Carbon addition and its effects on soil nitrogen and prairie development

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Abstract

Restoring prairies is essential to the preservation of grasslands that were once common to Illinois. A practice often associated with restoration is cultivation of the topsoil. This disturbance causes an increase in soil nitrogen (N) levels, which provides weedy species a competitive advantage over native species for space and resources. At the Chicago Botanic Garden's (CBG) Dixon Prairie we are studying the effects of incorporated materials with high C: N on soil where N levels are high. We hypothesize that carbon (C) addition will stimulate soil microbe activity thereby immobilizing soil N, causing a temporary decrease in soil N levels. In addition, we predict floristic quality and native plant biomass should increase with decreasing soil N. To test our hypothesis, the prairie was divided into sixteen plots each containing a control or one of three amendments in the form of wood chips, wood shavings, or a combination of chips and shavings. From these 16 plots data for NO_3 and NH_4, biomass, and floristic quality was collected. Our results showed that in 2003 and 2004, C addition reduced available N, except for plots with shavings. Floristic quality increased, especially in the chips and shavings/chips treatments. We also found that in 2003 and 2004, C addition increased native plant biomass in all plots and decreased all non-native plant biomass except for the control. Our data indicates that soil carbon addition may be useful in controlling weedy species in the early stages of prairie restoration

Background

Prairies once covered 20 million acres of land and now only 2,300 acres exist today (Neely and Heiste 1987). Efforts are underway to restore examples of this rare ecosystem in the CBG's Dixon Prairie. In one area of the Dixon Prairie topsoil was added to more closely compare topsoil profiles of natural prairies. The disturbance caused by adding topsoil compiled with the increase in organic matter, elevated soil N levels. Elevated N levels are problematic because weedy species have a competitive advantage over native species for space and resources when this nutrient is abundant, thereby arresting the development of prairies. The technique of incorporating materials with high C: N into the soil temporarily reduces soil N and has been used successfully in other prairie restoration work (Alpert and Maron 200, Morgan 1994, Paschke et al. 2000). The addition of C stimulates the growth of soil microbes which effectively immobilize soil N. The temporary immobilization of N creates a soil environment more suitable for the establishment of prairie.

Challenge

We predict that the incorporation of high C: N material into the Dixon Prairie soil will decrease the soil N levels. Several different high C materials were evaluated for their effect. With the decreased soil N levels we expect that it will cause native plant biomass to increase, non-native biomass to decrease, and the floristic quality to increase.

Methods/Materials

Plots were amended with 15cm of various C material to alter the ratio of soil C: N and then seeded in September 2001. The C materials selected were 1. wood shavings, 2. wood chips, and 3. combination of wood chip/wood shavings. Non-amended soils were used as controls. Next, we sampled and analyzed the soil, floristic quality, and biomass in order to find the effect of these various carbon amendments on plots in the Dixon Prairie (Chicago Botanic Garden). One of the 3 treatments, plus a control, were assigned randomly to a linear series of four, 4m x 4m plots. Each series was replicated four times for a total of 16 plots.

• Soil Sampling: Soil samples were collected at two randomly chosen points in the center meter of each of the sixteen plots using a bulb planter. All samples were dried (50 degrees centigrade, 30 hours) and sieved to 10mm.

•Soil Analysis: One sample from each plot was extracted with 2 M KCl, after which aliquots were analyzed for available nitrate and ammonium using colorimetric methods. [This method applies to 2004 data only. Different methods were used to analyze July soil samples from 2002-2003].

•Floristic Quality: Floristic quality was evaluated in two randomly chosen 1/4 meter square plots randomly chosen along the perimeter of the central plot. Within each 1/4 meter square plot, the percentage of each species was estimated. These data were analyzed using the Floristic Quality Assessment (Chicago Database) software to provide a floristic quality index

•(FQI). (Wilhelm and Masters 12-15).

$$FQI = \bar{c}\sqrt{n}$$

$\bar{c} =$ the mean C*

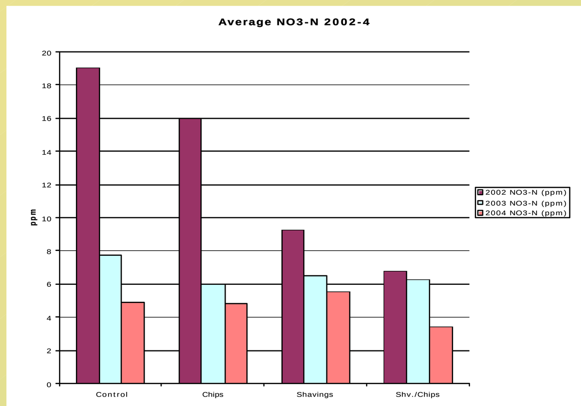
n= the number of native species

*Plants are assigned a coefficient of conservatism or C value between the 0-10. The higher the value, the more conservative the species. Zeros are designated to exotic species that were never members of our native plant communities.

