Quantifying Carbon Burial Rates as a Critical Ecosystem Service in the Mississippi Delta

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Abstract

The Mississippi River Delta has been active over the entire Holocene creating an expansive sediment package that spans the entire Louisiana coast and can be greater than 100 m thick in some places. This sediment package contains peat deposited by wetlands, and clastic material deposited in bays and floodplains or by channels. It is well-known that the current wetland sediment is a large carbon sink that plays a role in the global carbon cycle. In this study, we determine total organic carbon content of both wetland and non-wetland sediment that was deposited between 2,000 and 3,300 years ago (6 to 14 m depth). We find that the relationship observed between organic material to organic carbon that exists in the current wetland sediment (top 24 cm) does not hold for the sediment analyzed here. This shows that we need a better understanding of deep carbon sequestration in the Holocene sediment package to determine the role the Mississippi Delta has played in carbon sequestration throughout its existence. Despite these current uncertainties, we see that organic carbon is sequestered in both wetland and non-wetland environments. This work shows that it might be possible to use stratigraphy to estimate the total amount of carbon sequestered in the entire Holocene sediment package, as we show that different depositional environments that are characterized by different sediment types have different carbon accumulation rates.

I. Introduction

The Mississippi River deltaic margin plays a large role as a carbon sink in the global carbon cycle. Carbon sequestration is the process where carbon dioxide is removed from the atmosphere and held in carbon sinks, which are anything that sequester more carbon from the atmosphere than they release. The carbon stored in coastal ecosystems (e.g., salt marshes, mangroves, and seagrasses) is called blue carbon (Nellemann et al., 2009). Blue carbon reservoirs are not well quantified, however, and due to increased accommodation, the Mississippi River delta's capability for being a carbon sink is deteriorating. A quantification of the organic carbon burial rates in this region may help assess how the carbon sink can be enhanced, through sediment diversion for example (Shields et al., 2017).

In this study, the organic carbon burial rates are measured from a core collected by a geotechnical firm in January 2016 from Myrtle, Grove Louisiana. This area is a brackish marsh situated 2 km from the Mississippi River and 5 km south of the proposed Mid-Barataria sediment diversion (Figure 1), but has encompassed many coastal ecosystems (e.g., channel, marsh, bay) over the Holocene. The core is approximately 40 meters long and covers the entire Holocene, or the past 11,000 years. The core was previously analyzed for bulk density, organic matter content, grain size, and other sediment properties (Bridgeman, 2018). We expand on this previous work here by calculating total organic content. The goal of this work is to determine whether significant differences exist in organic carbon burial rates between terrestrial (delta plain) and marine (prodelta) environments, which could offer insight to how the proposed sediment diversion could enhance the potential ecosystem service of organic carbon burial.

Figure 1: The Myrtle Grove core is located in the Barataria basin, southeast of New Orleans, LA.

II. Methods

i. Total Organic Carbon

We remove a constant volume (5 cm^3) of sample from the core at various depths between 6 and 14 m. These samples are then dried in an oven at a temperature of 50°C for 24 hours, which is hot enough to remove any moisture from the sediment but not hot enough to burn the organic matter present in the sample. Once dried, a mortar and pestle are used to grind the block of sediment and break it down into its individual grains to ensure that there is no clumping in the sample for the following steps of preparation. A slurry of the sediment and water is then made, and the sediment is run through a 63-micron sieve to prevent anything larger than a very fine sand from making its way into the slurry. The slurry is then drained through another filter with the help of a vacuum pump. The sample is then dried again for 24 hours at 50°C. Once the sediment it is completely dried, the sample is weighed and then treated with a 0.1M solution of hydrochloric acid to dissolve any inorganic carbon from the sample. The samples are then rinsed thoroughly with multiple rounds of DI water to neutralize the sediment. The sediment is then dried again at 50°C and is now ready to be analyzed for total organic carbon.A small mass (~10-15 milligrams) of the dried sample is then put into a tin capsule and weighed. The prepared samples are then analyzed for their carbon concentrations (% carbon) at Tulane University's Coordinated Instrumentation Facility using a Fisons EA112 Elemental Analyzer. Each run consists of the duplicate samples, as well as standards and certified reference material to ensure accuracy and precision of the results.

ii. Theoretical Organic Carbon

Previous samples from the core were measured for organic matter (OM) content (% organic matter) using loss on ignition (LOI) by Bridgeman (2018). In this process, the samples were dried, ground, and then heated to 75°C to minimize the effects of humidity (W_1; g) and weighed. This process provided dry bulk density (g/cm^3) and water content (%). The samples were then analyzed for percent OM using the LOI method. To burn off the organic material, samples were placed in a muffle furnace at 550°C for 6-8 hours. After they were cooled to 75°C and then weighed again (W_2; g). Organic matter content (OM, %) is calculated as:

$$OM = \frac{W_1 - W_2}{W_1} * 100\,,$$

(Eq. 1)

Theoretically, organic carbon (OC) can be derived from OM using a functional relationship between organic matter and organic carbon from data acquired from the Coastal Protection and Restoration Authority (2012). A conversion factor of 0.4541 was used to establish organic carbon amounts for the core (Figure 2).

