Sediment Organic Carbon Accumulation and Erosion-induced CO2 Emissions in the Delaware Bay Estuarine Salt Marshes

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Abstract

Tidal salt marshes are the most productive “Blue Carbon” ecosystem and play a significant role in the Global Carbon Cycle (Mcleod et al., 2011, Chung et al., 2011). Salt marshes account for 75% of the organic carbon (C) found in “Blue Carbon” systems, yet cover less than 1% of Earth’s surface (Hopkinson et al., 2012, Howard et al., 2014). They have a high C storage capacity due to a continuous sediment C accumulation rate (CAR) greater than that of any other “Blue Carbon” ecosystem (Murray et al., 2011, Chmura, 2013, Ouyang and Lee, 2014). However, Global estimates of salt marsh C-stocks and CAR are subject to large uncertainties (Duarte et al, 2013, Chastain et al, 2018). The Delaware Bay (DB) salt marshes have been developing for ˜2000 years. When these systems are degraded they become a potential source of C-emissions. 8.85 km2 of salt marsh has converted to open water between 1996-2010 and future losses are estimated to reach 5 km2/yr by 2100 (Partnership for the Delaware Estuary, 2017). Conversion could outpace C storage if the depth of erosion is [?] the thickness of the marsh sediments (Theuerkauf et al., 2015). Most salt-marsh sediment C-stock assessments are reported within the top 1 m of the sediment column (Ouyang and Lee, 2014), thereby representing ˜ 100 years of salt-marsh accumulation as compared to the actual 1-6 m sediment sequences accumulated throughout the life span of most U.S. Mid-Atlantic regional salt marshes (Nikitina et al., 2015, Kirwan et al., 2013, Kemp et al., 2013). We estimate the average thickness of the DB salt marsh sediments is 2.6 m, C-stock is 0.1020 MgC/m2 and salt marsh C-stock loss over the 14 yr period is ˜0.9 TgC (3.3MMT CO2 equivalents). As this critical “Blue Carbon” habitat reportedly declines, the resulting CO2 degassing flux has a significant impact on the Global Carbon Budget contributing to climate change and ocean acidification (Cai W-J, 2011). Recognition of this sink-to-source conversion emphasized the need for more accurate stock estimates and risk assessments based on estimates of CO2 emissions from lost and degraded salt marshes (Lovelock et al., 2017). The results show that the DB salt marshes sequester significant amounts of C, suggesting that C-stock assessments focused on the top 1 m of sediment underestimate the total C-stock and potential C-emissions by more than three-fold

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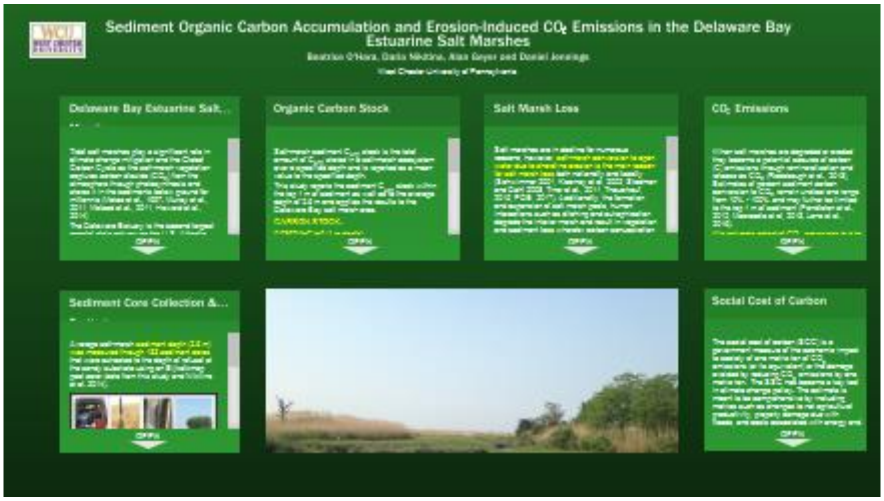

