SITE FACTORS INFLUENCING OAK DECLINE IN THE INTERIOR HIGHLANDS OF ARKANSAS, MISSOURI, AND OKLAHOMA

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Abstract—Oak decline is affecting the forests in the Interior Highlands of Arkansas, Missouri, and Oklahoma. In 2002 and 2003, field plots were established throughout the region to evaluate the influence of topographic position and aspect on oak decline. Density and basal area of dead and dying oaks did not significantly differ by either topographic position or aspect. Lack of differences by topographic position may be partially explained by the low number of sample plots on ridgetops. It is also likely that factors other than topography and aspect influenced oak decline severity.

INTRODUCTION

Oak decline involves an interaction of predisposing, inciting, and contributing factors that results in the death of oaks in general and red oaks in particular (Starkey and Oak 1989, Starkey and others 2004). Since the late 1990s, oak decline has affected forests throughout the Interior Highlands of Arkansas, Missouri, and Oklahoma (Oak and others 2004, Rosson 2004). The predisposing factors in this decline include advanced tree age, shallow and rocky soils, and a high proportion of red oaks. The inciting factor was an acute regional drought from 1998 through 2000. Contributing factors include red oak borer (*Enaphalodes rufulus* Haldeman) (Crook and others 2004), *Armillaria* spp. root rot (Bruhn and others 2000), and hypoxylon canker (*Hypoxylon* spp). The spatial extent and severity of the current decline may be unprecedented. Approximately one-third of red oak density and basal area in the Interior Highlands is either dead or dying (Guldin and others 2006). Due to the monetary value of the sawtimber and pulpwood at risk, as well as the aesthetic and wildlife values of oak forests in the region, oak decline has become an important issue for foresters and land management agencies.

The area affected extends from the Ouachita Mountains in eastern Oklahoma and western Arkansas to the Ozark Mountains in northern Arkansas and southern Missouri. It is unclear whether particular topographic positions and aspects are more or less susceptible to this decline. During an oak decline in the 1980s that impacted forests from Arkansas to Virginia, Starkey and Oak (1989) found that field plots with the highest incidence of mortality were associated with stony, gravelly soils < 46 cm deep; were on ridgetops or upper slope positions; and had average or lower site indices (< 21 m at 50 years). Using data from the 1980s decline, Oak and others (1996) developed oak decline risk rating models for the Ozark Mountains and northern and southern Appalachian Mountains. Significant site variables for the Ozarks included high clay content of soil and low slope gradient (i.e., ridgetops).

In summer 2002 and 2003, field plots were established in forests throughout the Interior Highlands to quantify the distribution and severity of oak decline. Preliminary results were presented by Heitzman and Guldin (2004), and a summary was reported by Guldin and others (2006). In the current study, we used data from these field plots to explore the relationship between site factors and oak decline. Specifically, we examined whether decline severity varied by topographic position and aspect.

METHODS

In 2002, 500 polygons with a data collection point centrally located in each were delineated on a digital map of the Highlands. Prior to field sampling, the points were stratified by their presumed susceptibility to oak decline (Oak and others 1996, Starkey and Oak 1989). Risk categories were as follows:

1. Very high risk – red oak basal area > 6.9 m^2/ha on ridgetops or south- to southwest-facing slopes
2. High risk – red oak basal area > 13.8 m^2/ha but on sites other than ridgetops or south- to southwest-facing slopes
3. Moderate risk – red oak basal area between 2.3 to 6.9 m^2/ha on ridgetops or south- to southwest-facing slopes, or 2.3 to 13.8 m^2/ha on other topographic positions or aspects
4. Low risk – red oak basal area < 2.3 m^2/ha regardless of topographic position or aspect.

Initially, the sampling objective was to visit all 500 field plots, the majority of which were in the very high and high risk categories. However, due to financial constraints, property access delays, and misinterpretation or misclassification of GIS data, only 225 field plots were sampled, most of which were in the moderate to low risk categories. The 225 field plots were established in Arkansas, Missouri, and Oklahoma during the summer of 2002 and 2003. Of these 225 plots, 181 contained at least 1 oak tree > 24.4 cm d.b.h. Data from these 181 plots (90 in Arkansas, 78 in Missouri, and 13 in Oklahoma) were analyzed for this study.

