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Fire damage effects on red oak timber product value

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ABSTRACT

Land managers use prescribed fire for a variety of resource objectives on sites containing merchantable trees. We analyzed how fire-caused injuries (i.e., fire scars) affect lumber volume and value in 88 red oak (*Quercus velutina, Quercus rubra, and Quercus coccinea*) butt logs from trees harvested from three sites in southern Missouri. Trees with varying amounts of external fire damage, time since fire, and diameter were harvested and milled into dimensional lumber. We tracked lumber grade changes and volume losses due to fire-related injuries on individual boards ($n = 1298$, 18.3 cubic meters (7754 board feet)). Most analyses considered value loss to the individual butt log. We identified threshold values for fire-scar height and percent basal circumference injured, beyond which value loss is expected. Our analysis produced two models to describe how butt log value loss relates to fire-scar dimensions and residence time (timespan between damage occurrence and tree harvest). Overall, value and volume losses due to fire damage were low. If fire damage is less than 50 cm in height and 20% of basal circumference, our study suggests little value loss is to be expected within 14 years of injury. If these thresholds are exceeded, value loss is likely, and increases over time. Value loss is very low if trees are harvested within approximately five years after fire damage, regardless of scar size. These findings are applicable for red oak trees which are at least 20 cm diameter at breast height at time of fire damage and with fire-scar residence times not greater than fourteen years.

1. Introduction

Prescribed fire use has recently increased in both occurrence and acceptance (Dey and Hartman, 2005; Nowacki and Abrams, 2008) in oak (*Quercus*) forests of the eastern United States. It is employed as a tool for natural community restoration, hazardous fuels reduction, and silvicultural objectives (Agee, 1996; Pyne et al., 1996; Brose and Van Lear, 1998; Hartman, 2005; Nowacki and Abrams, 2008; Burton et al., 2011; Arthur et al., 2012; Brose et al., 2013). Many studies have documented the ability of oak trees to survive different fire severity conditions with varying degrees of damage (Loomis, 1973; Abrams, 1992; Hengst and Dawson, 1994; Regerbrugge and Smith, 1994; Brose and Van Lear, 1999). Public land management agencies are commonly tasked with managing forestlands for multiple objectives. Among land managers in much of the deciduous forests of eastern North America, prescribed fire and timber production are perceived as conflicting practices (Ryan et al., 2013). More research is needed to understand how fire affects timber product values. Here we quantify the economic cost of applying prescribed fire in forest stands containing oak trees of merchantable size for typical dimensional lumber products.

Heating of cambial tissue leads to the scarring of tree boles, and thus provides an entry point for wood-degrading fungi and insects (Nelson et al., 1933; Berry and Beaton, 1972; Shigo, 1984; Gutsell and Johnson, 1996; Brose and Van Lear, 1999; Bova and Dickinson, 2005). Modern studies in oak ecosystems have investigated fire-scar characteristics (Smith and Sutherland, 1999), landscape and fire-intensity influences on fire scarring (Regerbrugge and Smith, 1994; Stevenson, 2007), fire-scar formation likelihood (McEwan et al., 2007), and relationships among fire-scar formation, tree diameter, and growth rate (Guyette and Stambaugh, 2004).

Very few studies have investigated timber product value losses on fire-damaged trees. Burns (1955) estimated scalable defect and cull on fire-damaged red oaks in southern Missouri. He found that much of the cull was associated with fire damage (compared to insect and branching defects), and that 70% of lumber value loss was due to volume loss and 30% due to quality loss (log grade change). Loomis (1974) scaled and graded (Ostrander, 1965) fire-damaged oak sawlogs to assess fire-related defects. Fire-scar measurements and tree characteristics (diameter and age) were used to predict lumber value and volume loss. This analysis showed that wound length, followed by wound age, were the

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strongest predictor variables. Guyette et al. (2008) investigated prescribed fire effects on volume and log grade on three oak species (*Quercus coccinea, Quercus velutina,* and *Quercus alba*) in southern Missouri. They reported that log grades changed very little and the volume of decayed wood was low 6 years after fire damage.

Previous research has emphasized the fire-damaged area, but ignored the portions of the log not affected directly by the fire wound. Nor have these studies discounted fire damage that does not affect lumber values because it lies outside the scaling cylinder, and is removed during the milling process. Also, studies have not considered that dimensional lumber of all grades allow for a range in levels of defect (NHLA, 2010), and that only when defect thresholds are surpassed does lumber grade decrease, resulting in value loss.

Rather than focusing solely on the fire-damaged area, we assessed the fire-caused value loss through analysis of the dimensional lumber sawn from fire-damaged butt logs. We measured value loss in terms of dimensional lumber products milled from fire-damaged red oak (genus *Quercus* section *Erythrobalanus*) trees in southern Missouri. We compared the expected (as if no fire damage occurred) and observed values of dimensional lumber products (boards and cants) sawn per butt log to determine the value loss of individual butt logs to fire damage. Dimensional lumber is an ideal unit for this evaluation because multiple grades are recognized within the hardwood industry for red oak lumber, thus allowing for fine-scale valuation (NHLA, 2010). This valuation allowed for the detection of losses due to lumber grade changes, rather than only volume. In this study, we determined if fire-scar extent, tree size (diameter breast height (DBH) measured at 1.37 m above ground), and fire-scar residence time effectively predict value loss in the butt log.

