

# Relationships between aboveground woody biomass and soil organic carbon in a semi-desert grassland

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## ABSTRACT

Proliferation of woody plants into grasslands and savannas has changed land cover globally. Increased cover of woody plants cover accounts for a significant fraction of the Northern Hemisphere carbon (C) sink, yet the effects of the magnitude and distribution of woody encroachment on C sinks is uncertain. Under-canopy soil organic carbon (SOC) pools are thought to be elevated, yet the spatial distribution of SOC relative to tree canopies is unknown. Understanding this distribution is critical for developing accurate landscape-scale assessments of the impacts of woody plant proliferation on ecosystem C pools.

We compared SOC and aboveground C pools for encroaching mesquite (*Prosopis velutina*) in an Arizona semi-desert grassland. We developed equations to predict (1) aboveground C and (2) SOC distribution relative to tree size and bole-to-canopy position.

SOC increased with tree size and decreased with distance from the bole. The proportion SOC of total C (SOC + aboveground C) decreased with tree size, such that SOC was less than 50% of total C for trees >10cm basal diameter.

Mesquite basal diameter can be used to predict both aboveground and SOC pools.

Understanding the relationships between above- and belowground C pools will facilitate landscape-level assessments of woody encroachment C sinks.

## OBJECTIVES

- Quantify total SOC and aboveground live C pools across a size gradient of mesquite.
- Develop predictive equations for below and aboveground C based on simple, non-destructive aboveground measurements.
- Assess relationships between aboveground and belowground C pools.

## STUDY SITE

- Santa Rita Experimental Range; 21,500 ha site administered by University of Arizona (Fig. 1).
- Dominant woody vegetation: velvet mesquite, which has established in over the past 100 years (Medina 1996).
- Mean annual rainfall: 37.5 cm. Elevation: 1100 m ASL.
- Management: rotational cattle grazing

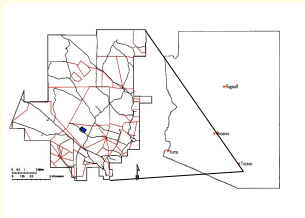


Fig. 1. Location of the SRER in southern Arizona. The blue rectangle indicates the study area for this project.

## ABOVEGROUND BIOMASS

### Methods

- Basal diameter, canopy height, and canopy area measured for 31 mesquite trees spanning a size gradient.
- Plants destructively harvested and biomass of live (leaf, fine branch, large wood) and dead components determined (Fig. 2).
- C analysis of subsamples used to convert biomass data to C mass.

### Results

- Basal diameter, canopy height, and canopy area all strongly predicted aboveground C mass (divided into components or as a whole); basal diameter was the best single predictive variable (Fig. 3).



Fig. 2. Field measurement of mesquite large wood biomass.

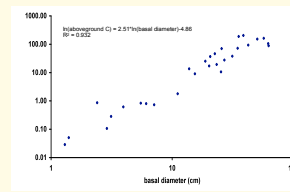


Fig. 3. Allometric relationship between mesquite basal diameter and aboveground C mass (sum of all live and dead components).

## SOIL ORGANIC CARBON

### Methods

- Soil cored (20 cm deep) around mesquite trees (n=17 trees, 10 cores/tree) radiating from bole to beyond dripline.
- Subsamples acid fumigated to remove carbonates (Harris et al. 2001) and analyzed for C and N content on an elemental analyzer.
- Multiple regression with SOC core data used to develop SOC equation based on tree basal diameter and distance from bole (SAS Proc Mixed).
- Total under-canopy SOC estimated for each cored tree by integrating SOC predictive equation for specified basal diameter (Fig. 4; Maple 10, Maplesoft).
- Under-canopy SOC for each tree compared with aboveground C estimates obtained from allometric equation (Fig. 3).

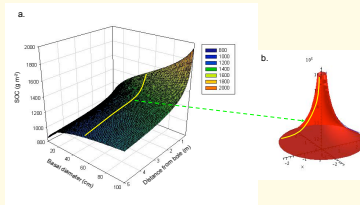


Fig. 4. (a) Predicted SOC as a function of basal diameter and distance from bole based on multiple regression,  $P < 0.005$  for all parameter estimates. (b) Total under-canopy SOC determined by rotating the function around an axis for each basal diameter of interest and integrating to determine the volume of the resulting solid of revolution. Illustration of modeled SOC under a 45cm basal diameter mesquite.

## SOIL ORGANIC CARBON, continued

### Results

- SOC increased with basal diameter and decreased with distance from bole (Fig. 4).
- Total under-canopy SOC increased with basal diameter; mostly due to increased under-canopy area of larger trees (Fig. 5).
- Relative proportion of tree-derived SOC increased with basal diameter (Fig. 6).
- Percentage of total SOC derived from trees increased with basal diameter
- Aboveground C responded more strongly to basal diameter than did SOC (Fig. 7).

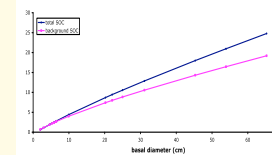


Fig. 5. Modeled SOC under trees of differing basal diameter. SOC accumulation from trees is the difference between total and background SOC (average intercanopy SOC x under canopy area).

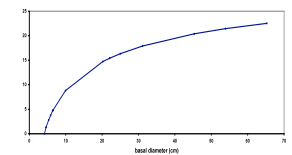
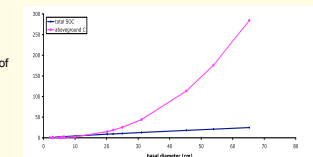


Fig. 6. Percentage of SOC from trees (total - background SOC) as a function of basal diameter.

Fig. 7. Comparison of modeled SOC and aboveground C as a function of basal diameter.



## IMPLICATIONS AND NEXT STEPS

- Woody encroachment of mesquite increases SOC and aboveground C pools. The proportion of C from SOC decreases with basal diameter.
- SOC strongly affected by tree size and position relative to bole; estimates of SOC based on limited spatial sampling may not accurately represent sub-canopy SOC pools.
- Simple, non-destructive measurements can successfully estimate both aboveground C and SOC mass.
- Root C may represent a substantial portion of the belowground C pool. Characterization of this pool is currently underway.

## LITERATURE CITED

Harris, D., W. R. Horwath, and C. van Kessel. 2001. Acid fumigation of soils to remove carbonates prior to total organic carbon or carbon-13 isotopic analysis. *Soil Science Society of America Journal* 65:1853-1856.  
 Medina, A. L. 1996. The Santa Rita Experimental Range: History and annotated bibliography (1903-1988). General Technical Report RM-GTR-276, Rocky Mountain Forest and Range Experiment Station, US Forest Service.

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