Plots consisted of one 0.08-ha overstory plot in which all living, dying, and dead trees > 24.4 cm d.b.h. were tallied by species, crown condition, and d.b.h. Crown condition was recorded as: alive and healthy (0 to 33 percent crown dieback), alive but dying (> 33 percent crown dieback), or dead within the past 3 years. Trees that had been dead for more than 3 years were not measured. In addition, living, dying, and dead trees 8.9 to 24.4 cm d.b.h. were tallied in a 0.04-ha midstory plot that was nested within the overstory plot. Midstory trees were recorded by species, crown condition, and d.b.h.

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Various site attributes were assessed at each point. These included topographic position (ridgetop, upper-slope, mid-slope, lower-slope, or floodplain), which was visually estimated, and aspect (from 0 to 360° azimuth), which was measured by compass. We defined north aspects as ranging from 315 to 45°, east aspects as 46 to 134°, south aspects as 135 to 224°, and west aspects as 225 to 314°.

Basal area and density of dead/dying oaks (of any species) were calculated for each plot. These values were grouped by topographic position to determine if decline severity (expressed as mean dead/dying oak basal area/ha and trees/ha) varied by topography. After this, plots were grouped into different aspect categories to determine if decline severity, expressed as mean dead/dying oak basal area and density, varied by aspect.

A Shapiro-Wilks test indicated that none of the data analyzed were normally distributed, so oak mortality was compared using a Kruskal-Wallis test. Significance was accepted at $P \leq 0.05$. Data were analyzed in SAS (SAS Institute 1993).

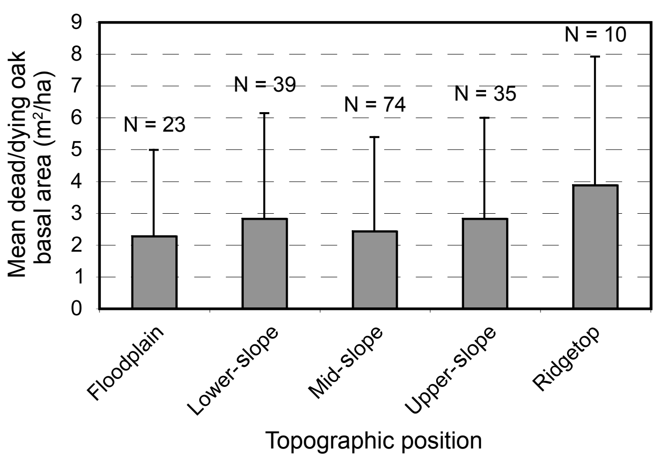

Figure 1—Mean dead/dying oak basal area by topographic position in the Interior Highlands. Bars are one standard deviation.

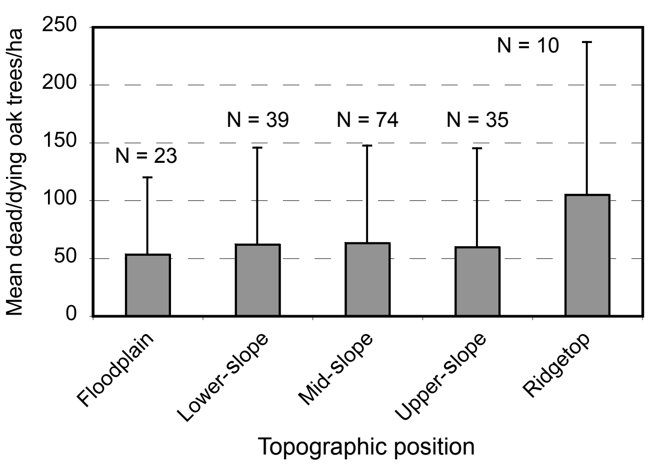

Figure 2—Mean dead/dying oak density by topographic position in the Interior Highlands. Bars are one standard deviation.

RESULTS AND DISCUSSION

There was no significant difference (P=0.72) between mean dead/dying oak basal area in different topographic positions (fig. 1). There was also no significant difference (P=0.59) between the mean number of dead/dying oak trees/ha on different topographic positions (fig. 2). In general, higher topographic positions had a greater amount of decline, both in basal area and density. Oak mortality was greatest on ridgetops (4.0 m^2/ha and 104 trees/ha) and least on floodplains (2.0 m^2/ha and 54 trees/ha).

