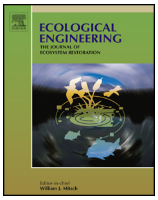
Ecological Engineering xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng



Determining total emissions and environmental drivers of methane flux in a Lake Erie estuarine marsh

A.C. Rey-Sanchez[a,d,*], T.H. Morin[a,d], K.C. Stefanik[a,b], K. Wrighton[c,d], G. Bohrer[a,d]

[a] Department of Civil andEnvironmental Engineering and Geodetic Science, The Ohio State University, Columbus, OH, USA
[b] School of Environment and Natural Resources, The Ohio State University, Columbus, OH, USA
[c] Department of Microbiology, The Ohio State University, Columbus, OH 43210 USA
[d] Environmental Science Graduate Program, The Ohio State University, Columbus, OH 43210 USA

ARTICLE INFO

Article history:
Received 6 April 2017
Received in revised form 17 June 2017
Accepted 20 June 2017
Available online xxx

Keywords:
Wetland
Methane
Estuary
Carbon
Environmental drivers
Marsh
Eddy covariance

ABSTRACT

Estuarine freshwater marshes can act as an important ecosystem for carbon storage and flux because of its strategic position in a watershed. We monitored CH_4 and CO_2 fluxes in Old Woman Creek, an estuarine wetland of Lake Erie, Ohio. The eddy covariance (EC) technique was used to measure fluxes of CH_4 and CO_2 continuously during the growing seasons of 2015 and 2016. Simultaneously, monthly sampling of gas exchange was conducted using non-steady state chambers in four distinct land-cover types in the wetland: open water, emergent vegetation (*Typha* spp.), floating vegetation (*Nelumbo* spp.) and mud flats. Chambers and EC measurements were combined to provide estimates of the continuous contributions of each land cover to the total methane emissions of the wetland. In addition, water and meteorological measurements were used to determine the most important environmental drivers of methane flux in the wetland. We found an average rate of emission from the *Typha* patch, the most abundant vegetated land cover, of 219.4_{CH_4}—C m^{-2} y^{-1}, which was much higher than rates reported in similar emergent vegetation types in other wetlands. Mud flats had the highest rates of CH_4 emission, followed by *Nelumbo* and *Typha* patches, and open water. Mud flats contributed 6.8% of the total CH_4 emissions of the wetland despite occupying only 1.5% of the wetland area, whereas open water contributed 16.1% despite occupying 47% of the wetland area. Water temperature and wind speed were the strongest environmental drivers of CH_4 flux to the atmosphere. Carbon fluxes were strongly correlated to methane fluxes. Fluctuating water levels above the wetland's surface had a weak effect on overall CH_4 emissions in the wetland, with stronger effects during the night than during the day. Providing an empirical model that predicts the influence of different environmental drivers CH_4 emissions in the wetland can aid in the design of estuarine wetlands that retain nutrients and reduce coastal eutrophication while minimizing greenhouse gas emissions.

1. Introduction

Estuarine freshwater wetlands serve an important role in the natural carbon cycle. Estuaries process upland river water before it is deposited into lakes or oceans (Larson et al., 2013). By processing transported nutrients, they help reduce the eutrophication of coastal waters and thereby the occurrence of harmful algae blooms (Horne, 2000; Michalak et al., 2013). Wetlands, including estuarine ones, can sequester large amounts of carbon due to their low soil oxygen contents that restricts the decomposition of biomass by aerobic microbes. In addition, wetland plants also assimilate carbon in the form of carbon dioxide (CO_2) through photosynthesis. In most wetlands, there is a net negative flux of CO_2, which means that more carbon enters the ecosystem through gross primary production (*GPP*) than carbon leaves through ecosystem respiration (R_e) (Bridgham et al., 2006; Mitsch et al., 2013). Estuarine wetlands have the potential to become even more productive than other classes of wetlands due to nutrient rich water that increases plant growth (Horne, 2000) and trapping of suspended matter and its associated organic carbon, which increases the long-term carbon sequestration pool (McLeod et al., 2011). However, the same low oxygen conditions that slow decomposition often make freshwater wetlands sources of methane (CH_4).

