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Physical and chemical properties of soils under some piñon-juniper-oak canopies in a semi-arid ecosystem in New Mexico

M.K. Shukla[a,*], R. Lal[b], M. Ebinger[c], C. Meyer[c]

[a]*Department of Plant and Environmental Sciences, New Mexico State University, MSC 3Q, P.O. Box 30003, Las Cruces, NM, USA*

[b]*Carbon Management and Sequestration Centre, The Ohio State University, Columbus, OH, USA*

[c]*Earth and Environmental Sciences Division, Los Alamos National Laboratory, Los Alamos, USA*

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Abstract

Piñon (*Pinus edulis*)-juniper (*Juniperus monosperma*)-ecosystems increased substantially in the western USA during the 20th century. Sustainability of these ecosystems primarily depends on soil quality and water availability. This study was undertaken with the objective of assessing the effect of tree species on soil physical quality in a semi-arid region in the western part of Sugarite Canyon, northeast of Raton, Colfax County, NM (37°56′32″N and 104°23′00″W) USA. Three cores and three bulk soil samples were obtained from the site under the canopy of three juniper, Gambel oak (*Quercus gambelii*) and piñon trees for 0–10 and 10–20 cm depths. These samples were analyzed for particle size distribution, soil bulk density (ρ_b), water stable aggregation (WSA), mean weight diameter (MWD) of aggregates, pH, electrical conductivity (EC) and soil organic carbon (SOC) and total nitrogen (TN) concentrations and stocks. Sand content was greater under juniper (48%) than oak (32%), whereas clay content followed the opposite trend. The ρ_b, WSA, MWD, pH and EC were similar under juniper, piñon, oak canopies for both depths. Estimated (from Philip and Green and Ampt infiltration models) and measured water infiltration parameters did not vary among these sites and were in accord with the values for ρ_b, WSA and MWD. The SOC concentrations and stocks were greater under oak (43.1 Mg ha^{-1} for 0–10 and 37.5 Mg ha^{-1} for 10–20 cm depths) than piñon (23.3 Mg ha^{-1} for 0–10 and 18.5 Mg ha^{-1} for 10–20 cm depths). The TN concentrations were greater under oak (3.4 g kg^{-1}) than piñon (1.7 g kg^{-1}) for the 0–10 cm depth only. Accumulation of detritus material under tree canopies reduced soil compaction and crusting caused by raindrop impact and increased SOC, and TN concentrations, and water infiltration. Coefficients of variation ranged from

*Corresponding author. Tel.: +1 (505) 646 2324; fax: +1 (505) 646 6041.
E-mail address: shuklamk@nmsu.edu (M.K. Shukla).

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low to moderate for most soil properties except infiltration rate at 2.5 h, which was highly variable. Overall, soil quality for each site was good and soil aggregation, water infiltration and SOC concentrations were high, and soil ρ_b was low.

Keywords: Detritus material; Soil bulk density; Soil organic carbon; Soil structure; Total nitrogen; Water infiltration; Water stable aggregates

1. Introduction

Piñon (*Pinus edulis*)-Juniper (*Juniperus monosperma*) woodlands occupy 20–30 million ha in western USA (Miller and Wigand, 1994). Semi-arid piñon-juniper-oak (*Quercus*) woodlands usually consist of mosaic tree canopies which are separated by open intercanopy areas (Martens et al., 2000). These trees extract nutrients and water from intercanopy soils leading to a drastic reduction in intercanopy vegetation (Pieper, 1990; Davenport et al., 1996; Breshears et al., 1997a, b; Allen and Breshears, 1998). Consequently, severe erosion occurs from the intercanopy areas of piñon-juniper-oak watersheds (Carrara and Carroll, 1979; Wilcox et al., 1996). Thus, there are concerns regarding the influence of these trees and shrubs on physical and chemical properties of soil of these important semi-arid ecosystems (Davenport et al., 1996).

Soil chemical properties have been extensively studied in a piñon-juniper woodlands (Klopatek, 1986; Padien and Lajtha, 1992; Davenport et al., 1996). Padien and Lajtha (1992) reported greater nitrogen (N) availability under canopy than intercanopy areas. Davenport et al. (1996) reported decreased pH and greater soil organic carbon (SOC) under canopy than intercanopy soils. The effects of piñon-juniper woodlands have been investigated on morphology and physical properties of soils under the canopy. Increased sand and decreased clay concentration in the A horizon of soils under tree canopy was reported, and attributed mainly to the accumulation of aeolian material under canopy (Barth, 1980). Decreased soil bulk density (ρ_b) and increased available water capacity (AWC) under the canopy were reported by Klopatek (1986). High cumulative water infiltration was reported under piñon-juniper rangelands in the US (Roundy et al., 1978) and under shrub in sagebrush rangelands (Seyfried, 1991; Pierson et al., 1994). Infiltration rates were also correlated to the vegetation cover (Seyfried, 1991).

The susceptibility of piñon-juniper-woodlands to soil erosion is an important issue in this ecosystem (Wood et al., 1987; Belsky, 1996). Gifford and Tew (1969) reported increased soil permeability in southwestern Utah in piñon-juniper woodlands. Williams et al. (1969) and Gifford et al. (1970) reported no consistent trends in infiltration during short term (< 38 min) simulated rainfall tests on sites where piñon-juniper woodland was cleared and seeded to grass in southern Utah. Addition of leaf litter and detritus can add N and C to the soil under the canopy, and can improve soil structure, soil aggregation, porosity, AWC, and infiltration rate and decreases soil ρ_b. Soil quality parameters, including infiltration rate, aggregation, extent of plant cover, and depth and amount of litter deposition on soil surface, are important in effective management of these lands. However, a few 'if any' studies have assessed soil physical quality under piñon-juniper ecosystem for the Sugarite Canyon experimental site. Our hypothesis for this study was that the accumulation of detritus material over the soil surface reduces erosion, increases