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Lightning, fire and longleaf pine: Using natural disturbance to guide management

Kenneth W. Outcalt *

Southern Research Station, USDA Forest Service, 320 Green Street, Athens, GA 30602, United States

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Abstract

The importance of lightning as an ignition source for the fire adapted longleaf pine (*Pinus palustris*) ecosystem is widely recognized. Lightning also impacts this system on a smaller scale by causing individual tree mortality. The objective of this study was to determine mortality due to lightning and other agents in longleaf stands on the Ocala National Forest in central Florida and to quantify lightning ignited fire. Mortality from lightning was also tracked in longleaf stands on the Savannah River Site in South Carolina. Lightning killed more trees than any other agent with a mean mortality of nearly 1 tree/3 ha/yr in Florida and 1 tree/8 ha/yr in South Carolina. The probability of a tree being struck by lightning increased as a function of tree height at both sites, i.e. lightning preferentially removed the largest trees from the stand. In addition lightning strikes were clumped within stands, sometimes killed multiple trees with a single strike, and often hit trees on the edge of existing gaps. The combination of these processes means gaps suitable for regeneration within longleaf stands are created quite rapidly. This information provides guidelines for the development of selection harvest systems based on this natural disturbance. Although lightning activity was greatest during the summer months in Florida and most fires occurred in June, the probability of a strike causing a fire was highest in February to May.
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Keywords: *Pinus palustris*; Disturbance; Wildfire; Mortality; Selection Silviculture

1. Introduction

Longleaf pine was once a very common tree in the Southeast dominating 24.3 million ha, stretching from southeastern Virginia, south to central Florida, and west into eastern Texas (Stout and Marion, 1993). As a result of cumulative impacts wrought by timber harvest followed by conversion to other tree species and land clearing for agriculture and urban uses, longleaf pine forest types have declined significantly and now occupy less than 5% of their original area (Outcalt and Sheffield, 1996). Longleaf communities have a diversity of ground cover plants with as many as 140 species of vascular plants in a 1000 m^2 area (Peet and Allard, 1993). Many of these species are local endemics or exist largely in the shrinking longleaf pine dominated habitats (Hardin and White, 1989; Walker, 1993).

It has been theorized that using techniques, which mimic natural disturbances, should maintain biodiversity and ecosystem integrity (Franklin, 1992). This is based on the premise that species within the community are adapted to natural disturbance and thus are resilient or resistant to these perturbations. This nature-based approach has been advocated for management and restoration of European forest types (Fries et al., 1997). Palik et al. (2002) also suggested modeling silviculture based on natural disturbance as a way to sustain the biodiversity of longleaf pine ecosystems of the southern United States.

A critical first step in development of nature based silvicultural systems is an understanding of natural disturbance processes for the forest type of interest. For longleaf pine these disturbances range from wide scale impacts like fire to individual tree mortality from insects or pathogens. Frequent low intensity surface fires were the most widespread and major disturbance factor shaping longleaf pine ecosystems. Prior to landscape fragmentation, these natural fires occurred every 2–8 years across the species' range (Christensen, 1981; Abrahamson and Hartnett, 1990; Ware et al., 1993). Lightning and Native Americans provided the ignition sources for these fires, which shaped the vegetation of the region (Komarek, 1964; Robbins and Myers, 1992).

* Tel.: +1 706 559 4309; fax: +1 706 559 4317.
E-mail address: koutcalt@fs.fed.us.

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Another significant disturbance agent in longleaf ecosystems was wind. A good portion of the longleaf range lies within 160 km of the coast. Thus, stands had a high probability of being impacted by a significant hurricane at least once every 100 years (Hooper and McAdie, 1995). Tornadoes were also prevalent within the longleaf range. For the period of 1880–1982 there were 969 major tornadoes across the south or 9.5 per year (Martin and Boyce, 1993). Although covering much smaller areas, tornadoes can cause significant disturbance on a local stand scale.

