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Predicting longleaf pine coarse root decomposition in the southeastern US

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ABSTRACT

Storage of belowground carbon (C) is an important component of total forest C. However, belowground C changes temporally due to forest growth and tree mortality (natural and via harvesting) and these fluctuations are critical for modeling C in forests under varying management regimes. To date, little progress has been made in quantifying the rate of decay of southern pines in general, and specifically in longleaf pine (*Pinus palustris* Mill.) coarse root systems. Decomposition rates of lateral roots and tap roots of longleaf pine were quantified *in situ* under field conditions across the species' range to create a model for necromass loss. The roots of 37 longleaf pine stumps were excavated from Florida, Georgia, Louisiana, and North Carolina. The age of the trees when cut ranged from 14 to 260 years, and the time since cut ranged from 5 to 70 years. Remaining lateral roots to a 1 m depth plus the entire tap root were removed, dried, weighed and analyzed for C and nitrogen (N) content. Total dry necromass of harvested roots ranged from 8 to 195 kg tree^{-1}. Soil C and N content at 15 cm depth were significantly higher near the stump compared to half-way between and adjacent to the nearest living longleaf pine. A regression model was developed to predict necromass loss. The final model included years since cut, stump diameter, and average minimum monthly air temperature as predictors (R^2 = 0.83). For example, a 100-year-old tree would have a predicted root decomposition rate (k) of −0.120 for lateral roots and −0.038 per year for tap roots. Results suggest that longleaf pine coarse roots persist in the environment longer than the tap roots of loblolly pine.

1. Introduction

Interest in ecosystem productivity and carbon (C) sequestration has led to accounting approaches to calculate the amount of biomass and C in longleaf pine (*Pinus palustris* Mill.) and other forest systems (Samuelson et al., 2014). Storage of belowground C in root biomass is an important but difficult to estimate component of total forest C (Radtke et al., 2009). Following tree mortality or harvest, C in root necromass can persist for many years, with decay rates dependent on species, wood chemistry, and climate (Schimel et al., 2001, Silver and Miya, 2001). Coarse root systems may require decades to decompose (Eberhardt et al., 2009, Weedon et al., 2009, Mobley et al., 2012, Palviainen and Finér, 2015). For example, in 10 to 60-year-old loblolly pine (*Pinus taeda* L.) planted in central North Carolina, 50% of the coarse root system decayed within the first 10 years (Ludovici et al., 2002). However, rapid rates of coarse root decomposition (80% in 10 years) were associated with wetter sites in a Monterey pine (*Pinus radiata* D. Don) plantation in New Zealand (Garrett et al., 2008).

Although not a long-term pool of C, root necromass can provide a short to medium term storage pool. Soil C content in the vicinity of old tap roots can stay elevated for at least 50 years (Ludovici et al., 2002, Garrett et al., 2008, Palviainen et al., 2010). Sucre and Fox (2009) found that soil associated with decomposing stumps was 1.2% of total soil volume but accounted for 10% of total soil C in a mature hardwood forest. Wang et al. (2012) determined that after 10 years, decomposing coarse roots of loblolly pine to a 1 m depth represented 13% of belowground C. In middle latitudes, decomposition of coarse roots is more dependent on temperature than decomposition rates of fine roots (Zhang and Wang, 2015). Decomposition of tap roots can be slowed by the buffering of temperature, decreased aeration, and lower population densities of decomposing organisms at depth in the soil profile (Richter and Markewitz, 2001). Decaying root systems play an important role in

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soil nutrient dynamics, C cycling, and thus forest productivity (Jurgensen et al., 1997, Clemmensen et al., 2013). Lower soil bulk density and the presence of macropores associated with decaying stumps provide a matrix for live root proliferation (Angers and Caron, 1998).

This research was part of a larger study that developed C sequestration models for longleaf pine plantations and natural stands (Gonzalez-Benecke et al., 2015) to help guide forest C management across the southeastern U.S. (Samuelson et al., 2014, 2017). Tap roots of old longleaf pine have been observed to last intact for many decades, showing little visual evidence of decay and are harvested as a source of quality kindling commonly called “fatwood” or “lighter wood”. Despite the general acceptance that dead longleaf pine tap roots can persist for decades, there is no quantitative data available for C sequestration models. An average root:shoot mass ratio of 0.43 was reported for longleaf pine trees older than 50 years of age (Samuelson et al., 2017), which is higher than many other conifers (Levy et al., 2004). Greater relative C allocation to roots in longleaf pine may lead to a larger live and dead belowground C pool compared to other species. Therefore, our objectives were to: (1) quantify C storage in decaying longleaf pine roots across a range of tree ages at time of harvest and times since harvest, and (2) develop a predictive model for longleaf pine coarse root decomposition that can be incorporated into C sequestration models. We hypothesized that coarse roots of longleaf pine decay at a slower rate than decay rates reported for other southern pines.

