Chapter 13. Risk Factors for Oak Decline and Regional Mortality Patterns in the Ozark Highlands of Arkansas and Missouri

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Introduction

Since the late 1970s, oak decline and mortality have plagued Midwestern-upland oak-hickory forests, particularly species in the red oak group (*Quercus* Section Lobatae) across the Ozark Highlands of Missouri, Arkansas, and Oklahoma (Dwyer and others 1995). Drought is a common inciting factor in oak decline, while advanced tree age is considered a predisposing factor, and opportunistic organisms such as armillaria root fungi and red oak borers are believed to contribute to oak decline and mortality. Declining trees first show foliage wilt and browning followed by progressive branch dieback in the middle and/or upper crown. Trees eventually die if crown dieback continues. Our objective was to analyze oak mortality by species group and inventory year to illustrate the general spatial and temporal trends of oak decline and mortality by using data from the Forest Inventory and Analysis (FIA) Program of the Forest Service, U.S. Department of Agriculture; specifically, we used the 1999–2006 annualized data from FIA plots in the Ozark Highlands of Arkansas and Missouri.

Methods and Data

The data for this study included 3,945 oak-present FIA plots measured from 1999 through 2006 in the Ozark Highlands of Arkansas and Missouri. The percentage of dead trees was calculated in terms of basal area (ba) for white oak group, red oak group, and non-oak species on each plot. Gaussian kernel density (smoothing) (Wand and Jones 1995) was used to evaluate the spatial trend of average oak mortality in terms of proportion of dead basal area for the decline-prone red oak group over the Ozark Highlands by using FIA plots measured from 2002 to 2006. To evaluate the impact of droughts on regional red oak mortality, the Palmer Drought Severity Index (PDSI) data from 1990 to 2006 for four climate divisions [Arkansas divisions 1 and 2, Missouri divisions 4 and 5 (http://www.esrl.noaa.gov/psd//data/usclimdivs/data/map.html)] were downloaded from the National Center for Atmospheric Research (NCAR) Web site and correlated with the transformed (taking arc sine square root of) average red oak mortality for each division with the lag time equal to 0, 1, 2,…, 17 years (Gottman and Roy 1990). Classification and regression tree (CART) (Breiman and others 1984) analysis was applied to Missouri Ozark Forest Ecosystem Project (MOFEP) 16-year data to identify site/stand and tree level risk factors contributing to oak decline and mortality.

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Results and Discussion

The proportion of dead basal area of red oak group species showed escalating relative mortality compared with non-oak and white oak group species. Red oak group species decline was the major determinant of this trend, while the white oak group and non-oak species maintained a relatively stable mortality rate (fig. 13.1).

Dead basal area for the non-oak and white oak groups fluctuated around 4 to 5 percent of total basal area during the sequence, while for the red oak group as a whole it increased from around 8 percent in 1999 to 16 to 18 percent by 2006. Fan and others (2008) found that red oak group trees had higher mortality (three or four times higher) than white oaks in this geographic region, which agrees well with the trends found in this study. Note that the mortality trends shown in fig. 13.1 are based on annualized data from the 3,945 FIA oak-present plots. Therefore, each year represents mortality on a subset (between 445 and 960) of those plots.

Two mortality peaks at 2001 and 2004 in the sequence corresponded to the dry cycles in the Ozark Highlands. Cross-correlation analyses

