Tamarack and black spruce adventitious root patterns are similar in their ability to estimate organic layer depths in northern temperate forests

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[1]*Michigan Technological University, Department of Biology, Houghton, MI, USA;* [2]*U.S. Forest Service, Northern Research Station, Houghton, MI, USA; and* [3]*University of Maryland at College Park, Department of Geography, College Park, MD, USA.* *Received 23 November 2011, accepted 15 May 2012.*

Veverica, T. J., Kane, E. S. and Kasischke, E. S. 2012. **Tamarack and black spruce adventitious root patterns are similar in their ability to estimate organic layer depths in northern temperate forests**. Can. J. Soil Sci. **92**: 799–802. Organic layer consumption during forest fires is hard to quantify. These data suggest that the adventitious root methods developed for reconstructing organic layer depths following wildfires in boreal black spruce forests can also be applied to mixed tamarack forests growing in temperate regions with glacially transported soils.

Key words: Adventitious roots, fire, peat, black spruce, tamarack, larch, organic soil

Veverica, T. J., Kane, E. S. et Kasischke, E. S. 2012. **Tamarack et Black Spruce Patterns de racines adventives sont similaires dans leur capacité à estimer profondeurs de la couche organique dans les Nord forêts tempérées**. Can. J. Soil Sci. **92**: 799–802. La consommation de matière organique dans les feux de forêt est difficile à quantifier. Ces données suggèrent que les méthodes de racines adventives développées pour reconstituer les couches de matière organique après les incendies dans les forêts boréales d'épicéas peuvent également être appliquées aux forêts de mélèzes mélangées dans les régions tempérées aux sols provenant des glaciers.

Mots clés: Racines adventives, le feu, la tourbe, l'épinette noire, le mélèze, le sol organique

In recent decades, a lengthening of the fire season has led to an increase in burn severity and extent across the North American boreal region, spanning Canada and Alaska (Kasischke and Turetsky 2006). These changes in fire regime have increased burning in lowland forest and peatland ecosystems, which harbor tremendous stores of carbon in deep organic layers. With more severe burning in recent decades, combustion of deep organic fuels present in northern peatlands has likely accelerated the rate of carbon emissions to the atmosphere (Turetsky et al. 2011). The carbon-based gases and particulates that are major products of boreal forest fires have consequences for both global carbon cycling (Preston and Schmidt 2006) and human health (von Donkelaar et al. 2011). Tools for assessing the combustion of carbon in wildfires are therefore needed. While burn indices are being developed for upland boreal forests (cf. Kasischke et al. 2008), methods for determining burn severity (defined here as the amount of organic matter consumed) in lowland peat fuels are relatively unexplored.

Previous research has shown that adventitious roots (AR), a rooting characteristic inherent to black spruce (*Picea mariana* Mill. BSP) growing in deep organic soil, can be reliable indicators of where the surface of the organic layer was prior to burning (Kasischke and Johnstone 2005; Kasischke et al. 2008; Boby et al. 2010). Adventitious roots grow above the initial root collar of *P. mariana* trees, allowing for rooting near the soil surface as moss aggrades and the organic layer develops, and they are visible around the root collar on standing charred trees following wildfire [see Kasischke et al. (2008) and references therein]. The distance from AR to soil surface has been shown to vary somewhat consistently with total organic layer depths within upland black spruce stands in Alaska, allowing for empirical estimates of carbon consumed in wildfires (Kane et al. 2007; Boby et al. 2010; Brown and Johnstone 2011). However, the AR method has yet to be tested in lowland systems with deep (>40 cm) accumulation of organic material. Moreover, the AR method has not been tested in temperate forests or on different lowland tree species also exhibiting AR growth patterns.

While black spruce and its associated forest cover types are broadly distributed across the North American

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Abbreviation: **AR**, adventitious root boreal region, it often occurs in mixed stands with tamarack [*Larix laricina* (Du Roi) K. Koch] in waterlogged soils. Tamarack exhibits AR growth and has one of the widest ranges of all North American conifers; it is also a characteristic tree of peatlands, especially in the southern limits of its range (Johnston 1990). These systems are also susceptible to burning, and harbor large stocks of carbon. Evaluating the ability of *L. laricina* adventitious roots to estimate organic layer depths would enable land managers and researchers to extend the range of landscapes where this method could be used to ascertain organic layer depth consumption following wildfires. In this study we compared organic layer and AR depths in pairs of burned and unburned *L. laricina* and *P. mariana* to determine the efficacy of the AR method at different northern temperate lowland forests with glacially transported parent materials.

MATERIALS AND METHODS

We measured adventitious root characteristics in stands dominated by both tamarack and spruce at 10 locations (spanning lat. 46.86077°N to 46.332004°N and long. −088.37785°W to −085.792501°W) throughout northern Michigan, USA. Site selection criteria included time since disturbance (>60 yr), hydrology (no open water or fen sites were selected), and overstory dominance (tamarack or spruce were the dominant or co-dominant species). The ground layer consisted of mixed *Pleurozium* and *Dicranum* moss species in denser stands and was dominated by *Sphagnum* species in more open stands. Forbs consisted of various grasses (*Poa* spp.), sedges (*Carex* spp.), *Vaccinium* spp., *Andromedea glaucipholia* and *Ledum groenlandica*.

