al.* 2002, Wolter *et al.* 1995), although fewer researchers have used TM imagery for forest species-level classification in urban areas (Wang 1988). TM imagery and ERDAS Imagine (Leica

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Geosystems) and ArcGIS (ESRI Inc.) software[1] were used to generate classified and image-differenced layers of the oak resource in 1991 and 1998 and the change between these years.

The seven-county, 770,000-ha study area includes all or parts of seven ecological subsections (Minnesota Department of Natural Resources 2001) (fig. 1). Subsections are differentiated by geologic, climatic, soil, and natural vegetation characteristics (Keys *et al*. 1995). The three largest subsections, the Big Woods, the St. Paul Plains and Moraines (Plains), and the Anoka Sand Plain (Anoka), make up 87 percent of the total land area and 93 percent of the oak forest area in the Metro. The four smallest subsections are the Oak Savannah (Savannah), the Rochester Plateau (Rochester), the Blufflands (Bluffs), and the Mille Lacs; these account for 13 percent of the total area and 7 percent of the Metro oak forest area. The ecological subsections were classified separately to minimize classification errors because of the greater homogeneity within subsections than between them.

Landsat TM images were acquired on June 16 and September 4, 1991, and on May 18 and September 7, 1998. ERDAS Imagine software was used for preparing and manipulating the imagery. Image rectification was performed with a root mean square error (RMSE) of less than 0.25 to UTM zone 15, GRS1980, NAD83 based on a Minnesota Department of Transportation roads basemap. A

[1]*Mention of trade names does not constitute endorsement of the products by the USDA Forest Service.*

