Transformation of the Oak Forest Spatial Structure in the Minneapolis/St. Paul Metropolitan Area

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Abstract

The oak (*Quercus* sp.) forest in the Twin Cities Metropolitan Area (TCMA) decreased by 5.6 percent between 1991 and 1998. It would be beneficial to know the types of forest transformation that occurred along with the loss of oak forest in the TCMA and this has not been documented previously. Transformation of the spatial pattern of the forest can have great impacts on forest health, water flow and quality, wildlife habitat, and the quality of life of urban residents. Quantitative landscape and patch metrics were used to describe the change in the spatial structure of the oak forest in seven ecological subsections in the TCMA over seven years. Oak forest patches in the TCMA as a whole have decreased in number, size and complexity. Attrition of oak forest occurred in four ecological subsections and fragmentation took place in three subsections. The information presented on how the oak forest has changed over time may help planners and managers make more informed development and zoning guidelines that could help minimize the impacts of construction on wooded areas and trees under increasing development and land conversion pressure.

Keywords: *Quercus,* fragmentation, attrition, remote sensing, Landsat

Introduction

▪ The Twin Cities Metropolitan area (TCMA) (Fig. 1) is a rapidly urbanizing region in east-central Minnesota.

▪ Northern red oak (*Quercus rubra*) (Fig. 2), northern pin oak (*Q. ellipsoidalis*), white oak (*Q. alba*), and bur oak (*Q. macrocarpa*) have a widespread distribution in the TCMA and are highly prized for landscape value, wildlife food and habitat, and aesthetics.

▪ The amount of oak forest in the area decreased by 5.6 percent (from 33,844 to 31,932 ha) from 1991 to 1998 (Tables 1 and 2, Fig. 3).

▪ Transformation of the spatial structure (e.g., shrinkage, attrition, fragmentation) of the oak forest (Fig. 4) may have occurred along with the loss of oak forest area.

▪ Landscape patterns are important because they exert strong influences over ecological processes and characteristics, including loss of biodiversity, changes in hydrology and microclimate, and reduced water quality.

Objectives

Given the potential impacts of forest transformation this study was undertaken to integrate remote sensing, Geographical Information Systems (GIS), and spatial structure metrics to quantify the temporal and spatial changes in landscape patterns that occurred in the TCMA oak resource from 1991 to 1998.

