Effects of *Rhamnus cathartica* (common buckthorn) invasion and restoration on woodland carbon sequestration

Chad Zirbel[1], Dan Larkin[2], Jim Steffen[2]

[1]University of Wisconsin-Madison [2]Chicago Botanic Garden

Abstract

We measured the effects of *Rhamnus cathartica* (common buckthorn) invasion and restoration of previously invaded areas on woodland carbon dynamics. Carbon storage is an important ecosystem service performed by natural habitats that can reduce concentrations of climate-changing greenhouse gases. Ecological restoration can increase the biodiversity of degraded habitats, but can it also increase the ability of ecosystems to store carbon? We measured carbon storage in the soil, carbon loss through CO_2 flux and soil erosion, and plant-community composition and litter biomass as indicators of habitat structure. Our data suggest that buckthorn invasion may decrease and restoration increase carbon storage in woodlands.

Introduction

It is widely accepted that restoration of invaded sites can increase plant diversity and enhance ecosystem functioning (De Deyn 2008). We tested whether restoration also increases performance of carbon-storage ecosystem services.

Rhamnus cathartica (common buckthorn) is a Eurasian species brought to the U.S. as an ornamental shrub (Heneghan 2004). It has become widely invasive throughout the upper Midwest including in the Chicago Botanic Garden's Mary Mix McDonald Woods (Glencoe, IL). Much of McDonald Woods has been restored over the past 14 years. Study locations for this research included areas restored in 1996, 2003, and 2010. The 1996 and 2003 areas also included plots that were or were not burned in spring 2010. We also used two sampling locations that have not been restored and are dominated by buckthorn.

In order to assess carbon dynamics, we performed vegetation surveys and sampled litter biomass to characterize each site. We measured CO_2 flux and soil erosion as forms of carbon loss and measured carbon stored in recalcitrant organic-soil fractions.

Hypotheses

- Restored areas will tend to have more herbaceous-plant and litter cover, thereby decreasing rates of soil erosion.
- Higher plant cover associated with restoration will increase root inputs of organic carbon to the soil, increasing carbon storage.
- Restored areas will tend to have lower and more stable CO_2 flux from the soil.
- Restored areas subjected to controlled burning will have greater carbon storage due to stimulation of herbaceous vegetation belowground growth.

Methods

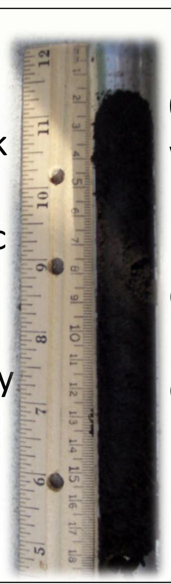
All of the following data were analyzed by ANOVA in R Version 2.11.1

CO_2 Flux: Respirometers with NaOH base traps were used to measure how much CO_2 was being released from the soil in each plot. Sampling was done over a period of five weeks.

(Zilbilske 1994)

Soil Organic Matter: 20-cm soil cores were taken from each plot. Bulk density and % moisture were determined. Organic carbon stored in litter, coarse, fine, and silt/clay fractions was measured by loss-on-ignition.

(Scharenbroch 2008)

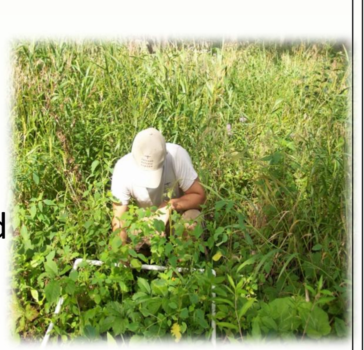


Litter: 0.25-m^2 quadrats were placed at random in each plot. Litter was collected, dried, separated into leaf and fine woody debris, and massed.

Soil Erosion: Mesh bag method used to capture soil loss from 6/21 to 7/19. No soil stayed in traps, possibly due to stiffness of material.

(Hsieh 1992)

Vegetation Survey: Five 0.5-m^2 quadrats were placed inside of each plot and four outside. Each plant species was identified and percent cover determined using the floristic quality index.