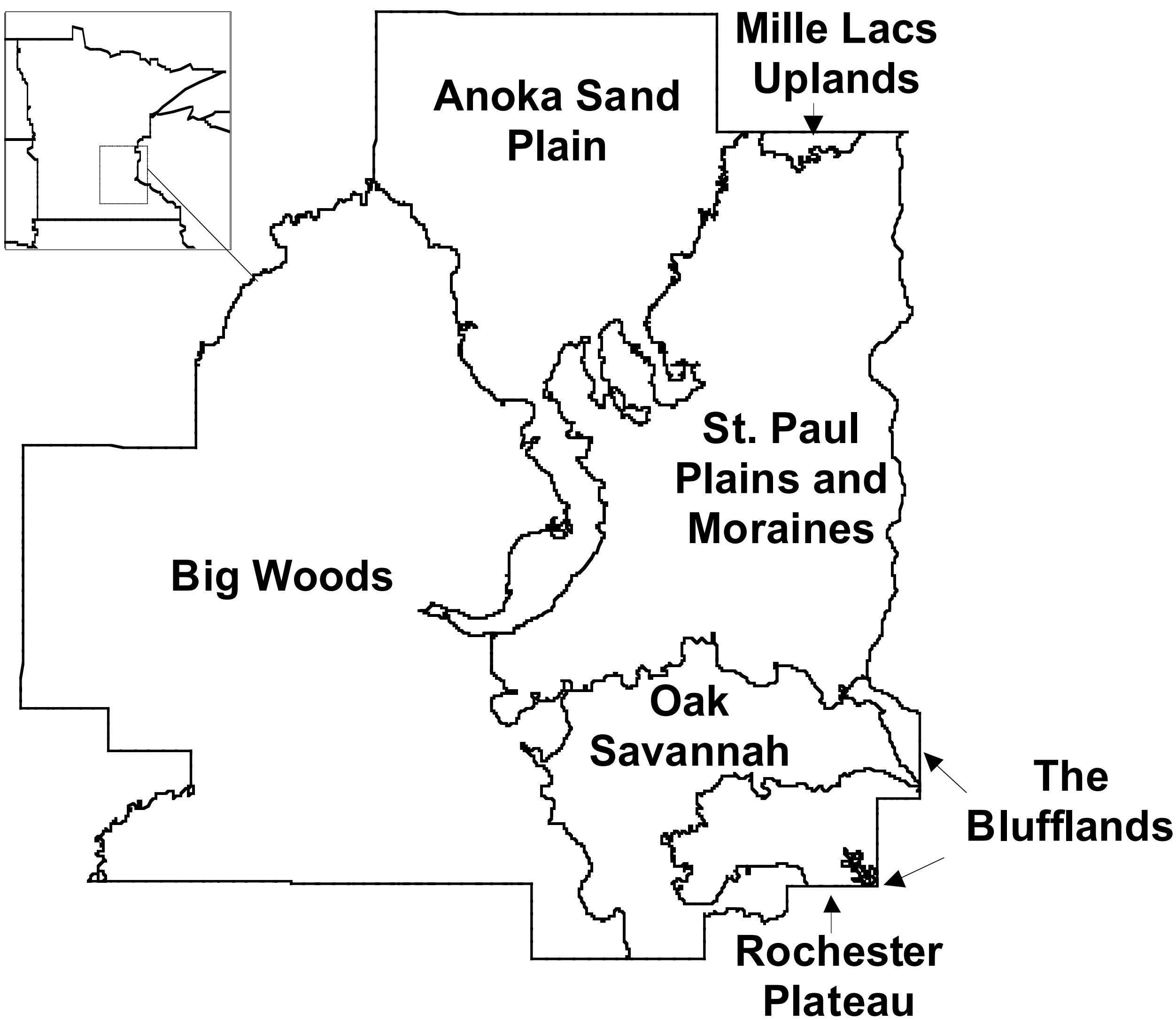


Figure 1.—*The seven ecological subsections in the Minneapolis/St. Paul, Minnesota, metropolitan area.*

random sample stratified by subsection was used to select test and training sites for collection in the field. Sites were located using a previously classified oak cover map and a Geoexplorer (Trimble) Global Positioning System (GPS). GPS data were input and differentially corrected using Pathfinder Pro software (Trimble). Test and training data from the Gap Analysis Program (Minnesota Department of Natural Resources 2002), and the Minnesota Land Cover Classification System (Minnesota Department of Natural Resources 2004) were also used.

The two images from 1991 were stacked, as were the two images from 1998. A 1990 land cover layer (Minnesota Department of Natural Resources 2002) was used as a mask to differentiate forested area from other land use/land cover classes in the imagery. Each of the seven ecological subsections was clipped from the masked imagery using boundary layers. Probabilities for each deciduous forest species commonly found in the Metro were calculated from the 1990 land cover layer (Minnesota Department of Natural Resources 2002) and were used in the classification process to obtain representative amounts of each forest species. The expected class frequencies for each species were used to modify the prior probability of each spectral signature class (Pedroni 2004) in the Signature Editor within ERDAS Imagine. Supervised classification was performed on bands 3, 4, and 5 in each image stack using the maximum likelihood algorithm, and classified images were produced of the Metro oak forest in 1991 and 1998. Image-differencing was used to create the image depicting the change in oak stands between 1991 and 1998. An error matrix was completed for both classifications, and Overall (OA), Producer's (PA), and User's Accuracies (UA) were calculated by subsection (table 1). OA indicates how well the training pixels were correctly classified overall. UA is a measure of commission error and indicates the probability that a pixel classified into a given category actually represents that category on the ground. PA shows how well the training pixels were classified for each class.

Table 1. —*Accuracy assessment for the 1991 and 1998 classifications of oak forest cover in the Minneapolis/St. Paul, Minnesota, metropolitan area*

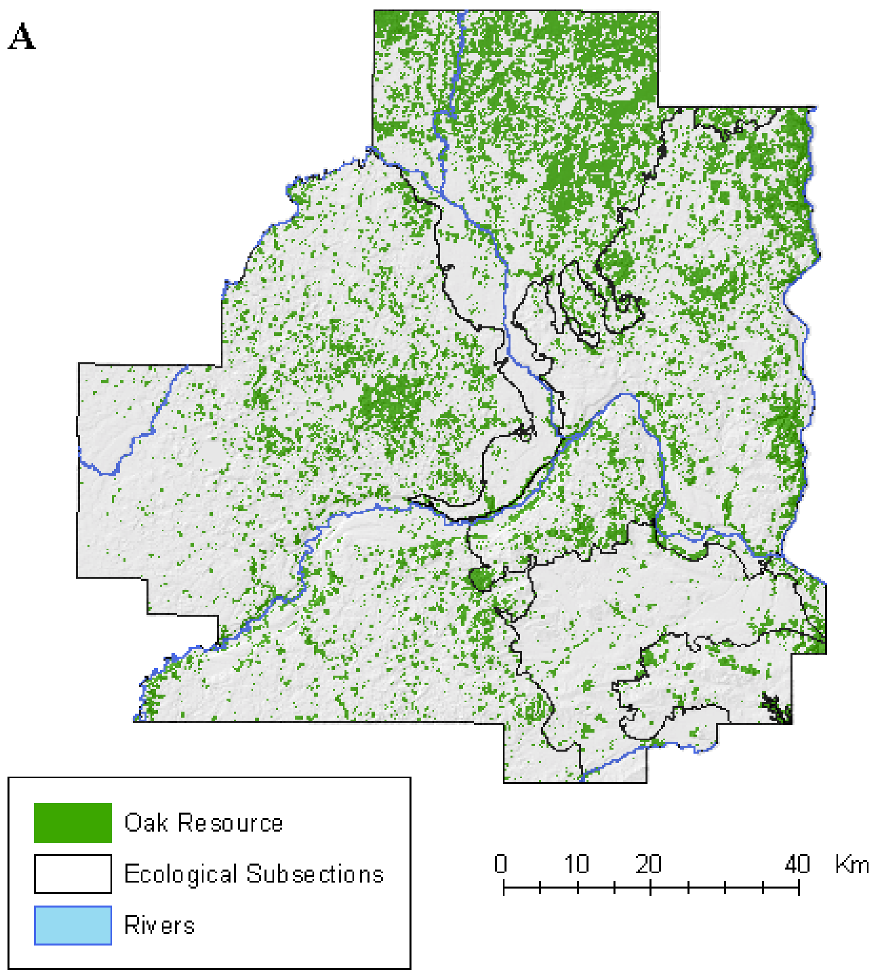
Ecological subsection	Year	Accuracy type		
		Overall (%)	Producer's (%)	User's (%)
Anoka	1991	61	67	65
	1998	58	66	60
Big Woods	1991	56	50	50
	1998	56	50	43
Bluffs	1991	75	69	42
	1998	71	54	39
Mille Lacs	1991	66	72	80
	1998	65	72	76
Plains	1991	60	64	70
	1998	56	65	70
Rochester	1991	64	73	78
	1998	65	75	78
Savannah	1991	52	62	54
	1998	58	67	59