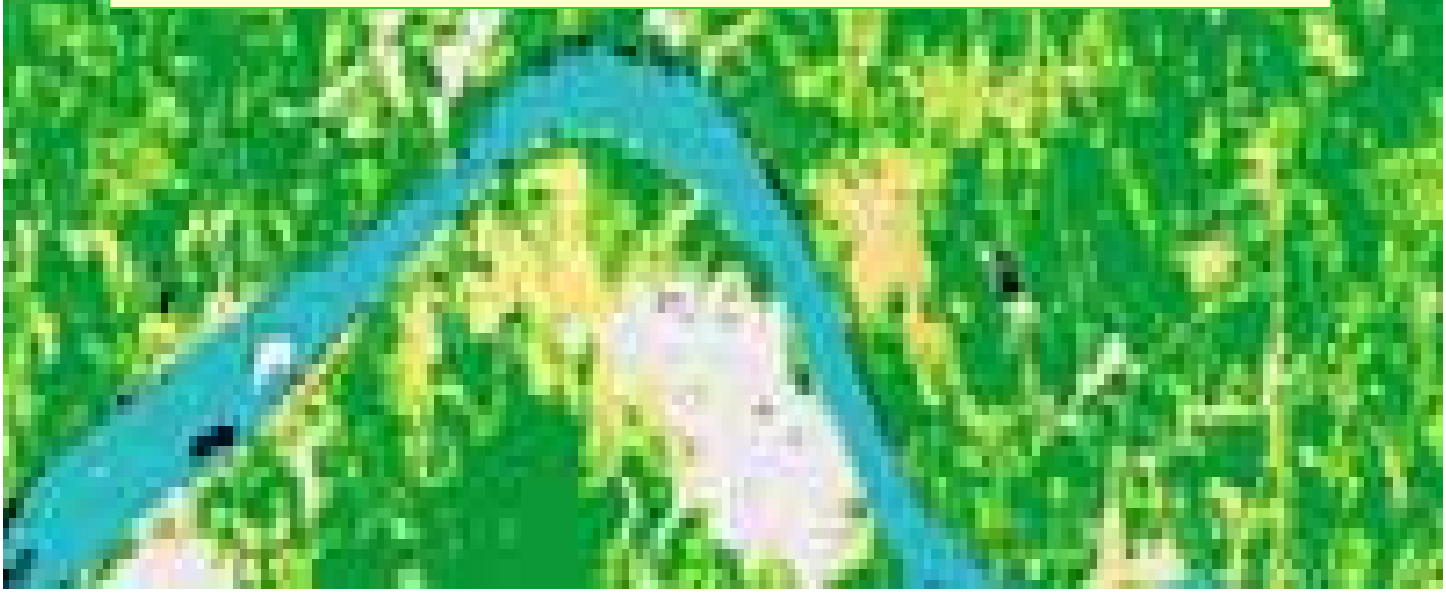

Fig. 1. The 770,000-ha study area covers seven counties in east-central Minnesota (Anoka, Carver, Dakota, Hennepin, Ramsey, Scott, and Washington), and includes all or parts of seven ecological subsections.

