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Introduction and Methods

Quantifying the Effects of Decreased Water Levels on the Carbon Storage of Northern Great Lake Coastal Wetlands

Abstract

As the concentration of carbon dioxide increases in the atmosphere, it is critical to assess the natural reservoirs in which carbon can be stored. Soils contain the third largest pool of carbon, behind geologic and oceanic pools, and store a disproportionate amount of carbon due to anaerobic conditions. Wetland soils in the Great Lakes region in particular are a potentially significant pool of carbon that has yet to be thoroughly studied and quantified. This study attempted to measure the carbon pools of the swamp, transitional, and wet meadow vegetation zones of three protected embayment wetlands located in eastern half of Michigan's Upper Peninsula. The relationship between soil C and vegetation zone was evaluated, as well as the relationship between soil C and tree basal area. An average of 53.22 kg/m^3 of soil C was found within the three wetlands studied, suggesting that Great Lake coastal wetlands may hold a disproportionally large amount of carbon. This study found no significant difference between soil C within the three zones, nor did it find a significant relationship between soil C and tree basal area. Future studies should examine the possible mechanisms that would contribute to variability in soil C in the Great Lakes region to better define ways in which soil C may change as lake water levels decrease.

Introduction

The need for enhanced carbon storage has increased over the last few decades due to the significant increase in fossil fuel combustion and associated atmospheric CO_2, which is largely responsible for anthropogenic climate change (IPCC, 2005). The atmospheric concentration of

CO_2 has increased by 31% since 1750 and continues to increase 0.4% or 0.66 ppm per year (Lal, 2004). In 2004, it was reported that 0.54 $\pm$.6 ppm of CO_2 a year is emitted from anthropogenic combustion of fossil fuels alone (Lal, 2004). In conjunction with deforestation, biomass burning, and the conversion of natural land to agricultural uses, CO_2 emission is quickly outpacing nature's ability to sequester carbon. As a result, CO_2 accumulates in the atmosphere, aiding in the greenhouse effect and causing negative environmental impacts around the world (IPCC, 2005).

Carbon sequestration and storage in natural pools is one way in which CO_2 is mitigated and removed from the atmosphere. Therefore, examining and identifying the carbon sequestration potential of natural carbon sinks is a priority. Soil is a significant carbon pool, the third largest behind oceanic and geologic pools (Lal, 2004), and can be enhanced through management. Wetlands, including peat lands, occupy approximately 5.3-7.8 million km^2 (~5% of terrestrial surface) of the earth's surface (Zelder and Kercher, 2005), yet store a disproportionate amount of soil carbon. Wetland soils account for the largest terrestrial pool of carbon, storing approximately 500-700 Gt globally (Kusler, 2005)**,** (Whiting and Chanton, 2001). Wetlands are especially equipped to act as carbon pools due to their often semi-flooded state and steady influx of organic material (Bridgham et al., 2006). When soil is flooded, the decomposition rates of biomass are restricted due to anaerobic soil conditions, allowing more carbon to accumulate than be released through decomposition, creating a sink of carbon (Whiting and Chanton, 2001). Wetlands in North America alone, which cover 2.42 million km^2 of land, are capable of sequestering approximately 0.049 Gt of carbon each year, demonstrating the potential of wetlands to serve as carbon sinks (Bridgham et al., 2006),(Zelder and Kercher, 2005).

Great Lakes coastal wetlands in particular provide an array of ecosystem services, ranging from acting as a wildlife habitat and water purifier to regulating climate change through carbon sequestration (Sierszen et al., 2012). However, the extent to which these wetlands act a sink of carbon that has yet to be thoroughly studied and quantified (Sierszen et al., 2012). Great Lake coastal wetlands are classified based on their hydrology, formation, location, and size, which may help to explain differences in their carbon storage potential (Albert et al., 2005). This study will focus on protected embayment wetlands, which are a common Great Lakes coastal wetland type in the study region. Protected embayment wetlands have till-derived shores and are less than 3-4 kilometers wide in addition to having typically 50-100 cm of organic accumulation (Albert et al., 2005). Protected embayment wetlands are exposed to the lake, but experience reduced wave action due to protection by a till or bedrock enclosed bay or other landforms (Albert et al., 2005). Within protected embayments, clear zones are present defined by the dominant vegetation and water levels. Three generalized wetland vegetation zones include, from lake to landward, emergent marsh, wet meadow, and swamp. Emergent marshes are characterized by non-woody vegetation that is continuously flooded with water (Maynard and Wilcox, 1997). Emergent marshes receive the most wave action from the lake, driving off most of the organic material formed. Wet meadows occur upland of the emergent marsh, have shallower water, and are dominated by sedges and grasses (Maynard and Wilcox, 1997). Wet meadow communities are protected from wave action, allowing organic material and carbon to accumulate. A transitional zone between the wet meadow and swamp is characterized by a combination of both wet meadow grasses and young swamp trees. The swamp zone is defined by woody vegetation, such as trees and shrubs, occurs upland of the wet meadow and transitional communities, and contains standing water during various times of the year (Maynard and

Wilcox, 1997). Swamps lack of connection to the lake allowing for the accumulation of carbon in the soil and significant organic soil depth. This study will attempt to quantify carbon storage in protected embayment wetlands in northern Lake Huron within three vegetation zones: swamp, transitional, and wet meadow.

