Urban Forestry at Virginia Tech

Characterization of Soil Carbon Pools Two Years after Urban Soil Rehabilitation

VirginiaTech Invent the Future

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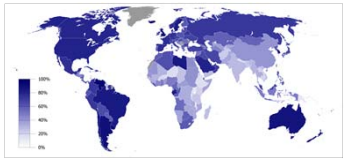
Forest Resources & Environmental Conservation

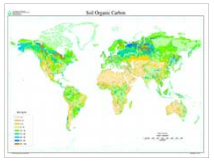
Abstract

Urban forests create significant effects on landscape and regional scale carbon (C) storage, even global climate change. But land-use conversions have resulted in poor soil conditions for plant growth. Urban soil rehabilitation is often needed and understanding the dynamics of urban soil C will help define long-term effects of soil rehabilitation. An ongoing long-term soil rehabilitation experiment will be used to study the interaction of soil C and root growth. This experiment has four soil treatments (Undisturbed, Minimum Effort, Enhanced and Profile Rebuilding) and five tree species (*Ulmus japonica* ×*wilsoniana* 'Morton', *Acer rubrum*, *Quercus bicolor*, *Prunus* spp. 'First Lady', and *Quercus macrocarpa*). Rehabilitated plots were pre-treated to replicate soil disturbance typical of urbanization. The aims of the new phase of this study are: (1) to compare the influence of rehabilitation treatments on urban soil C dynamics, including distribution in different C pools; (2) to evaluate rehabilitation treatments on long-term plant growth, in terms of photosynthesis, root growth, etc; and (3) to analyze effect of urban soil improvement practices on the relationship between soil C pool, efflux, availability and storage. Soil samples were collected from plots two years after installation. Recalcitrance of soil C was determined using a density fractionation procedure. The most intensive restoration treatment, profile rebuilding, increased recalcitrant C storage significantly as indicated by an increase of soil C in the slow pool (intra-aggregate particulate organic matter) at the 5-15cm depth.

Background



Percentage of Urban Population (UNICEF Report, 2006)



Soil Organic Carbon Map (USDA-NRCS,1997)

World soils play an important role in the global C cycle (Lal et al.,1997). But during the past two centuries, land-use practices such as deforestation and tillage have resulted in a net loss of soil C to the atmosphere. Urbanization and population growth have profoundly transformed many natural landscapes throughout the world. Cities are places of dense population and serious environmental problems. Compaction of urban soil and lack of organic matter can contribute to these problems. Thus, urban soil rehabilitation is needed, but the effects of rehabilitation practices on urban soils are unknown, specifically soil C dynamics.

Urbanization Process

Rural Area and Natural Soil

Clearing, Grading, Compacting, and Building

Urban Soil

Urban Area

Methods & Materials

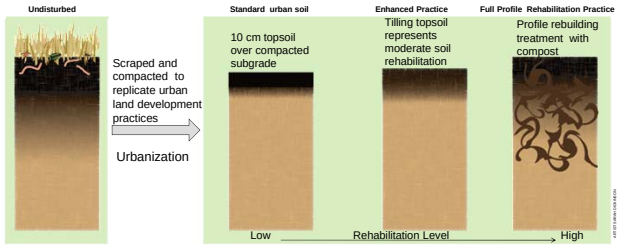
Experimental Pretreatment

Scraping and Grading

Experiment Site: Kentland Farm

In the urbanization process, land use transformation results in compacted and poor urban soil which is unfavorable for plant growth. In addition, C dynamics are unknown for these soils. In pretreatment of this experiment, we duplicated current land use development: clearing, grading and compacting, and different rehabilitation treatments were designed.

Experimental Design



Natural Soil

Disturbed Soil and Rehabilitation Treatments

This long term urban soil rehabilitation project is located at Kentland Farm, Blacksburg, VA. In this experiment site, we have four treatments (Undisturbed, Minimum Effort, Enhanced and Profile Rebuilding) and five tree species (*Ulmus japonica* x *wilsoniana* 'Morton', *Acer rubrum*, *Quercus bicolor*, *Prunus* spp. 'First Lady', and *Quercus macrocarpa*), and each treatment has 6 replicates.

