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# Analysis of Forest Structure Among Management Types at Land Between the Lakes, Kentucky

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# A Vegetation Analysis of Management Regimes that use Prescribed Fire in an Oak Forest

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**ABSTRACT** Fire is a dynamic disturbance that once created and maintained the oak savannas and oak forests of the Southeast. These ecosystems maintain open forest structures with herbaceous understories that provide significant habitat and food for native game and non-game wildlife species. In the absence of fire, canopies close, and fire-intolerant and shade-tolerant species begin to crowd the understory of traditionally open oak stands in a process called mesophication. Our objective was to quantify the vegetation on 20 sites in an oak forest that was subject to 4 different types of management at Land Between the Lakes National Recreation Area. The management types we studied included (1) areas not subject to any prescribed burning or thinning methods, (2) grasslands, (3) areas burned within 6 months of the study, and (4) areas burned more than 6 months prior to our study.

**KEYWORDS** fire ecology, forest management, Land Between the Lakes, Kentucky, oak forest, prescribed fire, vegetation analysis.

Among the variety of forest disturbances in the South, fire has been one of the largest influencing factors in the Southeast (Franklin 1994, Van Lear 2004, Knapp et al. 2009). Oak forests and oak savannas are maintained through periodic fire from lightning and anthropogenic means. Using historical data from Land Between the Lakes National Recreation Area (LBL), Franklin (1994) observed that the lightning caused fire regime in the area was complemented by Native Americans groups (Cherokee, Chickasaw, Choctaw, Creek, Shawnee, and Yuchi) who used periodic burning to provide space for wildlife grazing and movement (USFS 2004). For thousands of years Native Americans and, later, European settlers used fire to promote open woodlands with herbaceous understories (Johnson and Hale 2000, Van Lear 2004). Using fire scar data, Gueyette et al. (2010) observed a mean fire return interval of 5.22 years for the area that is now LBL from 1709-1944. The history of an oak dominated landscape at LBL is well understood through historical accounts and scientific studies (Franklin 1994, USFS 2004, Gueyette et al. 2010)

Forest structure within Southeastern oak savannas and open oak woodlands are characterized by open canopies and herbaceous understories that need to be maintained by periodic burning. This forest structure is what European settlers first experienced (Abrams 1992, Franklin 1994), and that provides food and habitat for native plants and wildlife (May 2002). In the absence of fire, ecosystems such as oak savannas and woodlands will experience increased canopy closure with an increase in shade-tolerant species such as Sugar Maple (*Acer saccharum*) and American Beech (*Fagus grandifolia*), a decrease in a grassy understory, and a decrease in ground fuel that is conducive to periodic burning (Nowacki and Abrams 2008, Knapp 2009, Ryan et al. 2015). Some of the first changes in the landscape in LBL and the surrounding area were noticed in the early 1800s as the Native Americans were pushed west. At this time, burning of prairies ended and small trees and shrubs took over forest understories (USFS 2004). An era of fire suppression in the early 1900s began to change the forest structure in the Southeast (Ryan et al. 2013). The importance of fire on certain landscapes is being re-recognized, but the seasons, timing, and intensity of fires is still not enough to replicate the fire regime that once occurred across the Southeast. While oaks are still currently the dominant species in many forests across the Southeast (Iverson et al. 2007), the regeneration of oaks is being stifled by competition from shade-tolerant and fast-growing pioneer species (Van Lear 2004, Iverson et al. 2007).

These changes in forest structure and species composition are part of a process called “mesophication” (Nowacki and Abrams 2008). According to Nowacki and Abrams (2008), mesophication occurs when increasingly cool, damp, and shaded conditions create a less flammable fuel bed and improve conditions for mesophytic species while creating deteriorating conditions for shade-intolerant, fire-adapted species. Mesophication occurs in large portions of oak forests especially on mesic sites. Mesophication is projected to occur more frequently in xeric uplands that oaks have traditionally dominated (USFS 2004, Van Lear 2004, Iverson 2007). These changes have significant impacts on the abundance of native plants, as well as insects and wildlife that rely on native plants for food and for shelter (Abrams 1992, Peterson and Reich 2001, May 2002, Hutchinson et al. 2005).

