Carbon Sequestration Through Belowground Carbon Allocation: Forest Stand Development vs. Soil Resource Availibility

Mark Coleman, USDA-Forest Service, Savannah River, PO Box 700, New Ellenton, SC 29809; Email: coleman.m@earthlink.net

Introduction

Substantial amounts of carbon can be sequestered in belowground biomass while forest plantations remain alive. Accurate estimates of belowground biomass are required to account for this carbon. Many stand-level growth process models are scaled to regional and continental levels for carbon accounting purposes, because they accurately predict aboveground production and require few input parameters. Such models assume belowground allocation is affected by soil resource availability (Figure 1). Yet, there is strong evidence that stand development, not soil resources, predominately controls belowground allocation. Limited opportunity to validate model assumptions regarding belowground production causes concerns that errors may multiply upon scaling. To understand the relative importance of stand development and soil resource availability, we measured above and belowground biomass in plots of southern forest tree species to test the following hypotheses:

Hypothesis 1. Fertilization and irrigation will decrease the relative amount of belowground biomass

Hypothesis 2. The stage of stand development will not affect the relative amount of belowground biomass

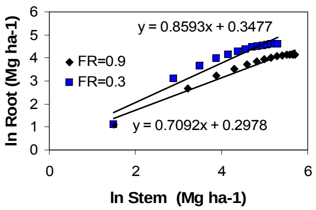

Figure 1. Growth process model (3PG) output for stem and root mass growing with two fertility ratings (FR) where 1 is optimal.

Methods

Site Description and Experimental Design.

Location: U.S. Department of Energy Savannah River Site near Aiken, SC (for details see Coleman et al. 2004. SRS, General Technical Report, SRS- 72).

Soil: Predominately a Blanton sand. We chose a site with deep sandy soil and low endemic soil moisture and nutrient levels to assure responses to water and nutrient amendments.

Tree Genotypes: Two *Populus deltoides* clones (ST66, S7C15) and *Platanus Occidentalis*. Results for *Pinus taeda* and *Liquidambar styraciflua* are not shown.

Treatments: Control, irrigation, fertilization, and combined irrigation + fertilization, applied through a drip irrigation system.

- 551 mm additional water applied to irrigated plots per year.
- 40, 80, and 120 kg N ha^{-1} yr^{-1} applied in 26 weekly applications during years 1, 2, and 3, respectively. Annual fertilizer increases corresponded to demand.

Biomass Measurements

- Measured diameters of 54 trees per plot
- Removed 5 trees each year from each species by treatment combination.
- Measured biomass of stem, branch, stump, coarse and fine roots (see photos)
- Developed allometric equations for each biomass fraction in each species by treatment

Figure 2. Photos of field proceedures clockwise from the left: Aerial view of Savannah River Short Rotation project Autumn 2001; Fine root sampling with push tube; Excavated coarse root sample hole; Stump removal using tree spade.

Aknowledgments

- David Coyle, Doug Aubrey provided technical assistance.

Results

Biomass and Allocation:

•Large growth differences occurred between treatments (Figure 3).
•Relative root biomass consistently declined with both age and resource availability (Figure 4).

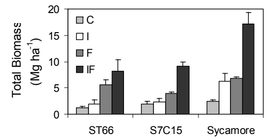

Figure 3. Whole-tree biomass after three growing seasons.

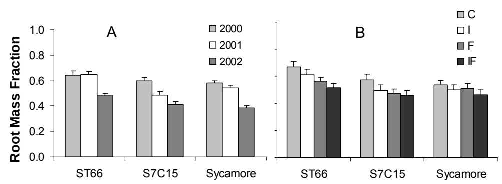

Figure 4. Root Mass Fraction (root mass / total mass) for (A) three growing seasons (n=12), and (B) for four treatments (n=9). Data from Coyle and Coleman 2005. For Ecol Manag 208, 137–152.

Allometry

- Root Mass Fraction depends on both the year of sampling (i.e. stage of development) and treatment (i.e. soil resource availability) (Figure 4).
- Therefore, accurate prediction using growth process models requires an understanding of which factor predominantly control allocation .
- When aboveground vs. belowground tissues were plotted on log-log plots to control for tree size, there were few slope differences among treatments despite more than a three-fold difference in growth (Figure 5).
- Strong developmental trends and lack of slope differences among treatments indicate that development predominately explains variation in allocation.

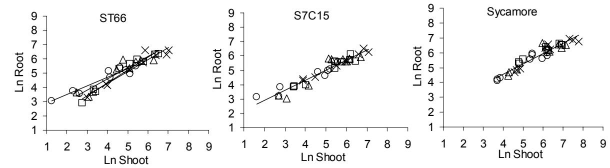

Figure 1. Allometric plots of shoot biomass vs. root biomass fractions for two cottonwoon clones ST66, S7C15, and Sycamore. Each tree contains data for control (○), irrigation (□), fertilized (Δ) and irrgation + fertilization (X).Data from Coyle and Coleman 2005. For Ecol Manag 208, 137–152.

•Consistent allometry occurs among each of the species examined (Figure 5).
•Enquist and Niklas demonstrate similar allometric relationships among a broad sampling of taxa in diverse habitat demonstrating insensitivity to local environmental conditions (Figure 6).
•Growth process models predicting significant control of soil resource availability over belowground carbon allocation are inconsistent with the overwhelming consistency of empirical data.

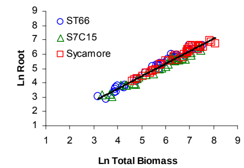

Figure 3. Allometric plots of shoot biomass vs. root biomass fractions for the three genotype.

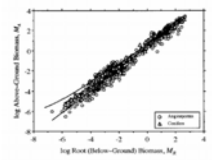

Figure 6. Enquist and Niklas (2002, Science 295: 1517) demonstrated theoretical relationships between root and shoot allometry.

Conclusion

•The relationships between above and belowground biomass is controlled mainly by development rather than soil resource availability.
•All species tended to fall on a single line.
•Literature verify a consistent relationships between above and belowground biomass.
•Use of soil resource availability to control allocation to roots in process models introduces errors that are not consistent with comprehensive empirical data.
•Prediction of belowground biomass as a proportion of stem biomass is a quantitatively accurate method of accounting for belowground carbon sequestration.