Water levels in the Laurentian Great Lakes are currently experiencing a low water period and further decreases in water levels are projected in the future due to climate change (USACE,2009). As water levels decrease, vegetation zones of wetlands move lakeward (Maynard and Wilcox, 1997). During low water phases, swamps zones are expected to increase and move lakeward, as woody vegetation requires lower water levels than wet meadow grasses and sedges. Likewise, wet meadows will also shift lakeward as its vegetation is suitable for lower water levels than the emergent marsh (Maynard and Wilcox, 1997). The transitional zone is also expected to move lakeward as the other two zones shift. Given projected future water level decline, analyzing shifts in vegetation and the ways in which carbon pools may change is important to understand how lowered water levels can affect protected embayment wetlands.

This study attempts to measure the amount of carbon stored in protected embayment wetlands and quantify the differences amongst three vegetation zones; swamp, transitional, and wet meadow. I hypothesize that, due to high biomass production and protection from wave energy, the swamp zones will contain more soil C than transitional zones, which will contain more soil C than wet meadow zones. I also hypothesized that soil C will be positively correlated with tree basal area, building on the first hypothesis that suggests that soil C is related to biomass production.

Experimental Design

Site Selection

Three study sites were chosen based on several criteria: 1) they were protected embayment wetlands as defined by Albert et al. (2005); 2) vegetation zonation was distinct with wet meadow, transitional, and swamp zones characteristic of the northern Great Lakes; 3) native wet meadow vegetation was dominated by *Carex stricta* and *Calamagrostis canadensis*, the most common native wet meadow graminoids. The three study sites chosen were Duck Bay (DB), Mackinac Bay (MB), and Cedarville Bay (CB), which were all located in the Les Cheneaux islands in the eastern half of Michigan's Upper Peninsula.

Data Collection

Within each wetland, two 100 meter transects were established perpendicular to the lake, from the wet meadow into the swamp zone, along a hydrologic gradient from high to low water levels. Four soil samples were taken within every zone along each transect, resulting in approximately 8 samples per zone per site. Soil samples were collected using a 5cm diameter hand-held corer to a depth of 25cm. At each point of sample collection, dominant vegetation, water level, organic depth, and coordinates were recorded. Within the transitional and swamp zones, the diameter at breast height (DBH) and tree type was recorded for every tree within a 10x10 meter area of the point of sampling. Basal area was then calculated for every site in which a core was retrieved.

Data Analysis

To quantify carbon storage, soil samples were sieved through a 2mm sieve, separated from any roots and rocks, and dried at 60°C in order to determine bulk density (g/cm^3). The samples were then homogenized using a ball grinder and tested for carbon content using a C:N analyzer . The soil carbon (g/cm^3) of each core was determined and, using the soil depth measurements collected, used to extrapolate to carbon content per cubic meter of the zone.

The relationship between soil C (g/m^3) and vegetation zone was analyzed using an Analysis of Variance (ANOVA). Linear regression was applied to determine the correlation between Soil C and basal area.

Results

Soil C in relation to vegetation zones and site

The average soil C in swamp, transitional and wet meadow zones were 86.7 kgC/m^3, 31.5 kgC/m^3, and 51.39 kgC/m^3, respectively. However, there was no significant difference between soil C in each zone (P = 0.089; Fig. 1). The average soil C within Mackinac Bay, Cedarville Bay, and Duck Bay was 56.72(kgC/m^3), 26.15(kgC/m^3), and 76.78 (kgC/m^3) respectively (Table 1). The differences among sites was also analyzed used using ANOVA. There was also no significant difference in soil C among sites (P = 0.096).

	Mackinac Bay	Cedarville Bay	Duck Bay
Swamp (kgC/m^3)	[redacted]	26.76	146.73
Transitional (kgC/m^3)	25.24	23.60	45.73
Wet Meadow (kgC/m^3)	88.21	28.09	37.88
Average per site(kgC/m^3)	56.72	26.15	76.78
Total Average(kgC/m^3)	53.22		

Table 1 Average soil C per vegetation zone (kg/m^3), per site, and across all sites.

