Belowground Carbon Distribution in a Piñon—Juniper / Short Grass Prairie Site

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Abstract*—Piñon-juniper woodlands encompass over 22.5 million hectares in the Western United States. However, little is known about the ability of these ecosystems to sequester carbon. This paper presents the preliminary results of an investigation on the belowground carbon distribution in a piñon-juniper/short grass prarie site in north-central New Mexico. Using a systematic sampling design the influence of tree cover, tree size, and sampling location (under tree canopy, under grass canopy, or under bare soil) were detected. However, these effects were only present in the upper most soil strata (< 20 cm below soil surface).*

Introduction

Piñon-juniper woodlands encompass over 22.5 million hectares in the Western United States (Mitchell and Roberts 1999). In north central New Mexico the dominant woody species of this community are piñon pine (*Pinus edulis* Englem.), Rocky Mountain juniper (*Juniperus scopulorum* Sarg.) and oneseed juniper (*J. monosperma* Sarg.) In the past 150 years, woody encroachment, both the increasing of density of woody plant cover and the encroachment into former grasslands by woody species, has increased in the southwestern United States (Van Auken 2000). Potentially, multiple ecosystem processes can be impacted by the species and structural changes associated with this encroachment. One process of interest are changes associated with carbon. Recent concerns over anthropogenic changes in greenhouse gases have elevated interest in ecosystem processes with particular attention on the carbon cycle.

The positive relationship between soil organic matter (carbon) content and soil quality (site productivity) has been widely accepted (NRC 1993). Improvements in soil quality with increased soil organic carbon have improved soil structure, nutrient availability and resiliency to erosion. Sine the mid-1980s direct and indirect roles of soil carbon pools on the carbon cycle have received attention from both policy makers and the scientific community.[3] In the context of forestry and forest soils much of the investigation on carbon dynamics has focused on boreal, mesic temperate, and tropical forest types. Comparatively, little research has examined carbon dynamics in semi-arid woodlands, such as piñon/juniper woodlands of the Western United States.

Objectives of this study were to examine the influence of vegetation type on soil carbon in a piñon-juniper – short grass prairie community in north central New Mexico. Information presented here is one part of a multi-disciplinary investigation on carbon dynamics in semi-arid and arid woodlands of the southwestern United States.

In: Gottfried, Gerald J.; Shaw, John D.; Ford, Paulette L., compilers. 2008. Ecology, management, and restoration of piñon-juniper and ponderosa pine ecosystems: combined proceedings of the 2005 St. George, Utah and 2006 Albuquerque, New Mexico workshops. Proceedings RMRS-P-51. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

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[3] A good reference on this topic is Soil Processes and the Carbon Cycle. CRC Press 1999.

Materials and Methods

The study site was located in a piñon-oneseed juniper woodland – short grass prairie community in Mora County, New Mexico (35º5'N, 105º10'W). The woodland lies in a transition between a blue grama (*Bouteloua gracilis* (H.B.K.) Lag.) dominated short grass prairie community at lower elevations and ponderosa pine (*P. ponderosa* Laws.) dominated forest at higher elevations. In addition to piñon and oneseed juniper, other woody plants include oak (*Quercus* spp.) and skunkbush sumac (*Rhus trilobata* Nutt.). In addition to blue grama, other ground covers include fringed sage (*Artemesia frigida* Willdenow) and snakeweed (*Gutierrezia sarothrae* Pursh.). The project site is situated at 2100-2150 m on a south-east facing slope of 30-40 perecent. Soils at the site are Haplustolls-Rock outcrop complex (Sellnow 1985). The soils are derived from sandstone and shale, creating a very stony, sandy loam across the study site. Depth of soil within the site is variable, ranging from shallow to deep. Exposure of the underlying sandstone is evident throughout the area, which suggests high runoff and water erosion potentials.

Climate is semi-arid and annual precipitation is variable, averaging 446 mm (Western Regional Climate Center 2004). The majority of precipitation occurs as rainfall in July and August. Mean annual snowfall is 940 mm occurring between October and May with the highest amounts in December and March. Mean annual temperature is 7.9 °C with mean January and July temperatures of –1.11 °C and 18.3 °C, respectively.