•Biomass: The same method used to collect data for floristics was also used for biomass. The exception is that with productivity measurements, everything inside the square meter was cut at ground level, sorted to species, and placed into paper bags to dry. Once the plants were dry, each was weighed and the weight was recorded.

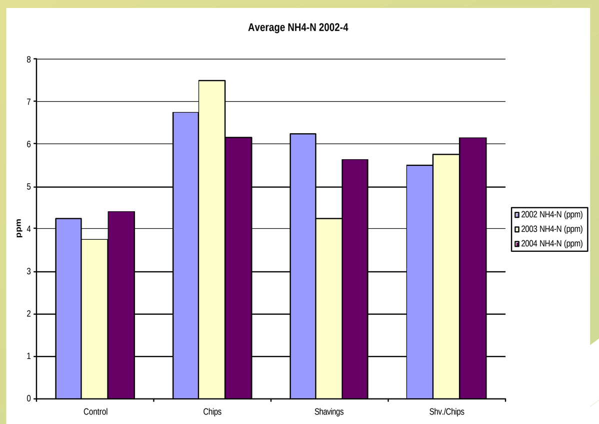
Results

Average NO3 2002-4



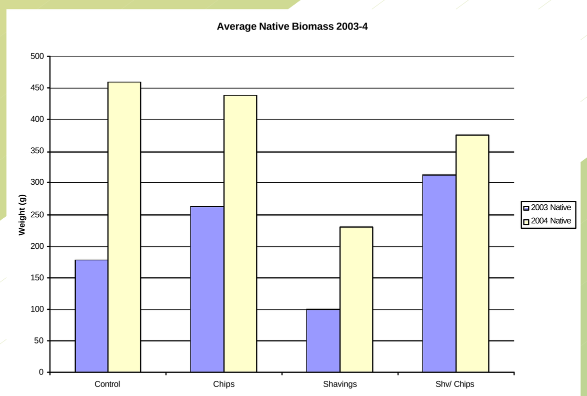
Over time, the soil NO3 concentration decreased by at least half. The two treatments that exhibited the greatest effect were shavings alone (nitrate decreased 50%) and shavings/ chips (nitrate decreased 60 %).

Average NH4 2002-4



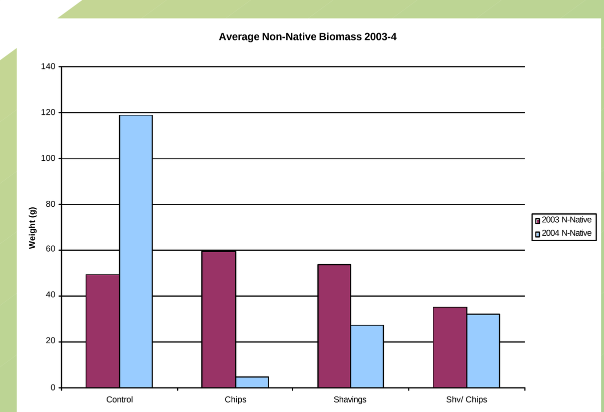
Soil NH4 levels were extremely variable throughout the years and among plots. Overall, the total nitrogen decreased in every amended plot.

Average Native Biomass 2003-4



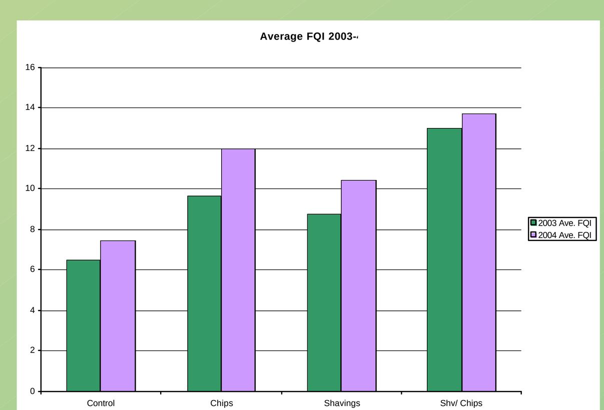
Native plant biomass increased in plots amended with shavings alone or chips alone.

Average Non-Native Biomass 2003-4



The non-native plant biomass decreased in plots amended with shavings alone or chips alone.