---

[*] Corresponding author at: The Ohio State University, Department of Civil, Environmental and Geodetic Engineering, 2070 Neil Ave Columbus, OH 43210, USA.
E-mail addresses: reysanchez.1@osu.edu, camiloreysanchez@gmail.com (A.C. Rey-Sanchez).

http://dx.doi.org/10.1016/j.ecoleng.2017.06.042
0925-8574/© 2017 Elsevier B.V. All rights reserved.

Please cite this article in press as: Rey-Sanchez, A.C., et al., Determining total emissions and environmental drivers of methane flux in a Lake Erie estuarine marsh. Ecol. Eng. (2017), http://dx.doi.org/10.1016/j.ecoleng.2017.06.042

Environmental factors can strongly influence methane emissions in wetlands. Temperature is perhaps the most commonly cited driver of CH_4 emissions. Microbial processes are directly dependent on temperature, which increases their metabolic rates (Bohn et al., 2007; Kim et al., 1999; Segers, 1998). However, its linkage to CH_4 emissions is complex due to the competing interaction of anaerobic methanogenesis and aerobic methanotrophy, both of which are stimulated by higher temperatures. Water level is commonly cited as a driver of CH_4, typically due to its association with oxygen availability (Kettunen, 2003; White et al., 2008). Oxygen is the preferred terminal electron acceptor for most methanotrophs, which can oxidize 60–90% of the methane produced in wetlands before it can escape to the atmosphere (Le Mer and Roger, 2001). It has been shown that intermittent flooding can reduce methane emissions relative to permanently flooded wetlands (Altor and Mitsch, 2006), but few studies have examined the effect of short time scale variations of water level on permanently flooded, nontidal marshes. Other variables that have an influence on methane emissions are the availability of labile carbon substrate concentration in the soil (Sha et al., 2011; Updegraff et al., 1995) and the pH, as methanogens prefer neutral to slightly alkaline conditions (Wang et al., 1993).

Wetlands are often composed of a mosaic of different land cover types, including open water, emergent vegetation, floating vegetation, mud flats, and dry upland. The rates of CH_4 emission among these land cover types can be variable and their arrangement and relative coverage can strongly influence the total methane emissions from the wetland site as a whole (Matthes et al., 2014; Morin et al., 2017). Methane emissions from vegetated areas have been reported to increase by a factor of 3–4 in comparison to areas within the wetland with no vegetation (Hamilton et al., 1994). In addition, the type and composition of plants within a wetland can also have an important effect on methane emissions (Baldocchi et al., 2012; Forbrich et al., 2011; Leppala et al., 2011; Sachs et al., 2010; Schultz et al., 2011), sometimes showing that an increase in species richness is linked to a decrease in CH_4 emission (Bouchard et al., 2007).

There are several methodologies to quantify CH_4 fluxes. The most common one uses non-steady-state chambers, in which the rate of accumulation of a gas in the headspace of a chamber with known volume provides the flux rate. Chambers are relatively simple, low-cost, and can work in a wide range of applications and ecosystems. Chambers are, essentially, point measurements, and thus, provide spatially detailed observations of the flux rates of particular land-cover types, but over a small number of spatially replicated points. When the chamber deployment is done manually and is not automated, they are limited to a very small and intermittent temporal representation. The eddy covariance approach combines high-speed wind and gas concentration data to determine the site level fluxes at a high temporal resolution (typically 10–20 Hz processed to half-hourly block averages). The eddy covariance approach measures a mixture of gases originating from a source footprint area that changes with wind speed, direction and turbulence mixing of the atmospheric boundary layer (Detto et al., 2006; Hsieh et al., 2000; Kljun et al., 2004), and often includes various land-cover types that make up the entire site.