RESULTS AND DISCUSSION

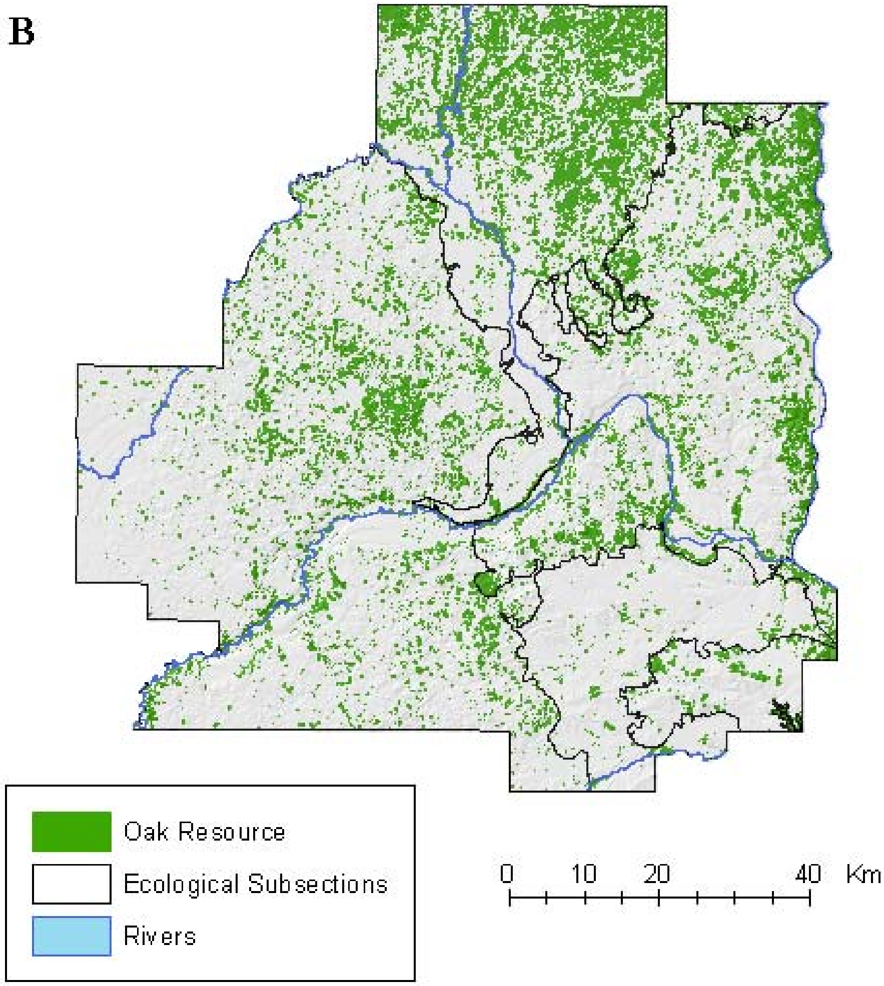
Based on our classifications, the total area of oak cover in the Metro decreased by 5.6 percent (33,844 to 31,932 ha) from 1991 to 1998 (fig. 2A-C). The largest losses of oak were in the subsections with the largest land areas and oak coverage: 1,229 ha, Anoka; 378 ha, Plains; and 229 ha, Big Woods. Losses were lesser in almost all of the smaller subsections: 49 ha, Savannah; 28 ha, Rochester; and 12 ha, Mille Lacs. There was a 13-ha increase in oak in the other smaller subsection (the Bluffs).

