Science of the Total Environment 533 (2015) 391–409

Contents lists available at ScienceDirect

Science of the Total Environment

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

Effects of land use on greenhouse gas fluxes and soil properties of wetland catchments in the Prairie Pothole Region of North America

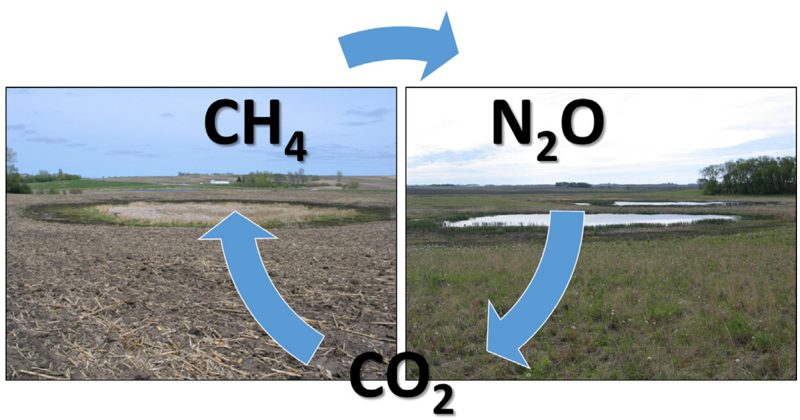
Brian A. Tangen *, Raymond G. Finocchiaro, Robert A. Gleason

U.S. Geological Survey, Northern Prairie Wildlife Research Center, 8711 37th Street Southeast, Jamestown, ND 58401, USA

HIGHLIGHTS

- Soil carbon sequestration can be enhanced through wetland restoration.
- Methane emissions may offset wetland soil carbon sequestration.
- Greenhouse gas fluxes and soil properties were assessed from wetland catchments.
- All variables were affected by land use, but relations were variable.
- Restoration type must be considered when assessing wetland greenhouse gas fluxes.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 12 May 2015
Received in revised form 30 June 2015
Accepted 30 June 2015
Available online xxxx

Editor: D. Barcelo

Keywords:
Agricultural drainage
Carbon sequestration
Methane
Nitrous oxide
Water-filled pore space
Wetland restoration

ABSTRACT

Wetland restoration has been suggested as policy goal with multiple environmental benefits including enhancement of atmospheric carbon sequestration. However, there are concerns that increased methane (CH_4) emissions associated with restoration may outweigh potential benefits. A comprehensive, 4-year study of 119 wetland catchments was conducted in the Prairie Pothole Region of the north-central U.S. to assess the effects of land use on greenhouse gas (GHG) fluxes and soil properties.

Results showed that the effects of land use on GHG fluxes and abiotic soil properties differed with respect to catchment zone (upland, wetland), wetland classification, geographic location, and year. Mean CH_4 fluxes from the uplands were predictably low (<0.02 g CH_4 m^{-2} day^{-1}), while wetland zone CH_4 fluxes were much greater (<0.001–3.9 g CH_4 m^{-2} day^{-1}). Mean cumulative seasonal CH_4 fluxes ranged from roughly 0–650 g CH_4 m^{-2}, with an overall mean of approximately 160 g CH_4 m^{-2}. These maximum cumulative CH_4 fluxes were nearly 3 times as high as previously reported in North America. The overall magnitude and variability of N_2O fluxes from this study (<0.0001–0.0023 g N_2O m^{-2} day^{-1}) were comparable to previously reported values.

Results suggest that soil organic carbon is lost when relatively undisturbed catchments are converted for agriculture, and that when non-drained cropland catchments are restored, CH_4 fluxes generally are not different than the pre-restoration baseline. Conversely, when drained cropland catchments are restored, CH_4 fluxes are noticeably higher. Consequently, it is important to consider the type of wetland restoration (drained, non-drained) when assessing restoration benefits. Results also suggest that elevated N_2O fluxes from cropland catchments

* Corresponding author.
E-mail addresses: btangen@usgs.gov (B.A. Tangen), rfinocchiaro@usgs.gov (R.G. Finocchiaro), rgleason@usgs.gov (R.A. Gleason).

http://dx.doi.org/10.1016/j.scitotenv.2015.06.148
0048-9697/Published by Elsevier B.V.

likely would be reduced through restoration. The overall variability demonstrated by this study was consistent with findings of other wetland investigations and underscores the difficulty in quantifying the GHG balance of wetland systems.

1. Introduction

Investigations into global climate patterns and carbon cycles historically have recognized three overarching carbon pools consisting of marine and terrestrial environments, and the atmosphere (Tans et al., 1990; Sundquist, 1993; Canadell et al., 2007; Denman et al., 2007). Research associated with quantifying and modeling carbon pools (Tans et al., 1990; Fan et al., 1998; Pacala et al., 2001) has resulted in more refined efforts to segregate the terrestrial portion into major constituents such as soils, forests, agricultural lands, and inland aquatic ecosystems (Ciais et al., 1995; Houghton et al., 1999; Pacala et al., 2001; Bridgham et al., 2006, 2013; Euliss et al., 2006; CCSP, 2007; Sundquist et al., 2009; Zhu et al., 2010, 2011; Zhu and Reed, 2012; Byrd et al., 2013). As data have become available and coarse-scale models refined, a variety of studies have recognized the contribution of inland aquatic ecosystems (e.g., wetlands, peatlands, reservoirs) to the terrestrial carbon budget (Armentano and Menges, 1986; Gorham, 1991; Algesten et al., 2003; Bridgham et al., 2006, 2013; Cole et al., 2007; Downing et al., 2008; Battin et al., 2009). Despite this, soil organic carbon (OC) and greenhouse gas (GHG) flux data characterizing wetland ecosystems are relatively sparse, often region- or classification-specific, and associated with a high degree of uncertainty (Bridgham et al., 2006, 2013; Euliss et al., 2006; CCSP, 2007; Phillips and Beeri, 2008; Gleason et al., 2009; Badiou et al., 2011; Pennock et al., 2010; Finocchiaro et al., 2014).