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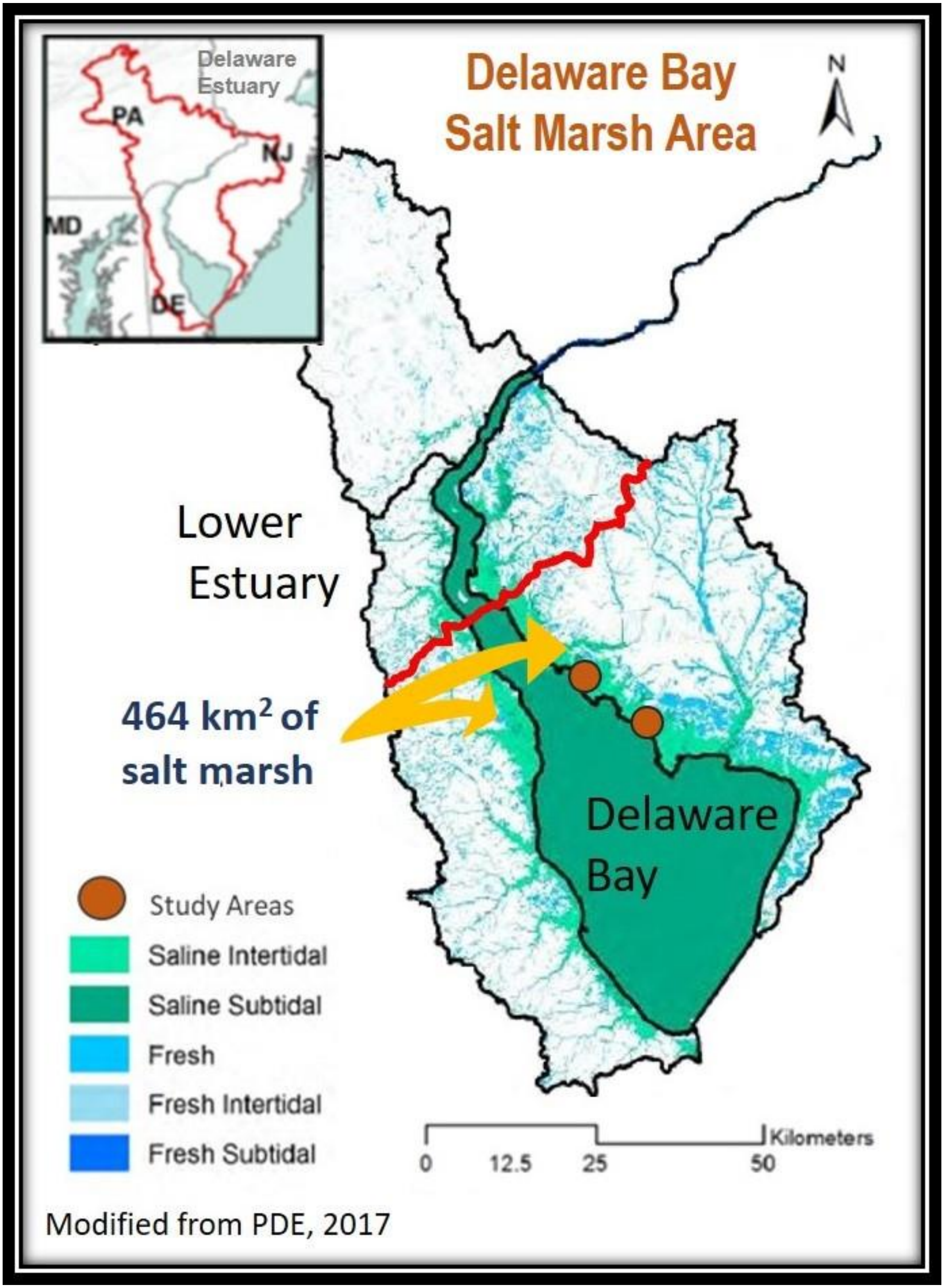
SECTION 1

Delaware Bay Estuarine Salt Marsh

Tidal salt marshes play a significant role in climate change mitigation and the Global Carbon Cycle as the salt-marsh vegetation captures carbon dioxide (CO_2) from the atmosphere through photosynthesis and stores it in the sediments below ground for millennia (Mateo et al., 1997. Murray et al., 2011, Mcleod et al., 2011, Howard et al., 2014)

The Delaware Estuary is the second largest coastal plain estuary on the U.S. Atlantic coast and is home to 596 km^2 of tidal salt marsh. 464 km^2 (78%) of the salt marshes are located in the Delaware Bay area of the estuary (Partnership for the Delaware Estuary (PDE), 2017)).