2. Methods

2.1. Study sites

Ninety trees were harvested from prescribed burned units and areas of known wildfires at three Conservation Areas (CA) managed by the Missouri Department of Conservation (MDC) in southern Missouri: Peck Ranch (Carter Co.), Lead Mine (Dallas Co.), and Graves Mountain (Wayne Co.). Stand overstories were comprised of even-aged cohorts of oak and hickory (*Carya*) trees, with sparse mid- and under-stories due to repeated prescribed fires. Trees species selected for harvest included black oak (*Q. velutina* Lam.), northern red oak (*Q. rubra* L.), and scarlet oak (*Q. coccinea* Muenchh.). Dimensional lumber products from these species are considered interchangeable (Hardwood Market Report, 2011).

Prescribed fire was used at all sites to restore and manage woodland natural communities (Nelson, 2005). Peck Ranch and Graves Mountain had been prescribed burned 4 times over a 14 year period. Prescribed fire was applied three times at Lead Mine over 10 years. Management objectives for using prescribed fire at these sites included top-killing understory woody stems, stimulation of native ground flora, and leaf litter depth reduction. Merchantable-sized trees (i.e., DBH > 20 cm) were harvested from areas adjacent to glades at Lead Mine and Graves Mountain and woodlands at Peck Ranch. All trees were harvested from MDC "Site Class 2" sites (MDC Staff personal communication May 2012), that have a black oak site index of 17–20 m (55–64 feet) (McQuilkin, 1974). Time between prescribed fire events and harvest of sample trees (fire-scar residence time) ranged from 1 to 14 years.

2.2. Field sampling

Trees of varying merchantable size, log grade (Rast et al., 1973), time since fire, and severity of fire-caused injury (fire scar) were purposely selected for sampling. To be considered for sampling, trees were required to be at least 20 cm (9 in.) DBH, and have evidence of fire damage (i.e., tree tissue growth initiated by fire-caused local cambial death). The tree selection process sought to include a diverse combination of fire-scar and tree sizes. We identified external fire scars by their triangular shape typically on the uphill side at the base of trees, and presence on adjacent trees in the immediate area (Paulsell, 1957; Gutsell and Johnson, 1996; Guyette and Cutter, 1991; Smith and Sutherland, 1999; Guyette and Stambaugh, 2004). Tree DBH and external fire-injury dimensions (scar height (ScarH), scar width (ScarW), and scar depth (ScarD)) for each tree were measured in the field (Fig. 1). ScarH was measured from the base of the leaf litter to the top of the damaged area; ScarW at the widest point; and ScarD at the deepest point within the fire-scar area. ScarD was measured as the distance from the dead cambial tissue to the outside edge of the encroaching new growth, i.e., 'woundwood ribs', defined as the new growth covering the dead cambium caused by the thickened annual growth rings (Smith and Sutherland, 1999). The fire-damaged area was defined as the area of new cambial growth (including smooth newly formed bark) immediately surrounding the exposed killed cambium. In the case of closed fire scars (i.e., already healed over fire scars), depth was not measurable and was recorded as 0.3 cm (0.1 in.). All other scar types had exposed dead cambium visible surrounded by encroaching new growth.

Professional loggers were contracted to harvest and deliver the butt logs to a local mill. Each tree was cut as low as possible to the ground to retain the fullest extent of fire damage. The butt log was cut to a 2.6 ($n = 14$) or 3.2 ($n = 76$) meter length (8.5 or 10.5 feet). The base of each butt log was painted a unique color combination to facilitate log and board tracking through the milling and grading process. A basal cross-section was retained from the top of each stump for fire-scar analysis.

2.3. Laboratory

Basal cross-sections were sanded with progressively finer sand paper (80–600 grit) to reveal cellular detail of annual rings and fire-scar injuries. Fire scars on cross-sections were identified by the presence of callus tissue, cambial injury, and woundwood ribs that covered the dead cambium (Smith and Sutherland, 1999). Fire injury years and tree ages were identified using standard dendrochronological methods (Stokes and Smiley, 1968). Fire-scar years were reported as the first year showing growth response to the fire injury. Measurements made on each basal cross-section included: radius at time of each fire injury and at time of harvest (pith to year of injury or outside bark), and the length injured along

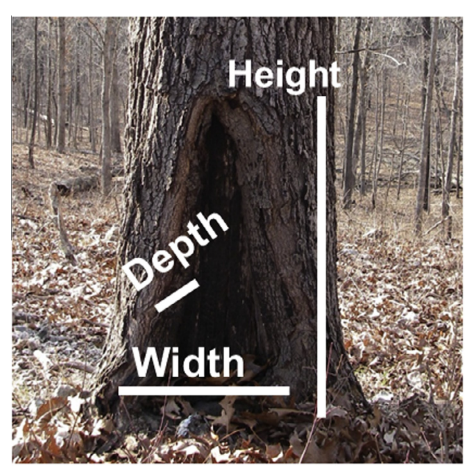

Fig. 1. External scar measurements measured in the field.