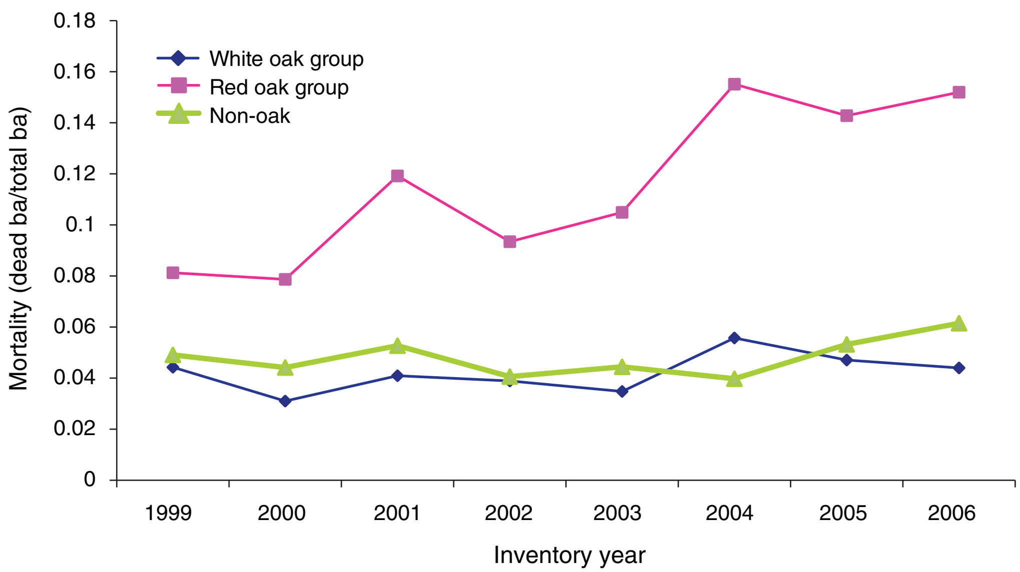

Figure 13.1—Temporal mortality trends for the white oak group, red oak group, and the non-oak group. (Data source: U.S. Department of Agriculture Forest Service, Forest Inventory and Analysis Program)

indicated that mortality was significantly correlated with the growing season PDSI and usually lagged 2 to 3 years behind single drought events. Moreover, the cumulative impact of droughts on red oak decline and mortality might last up to 10 years based on the past 17 years of PDSI data. The Ozarks experienced a severe drought period from 1998 to 2000 and a mild drought period in 2005 and 2006. These likely triggered the escalation of mortality starting from 2000 (fig. 13.1).

Spatially, high red oak mortality areas (hot spots with a cumulative proportion of dead basal area > 0.15) mainly occurred in the central area of the Ozarks (fig. 13.2). Moderate mortality (with the proportion of dead basal area of 0.10~0.15) was widespread over most areas of the Ozarks and low mortality was distributed around the outer area of the region (fig. 13.2).

Cross-correlation analysis between PDSI and red oak mortality in FIA plots indicated that drought pattern appears to be the major driver of large-scale (e.g., region) oak decline and mortality patterns compared to temperature regimes. In addition, at small scales like a stand or management unit, tree characteristics (crown class and d.b.h.) and competition condition (e.g., basal area in larger trees) were most important to oak decline and mortality based on 16-year monitoring data from the MOFEP (Fan and others 2006, Shifley and others 2006). On the MOFEP study sites, seven risk groups of declining red oak group species (black oak and scarlet oak) were identified by CART based on tree crown class, d.b.h., and basal area in larger trees (bal), with annual mortality ranging from 0.9 to 7.3 percent (fig. 13.3). Resource managers and foresters could use the identified risk groups to treat declining stands to mitigate oak decline and mortality. We will use a hierarchical approach to explore how regional climatic conditions like drought interact with local factors to affect oak decline and mortality in our follow-up study.