Differences in management strategies will influence forest structure, and consequently, which plant and animal species are maintained in a forest. Over the past 100 years the use of fire as a method for management in the Southeast has shifted from suppression due to negative public opinion and lack of resources, to a growing base of knowledge and technology that supports prescribed burning as a method for increasing the ecological and economic value of forests (Ryan et al. 2015, Franklin 1994). The Southeast was one of the first regions to begin utilizing controlled burning as method to increase ecological value of forests and encourage habitats beneficial to upland game species (Johnson and Hale 2000). The objectives of forest management in the Southeast have developed to include increasing abundance and connectivity in oak or pine savannas and woodlands (Peterson and Reich 2001).

The techniques most frequently used by land managers in the Southeast to promote open oak forests include prescribed burning and thinning (Van Lear 2004, Iverson et al. 2007, Knapp 2009). According to Iverson et al. (2007) a combination of techniques is necessary to maintain open, oak-dominated stands. Even when the understory is burned, mesophication may still occur because the shade caused by a closed canopy will favor maple saplings over oak saplings (Van Lear 2004, Nowacki and Abrams 2008, Ryan et al. 2015). On the other hand, if the forest canopy is mechanically thinned, the resulting increase in light may give oaks a competitive edge over mesophytic species (Iverson et al. 2007, Ryan et al. 2015). Our study area, LBL, is one of the management areas in the Southeast that has adopted prescribed burning and mechanical thinning as a means to combat mesophication on mesic and xeric sites and increase the sustainability of oak forests.

In 2004, LBL wrote a land and resource management plan that included objectives for increasing oak grasslands and open oak woodlands (USFS 2004). These objectives address the Continuous Forest Inventory (CFI) conducted in 1996, which indicated an increase in maples and poplar trees and a decrease in oaks in LBL. The decrease in oaks is due in part to impaired oak regeneration even on dry uplands where oaks would naturally have a competitive advantage over mesophytic species (USFS 2004). The age and condition of the current oak population raises concern over the sustainability of oak dominated forests in the area. The desired conditions in LBL include having grasslands (> 10% canopy closure), open oak woodlands on upper slopes and ridges (10-60% canopy closure), and open oak forests (60-80% canopy closure) throughout the landscape (USFS 2004).

Maintaining canopy openness, an open midstory, and an herbaceous understory requires periodic fire and other methods such as mechanical thinning (Abrams 1992, Hutchinson et al. 2005, Iverson 2007). LBL intends to increase the use of varying levels of prescribed fire and mechanical thinning to create a heterogenic landscape with stands of varying ages and canopy openness (USFS 2004). Prescribed fire will be used to open the canopy and stimulate herbaceous understory growth. Tree thinning will be used in dense forests to stimulate the growth of young trees to increase the diversity in age structures (USFS 2004). Increasing the amount of sunlight that reaches the forest floor in stands that are subject to thinning and burning will allow for an increase in an herbaceous understory that is important for maintaining healthy populations of native species of plants and wildlife (May 2002, USFS 2004).

Currently, there are some areas of LBL that are subject to prescribed burning while other areas are unmanaged. In order to better understand the forest structures that these contrasting management strategies create, we will study 20 sites throughout LBL that have been subject to 4 different management regimes. Within each of these management regimes we will study the differences in forest structure at each forest stratum. By quantifying the vegetation in unmanaged areas, grasslands, areas that have been burned greater than 6 months prior to the study, and areas burned less than 6 months prior to the study we will be able to better understand the effect that fire has on an oak forest structure.

## STUDY AREA

Land Between the Lakes National Recreation Area has been under the jurisdiction of the U.S. Forest Service since 1999. Throughout the 18th and 19th centuries our study area was known as Between the Rivers and was dominated by agriculture, iron, and logging industries that all led to a substantial extraction of the natural resources (Franklin 1994, USFS 2004). Throughout the 20th century several government agencies managed LBL and in 1964 the Tennessee Valley Authority assumed total authority of the land until it was transferred to USFS in 1999.

LBL is a 69,000 ha peninsular land mass located between 36°36’45” and 37°02’45” N latitude, and 87°52’25” and 88°13’35” W longitude, all within Lyon County, KY, Trigg County, KY, and Stewart County, TN. The area ranges from 6-13 km wide, with Lake Barkley on the east and Kentucky Lake on the west, and is 64 km long (Franklin et al. 1993). LBL receives a mean precipitation of 1,210mm annually and the average temperatures are 3° C in the winter and 28° C in the summer (Franklin et al.