(Masters 1997)

crzirbel@wisc.edu

Results

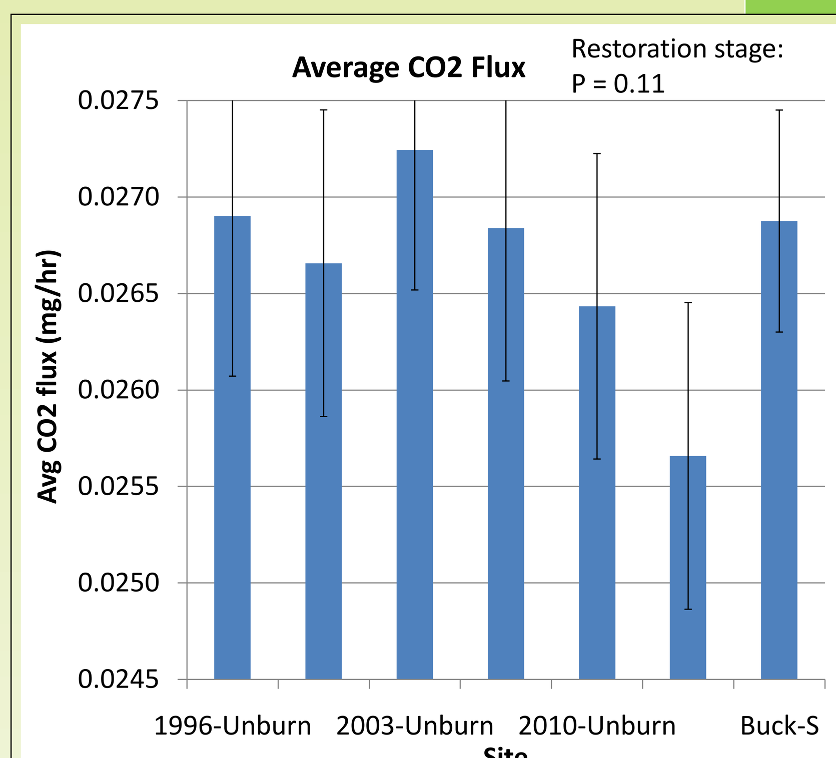


Figure 1. Average CO_2 flux from soil over five weeks by restoration treatment. Error bars are ± 1 S.E.