Delaware Bay
Salt Marsh Area
N
Delaware
Estuary
PA
NJ
MD
DE
Lower
Estuary
464 km² of
salt marsh
Delaware
Bay
Study Areas
Saline Intertidal
Saline Subtidal
Fresh
Fresh Intertidal
Fresh Subtidal
0
12.5
25
50
Kilometers
Modified from PDE, 2017

- The salt marshes of the Delaware Bay have been developing for over 2,000 years.
- Spartina grasses are the primary vegetation.
- Salt-marsh sediments are highly organic.
- Sediment depth varies locally and ranges from 1 to 6 meters (m) below the surface.
- The average salt-marsh sediment depth is 2.6 meters.

SECTION 2

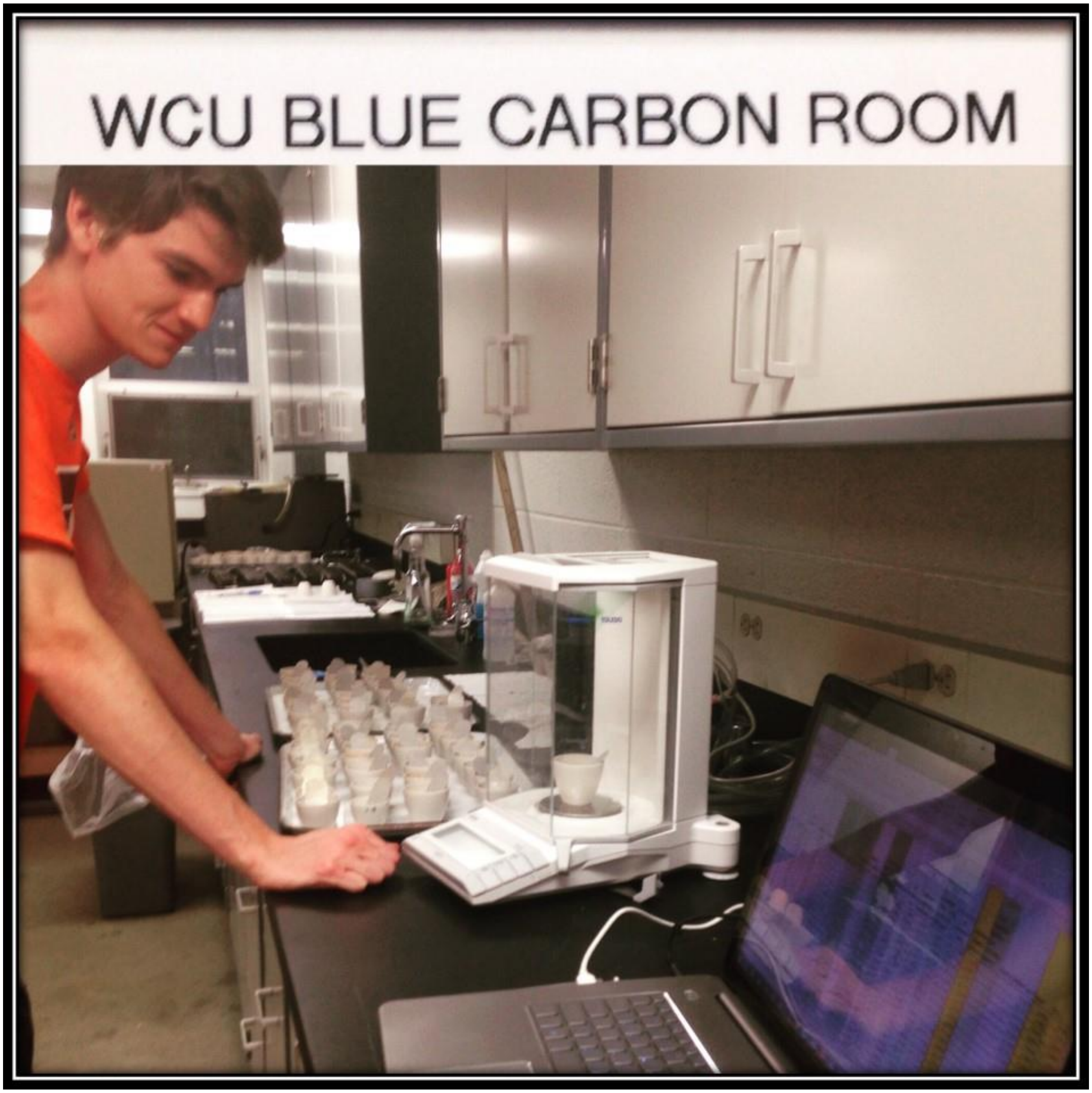
Sediment Core Collection & Testing

Average salt-marsh sediment depth (2.6 m) was measured through 133 sediment cores that were extracted to the depth of refusal at the sandy substrate using an Eijkelkmap peat corer (data from this study and Nikitina et al. 2014).