Adventitious rooting patterns were measured as previously described in detail for boreal black spruce forests of Alaska, USA (Kasischke and Johnstone 2005; Kasischke et al. 2008; cf. Boby et al. 2010). We first located a 100×100 m area that had homogenous stand density in each location. A plot center was established, through which a 50-m baseline transect was run in a random direction (bisected by plot center). This baseline bisected three 30-m sample transects, one located at the center of the baseline and the other two located at a random distance between 5 and 20 m from the center in each direction. Seven sampling points were located every 5 m along each transect and four points were located along the baseline at 5, 15, 25, and 35 m.

At each plot, pairs of tamarack and spruce trees were selected every 5 m along the intersecting transects and every 10 m along the baseline (total $n = 382$ trees). Trees were at least 1.5 m in height and did not exceed 10 m from the transect or baseline. At each tree, the basal diameter, distance from soil surface to closest AR, and total organic layer depths were measured by excavating the peat surrounding the root collar and measuring the depth to mineral soil. When depth to mineral soil exceeded 40 cm, total organic layer depth was determined by probing with a rebar rod. Mean stand densities at each plot were determined by tallying every tree (>1.5 m height) within 1 m of the three 30-m transects (0.018 ha plot tally).

Previous studies have shown there to be differences in organic layer combustion beneath trees vs. between trees, owing to differences in fuel moisture beneath a canopy [see Boby et al. (2010) and references therein]. To examine possible differences in the effects of burning either at the bases of spruce or tamarack trees or between trees, we also quantified organic layer depths in a recently burned forest (160 ha Rice Lake fire, Houghton County, MI). Depths from AR to residual organic layer surface and total organic layer depths (post fire) along transects (every 5 m) were measured as previously described in this study.

Differences between tamarack and spruce organic matter depths below and above the uppermost AR across the full range of organic layer depths measured were determined by linear regression, and were significant when the slope coefficient of the regression line was significantly different from 1. Differences in mean organic layer depths and mean depths from AR to soil surface between tamarack and spruce forests were determined with independent sample t-tests ($\alpha = 0.05$).

RESULTS AND DISCUSSION

Mean (± standard deviation) stand density was 2084 ± 990 trees ha^{-1} (range = 2856) and mean basal diameter was 8.7 ± 2.4 cm (range = 6.7) across all sites. *Picea mariana* generally dominated stand basal area across all plots (median of 69% of basal area, with *P. mariana* ranging from 38 to 87% of total stand basal area).

There was a considerable range in organic layer depths measured across all sites, with plot means ranging from 17.5 ± 14.9 to 188.7 ± 50.9 cm. We detected no differences in the depths from AR to mineral soil between pairs of spruce and tamarack occurring across a wide range of organic layer depths in this study (Fig. 1). In fact, sites where *P. mariana* generally exhibited greater depths to AR from the organic soil surface also had *L. laricina* with greater AR depths (Fig. 2; slope not different from 1). These data suggest that AR rooting patterns between these two tree species are similar for a given site, and therefore both tree species can be used in the development of allometric equations for recreating total organic layer depths following wildfire.

Previous research in interior Alaskan black spruce forests has shown a linear increase in total organic layer depths with increasing depth from AR to mineral soil (~4–34 cm), with an intercept (± standard error) of 8.01 ± 2.43 and a slope of 0.89 ± 0.13 (Adj. $R^2 = 0.76$, $P < 0.001$; Kasischke et al. 2008). In these Alaskan forests, the depth from the soil surface to AR generally increased with increasing depth from AR to mineral soil following a quadratic function, with the asymptote in depth to AR from soil surface occurring at about 6.5 cm and a depth from AR to mineral soil of 25 cm

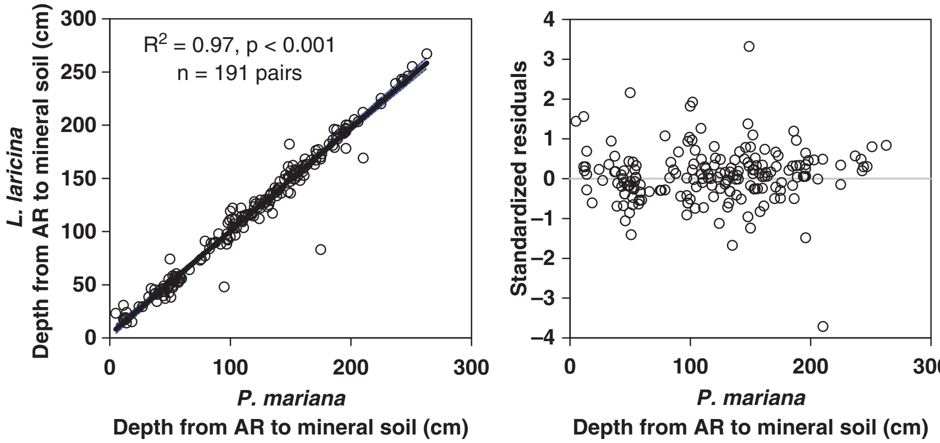

Fig. 1. Depths from adventitious roots (AR) to mineral soil were identical in *L. laricina* and *P. mariana*, and residual error was normally distributed. The regression line is described by the coefficients: slope = 0.97 (95% confidence, 0.95–0.99), intercept = 3.33 (95% confidence, 0.07–6.58).