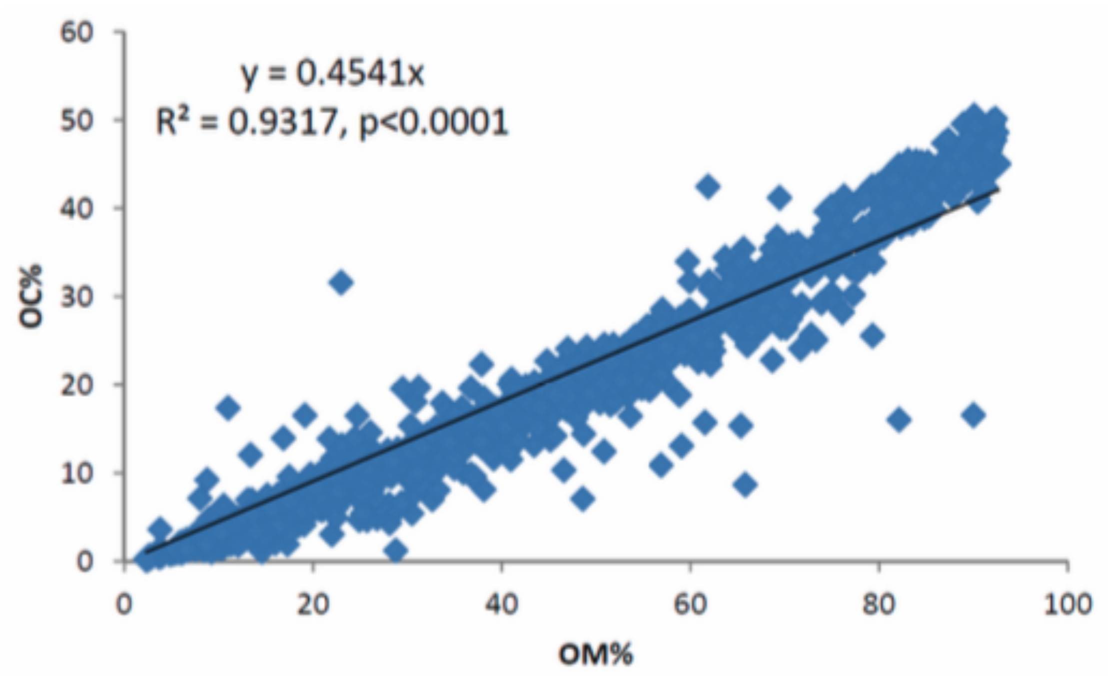

Figure 2: The relationship between percent organic matter (derived from loss-on-ignition analyses) and percent organic carbon for coastal Louisiana wetland sediments (CPRA, 2012).

III. Results

The measured percent total organic carbon (TOC) from sample preparation at Tulane University's Coordinated Instrumentation Facility (CIF) were plotted against theoretical organic carbon measurements calculated from the organic matter content measured by Bridgeman (2018). While the measured TOC are much lower than the theoretical measurements (Figure 3), a relationship between organic matter and organic carbon still exists (Figure 4).

