Untangling the belowground knot

Nathan G. Phillips

Department of Earth and Environment, Boston University, Boston, MA 02215, USA; Corresponding author (nathan@bu.edu)

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The most basic properties of whole-tree root systems have remained essentially impossible to determine non-destructively. The alternative, excavation and destructive root sampling, remains the bane of root physiologists’ existence. In this issue, Ellis et al. (2013) have made progress on electrical capacitance, one of the more promising non-destructive techniques to disentangle the belowground maze. Among their several findings, Ellis et al. (2013) demonstrate that the electrical capacitance technique can (i) separate intermingled tree root systems; and (ii) has the potential for estimating root length across orders of magnitude of root system length. Although it remains to be seen whether this second finding is influenced by allometric autocorrelation, Ellis et al. (2013) have raised the bar on field root research by considering how the physics of both the capacitance method and the root processes themselves operate across scales of organism size, and across individual trees in natural or managed ecosystems.

Ellis et al. (2013) build on the electrical capacitance and impedance groundwork laid by previous workers in this area (Chloupek 1977, Dalton 1995, van Beem et al. 1998, Ozier-Lafontaine and Bajazet 2005, Čermák et al. 2006, Cao et al. 2011, Urban et al. 2011, Dietrich et al. 2012). Where Ellis et al. (2013) have gone farther is in the range of plant sizes considered, covering two orders of magnitude in plant size, and an unprecedented species (25) and site (7) diversity. Moreover, this study is the first to apply the electrical capacitance technique in forests.

Among key findings of Ellis et al. (2013) was a simple, but potentially powerful one: intermingled root systems can be...
distinguished using the electric capacitance technique. The impedance (an alternating current form of resistance) between tree root systems was large compared with impedances within a tree circuit. This finding could add an important tool to a root identification toolkit that includes genetic fingerprinting methods (Linder et al. 2000). One question this raises is whether species connected by mycorrhizal associations (Simard et al. 1997) may show a different result. Testing sites containing biophysically connected species may shed light on the nature and extent of the root capacitor.

Another notable finding from this study is an apparent relationship between capacitance, root tissue density and root system length, which covered over two orders of magnitude of root system size. Interestingly, the power law relationship between these variables had a value near 4/3—a signature of fractal geometry and flow optimality that has been investigated by others (West et al. 1997, McCulloh et al. 2003). Does the relationship found by Ellis et al. (2013) reflect underlying allometrics of the root hydraulic system? It remains to be seen whether this result is fortuitous or fundamental, and surely this will be followed up by the authors and others over larger size ranges.

Studying roots has long been hampered by a version of physics’ uncertainty principle: measuring roots requires destroying them or disrupting their delicate soil environments. Yet the need to quantify root properties is growing more acute. The largest repository of terrestrial carbon is belowground (Pan et al. 2011), and roots regulate the increasingly perturbed global carbon, water and nutrient cycles. While not yet ready for routine use, Ellis et al. (2013) have made a key step toward opening up a potentially cheap, simple and non-destructive tool for belowground research.

References