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Optimizing ground-penetrating radar for measurement of coarse root biomass and its application in determining elevated CO_2 legacy effects in an 11-year Florida experiment

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Coarse roots may play a significant role in belowground carbon sequestration as atmospheric CO_2 levels continue to rise, but temporal and spatial quantification of coarse roots is one of the most difficult aspects of belowground ecology. Ground-penetrating radar (GPR) has been shown to be a useful, nondestructive method of quantifying coarse root biomass. GPR propagates electromagnetic waves into the soil, reflecting a portion of the energy back to the surface when an object is contacted. Despite promising results, this application of GPR is in its infancy, and neither the full potential nor limitations of the technology have been fully evaluated. Using a 1500 MHz antenna, we tested various scanning protocols and thresholds of application for GPR under a variety of environmental conditions in the sandy soils of a sand-hill mixed oak community in Southeastern Virginia. We then applied the optimized protocols to measurement of coarse root biomass in previous experimental plots from an 11-year CO_2 enrichment study at Kennedy Space Center (KSC), Florida that ended in 2007 and in a longleaf pine flatwoods ecosystem at Disney Wilderness Preserve, Florida. Regressions developed for Virginia and Florida showed significant correlations between number of pixels identified as roots by GPR and actual observed biomass (R2 = 0.75 and 0.62 respectively). Multi-directional scans of each sample area were most effective, and the results suggest that all scanning should be completed within a window of consistent weather conditions. We showed that GPR can recognize increasing root density over time, but we were not able to differentiate increases in cross-sectional area. We found that 88% of smaller roots shadowed under larger roots were identified compared with 98% of unshadowed roots. Moisture is a key factor in GPR success as GPR does not identify dead roots after their moisture content has equilibrated with the surrounding soil; only 15% of these roots were identified. Also, even slight increases in soil moisture (5-10%) degrade the root detection capability of GPR. We found that aboveground biomass at the KSC study site was significantly higher ($P < 0.01$) in the previously elevated plots (675 g/m2) compared to the ambient plots (480 g/m2) suggesting there are legacy effects in the form of more rapid aboveground recovery from fire on previously elevated CO_2 plots. Preliminary results also indicate that belowground biomass was higher in the elevated plots as well.