Lightning also has long been recognized as an important disturbance in southern pine ecosystems where in addition to being an ignition source it also impacted this system on a smaller scale by causing individual tree mortality (Komarek, 1968; Taylor, 1974). Reynolds (1940) reported 70% of pine mortality on the Crossett Experimental Forest in Arkansas over a 2-year period was due to lightning. In 182 ha of mature pine and pine hardwood stands near Georgetown, South Carolina 80 trees were killed by lightning over a 3-year period (0.44 trees/ha/yr) (Harlow and Guynn, 1983). Baker (1974) recorded one lightning struck tree per 18 ha annually (0.055 trees/ha/yr) in pine stands at Tall Timbers Research Station near Tallahassee, Florida. In southeast Georgia pine stands, lightning mortality in 1968 was much higher at 27 trees on 16 ha (1.68 trees/ha/yr) (Paul and Waters, 1978). Although lightning caused tree mortality data does exists, it is apparent that it is variable from place to place and from year to year. In addition, existing data does not provide information on seasonal variation within a given year. The major objective of this study was to quantify tree mortality from lightning and other agents in longleaf pine stands and to determine seasonal and annual variation in lightning caused mortality. A secondary objective was to estimate seasonal lightning ignition probabilities for central Florida.

2. Methods

2.1. Study sites

The primary portion of this study was located on the Ocala National Forest in central Florida. The climate of this region is humid subtropical with abundant rainfall of 1300 mm/yr (Chen and Gerber, 1990). Much of this rainfall comes during the spring and summer months from thunderstorms. Central Florida averages 90 thunderstorm days per year, more than anywhere else in the United States. It has a correspondingly high number of lightning strikes with 10–12 cloud to ground discharges/km^2/yr (Hodanish et al., 1997). The soils are mostly entisols derived from sandy marine and Aeolian deposits of past glacial and interglacial episodes (Laessle, 1958). The dominant natural vegetation of the area was composed of two contrasting types, scrub and high pine (Myers, 1990). Historically scrub was dominated by a twisted overstory of Ocala sand pine (*Pinus clausa* var. *clausa*) with an understory of evergreen shrubs. High pine areas were dominated by longleaf pine growing in an open park-like stands over a grass-dominated understory with occasional individual or clumps of oaks (*Quercus* spp.).

A secondary study area was located on the U.S. Department of Energy Savannah River Site in west central South Carolina. This area has a long growing season of 246 days, a summer mean temperature of 26.5 °C, and annual precipitation of 1200 mm with about half falling between April and September (USDA, 1941). Thunderstorms are less prevalent than in Florida, but still common, with associated lightning strikes occurring at a density of 3–5 cloud to ground strikes/km^2/yr (Orville, 1994). The Savannah River site lies in the fall line transition zone from upper coastal plain to piedmont. It is composed of Pliocene and Pleistocene coastal terraces and sandhills. Soils derived from predominately sandy parent materials are mostly entisols, which occupy 60–80% of the area (Brooks and Crass, 1991). Longleaf pine forests dominated these sandy sites prior to clearing for agriculture beginning in 1740.

In April 1992, four longleaf pine stands were randomly selected on the Ocala National Forest. The stands on the Lake George district were 27.7 and 25.9 ha while those on the Seminole were 18.9 and 7.6 ha. The Lake George stands were on Riverside Island, which is a large area of longleaf pine surrounded by stands of Ocala sand pine. These stands of longleaf were called islands by early settlers because they were oval, there was a sharp boundary between them and the surrounding sand pine scrub, and they differed markedly in appearance. Stands on the Seminole district were in Paisley Woods, which is a much more contiguous concentration of longleaf dominated community with some fingers and inclusions of Ocala sand pine. All stands were second growth longleaf pine that originated following logging in the early 1900s, from trees too small to harvest or subsequent natural regeneration. Some selective harvesting via thinning had occurred between 1940 and the late 1970s when cutting was discontinued to protect red-cockaded woodpecker habitat. Stands had been prescribed burned every 3–4 years for at least two decades with a majority of burning during the growing season for the last 10 years.

2.2. Data collection and analyses

After selection, the perimeter of each stand was mapped using a GPS unit. Data from the GPS files were used to calculate total stand area. During an initial survey of each stand, all existing dead standing trees were marked with red paint. Within each stand 0.125 ha circular plots, one for each 5 ha of stand area, were systematically located beginning from a randomly selected starting point. Species, diameter breast height (dbh), and height were recorded for all trees greater than 5 cm dbh on these plots. An additional 50 m × 100 m plot was randomly located in each stand. Within these plots, the location of each tree greater than 5 cm dbh was mapped and dbh and height data were gathered. Data from circular and rectangular plots were combined to determine stand characteristics including mean dbh and height, diameter and height class distribution and basal area.