Six study plots, approximately 25 by 50 m, were established to represent degrees of piñon/juniper density ranging from 24% to 49% canopy coverage. Percent tree canopy cover and interspace within each plot were determined using digital analysis of a 1997 digital orthophoto quadrat.

Within each plot, 12 trees, six piñon and six oneseed juniper, were selected. Within each species two trees representing three size classes based on height (small (S) < 2.5 m; medium (M) = 2.5 to 4.5 m; and, large (L) > 4.5 m) were selected. Tree selection criteria were based on whether a tree was an isolated tree or a dominant tree on the periphery of a clump of trees.

Three 1-m deep soil cores were taken at each tree using a hydraulic ESP Plus subsoil sampler (Clements Associates, Inc.). Cores were taken along a transect at the mid-point from the stem to the drip line, 2 m from the canopy edge in a bare spot, and 2 m from the canopy edge directly beneath grass. Transect orientation was placed away from nearby trees and into an area of appropriate interspace (a minimum of 2.1 m to the drip line of the nearest tree). Each soil core was divided into 7 depth increments: 0-5, 5-20, 20-40, 40-60, 60-80 and 80-100 cm beneath the soil surface. In some locations depth to bedrock was less than 1m.

Samples were analyzed for total soil carbon content at the Soil Genesis Laboratory at New Mexico State University, Las Cruces, NM. Sample preparation included removal of particles greater than 2 mm and subsequent grinding with a Certiprep Shatterbox to pass a ~0.080 mm screen. Ground samples were weighed to the nearest one-thousandth of a milligram using a Sartorius microbalance. For elemental carbon analysis, each weighed sample was introduced into an elemental analyzer (Eurovector, Milan, Italy) interfaced to an isotope ratio mass spectrometer (Isoprime, Manchester, U.K.). Each sample underwent combustion at 1030 ºC by means of a He carrier gas at a flow rate of ~90mL/min with a purge rate of ~50mL/min. A soil reference standard (Eurovector, Milan, Italy) was used to maintain a high level of accuracy and precision. Soil carbon data was analyzed using analysis of variance procedures in SAS (PROC GLM; SAS Institute 1999).

Results

Observed effects on soil carbon were depth dependent with the greatest effects evident only in the upper two soil layers, 0 to 5 cm and 5 to 20 cm beneath the surface (table 1). More subtle differences in soil carbon were observed in the first-order interactions from the 20 - 40 cm depth interval but will not be presented nor discussed here. Therefore, presentation and discussion of results are limited to the upper two soil layers. While percent canopy cover influenced soil carbon percentage in the upper two soil layers there was no clear response with the 28 and 45 percent woody canopy cover, which have the greatest soil carbon percentages at both upper sampling intervals. In contrast, samples collected from plots in the lowest tree canopy percentage, 24 percent did not differ from those collected in the highest tree canopy percentage, 49% (fig. 1). Soil carbon percentage in the 0 to 5 cm layer was greatest under the canopy of larger trees but did not differ between medium and small trees (fig. 2). Elevated soil carbon percentage was observed under tree canopies relative to beneath grass canopies, which in turn was greater than that observed in the upper sampling layer beneath bare areas (fig. 3). This trend, while not as pronounced, persisted into the lower sampling layers. Influence of tree canopy on soil carbon levels in the uppermost sampling layer was influenced by tree size where soil carbon percentages increased as tree size became larger and, presumably, older (fig. 4).

Table 1—Observed significance levels for the influence of tree cover (Cover (C)), tree species (Species (S)), tree size (Size (Z)) and sampling location (Location (L)) on soil carbon percent in a soil profile for a piñon/juniper-short grass prairie community. [*** p≤0.0001; ** 0.0001≤p≤0.001; * 0.001≤p≤0.01; and, X 0.01≤p≤0.05].