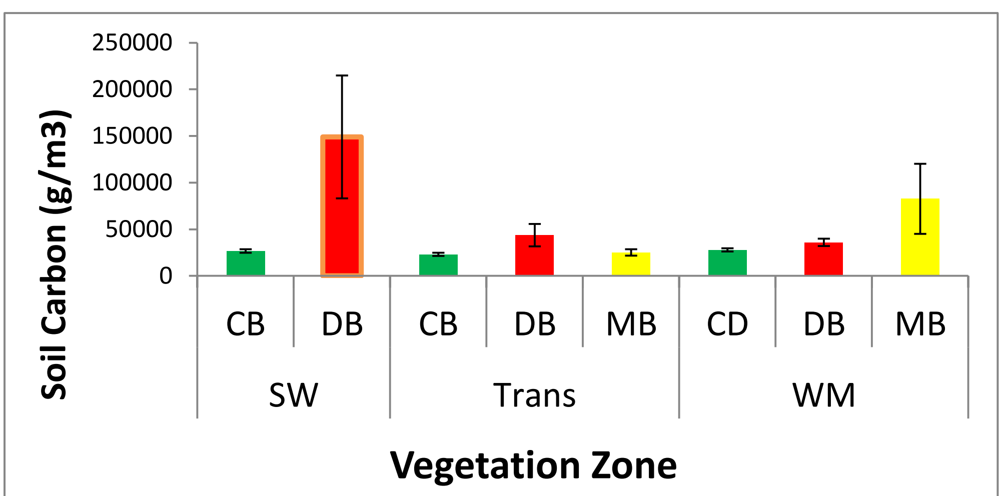

Fig. 1 Average soil C (g/m^3) per vegetation zone per site.

Soil C in relation to Basal Area

There was no significant correlation of Soil C to basal area within Cedarville Bay, Duck Bay, or Mackinac Bay, with R^2 values of 0.26, 0.12, and 0.02 respectively.

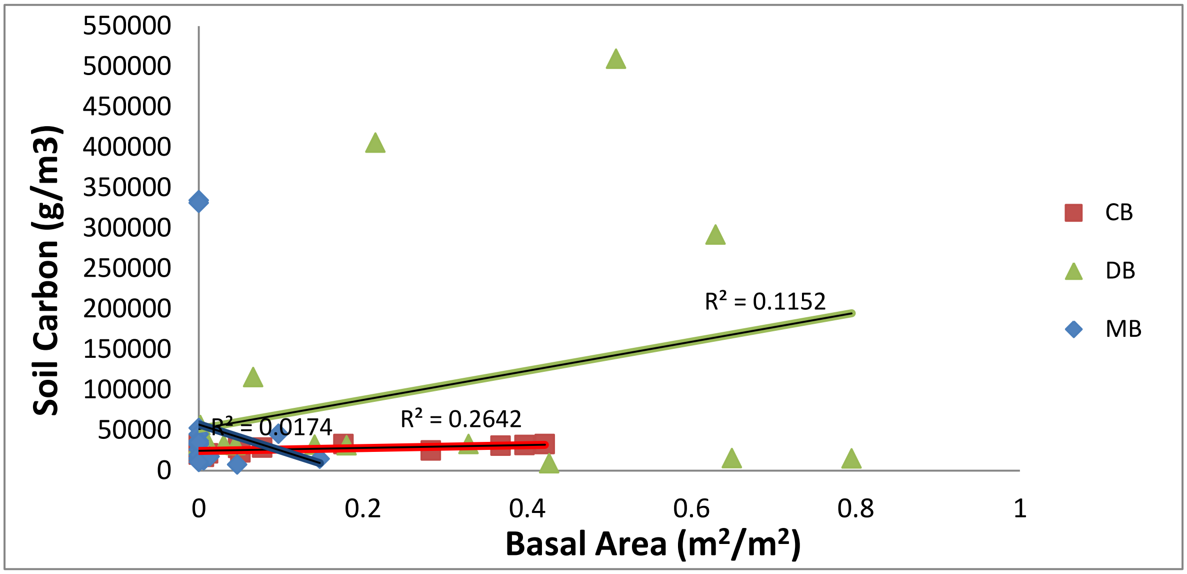

Fig 2 Soil carbon (kg/m^3) as a function of tree basal area (m^2/m^2)

Discussion

I hypothesized that there would be variation of soil C content within three wetland vegetation zones: swamp, transitional, and wet meadow. This was not supported by this study as there were no statistical difference in soil C among the three different vegetation zones, suggesting that carbon storage is not related to vegetation within these wetland zones. My second hypothesis stated that soil C would be positively correlated with an increase in tree basal area. This hypothesis was also not supported, as this study did not find a statistical significant relationship between soil C and basal area.

As this study found no correlation between soil C and vegetation zone or basal area, there was significant variation in the amount of soil C across sites and across zones. Since this study only analyzed preliminary data, future research should look in to finding the source of this variability with the current data collected. The soil C determined in this study can be compared to other estimates of soil C in wetlands to understand the way in which Great Lake coastal wetlands may contribute to the storage of carbon in soils. Bridgham et al. (2006) estimated that U.S and Mexico wetlands store approximately 16.2 kgC/m^3 of carbon, while the sites in the study had a average of 53.2 kgC/m^3 suggesting that Great Lake coastal wetlands may contain a disproportionally large amount of carbon, although this is uncertain and would require further study. Future studies should consider and test possible mechanisms that would contribute to the widely different values of soil C found in this study.

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