Organic matter content was determined through loss-on ignition (LOI) sampling of 18 cores.

Percent organic carbon (C_{org}) was calculated using Craft et al. (1991) equation derived for estuarine salt marshes on the Mid-Atlantic coast.

$\% C_{org} = 0.04(\%LOI) + 0.0025(\%LOI)^2$



SECTION 3

Organic Carbon Stock

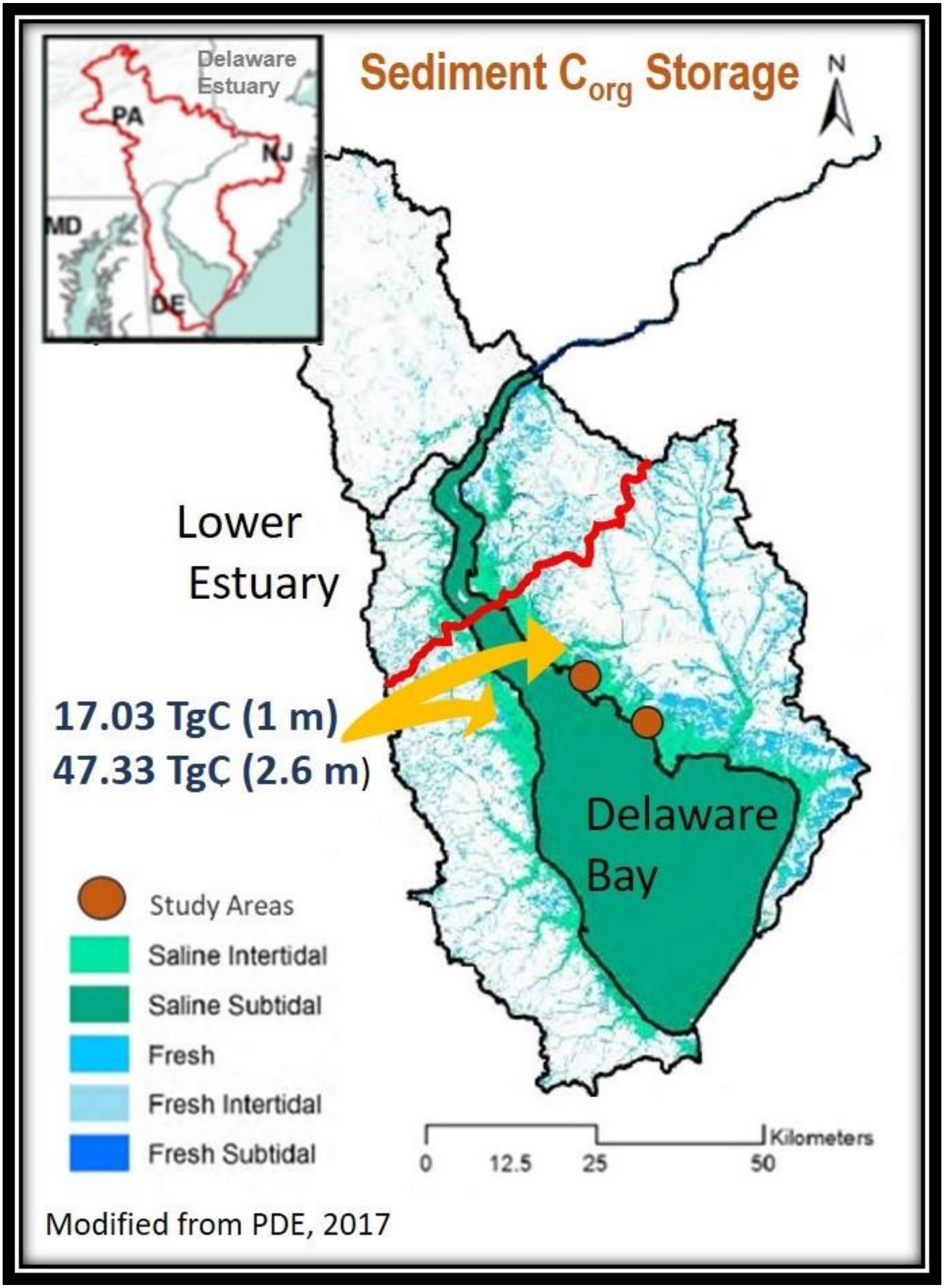
Salt-marsh sediment C_{org} stock is the total amount of C_{org} stored in a salt-marsh ecosystem over a specified depth and is reported as a mean value to the specified depth.