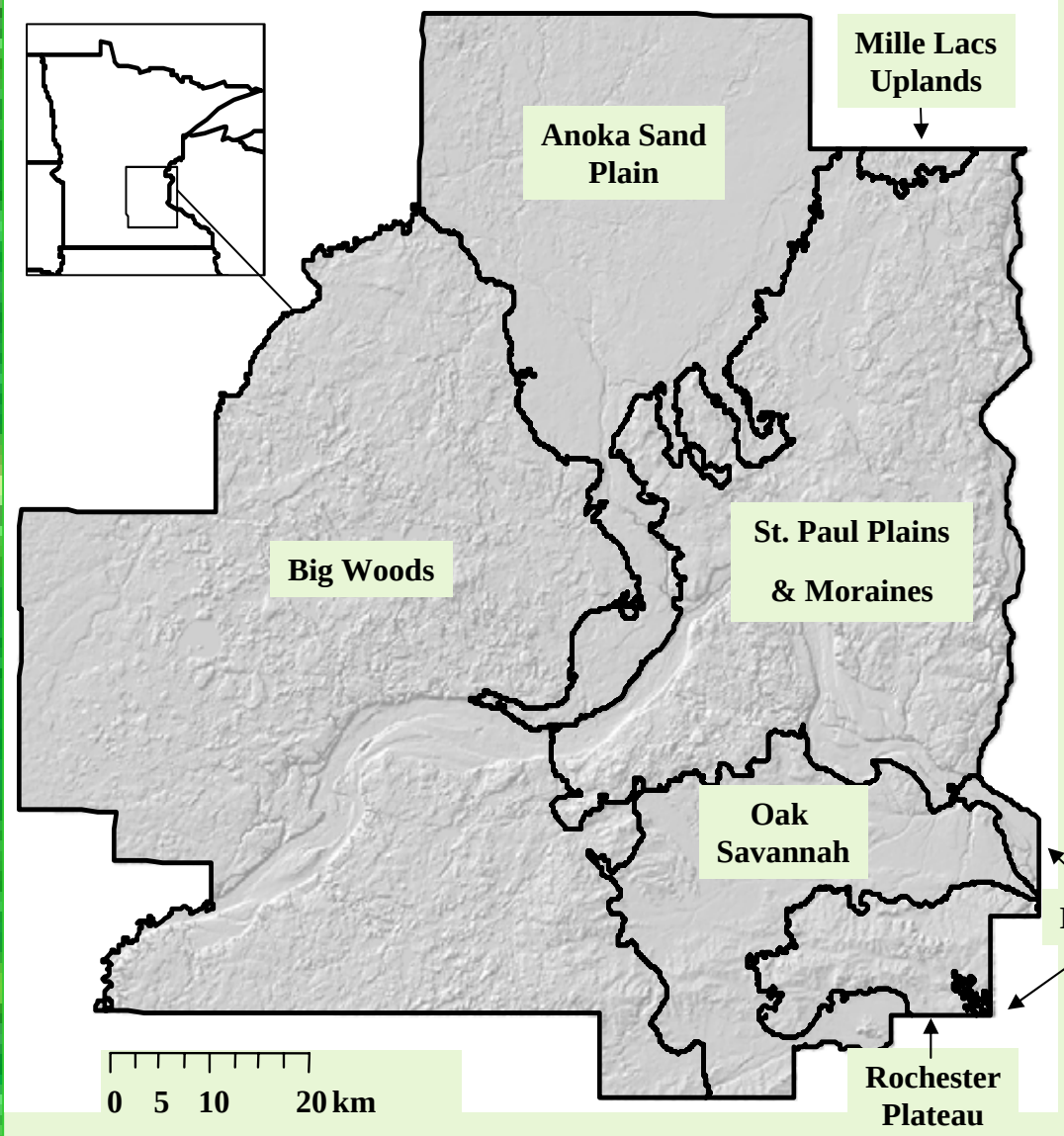

Fig. 2. Northern red oak form with fall coloration.

Fig. 3. Loss of oak (in red) from 1991 to 1998.