1993), with a total of approximately 195 growing days. The area lies within the Mississippi Loess Valley ecoregion of Kentucky and the Western Highland Rim subsection of the Interior Low Plateau Province physiographic region. According to Franklin (1993), most of the area consists of highly dissected uplands, with bedrock of limestone and loess (Chester 1993).

According to the most recent USFS management plan, LBL is 92% forested and predominantly covered by mature oak forests (USFS 2004). Küchler (1964) maps the potential vegetation for the area as oak-hickory. About 6% of the land cover is open land consisting of cropland, wildlife plantings, hayfields, maintenance openings, ecological restoration openings, old fields, and roads. Little recent data was available that detailed the species composition, but Chester (1993) summarizes that ridges and upper slopes are dominated by *Quercus* spp. such as scarlet, blackjack, chestnut, post, and black oaks. The *Carya* spp. on these slopes include pignut, sand, and mockernut hickories. Highly mesic slopes contain sugar maple, bitternut hickory, American beech, tulip tree, black gum, and wild cherry. To summarize, Chester (1993) found that the major woody genera in LBL are *Quercus* and *Carya,* with *Ulmus* and *Acer* "contributing significantly".

## METHODS

Initial data for the analysis were collected from May-August 2014. We used remote sensing data to select 20 sites representing 4 vegetation types within 4 USFS management overlays of LBL. We selected the sites based on vegetation from the remote sensing data followed by ground truthing. We defined "unmanaged" as forest that had no management, such as cutting or burning, be applied to that area. "Grasslands" were defined as areas that were dominated by native species of grasses and that had little or no trees on the landscape. Finally, we separated the areas being managed with prescribed burning into two categories: “recently burned” referred to areas that had been burned within 6 months of collecting data and “previously burned” referred to areas that had been burned longer than 6 months prior to collecting data.

At each of the 20 locations, we collected data for the overstory, midstory, understory, and the ground level at 5 points representing each cardinal direction and a central point. At the overstory level, we used a densiometer to measure canopy openness. We then measured the number of live stems less than 10 cm diameter at breast height (DBH) in 16 $m^2$ plots at the midstory level. For the understory, we measured the number of bunchgrass tussocks/$m^2$ by counting the number of bunchgrass tussocks within $m^2$ quadrats. Finally, we measured the percentage of ground covered by leaf litter using quadrats with 10 bands running lengthwise and across, counting the cross sections for presence or absence of leaf litter.

After collecting data from across LBL, we wanted to see if there were differences in vegetation structures subject to different management regimes. Using the forest structure data, we tested the analysis of variance of a fixed effect model including the four management regimes: unmanaged, grassland, recently burned, and previously burned. The response variables for each included the percent canopy openness, the number of living stems in the midstory, the number of bunchgrass tussocks in the understory, and the coverage of leaf litter on the ground. Before running tests, we applied a logistic transformation to the overstory and the ground level data since these data were in percent form. We applied a logarithmic transformation to the midstory and understory data (which were counts) to adjust for skew.

We first tested the data for normality using a Shapiro-Wilk test and quantile-quantile plots (QQP). We then used an analysis of variance (ANOVA) for each forest strata to test for any significant differences between the means of the 4 vegetation types. After this, we used Tukey's post-hoc significance test to check for individual differences between each of the vegetation types within forest strata. For all statistical analysis we used R version 3.2.2 using the aov function in the base package and the lsmeans function in the lsmeans package for the post-hoc analyses.

## RESULTS

Overall, the least amount of variation among the management types was found in the midstory, and the greatest variation was found on the ground. We also found that areas that had not been burned within 6 months of the study were most similar to unmanaged areas for all forest strata except the overstory.

Canopy openness averaged 70.6 ± 3.82 % in grasslands, 17.3 ± 0.53 % in unmanaged areas, 30.55 ± 0.02 % in recently burned areas, and 23.8 ± 0.83 % in previously burned areas. The average number of living stems < 10 cm DBH in the midstory were 3.2 ± 0.44 in the grasslands, 4.8 ± 0.34 in unmanaged areas, 4.7 ± 0.35 in recently burned areas, and 5.5 ± 0.34 in previously burned areas. We found an average of 7.9 ± 0.23 bunchgrass tussocks per square meter in grasslands, 1.2 ± 0.6 in unmanaged areas, 2.5 ± 0.55 in recently burned areas, and 1.9 ± 0.61 in previously burned areas. On the ground, we found an average of 52.8 ± 3.46 % coverage by leaf litter in grassland areas, 72 ± 2.68 % in unmanaged areas, 21.4 ± 2.56 % in recently burned, and 82.4 ± 1.27 % in areas not recently burned.