The Prairie Pothole Region (PPR) of North America (Fig. 1) covers approximately 821,859 km^2 and includes portions of five U.S. states and three Canadian provinces (Gleason et al., 2008). The PPR is characterized by relatively small (often <5 ha), highly productive, mineral-soil wetlands dispersed throughout an agriculture-dominated landscape, and prairie pothole wetlands have potential to be important ecosystems in terms of the North American carbon balance (Bridgham et al., 2006; Euliss et al., 2006; Badiou et al., 2011). Studies from North America, including the PPR, have shown that minimally disturbed wetland catchments in native grasslands have relatively high soil OC levels, and soils of wetland catchments in an agricultural setting are capable of sequestering OC when restored to a similar natural state (Follett et al., 2001; Desjardins et al., 2005; Euliss et al., 2006; Gleason et al., 2008, 2011; Badiou et al., 2011). Consequently, natural resource organizations have promoted the benefits of conservation and restoration programs for moderating atmospheric GHG levels, as well as for providing numerous other ecosystem services (Gebhart et al., 1994; Litynski et al., 2006; Gleason et al., 2008; PCOR, 2008; Hansen, 2009; Brinson and Eckles, 2011; Gleason et al., 2011). However, abiotic conditions that promote OC sequestration in soils also can be conducive for the production of methane (CH_4), a potent GHG that may offset the benefits of increased

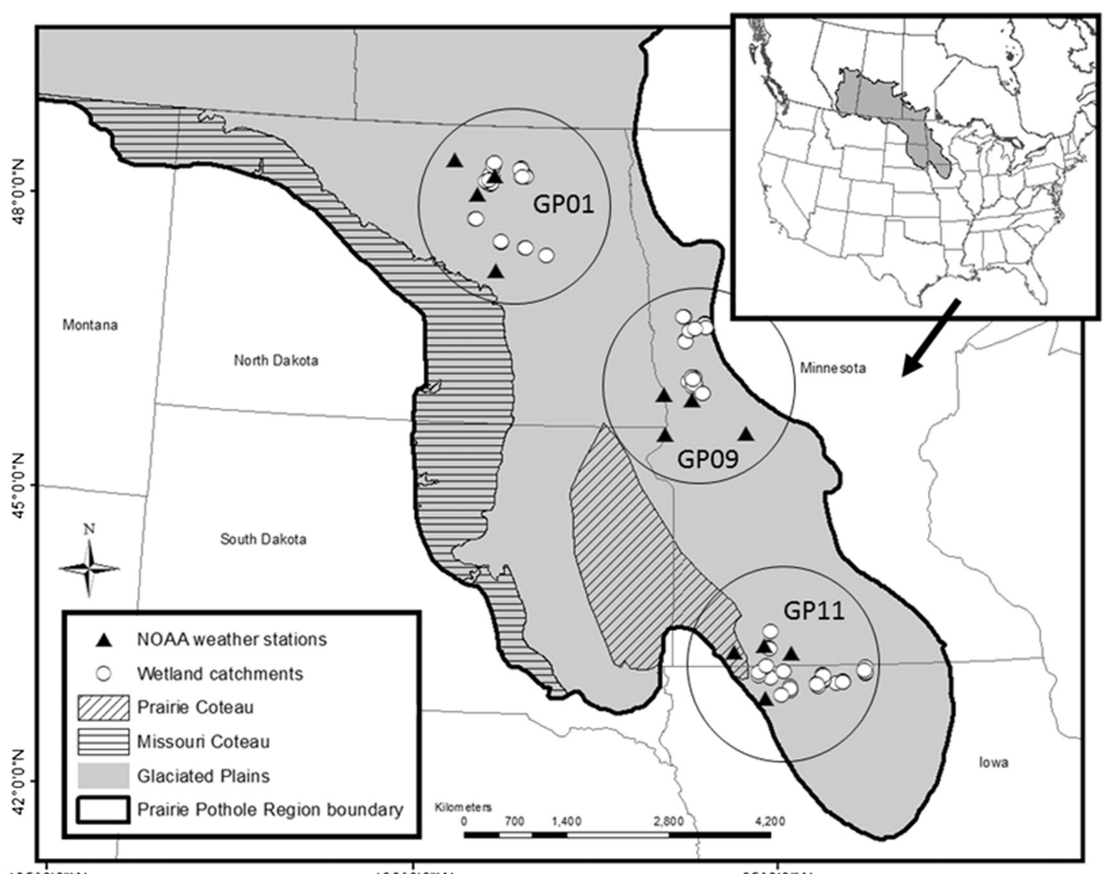


Fig. 1. Location of wetland catchments and National Oceanic and Atmospheric Administration (NOAA) weather stations within the three study points (GP01, GP09, GP11) in the glaciated plains area of the Prairie Pothole Region.