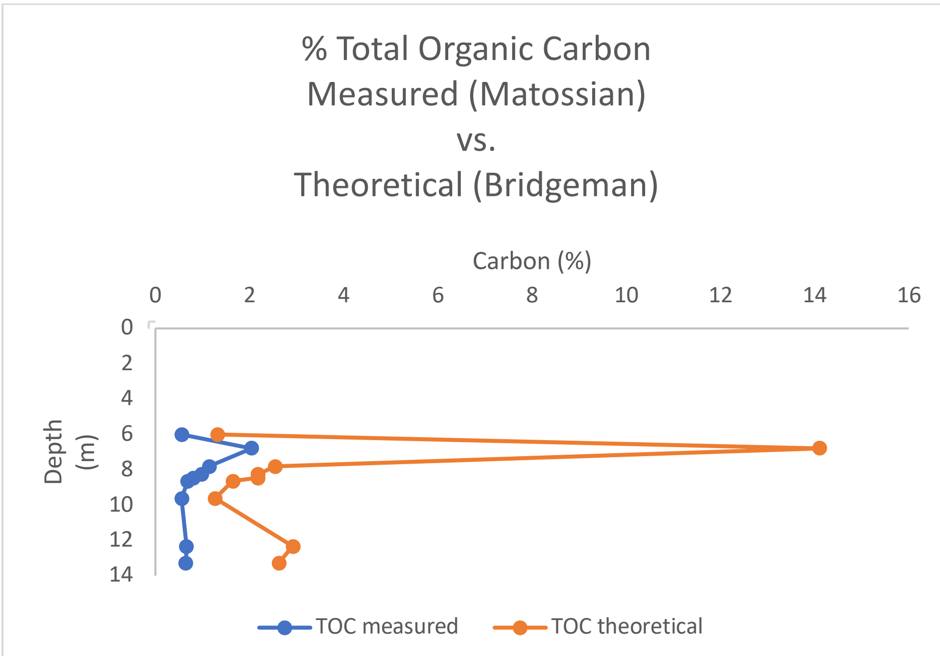

Figure 3: Measured total organic concentrations (%) plotted against the theoretical total organic concentrations (%) calculated using the conversion factor from CPRA (2012).

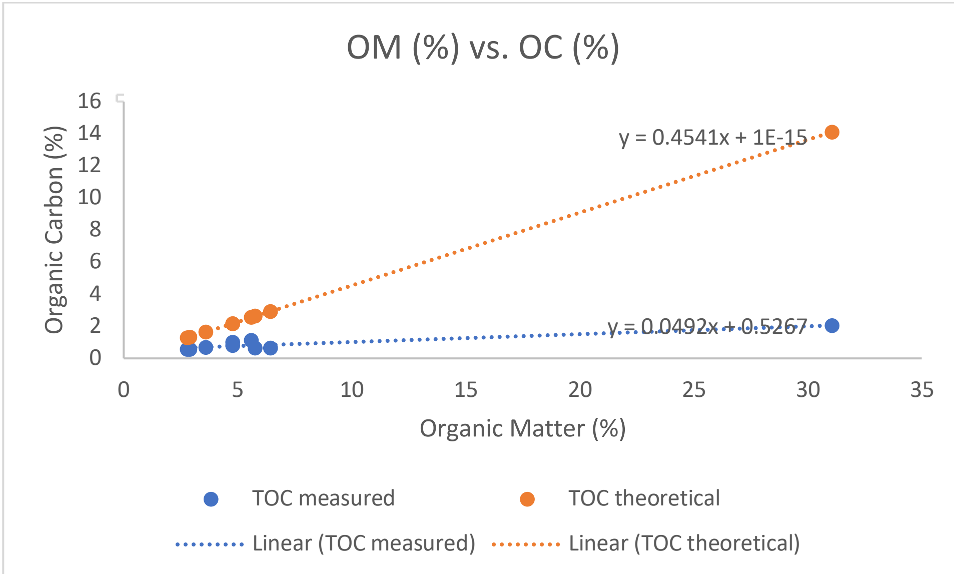

Figure 4: The relationship between total organic matter (OM; %) and total organic carbon (OC; %) for both measure TOC and theoretical TOC.

The Myrtle Grove core encompasses many different environments and sediment types. The top 11 m, categorized by Unit 1, represents the emergence of the delta plain at the core site, including marsh ecosystems, while Unit 2 represents shallow marine (prodelta) conditions (Figure 5). Figure 5 also shows sediment types and bulk densities for various depths in the core. The black boxes are the sections that were targeted by this study.