There was no significant difference (P=0.14) between mean dead/dying oak basal area on different aspects (fig. 3). Oak mortality was greatest on south-facing (3.1 m^2/ha) and west-facing (3.0 m^2/ha) slopes and least on east-facing slopes (1.8 m^2/ha). There was also no significant difference (P=0.50) between the mean number of dead/dying oak trees/ha on different aspects (fig. 4). In general, south-facing slopes had the highest density (69 trees/ha) of oak mortality, followed by west-facing slopes (68 trees/ha). The lowest mortality (50 trees/ha) was on eastern slopes.

Previous studies have demonstrated that ridgetops had the greatest amount of oak decline (Oak and others 1996, Starkey and Oak 1989). However, we found no significant differences in oak decline by topographic position. This might be because the majority of field plots in this study were not on ridgetops.

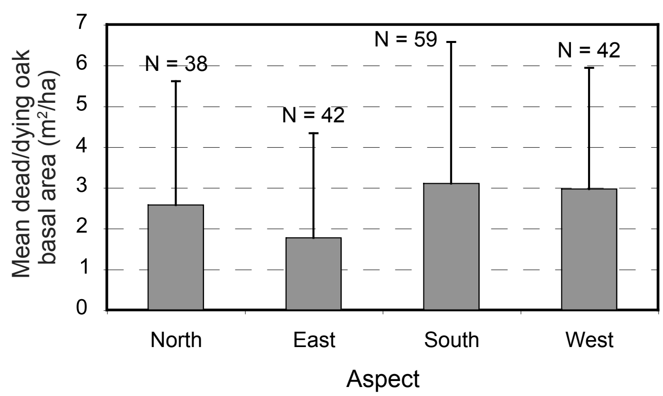

Figure 3—Mean dead/dying oak basal area by aspect in the Interior Highlands. Bars are one standard deviation.

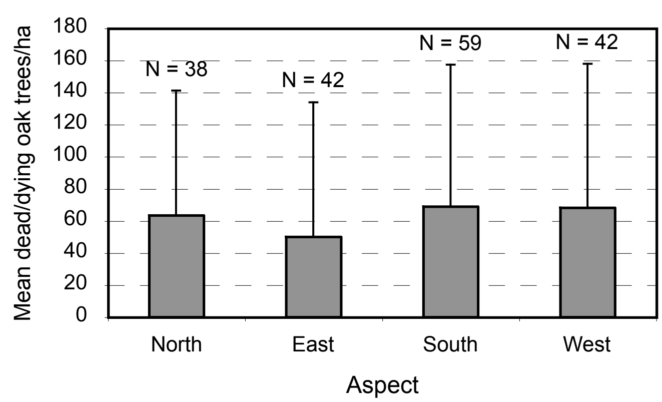

Figure 4—Mean dead/dying oak density by aspect in the Interior Highlands. Bars are one standard deviation.

Only 10 plots fell on ridgetop positions, whereas 35 plots were on upper-slopes, 74 on mid-slopes, 39 on lower-slopes, and 23 on floodplains. The low sample size on presumably susceptible sites may have contributed to the lack of significant differences. In addition, we found no statistical differences in oak decline on different aspects, although the field plots were more evenly distributed by aspect. Starkey and Oak (1989) did not detect significant differences in oak decline by aspect, although they reported that north and western aspects had the greatest mortality. Oak and others (1996) stated that aspect was not a significant variable in oak decline risk models developed for the Ozark and Appalachian Mountains.

Field observations in the Interior Highlands indicated that oak decline seemed to be most severe on ridgetops and xeric aspects, but not all forests on ridgetops and xeric aspects were in decline. Our results support this finding and suggest that factors other than (or perhaps in addition to) topography and aspect influenced the severity of oak decline in the Interior Highlands. Recent work by Kabrick and others (2004) in the Ozark Mountains of southern Missouri showed that oak species and crown class were more important than site factors in affecting oak mortality from 1992 to 2002. The mortality rate of red oaks was four times greater than for white oaks, and suppressed oaks were about three times more likely to die than upper canopy oaks. Also, mortality sharply increased for red and white oaks larger than the 33 to 38 cm d.b.h. class. Thus, severity of the current oak decline in the Interior Highlands is influenced by a combination of individual tree, stand, and site variables.

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