This study reports the sediment C_{org} stock within the top 1 m of sediment as well as to the average depth of 2.6 m and applies the results to the Delaware Bay salt marsh area.

CARBON STOCK:

0.0367MgC/m^2 (1 m depth).

0.1020 MgC/m^2 (2.6 m depth).


Sediment Corg Storage
N
Delaware
Estuary
PA
NJ
MD
DE
Lower
Estuary
17.03 TgC (1 m)
47.33 TgC (2.6 m)
Delaware
Bay
Study Areas
Saline Intertidal
Saline Subtidal
Fresh
Fresh Intertidal
Fresh Subtidal
0
12.5
25
50
Kilometers
Modified from PDE, 2017

SEDIMENT CORG STORAGE:

17.03 TgC (1 m depth).

47.33 TgC (2.6 m depth).

SECTION 4

Salt Marsh Loss

Salt marshes are in decline for numerous reasons, however, salt-marsh conversion to open water due to shoreline erosion is the main reason for salt marsh loss both nationally and locally (Schwimmer 2001, Kearney et al, 2002, Stedman and Dahl 2008, Tiner et al., 2011, Theuerkauf, 2015, PDE, 2017). Additionally, the formation and expansion of salt marsh pools, human interactions such as ditching and eutrophication degrade the interior marsh and result in vegetation and sediment loss whereby carbon sequestration ceases and stored sediment C_{org} has the potential to be released as CO_2.

Globally, more than 35% of all salt marshes have been lost to date (Duarte et al., 2008, Crooks et al., 2011, Pendleton et al., 2012).

Locally, the salt marshes of the Delaware Bay are being lost at a rate of 0.63 km^2/yr based on 8.85 km2 of salt marsh loss from 1996 - 2010 and losses are expected to reach 5 km^2/yr by 2100 (PDE, 2017).

We estimate 0.325 TgC were lost between 1996-2010 and 11.744 TgC will be lost by 2100.

DELAWARE BAY SALT MARSH
SEDIMENT CORG STOCK, STORAGE & LOSSES

MEASUREMENT	AREA	SEDIMENT DEPTH (m)	
		1	2.6
Salt Marsh[1]	464 km^2		
C_{org} Stock		0.0367 TgC/km^2	0.1020TgC/km^2
C_{org} Storage		17.03 TgC	47.33 TgC
Salt Marsh Loss (1996-2010)[1]	8.85 km^2		
Salt Marsh Loss Rate (1996-2010)[1]	0.63 km^2/yr.		
C_{org} Loss (1996-2010)		0.325 TgC (0.0232 TgC/yr.)	0.903 TgC (0.0645 TgC/yr.)
Salt Marsh Loss (2010-2100)[1]	320 km^2		
C_{org} Loss (2010-2100)		11.744 TgC	32.640 TgC

* 1 Megagram (Mg) = 0.000001 Teragram (Tg)
[1] PDE, 2017

Marsh Gallery pics


SECTION 5

CO_2 Emissions

When salt marshes are degraded or eroded, they become a potential source of carbon (C) emissions through remineralization and release as CO_2 (Radabaugh et al., 2018). Estimates of percent sediment carbon conversion to CO_2 remain unclear and range from 10% - 100% and may further be limited to the top 1 m of sediment (Pendleton et al., 2012, Macreadie et al, 2013, Lane et al., 2016).

We estimate potential CO_2 emissions due to salt marsh loss the Delaware Bay from 1996-2010 and 2010-2100 at both 1 m of sediment depth and to the average sediment depth of 2.6 m.