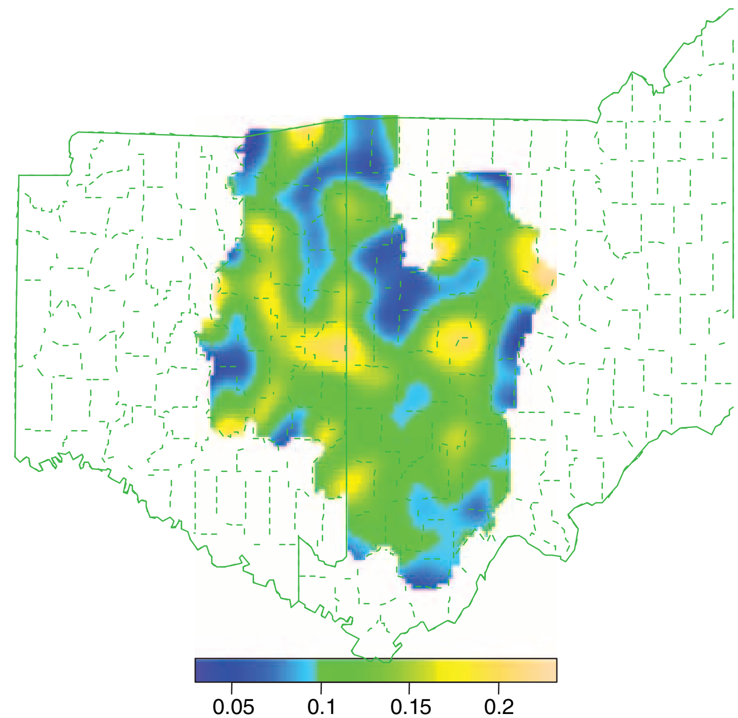

Figure 13.2—Spatial mortality (dead basal area/total basal area) trends of red oak group in the Ozark Highlands. (Data source: U.S. Department of Agriculture Forest Service, Forest Inventory and Analysis Program)

Conclusions

Oaks are a major component of the upland oak-hickory forests of Arkansas and Missouri. Episodes of drought and subsequent decline have been a persistent problem in these forests. Of the groups examined in this study, the red oak group consistently dominated dead basal area as a proportion of the total basal area. Regionally, this mortality was significantly correlated with growing season PDSI with 2- to 3-year lag behind single drought events, but at stand level, tree mortality was mainly correlated with tree crown class, d.b.h., and competition. Spatially, hot spots of mortality mainly occurred toward the central part of the Ozarks.

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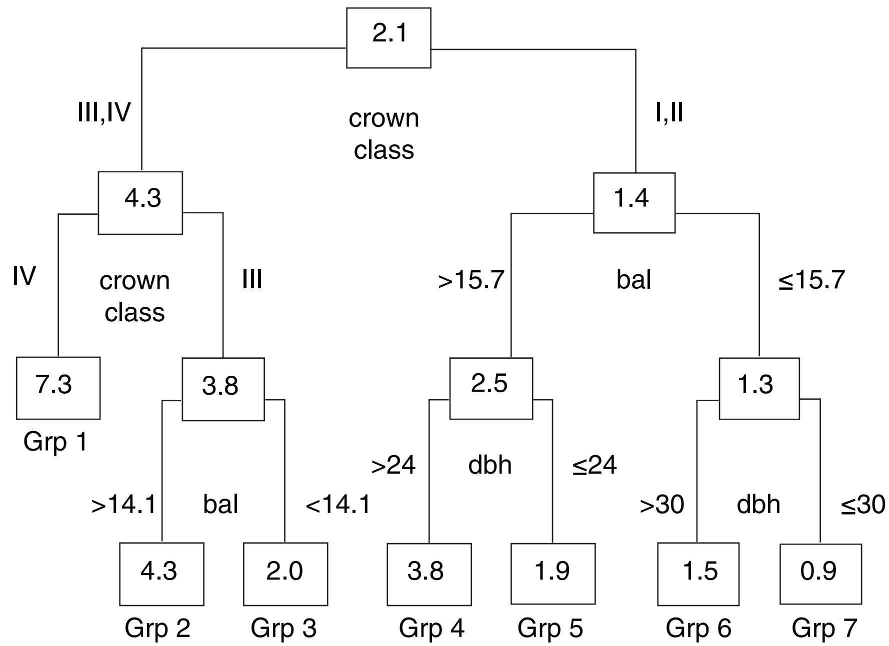

Figure 13.3—Annual mortality (percent) of red oak group species by risk factors for the Missouri Ozark Forest Ecosystem Project (MOFEP) sites. Crown classes are: (I) dominant, (II) codominant, (III) intermediate, and (IV) suppressed. Basal area in larger trees (bal) is computed uniquely for each tree on an inventory plot as the total basal area (m^2/ha) of the trees on that plot that are as large or larger in diameter at breast height (d.b.h.). Tree d.b.h. classes are in cm (from Shifley and others 2006). Note: the numbers in the boxes are the mortality percent at each node.