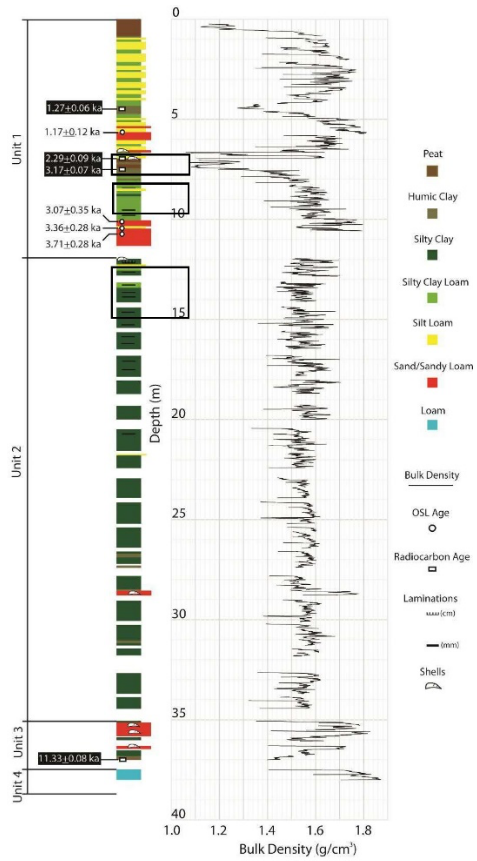

Figure 5: The Myrtle Grove core illustrated by means of sediment types and wet bulk density (Bridgeman, 2018).

Using the bulk density and geochronology from ^{14}C and optically stimulated luminescence (OSL) dating from Bridgeman (2018), carbon deposition rates were calculated for each of the targeted sections of the core for both the measured and theoretical OC measurements. Carbon deposition rates (CA; g/cm^2yr) are calculated as:

$$CA = \frac{\rho * L * TOC}{t},$$

(Eq. 2)

where ρ is bulk density (g/cm^3), L is the length of section (cm), TOC is total organic carbon concentration (%), and t is time (years).

Depth (m)	Measured Carbon Deposition Rate (g/cm^{2}yr)	Theoretical Carbon Deposition Rate (g/cm^{2}yr)
6 - 6.78	0.105404656	0.6254352
7.81 - 9.62	0.201183579	0.472530667
12.33 - 13.28	0.11049956	0.470161333

*Table 1: Carbon deposition rates (g/cm^2*yr) calculated using both measured and theoretical carbon concentration data.*

Table 1 contains the carbon deposition rates for both measured and theoretical carbon concentrations. The carbon deposition rates for the measured organic carbon concentrations appear to be fairly consisten with a peak in the middle section of the core samples. This differs from the theoretical carbon deposition rates as they display a peak in the shallowest section while remaining consistent for the next two sections of the core samples.

IV. Discussion

We find that the total organic carbon concentrations measured through sample preparation and Tulane University's Coordinated Instrumentation Facility (CIF) were significantly lower than the theoretical organic carbon concentrations calculated from the LOI data presented in Bridgeman (2018). There are multiple reasons this could be the case. First, and the option we think is the most unlikely, is that the samples used to measure loss on ignition were not completely dried and the additional weight could have skewed the data to appear as if it contained more organic matter than it actually did. Another possibility, which we think is more likely, is that the relationship between organic matter and organic carbon does not hold with depth. The theoretical organic material to organic carbon relationship is based on the surficial wetland sediments of the Louisiana coast (top 24 cm). We know that decomposition of organics occurs through time, so it is possible that the organic carbon contained in deltaic sediments decomposes faster than other types of organic material. Further, this study analyzes sediments that are not characterized by wetland environments, but rather open water/bays and channel deposits.

More research is needed to understand the relationship between organic matter and organic carbon in coastal environments along the Louisiana coast. The total organic carbon concentrations measured through sample preparation and CIF used for this study are consistent with measurements taken previously. We plan to double check the percent organic material by re-doing LOI on the samples.

The 2013 IPCC Wetlands Supplement reports the average carbon storage as 0.027 g C/cm^3 over 1m (Holmquist et al., 2018). Comparing the carbon concentrations measured in the Myrtle Grove core to modern deposition and carbon contents allows us to understand what role all coastal environments, not just wetlands, play in the blue carbon sequestration. Further, this work shows that a good understanding of sediment type and depth could allow us to calculate the total organic carbon sequestered in the Mississippi Delta Holocene sediment package.

V. Conclusion

Although the measured total organic carbon was lower than anticipated, we were able to calculate the amount of carbon stored in this Myrtle Grove core for the section from 6-14m. This study showed us that the relationship between organic material and organic carbon may differ depending on depositional environment and with depth. From this, we conclude that it may not be as straightforward as previously shown to calculate the role of the Mississippi Delta as a blue carbon sink, and more work will be needed to tease out these differences. We do find that there is a relationship between organic material and organic carbon for this section. While the rates of carbon deposition are fairly consistent throughout the three sections focused on in this research, we see a peak in carbon concentrations in the peat soils at 6.78 m depth. Using this data and quantifying the organic carbon burial rates allows for a deeper understanding of how carbon is stored in different environments of the Mississippi River delta. This has implications for how proposed sediment diversions can provide an ecosystem service of carbon burial and could inform future policies.

VI. Works Cited

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