The results from the ANOVAs revealed significant variations among sample means for the overstory, understory, and ground level. Our p-values were <.00001 for the overstory, 0.163 for the midstory, <.00001 for the understory, and <.00001 for the ground. Tukey's post hoc revealed significant differences among many of the vegetation types at each forest strata (Figure 1).

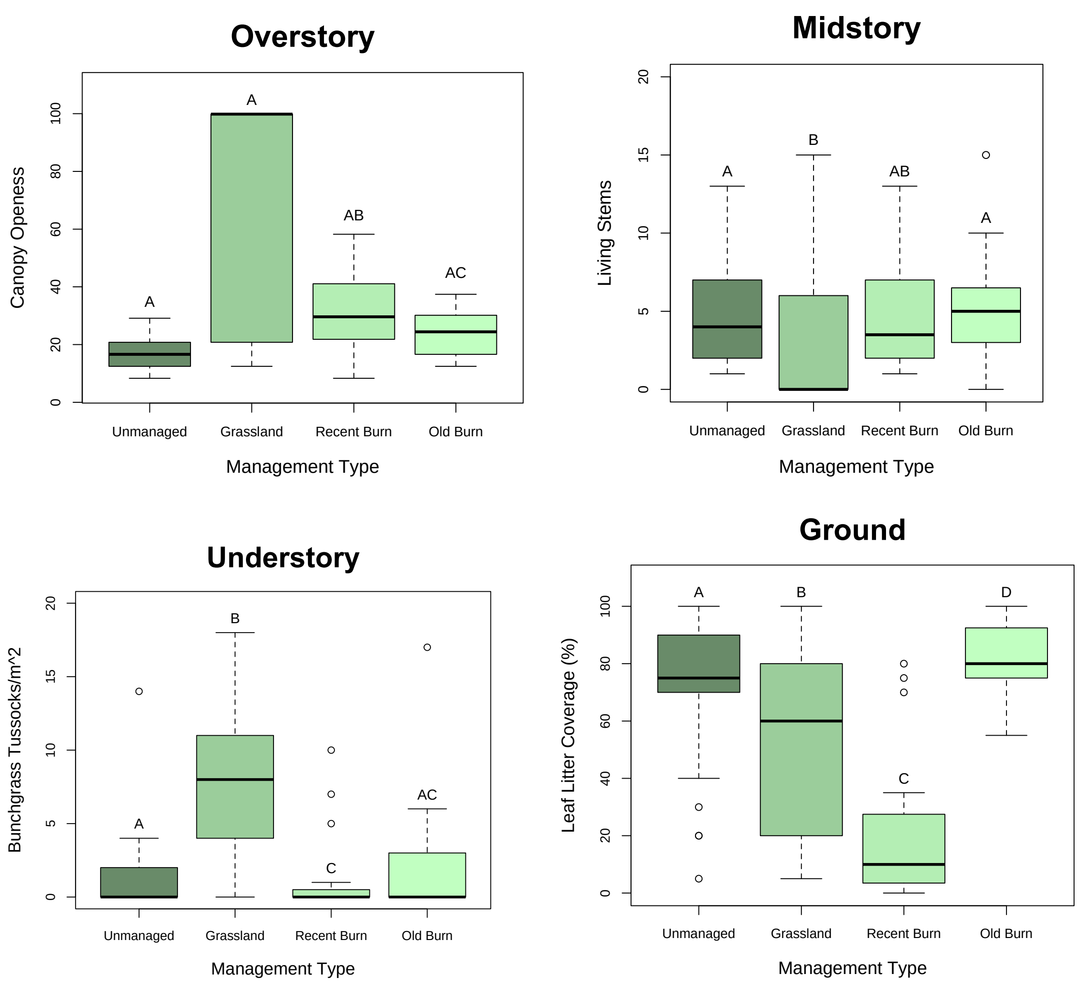


Figure 1. Boxplots showing the means and standard errors of 4 management types at each forest strata. Letters designate differences between management types according to post-hoc tests.