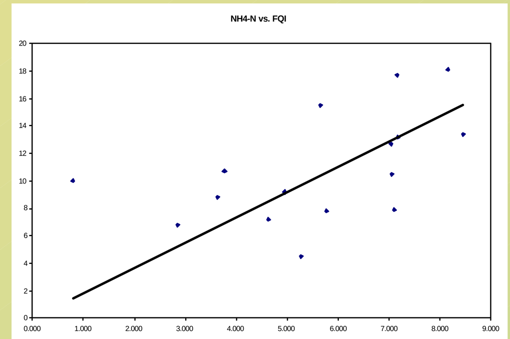
Average FQI 2003-4



Average FQI 2002-4

Overall, the floristic quality increased over time. Plots showing the greatest increase were those that received chips, (FQI increased 40%) or a combination of shavings and chips (FQI increased 50%).

NH4 vs. Floristics



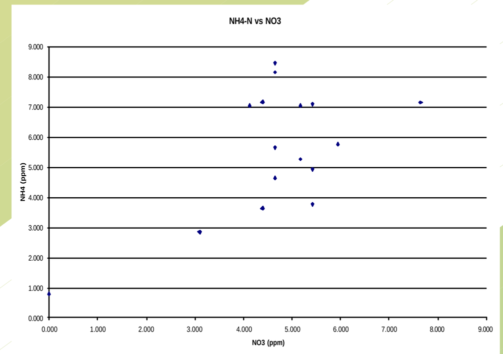
Soil ammonia and floristic diversity were found to be significantly correlated (r=0.517; p<0.10).

Correlation

	NO3-N	NH4-N	Native Bio.	N-Native Bi	FQI
NO3-N		***0.62**	-0.154	0.206	0.224
NH4-N			0.107	-0.120	***0.517**
Native Bio.				-0.061	-0.085
N-Native Bio.					-0.348
FQI					

* Denotes a significant correlation.

NH4 vs. NO3 2004

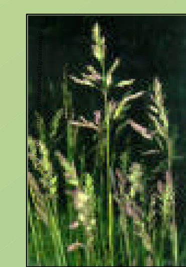


A significant correlation (p<0.10) was found between soil nitrate and ammonia levels (r=0.620).

Best overall performing species

Control

Solidago rigida



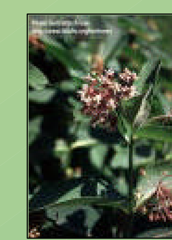
Poa pratensis

Ratibida pinnata

Chips

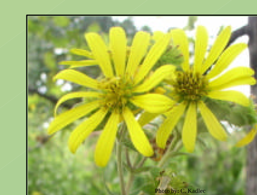
Solidago rigida

Silphium laciniatum

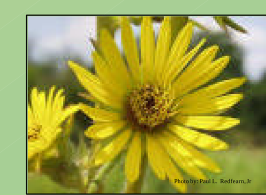


Asclepias syriaca

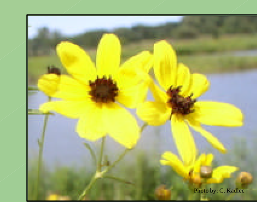
Shavings



Silphium integrifolium



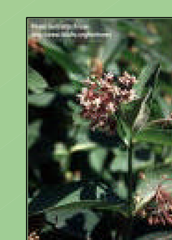
Silphium laciniatum



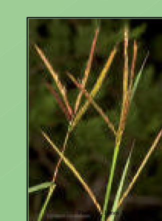
Coreopsis tripteris

Shv./ chips

Silphium integrifolium



Asclepias syriaca



Andropogon gerardii

Conclusion

The three years proceeding carbon addition to the Dixon prairie, a decrease in overall soil nitrogen levels were found, except for shavings. Nitrate levels showed a significant drop after the first year and then a slight decrease the following two years. In contrast to NO_3 results, NH_4 was variable throughout all plots for all three years tested. Dana Blumenthal (2001) conducted a similar study at University of Minnesota and found that her NH4 results were unaffected by C addition as well. As a result of decreased nitrogen, native biomass increased in all plots and non-native biomass decreased in all plots except for the control plot. The increase of non-native biomass in the control plot could have resulted from greater seed contact with the soil. Seed to soil contact for the amended plots was impaired by the unusually high concentration of C material that was added to the soil (15cm). The maximum depth of the tiller used to incorporate the carbon material was 20cm resulting in a ratio of C to soil at about 3:1. Blumenthal (*pers. comm.*) reported that a maximum of 1500 g/m2 of C was required for a positive effect. The concentration of C materials applied in this experiment ranged from 20-7 times greater than what was necessary. Despite this oversight, seed survival rates in the treatment plots were high enough to show an increase in native biomass and floristic quality. With these results, C addition has helped native species regain a spot in the sunlight at the Dixon Prairie.

Acknowledgements

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