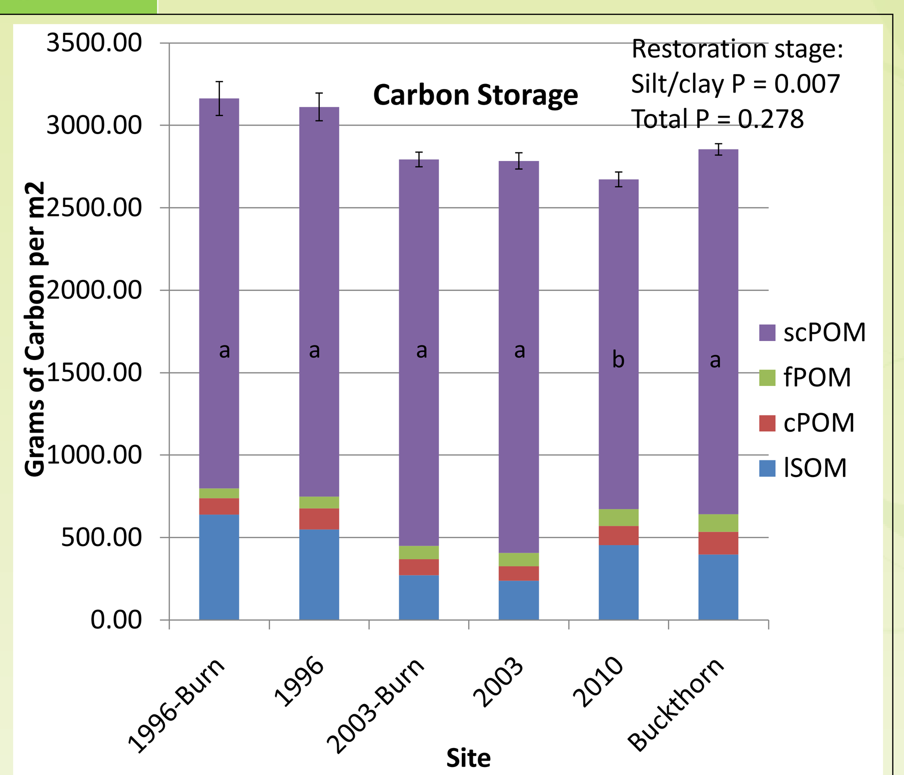


Figure 2. Average soil organic carbon storage by restoration treatment. Error bars are ± 1 S.E.

R. cathartica

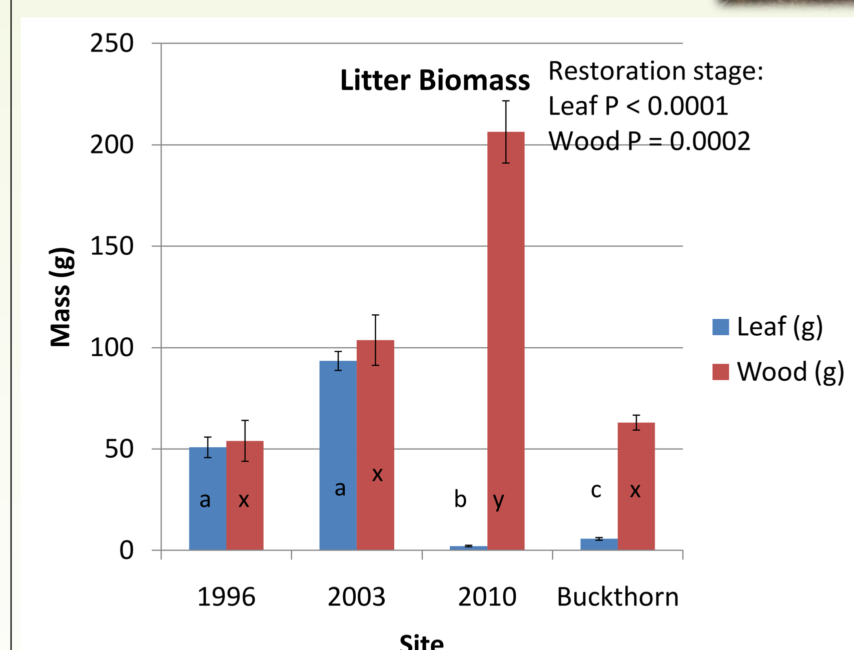


Figure 3. Average leaf litter and fine woody debris biomass by restoration treatment. Error bars are ± 1 S.E.