($\beta_0 = -0.51 \pm 1.22$, $\beta_1 = 0.57 \pm 0.14$, $\beta_1^2 = -0.0115 \pm 0.0074$; Adj. $R^2 = 0.62$, $P = 0.001$). While a quadratic equation describing the distance from soil surface to AR is certainly not appropriate for sites with deeper organic layers (in this case a negative value for the depth from soil surface to AR occurs when the depth from AR to mineral soil > 48 cm), these data suggest that a fixed value for the depth from soil surface to AR in the range of 6 ± 2 cm is appropriate. In a more extensive dataset, Boby et al. (2010) also determined that total

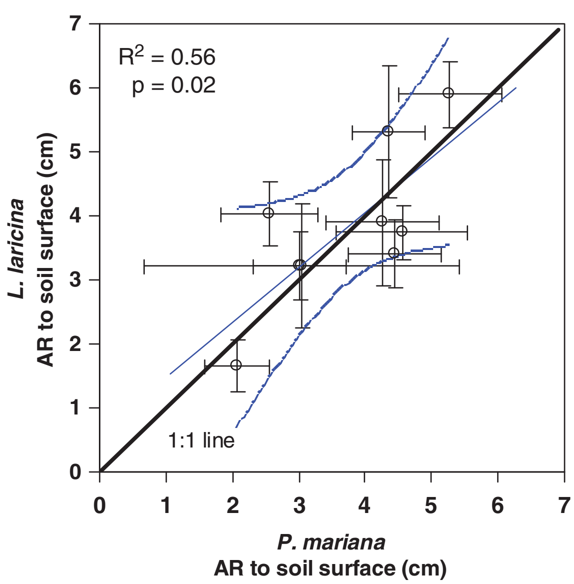

Fig. 2. Mean distances from organic soil surface to the nearest AR did not differ between *P. mariana* and *L. laricina* across the nine unburned sites in this study. Error bars represent standard errors of the mean values, and a 95% confidence interval is depicted. The regression line is described by the coefficients: slope = 0.86 (95% confidence, 0.18–1.53), intercept = 0.62 (95% confidence, −1.99–3.23).

organic layer depths can be reasonably approximated by adding 3.2 ± 0.43 cm to the depth from AR to mineral soil (× 1.06 to account for a "tree bias" of increased depth of burning measured at the base of trees), to account for surface moss above the AR. In our study, the depth from soil surface to AR linearly increased as the depth from AR to mineral soil increased, across all plots and tree species ($R^2 = 0.38$, $P = 0.007$), with the intercept being similar to that of Boby et al. (2010) (intercept = 2.37 ± 0.50, slope = 0.01 ± 0.004). Moreover, there was a linear increase in total organic layer depths with increasing depth from AR to mineral soil, with an intercept of 2.37 ± 1.07 and a slope of 1.01 ± 0.009 ($R^2 = 0.99$, $P < 0.001$). These findings suggest that organic layer depths can be reasonably approximated in these lowland mixed conifer forests by adding 2.4 cm to the depth measured from AR to mineral soil.

In a recently burned mixed spruce and tamarack forest, we observed no significant differences in residual organic layer depths beneath black spruce (86.3 ± 8.1 cm) or tamarack (74.7 ± 8.6 cm) ($t = 0.97$, $P = 0.34$), and there were no differences between residual organic layer depths measured along the baseline transect and those measured beneath trees near bisecting transects ($t = 1.76$, $P = 0.09$). These data suggest that canopy shading effects on organic layer combustion beneath trees vs. between trees in lowland mixed tamarack and spruce forests are likely to be negligible. It is important to note that variation in organic layer depths within a plot was considerable (coefficient of variation in organic layer depths ranging from 23 to 83% across all unburned plots, and 46% in the burned plot). In these lowland systems underlain with glacially transported parent material, the thickness of deep peat was independent of the microtopographical variation in mineral soil; this resulted in large variation in the depths measured from AR to mineral soil in sites with deep (>40 cm) organic layers. Organic layer depths are therefore likely to be much more variable in these lowland forests underlain with glacially transported parent materials (outwash and till) than what was observed in eolian, alluvial, and colluvial parent materials of interior Alaska, where the AR methods were developed (Kasischke et al. 2008; Boby et al. 2010). Therefore, while these data assert that the AR methods are applicable in temperate spruce and tamarack forests occurring in dissected landscapes with outwash parent materials, more AR measurements may be needed to constrain variability than would be required in boreal systems underlain with different parent material.

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