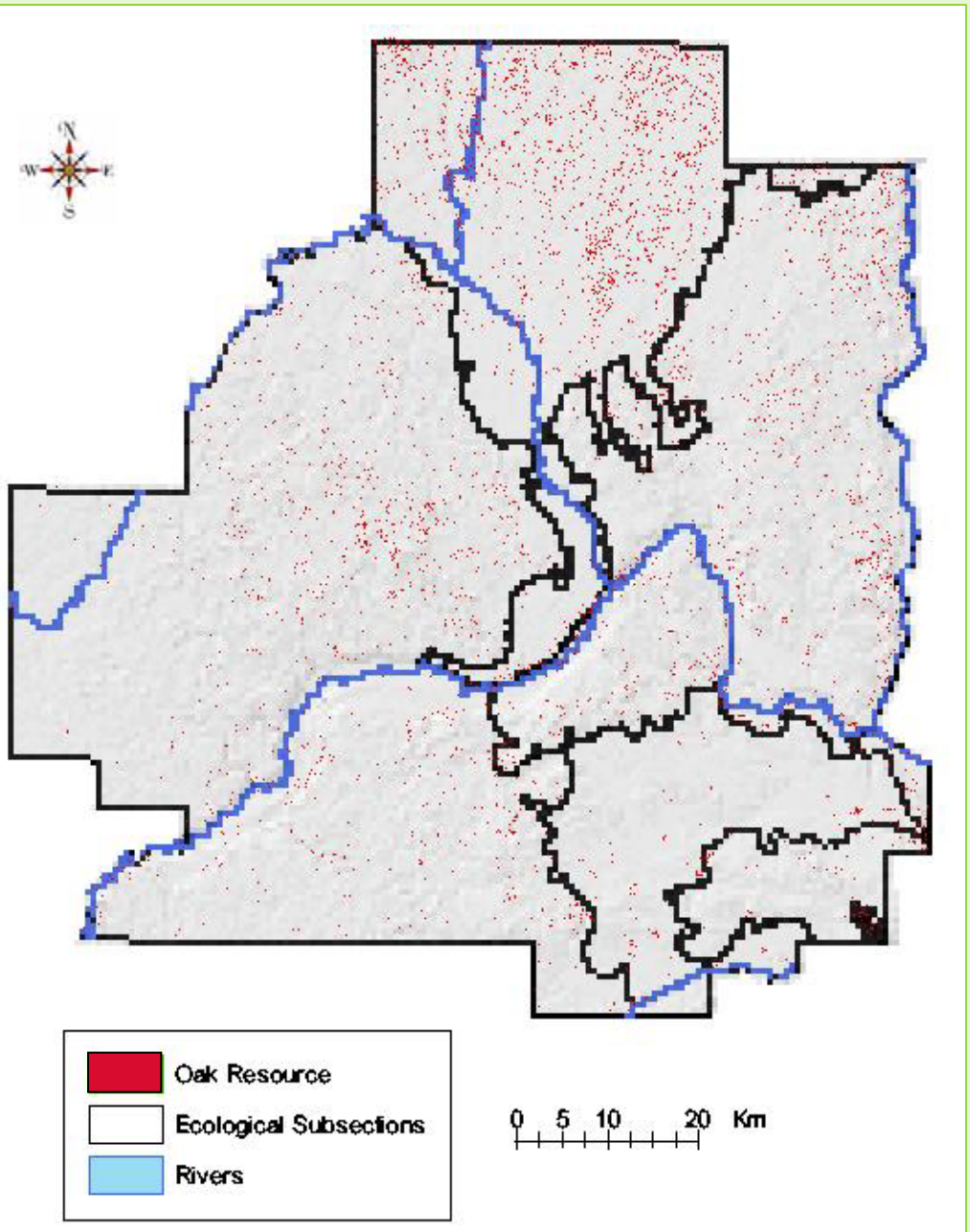

Fig. 4. Oak forest transformation due to new home construction in the St. Paul Plains & Moraines subsection.

Methods

- Four Landsat Thematic Mapper satellite images were used – from June and Sept., 1991 and May and Sept., 1998.
- The 1993 GAP land cover layer was used to mask out non-forested area.
- The subsections were classified separately to minimize classification errors.
- Supervised classification, the maximum likelihood algorithm, and ERDAS Imagine were used to classify oak and non-oak species from the satellite imagery.
- Overall accuracies for the oak class varied by subsection (from 52% to 75%).
- ArcGIS was used to convert the 1991 and 1998 oak layers to grids, and Fragstats software was used to generate the spatial structure metrics for the layers.
- The selected metrics were useful for determining landscape extent (patch area) and fragmentation (patch number and size); and patch magnitude (radius of gyration), shape complexity (perimeter to area ratio), and isolation (Euclidean nearest neighbor distance).

Results and Discussion

- Oak stands became more infrequent, more isolated, and less complex in shape across the TCMA as a whole (Tables 1 and 2).

- Based on changes in number of patches and mean patch size in each subsection the oak forests in the Anoka Sand Plain, the Rochester Plateau, and Blufflands subsections appear to have primarily undergone fragmentation, while oak forests in the St. Paul Plains & Moraines, Big Woods, Mille Lacs Uplands, and Oak Savannah tended more towards attrition.

- The subsections may be in different phases of forest transformation, which may be due in part to different rates and types of urban development that have occurred.

- The Anoka Sand Plain, Oak Savannah and Blufflands subsections are not in the same stages of transformation, but based on the absolute combined levels of percent change in patch numbers and sizes, they are changing at a faster rate than the other subsections (Fig. 5).

- As population increases and development intensifies, forest transformation and landscape changes are expected to continue.

- Information on how the oak forest pattern has changed over time can be used by land planners and natural resource managers to make informed development and zoning guidelines for areas under increasing development and pressure for land conversion in the future.