2. Materials and methods

2.1. Study sites

Based on access and degree of documentation of stand age and years since tree harvest, 11 locations were selected across the east–west range of the longleaf pine, from Louisiana to North Carolina (Fig. 1). Stump location, age of the tree when cut (Age), and years since cut (YSC) were determined with the help of on-site land managers and land use records. Stumps selected for this study were from trees cut either for production harvest or research. Those that died naturally (i.e. not cut) were not selected. A total of 37 stumps were identified and excavated (Fig. 1). Age ranged from 14 to 260 years and YSC ranged from 5 to 70 years (Table 1). Average minimum monthly air temperature value (T_{min}) was assigned to each site using the USDA Plant Hardiness Zone map (PHZ) (Table 1).

2.2. Stump collection

After identifying stumps, underbrush and leaf litter were removed from the soil surface. A square pit 1 m from the stump edge was then laid out. The area of these pits ranged from 4.7 to 6.8 m^2, depending on stump diameter. For stumps decayed at the ground line, the remaining bark ring was used to estimate the diameter of the stump (DS). Remaining lateral roots were hand excavated and sorted by depth (0–10, 10–20, 20–30, 30–50, and 50–100 cm). Soil from the pit was sifted through a 6 mm screen. Few lateral roots were found below 30 cm. A small backhoe was used to loosen soil and remove the tap root. Tap roots were taken to the laboratory, cleaned, and cut at ground level and by depth (0–10, 10–20, 20–30, 30–50, 50–100 cm and every 50 cm below 100 cm). All woody components were dried at 65 °C to a constant mass and weighed. Samples were then ground using a wood chipper. Subsamples were taken from the chipped material and ground using a Wiley mill. Wood C and nitrogen (N) concentrations were determined by dry combustion with detection by thermal conductivity (Flash EA 1112 series CN analyzer, Thermo Finnigan Instruments, Milan, Italy). To correct for mineral soil contamination, loss on ignition was measured on all samples.

2.3. Total soil C, N, and bulk density

To characterize spatial variation in soil C and N contents and soil bulk density proximal to stumps and residual live trees, two linear transects 90° apart were run from each stump to the nearest live trees. In plantations, the transect distance was consistent, but in older, naturally regenerated stands, the distance was variable. Prior to excavation, two samples were taken at a distance 0.5 m from the stump. Two samples were also taken 0.5 m from the nearest live tree and another two from the mid-point between the stump and the nearest living tree. Samples for determination of soil C and N, concentration and soil bulk density were collected at five depths (0–10, 10–20, 20–30, 30–50, 50–100 cm). Soil was air-dried to a constant mass and passed through a

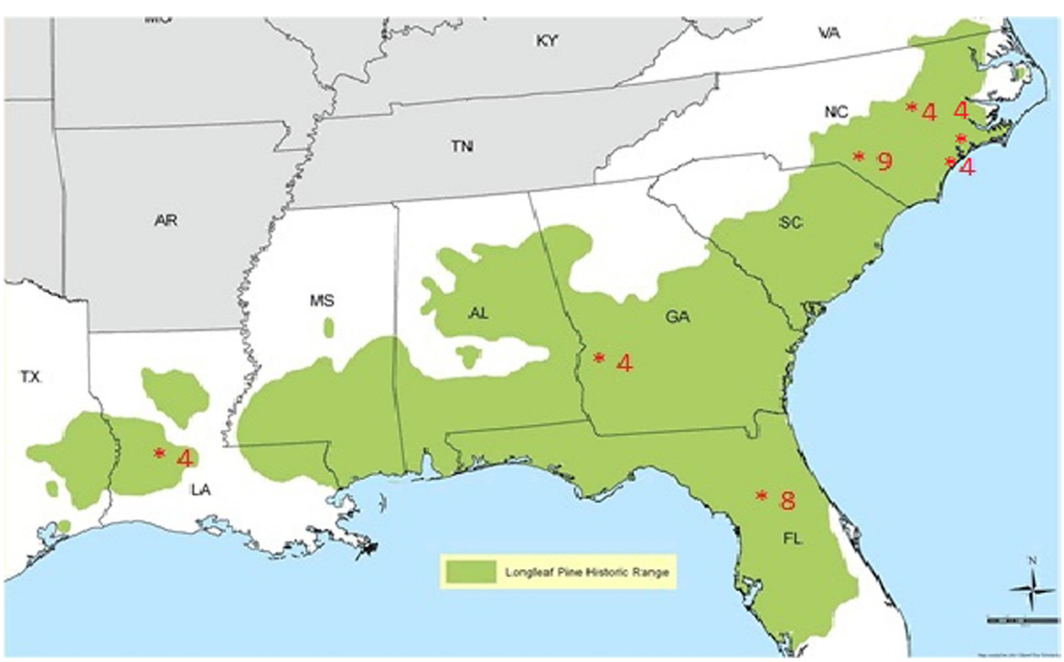

Fig. 1. Map of longleaf pine range in the southeastern US (htpp://www.fws.gov/news/blog/images/range500.gif). Asterisks represent sites where tap roots were removed and the number removed from each site.

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