Profile Rebuilding Treatment

Objectives & Steps

Objectives:

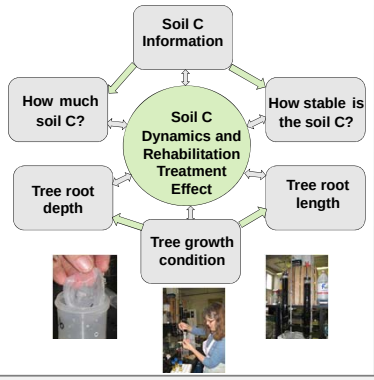
- To measure soil C pool size and stability;
- To compare its long-term dynamics;
- To determine the role of urban trees, especially tree roots.

Steps:

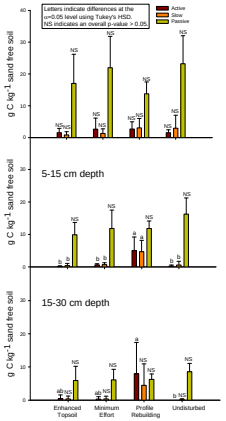
- **First Phase:** Gather baseline soil C information;
- **Second Phase:** Analyze soil C in different soil pools (active, slow and passive) **(Wick et al., 2008)**;
- **Third Phase:** Observe tree root growth and measure root length and depth;
- **Fourth Phase:** Analyze the relationship between tree roots and soil C;
- **Fifth Phase:** Compare rehabilitation treatment effects on soil C dynamics and plant growth.

(It's the second phase of this experiment now, so we are just presenting soil C pool results here.)

Expected Outcome



Results & Discussion



The Soil C Concentrations in 0-30cm Depths of Three Rehabilitation Treatments and Undisturbed Soil after Two Years

Active C indicated by Light Fraction (LF) has a short turnover time (1-5 yr); Slow C indicated by Intra-Aggregate Particulate Organic Matter (iPOM) has an intermediate turnover time (20-40 yr); Passive C indicated by organic matter directly bound to silt and clay has the longest turnover time (200-1500 yr) (**Parton et al.,1987**).

Active C

Carbon in the active pool is most reflective of soil management techniques, mainly because it is most susceptible to decomposition. The profile rebuilding treatment contained significantly higher C concentrations and pool sizes in both the 5-15 and 15-30 cm depths (3.56 and 11.2 Mg ha^{-1}, respectively) relative to other treatments (ranging from 0.00 - 0.628 Mg ha^{-1}).

Slow C

Carbon in the slow pool is generally physically protected by soil aggregates. Again, the profile rebuilding treatment resulted in significantly higher C concentrations and pool sizes in the 5-15 and 15-30 cm depths (3.37 and 6.36 Mg ha^{-1}, respectively) relative to other treatments (ranging from 0.161-0.678 Mg ha^{-1}).

Passive C

Carbon in the passive pool is chemically attached to fine soil fractions and is the most stable of the pools. All three rehabilitation treatments appear to have resulted in a slightly smaller passive C pool compared to undisturbed soil.

Take Home Message

Tree and soil biological and physical responses to management techniques were reflected in soil C concentrations and pools after only two years. Incorporation of organic matter (as indicated by C) into more stable soil pools, i.e. within soil aggregates, was accomplished by rebuilding the soil profile with compost and incorporating it at depth. This has important implications for C storage and successful re-development of soil physical properties following urban disturbances.

References

1. Layman, R.M., J.R. Harris, S.D. Day, W.L. Daniels, and P.E. Wiseman. 2009. Rehabilitation of severely compacted urban soil to optimize tree establishment and growth. 2nd International Conference on Landscape and Urban Horticulture, International Society for Horticultural Science. Bologna, Italy (In press).
2. Lal, R., J. M. Kimble, R. F. Follett, and B. A. Stewart.1997. Soil processes and the carbon cycle. Boca Raton, FL:CRC Press.
3. Parton, W. J., D. S. Schimel, C. V. Cole, and D. S. Ojima. 1987. Analysis of Factors Controlling Soil Organic Matter Levels in Great Plains Grasslands. Soil Sci Soc Am J 51(5):1173-1179.
4. Wick, A. F., J. I. Lachlan, and D. S. Peter. 2009. Aggregate and organic matter dynamics in reclaimed soils as indicated by stable carbon isotopes. Soil Biology & Biochemistry 41:201-209.

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