In this study we calculate site level CH_4 emissions using the approach of Morin et al. (2017) that combines point-wise flux rate estimates from each land-cover type using non-steady-state chamber campaigns, and continuous site-level eddy covariance measurements. By combining these two data streams, it is possible to estimate the separate contributions of different land cover types throughout the site, and provide an integrated whole-site-level estimate of methane flux from the wetland. We studied the Old Woman Creek National Estuarine Research Reserve wetland (OWC), a natural estuarine marsh in Northern Ohio at the coast of Lake Erie (Fig. 1). The first objective of this study is to calculate the total summer-time emissions of CH_4 from the OWC wetland, by integrating the contributions of different land cover types. The second objective is to identify the most important environmental drivers of CH_4 flux and identify environmental variables that are most strongly correlated with methane flux, and thus develop an empirical model of methane emissions in the wetland. The application of this methodology can provide useful information for the design of estuarine wetlands that minimize CH_4 emissions.

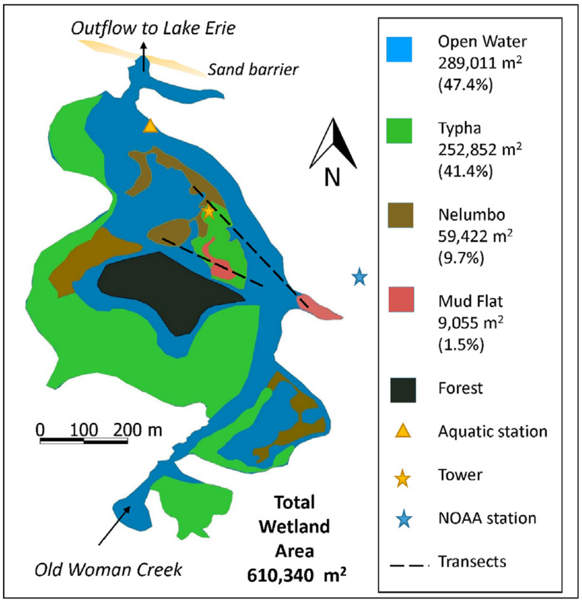


Fig. 1. Map of the study site showing the area distribution of each of the four predominant land covers and the meteorological, flux and aquatic stations used in the study. The dotted lines indicate the chamber measurement transects. The area calculation was done by interpretation of Google Earth satellite imagery for the year 2015 and field corroboration.

2. Materials and methods

2.1. Study site

The Old Woman Creek (OWC), in Northern Ohio, is a State Nature Preserve, part of NOAA's National Estuarine Research Reserve (NERR) network. OWC includes 61 Ha of natural wetland area managed by NOAA and the Ohio Department of Natural Resources. There are four main land-cover types in the wetland: 1) open water, 2) mud flats, 3) Emergent vegetation: a mix of emergent vegetation dominated by *Typha* spp with a small amount of the invasive species *Phragmites* spp., (for simplicity, we name this land-cover type – *Typha*) and 4) floating-leaf vegetation dominated by *Nelumbo lutea*. Fig. 1 shows the land cover arrangement for the period of the study. Water flows into the wetland from Old Woman Creek as it travels northwards into Lake Erie (Fig. 1). A natural sand barrier acts as a levee that intermittently blocks the exchange of water between Lake Erie and the estuary. Typically, the sand barrier limits the flow from the wetland into Lake Erie (Tomaszek et al., 1997), especially during summertime low-flow periods. Periodically, during storms in the lake, the sand barrier ruptures and allows a rapid flux of water between the wetland and Lake Erie. With the exception of the open-water area in the main channel, most of the wetland is shallow, no deeper than 0.5 m (Whyte et al., 2008).

Please cite this article in press as: Rey-Sanchez, A.C., et al., Determining total emissions and environmental drivers of methane flux in a Lake Erie estuarine marsh. Ecol. Eng. (2017), http://dx.doi.org/10.1016/j.ecoleng.2017.06.042