## DISCUSSION

Our analysis showed that burning an area may initially lead to changes in the forest floor but fire will have little lasting impact on the forest structure, especially in the midstory and canopy. In the midstory, we only observed significant differences between grasslands and unmanaged areas, and grasslands and previously burned areas, showing that fire has little initial impact on the midstory density. Along with this, there were differences between the canopy openness of all forest strata; however, the smallest difference was between the unmanaged and previously burned areas. Again, this suggests that fire has little initial impact on structure in the short run. The idea that few low intensity burns will fail to have a lasting impact on the forest structure is not unique to our study. Several other sources have documented field studies that resulted in changes in the forest structure only when several years of repeated burning along with thinning methods were applied to an area (Van Lear 2004, Hutchinson et al. 2005, Iverson et al. 2007, Ryan et al. 2013).

A study similar to ours conducted on the Cumberland Plateau in Kentucky looked at the effect of stand structure in burned and fire excluded oak stands (Blankenship and Arthur 2006). Blankenship and Arthur (2006) found that repeated burning reduced midstory stem density by 91%, whereas our study showed no significant difference in the average number of stems between old burns and unburned areas. Our study areas had not been subjected to as many burns as other studies, showing the difference that repeated burning makes for an area.

It is important to note than in the Blankenship and Arthur study, mesophytic species such as red maple (*Acer saccharum*) resprouted vigorously after the first three fires. Red maples and other shade tolerant species are capable of germinating through dense leaf litter whereas most species of *Quercus* must have direct contact with mineral soil. Because of this, repeated burning over several years is necessary to slowly reduce the density of a mesophytic midstory. Otherwise, a moist, dense forest floor will accumulate and will create undesirable conditions for oak regeneration. Iverson et al. (2008) found that by year 7 in their study on an oak forest in Ohio, oak seedlings numbered 3 x more in areas that were subject to thinning and burning than the control sites.

What the Iverson et al. (2008) study and other studies have found is that repeated burning in conjunction with other methods is necessary in order to maintain oak dominated forests (Van Lear 2004, Hutchinson et al. 2005, Iverson et al. 2007, Ryan et al. 2013). Van Lear (2004) points out that with long-term fire exclusion, the fuel bed becomes increasingly wet which, coupled with colder temperatures due to a closed canopy, reduces the flammability to such a degree that beginning a new fire regime would be extremely difficult. Ryan et al. (2013) emphasizes that an abundance of fine, dry fuels that are continuous are required for natural fires to occur in an ecosystem, and that wet forests may accumulate fuel bed continuity but are rarely dry enough to burn.

Much of the Southeast, including our study area, has historically been a fire-adapted landscape (Küchler 1964, Guyette et al. 2010, Ryan et al. 2013). Fire suppression in these areas leads to mesophication: increasingly cool, damp, and shaded conditions that create a less flammable fuel bed that improves conditions for mesophytic species while causing deteriorating conditions for shade intolerant species. The repercussions of this include a decreased fuel bed and a decrease in herbaceous species at the understory, along with the implications that this decrease in plant diversity has on wildlife species (May 2002, Ryan et al. 2013). While the mixed oak forest of LBL naturally exhibits mesophytic characteristics in lowlands and near water sources, the encroachment of mesophytic species into areas that are naturally oak dominated (ridges and east facing slopes with poor soil) has been observed in many historically oak dominated areas (Iverson et al. 2007, Nowacki and Abrams 2008).

Overall, our analysis of the vegetation at LBL exhibited patterns of mesophication and showed that fire only creates initial impacts on the forest floor and understory. Our findings are similar to that of other studies on oak forests in the Southeast and Midwest. While LBL has objectives to increase the amount of open oak forest in their area, our studies show that they will need to increase the amount of thinning and prescribed fire in areas that are becoming increasingly mesophytic in order to meet these objectives.

## MANAGEMENT IMPLICATIONS

In order to maintain oak dominated forests, forest managers need to strongly consider using periodic burning accompanied by other thinning methods. Prescribed burns will decrease the amount of moist leaf litter and the number of mesophytic seedlings. The addition of thinning methods will ensure that shade intolerant species such as several *Quercus* and *Carya* species will be able to compete in the understory. Over time, these methods will reduce the density of the midstory, allowing more light to reach the understory. By maintaining open oak forests, areas such as LBL could resemble the historic fire-adapted landscapes of the Southeast and support greater species diversity of herbaceous and woody plants along with endangered and game wildlife species.

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