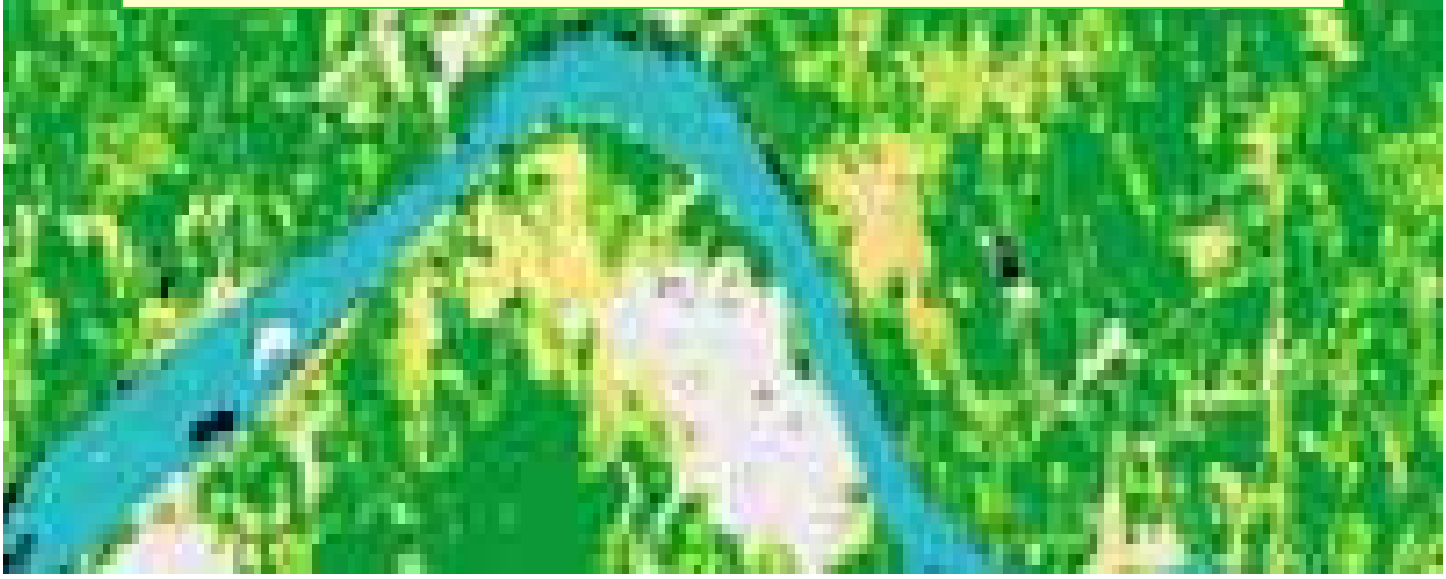

Table 1. Mean oak forest patch metrics for seven ecological subsections in 1991 and 1998.

1991

Subsection	Area (ha)	Number	Mean Size (ha)	Radius of Gyration (m)	Perimeter to Area Ratio	Euclidean Nearest Neighbor (m)
Anoka	13533	14673	0.92 b[1]	28.31e	1916.50 d	49.86 a
Big Woods	6645	19255	0.34 a	22.76 ab	1908.69 bcd	56.17 b
Blufflands	265	807	0.33 a	20.04 a	1940.69 cd	54.49 ab
Mille Lacs	373	310	1.20 bc	33.70 c	1763.83 a	53.90 abc
St. Paul Plains	11393	11235	1.01 b	30.30 c	1838.43 a	60.65 c
Rochester	841	489	1.72 c	39.58 d	1809.90 abc	86.54 d
Oak Savannah	792	1974	0.40 a	23.66 b	1923.91 cd	69.22 e
Total	33843	48743	0.69	26.40	1894.08	56.09

1998

Subsection	Area (ha)	Number	Mean Size (ha)	Radius of Gyration (m)	Perimeter to Area Ratio	Euclidean Nearest Neighbor (m)
Anoka	12304	16262	0.76 b	27.88 c	1765.25 c	46.49 a
Big Woods	6416	17695	0.37 a	22.46 a	1785.45 c	61.13 c
Blufflands	279	969	0.29 a	19.78 d	1596.11 a	49.19 ab
Mille Lacs	362	298	1.22 bcd	34.75 b	1538.96 a	57.11 bc
St. Paul Plains	11015	10946	1.01 c	30.55 b	1672.44 b	61.17 c
Rochester	813	491	1.66 d	41.72 e	1595.65 ab	89.94 d
Oak Savannah	743	1504	0.49 a	23.83 a	1782.97 c	80.87 e
Total	31931	48165	0.66	26.39	1745.60	56.84

[1]Measures in the same column followed by the same letter were not significantly different (P>0.05) as determined by ANOVA and Fisher's LSD.