Oak and other forests in the Metro provide valuable economic, social, and environmental benefits, and loss of this resource may have far-ranging consequences. Wooded areas are complex ecosystems in which trees are the dominant life form interacting with animals and other plants in a delicate balance (Mouelle 2000). Destruction and fragmentation of wooded areas and farmlands, loss of individual trees, and loss of wildlife habitat threaten the ecological integrity and functions of natural systems and the quality of life in urbanizing areas (Mouelle 2000). For

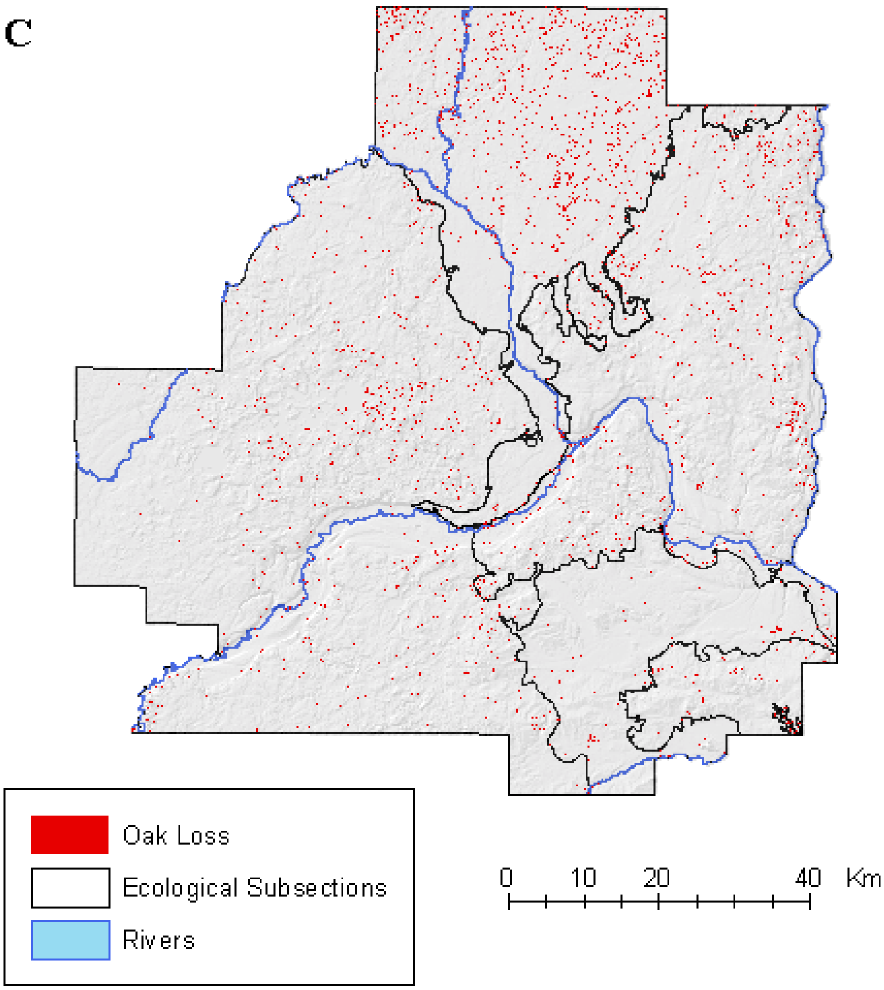
Figure 2.—*Classified layers of oak resource in the Minneapolis/St. Paul, Minnesota, metropolitan area in 1991 (A) and 1998 (B), and loss of oak between 1991 and 1998 (C) determined using Landstat Thematic Mapper imagery and ERDAS Imagine and ArcGIS software.*



B



C



example, wildlife biodiversity decreases with increased forest fragmentation (Saunders *et al.* 1991). Furthermore, ambient air and land surface temperatures increase with loss of tree cover (Saunders *et al.* 1991).

Because continued expansion of urban areas is anticipated, additional loss of oak forests can also be expected. Community leaders will face important decisions on how to balance economic growth and protection of the natural resources. Information on the changes in the landscape over time and the relationship of those changes to the ecological integrity of the communities is essential to the decisionmaking process. These results provide visual information to decisionmakers on the loss of oak resources in the Metro during the 1990s. The maps and accompanying spatial data layers give analysts and decisionmakers a tool to further explore how policies, regulations, or management practices in place in the early 1990s affected the oak forests 8 to 10 years later.

The classifications are available for downloading as shapefiles at

http://ncrs.fs.fed.us/pubs/3037

ACKNOWLEDGMENTS

The authors thank Marvin Bauer and Fei Yuan, University of Minnesota, for advice and guidance on remote sensing aspects of this study, and Paul Castillo, USDA Forest Service, for assistance in field data collection. The technical reviews of this manuscript by Marvin Bauer, Eric Gustafson, and Robert Haight are gratefully acknowledged.

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