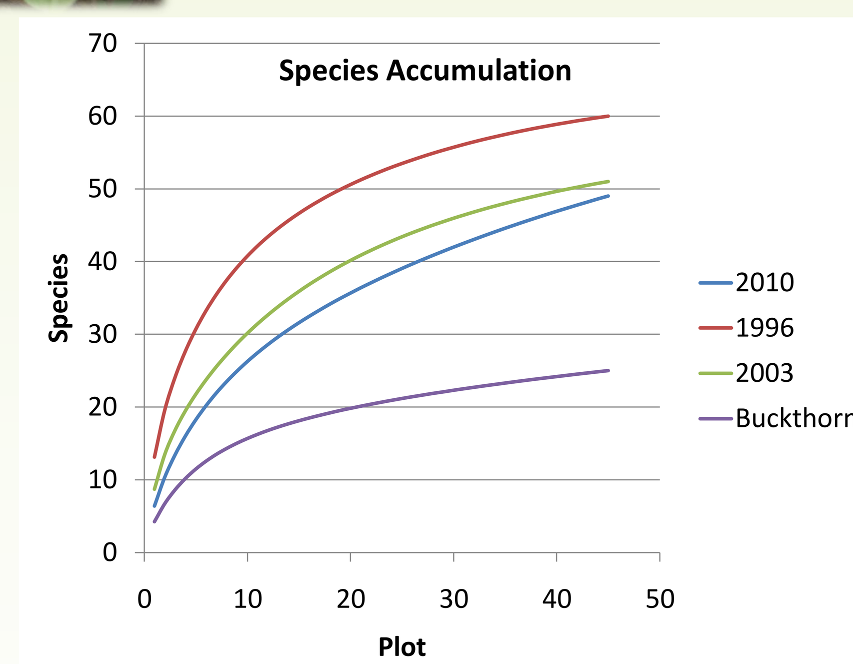


Figure 4. Plant species accumulation curves by restoration treatments.

Discussion

Vegetation Survey:

- There was greater diversity and cover in the restored plots.
- High plant species diversity for the 2010 plot was the result of seed being scattered after buckthorn clearing.
- Increased diversity and cover of native plants with restoration age suggests increased structural complexity both above and below ground.
- This increased complexity is likely to promote greater carbon storage over time.

Litter:

- Leaf litter biomass was significantly higher in the oldest restoration plots and was greater in restored plots than in buckthorn plots.
- The high fine woody debris biomass in the 2010 restoration was a result of the area having been recently cleared of buckthorn leaving behind debris.
- The greater leaf litter cover in restored areas shows that there is a stable (slowly decomposing) source of soil carbon in these areas and the litter could also slow erosion rates.

CO_2 Flux:

- There was an interactive effect between restoration treatment and sample date.
- The only variable that was significant on its own was sample date.
  These results show that carbon dioxide flux was quite variable over time.
  Flux measurements between buckthorn plots were quite variable while those from restored areas were more consistent.
- CO_2 Flux was lower in the buckthorn invaded plots.
  This unanticipated result may be a temporal effect. Buckthorn typically drops all of its foliage in late November, which rapidly decomposes (within 2-3 weeks). This could cause a fall spike in CO_2 flux not captured by this study.

Soil Carbon Storage:

- Total carbon storage appeared higher in the oldest restored area (1996) but this trend was not significant.
- Recalcitrant organic carbon (silt/clay fraction), was much higher (+100 g/m^2) in the oldest restored plots (1996 and 2003).
- In the short term, burning had no effect on carbon storage in soils.

Conclusion:

Restoration appeared to promote carbon storage in woodlands through increased litter biomass and herbaceous plant cover, and increased storage of carbon in recalcitrant soil fractions. There was also more stable release of CO_2 from soil in restored areas than in buckthorn-dominated areas. More sampling needs to be done to determine seasonal patterns of CO_2 release.

Acknowledgements and References

Thank you to the National Science Foundation for support (NSF-REU grant 0648972) and Kasey Altantulkhuur (College First student) and Emma Bialecki, Elina Dilmukhametova, Grace Kapov, Brittney Sponholz, and Becky Tonietto (Chicago Botanic Garden) for research assistance.

Coleman, B. D. 1981. On random placement and species area relations. *Mathematical Biosciences* 54:191-215.

De Deyn, G. B., Cornelissen, J. H., & Bardgett, R. D. 2008. Plant functional traits and soil carbon sequestration in contrasting biomes. *Ecology Letters* 11:516-531.

Heneghan, L., Rauschenberg, C., Fatemi, F., & Workman, M. 2004. European Buckthorn (*Rhamnus cathartica*) and its Effects on Some Ecosystem Properties in an Urban Woodland. *Ecological Restoration* 22:275-280.

Hsieh, Y.-P. 1992. A mesh-bag method for field assessment of soil erosion. *Soil and Water Conservation* 47:495-499.

Masters, L. A. 1997. Monitoring Vegetation. *The Tallgrass Restoration Handbook*. Society for Ecological Restoration, 279-301.

Scharenbroch, B. 2008. Particle Size Fractionation. Lisle, IL: Morton Arboretum Soil Science Laboratory.

Zilbiliske, L. 1994. Carbon mineralization. In Weaver, R. W., et al., *Methods of Soil Analysis. Part 2. Microbiological and Biochemical Properties.*