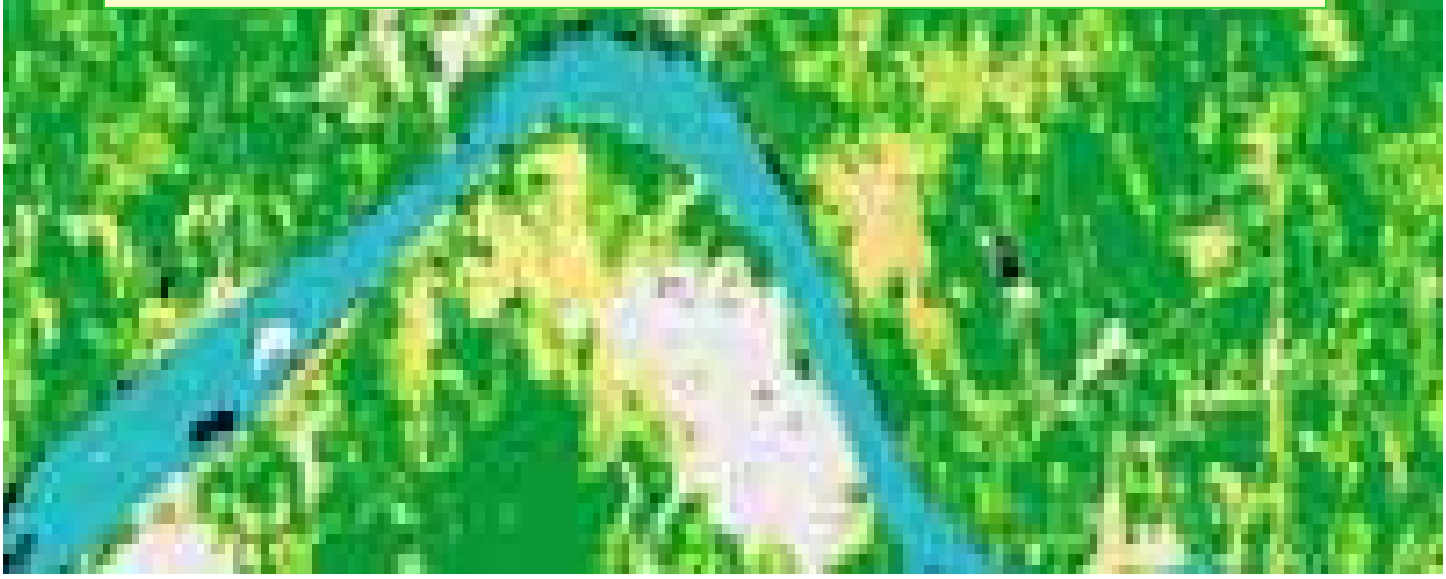

Table 2. Changes in mean oak forest patch metrics from 1991 to 1998 in seven ecological subsections.

	Change between 1991 and 1998 (%)					
Subsection	Area (ha)	Number	Mean Size (ha)	Radius of Gyration	Perimeter to Area Ratio	Euclidean Nearest Neighbor
Anoka	-9.08	10.83	-17.39	-1.52	-7.89	-6.76
Big Woods	-3.44	-8.10	8.82	-1.32	-6.46	8.83
Blufflands	5.25	20.07	-12.12	-1.30	-17.76	-9.73
Mille Lacs	-3.01	-3.87	1.67	3.12	-12.75	5.96
St. Paul Plains	-3.32	-2.57	0.00	0.83	-9.03	0.86
Rochester	-3.42	0.41	-3.49	5.41	-11.84	3.93
Oak Savannah	-6.27	-23.81	22.50	0.72	-7.33	16.83
Mean (%)	-5.65	-1.19	0.00	0.85	-10.44	2.85

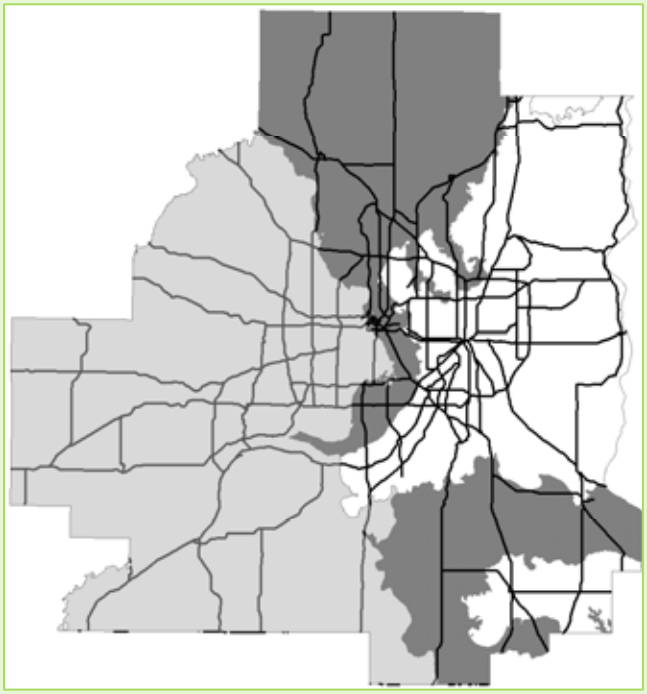

Figure 5. Magnitude of the absolute value of the combined percent change[1] from 1991 to 1998 in the numbers of oak patches and mean patch sizes.

[1] (| mean change (%) in patch number | + | mean change (%) in patch size |)