	Soil Depth Interval (depth from surface (cm))					
Variable	**0 – 5**	**5 – 20**	**20 – 40**	**40 – 60**	**60 – 80**	**80 – 100**
Cover (C)	***	***	ns	ns	ns	ns
Species (S)	ns	X	ns	ns	ns	ns
Size (Z)	*	ns	ns	ns	ns	ns
Location (L)	***	**	ns	ns	ns	ns
Z * L	***	ns	ns	ns	ns	ns
S * L	ns	ns	ns	ns	ns	ns
C * L	ns	ns	ns	ns	ns	ns
S * Z	ns	ns	X	ns	ns	ns
C * Z	X	ns	X	ns	ns	ns
C * S	ns	ns	X	ns	ns	ns
S * Z * L	ns	ns	ns	ns	ns	ns
C * Z * L	ns	ns	ns	ns	ns	ns
C * S * L	ns	ns	ns	ns	ns	ns
C * S * Z	ns	ns	X	ns	ns	ns
C * S * Z * L	ns	ns	ns	ns	ns	ns

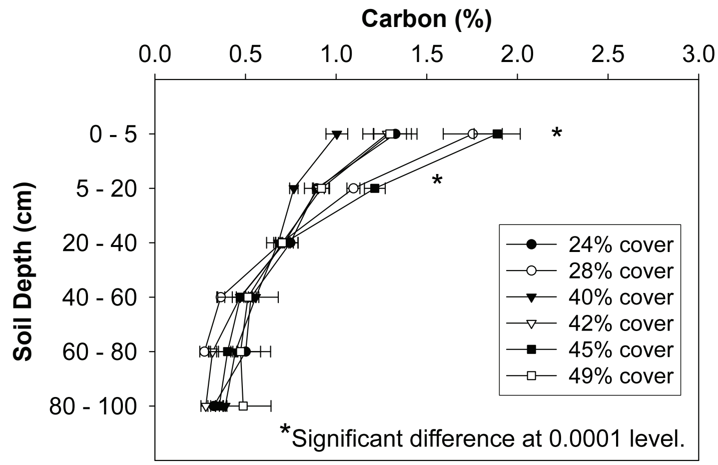

Figure 1—Soil carbon percent through a 1-meter soil profile as influenced by percent tree cover in a piñon/juniper – short grass prairie community in north central New Mexico. Bars reflect ± 1 standard error of the mean.

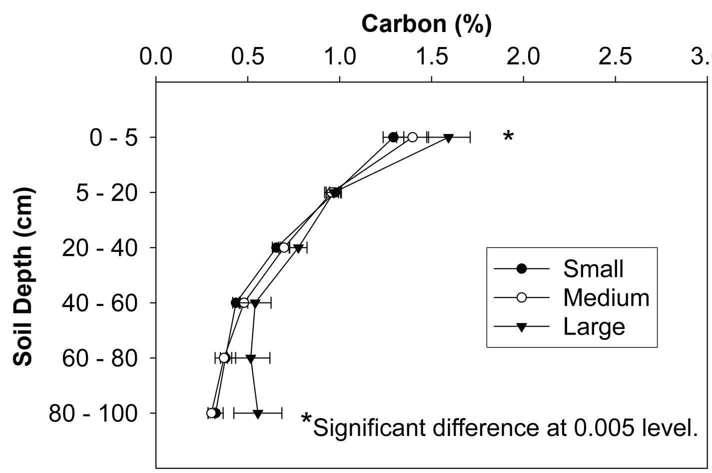

Figure 2—Soil carbon percent through a 1- meter soil profile as influenced by tree size in a piñon/juniper – short grass prairie community in north central New Mexico. Bars reflect ± 1 standard error of the mean.