DELAWARE BAY SALT MARSH LOSS CO_2 EQUIVALENTS			
MEASUREMENT	AREA	SEDIMENT DEPTH (m)	
		1	2.6
Salt Marsh[1]	464 km^2		
C_{org} Stock		0.0367 TgC/km^2	0.1020TgC/km^2
C_{org} Storage		17.03 TgC	47.33 TgC
Salt Marsh Loss (1996-2010)[1]	8.85 km^2		
C_{org} Loss (1996-2010)		0.325 TgC (0.0232 TgC/yr.)	0.903 TgC (0.0645 TgC/yr.)
CO_2 equivalents (in millions of metric tons) ** (1996-2010)		1.2	3.3
Salt Marsh Loss (2010-2100)[1]	320 km^2		
C_{org} Loss (2010-2100)		11.744 TgC	32.640 TgC
CO_2 equivalents (in millions of metric tons) ** (2010-2100)		43.1	119.8

* 1 Megagram (Mg) = 0.000001 Teragram (Tg)
** 1 Mg = 1 metric ton; 1 metric ton carbon = 3.67 metric tons CO_2 equivalents
[1] PDE, 2017

SECTION 6

Social Cost of Carbon

The social cost of carbon (SCC) is a government measure of the economic impact to society of one metric ton of CO2 emissions (or its equivalent) or the damage avoided by reducing CO2 emissions by one metric ton. The SSC has become a key tool in climate change policy. The estimate is meant to be comprehensive by including metrics such as changes to net agricultural productivity, property damage due with floods, and costs associated with energy and human health changes. Nordhaus (2017) estimates the SCC to be $31/metric ton and increasing 3% per year. However, some researchers such as Moore and Diaz (2015) think the cost is greatly underestimated and could be as high as $220/metric ton.

We apply Nordhaus (2017) estimate of SCC to calculate the potential economic impact of CO_2 emissions due to salt marsh loss to the year 2100 to be $16.4 billion (to 2.6 m depth of sediment).

DELAWARE BAY SALT MARSH LOSS THE SOCIAL COST OF CARBON (SCC)			
MEASUREMENT	AREA	SEDIMENT DEPTH (m)	
		1	2.6
Salt Marsh[1]	464 km^2		
C_{org} Stock		0.0367 TgC/km^2	0.1020TgC/km^2
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C_{org} Loss (1996-2010)		0.325 TgC (0.0232 TgC/yr.)	0.903 TgC (0.0645 TgC/yr.)
CO_2 equivalents (in millions of metric tons) ** (1996-2010)		1.2	3.3
SCC[2] (in millions of US$) (1996-2010)		$37.2 M	$102.3 M
Salt Marsh Loss (2010-2100)[1]	320 km^2		
C_{org} Loss (2010-2100)		11.744 TgC	32.640 TgC
CO_2 equivalents (in millions of metric tons) ** (2010-2100)		43.1	119.8
SCC[2] (in billions of US$) (2010-2100)		$5.9 B	$16.4 B

* 1 Megagram (Mg) = 0.000001 Teragram (Tg)
** 1 Mg = 1 metric ton; 1 metric ton carbon = 3.67 metric tons CO_2 equivalents
SCC ~ $31/ metric ton (based on 2010 US$) and increasing at 3% per year
[1] PDE, 2017
[2]Nordhaus, W.D., 2017

Abstract

Tidal salt marshes are the most productive 'Blue Carbon' ecosystem and play a significant role in the Global Carbon Cycle (Mcleod et al., 2011, Chung et al., 2011). Salt marshes account for 75% of the organic carbon (C) found in 'Blue Carbon' systems, yet cover less than 1% of Earth's surface (Hopkinson et al., 2012, Howard et al., 2014). They have a high C storage capacity due to a continuous sediment C accumulation rate (CAR) greater than that of any other 'Blue Carbon' ecosystem (Murray et al., 2011, Chmura, 2013, Ouyang and Lee, 2014). However, Global estimates of salt marsh C-stocks and CAR are subject to large uncertainties (Duarte et al, 2013, Chastain et al, 2018).
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representing ~ 100 years of salt-marsh accumulation as compared to the actual 1-6 m sediment sequences accumulated throughout the life span of most U.S. Mid-Atlantic regional salt marshes (Nikitina et al., 2015, Kirwan et al., 2013, Kemp et al., 2013). We estimate the average thickness of the DB salt marsh sediments is 2.6 m, C-stock is 0.1020 MgC/m2 and salt marsh C-stock loss over the 14 yr period is ~0.9 TgC (3.3MMT CO_2 equivalents).
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