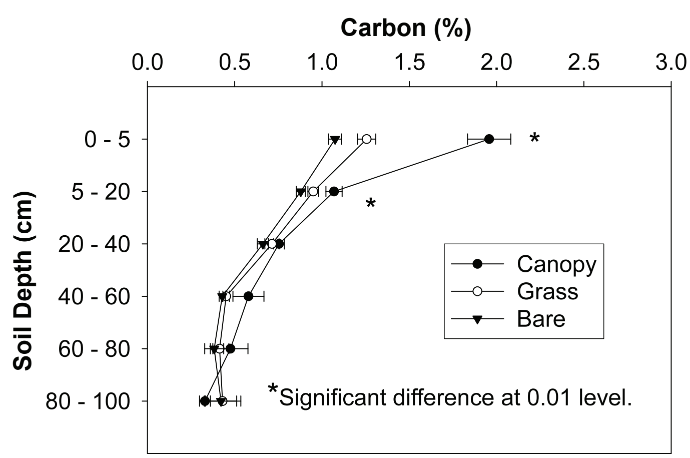

Figure 3—Soil carbon percent through a 1-meter soil profile as influenced by sampling location (tree canopy, grass or bare soil) in a piñon/juniper – short grass prairie community in north central New Mexico. Bars reflect ± 1 standard error of the mean.

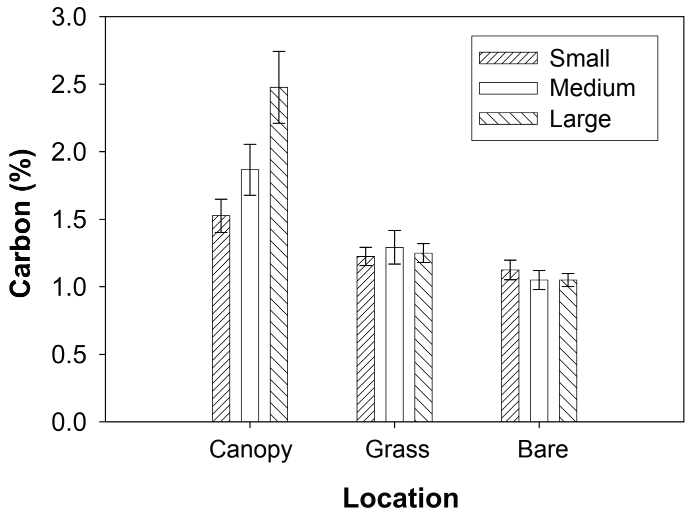

Figure 4—Soil carbon percent through a 1-meter soil profile as influenced by the interaction of tree size and sampling location in a piñon/juniper – short grass prairie community in north central New Mexico. Bars reflect ± 1 standard error of the mean.

Discussion

Increased soil carbon levels under trees relative to soil carbon levels under herbaceous plants and bare soil was also found in a companion study conducted on Mesita del Buey near Los Alamos, New Mexico (Reiley 2003). The trend of elevated soil carbon under tree canopies in piñon-juniper ecosystems has been reported elsewhere (Conant and others 1998; Krammer and Green 2000). Conclusions drawn by Guo and Gifford (2002) indicate that increases in soil carbon accumulation associated with woody vegetation encroachment is influenced by precipitation. Specifically, soil carbon increases are more evident in semi-arid and arid environments. This is in contrast to total system (above and below ground) carbon accumulation in either boreal or tropical forested systems where the majority of accumulation is in above ground or soil surface components. Potentially, enhanced below-ground carbon pools in semi-arid woodlands will be retained longer than in the two former forested types where decomposition rates are slower.

Implications

How do these findings influence woodland management in southwestern piñon/juniper woodlands and interface sites? First, effects of vegetation (tree, grass, bare) on soil carbon are evident only in the upper soil strata, 0 to 20 cm below the surface. Hence, management activities which influence soil stability will have an effect on soil carbon pools. These activities include, but are not limited to, tree thinning/harvesting, grazing, and management activities that alter fire behavior. Secondly, if a management goal is carbon accumulation in the system, including soil carbon strategies should encourage development or protection of larger and, presumably, older trees.

Acknowledgments

This research was funded, in part, through grants from McIntire-Stennis, the New Mexico Agricultural Experiment Station, University California NUCOR Program and the Environmental Protection Agency.

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