Geoderma 309 (2018) 41–49

Contents lists available at ScienceDirect

Geoderma

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

Topographic and physicochemical controls on soil denitrification in prior converted croplands located on the Delmarva Peninsula, USA

Xia Li[a], Gregory W. McCarty[b,*], Megan Lang[c], Thomas Ducey[d], Patrick Hunt[d], Jarrod Miller[d]

[a] Department of Geographical Sciences, University of Maryland, College Park, MD 20742, USA
[b] USDA ARS, Hydrology & Remote Sensing Laboratory, Beltsville, MD 20705, USA
[c] Fish and Wildlife Service, Falls Church, VA 22041, USA
[d] USDA ARS, Coastal Plains Soil, Water, and Plant Research Center, Florence, SC 29501, USA

ARTICLE INFO

Handling Editor: I. Kögel-Knabner

Keywords:
Topographic metrics
Soil texture
Soil chemistry
Denitrification potential
Denitrification capacity
Prior converted cropland

ABSTRACT

Topographic and soil physiochemical characteristics exert substantial controls on denitrification, and the effect of these controls is especially evident in fertilized agricultural lands. To depict these controls at a landscape scale for decision support applications, metrics (i.e., proxies) must be developed based on commonly available geospatial data. In this study, we carried out an observational study on denitrification potential (DP) and capacity (DC) in three actively farmed crop fields that were converted from forested wetlands (i.e., prior converted croplands). The combined effects of ten topographic and physiochemical factors, including three topographic attributes (relief, topographic wetness index, and positive openness), two soil texture indices (sand and clay), and five soil properties (soil moisture, pH, electrical conductivity, soil organic carbon and total nitrogen), on DP and DC were analyzed. The three topographic attributes were developed using a digital elevation model (DEM) derived from light detection and ranging (LiDAR) data. Nitrate and carbon addition led to a doubling in DP compared to DC without soil amendment. Topography explained the greatest amount of variation in DP across the three sites. The relationship between topography and DP may partly be explained through the relatively robust relationships between topography and soil moisture, texture, and carbon content. Soil electrical conductivity (EC) exhibited the highest correlation with DC (r^2 = 35%). DP and DC were higher under drought conditions with low soil moisture, relative to average conditions with relatively higher soil moisture, which may be related to the substantial increase in soil EC under drought conditions. However, DP and DC were less responsive to soil EC at sandy sites that tended to have low soil moisture. Results of this study suggest that the spatial-temporal variations in denitrification at these croplands were primarily caused by complex interactions between soil properties and landscape position. Topographic metrics derived from LiDAR data have the potential to improve understanding of denitrification variability at the landscape scale.

1. Introduction

Denitrification is the primary process supporting nitrate removal from terrestrial ecosystems (Knowles, 1982; Hunter et al., 2009). Under anaerobic conditions, nitrate (NO_3^-) is typically reduced to molecular nitrogen (N_2) and nitrous oxide (N_2O), which are subsequently emitted to the atmosphere. Denitrification is affected by three controlling factors, including oxygen, NO_3^-, and organic carbon (C) levels (Seitzinger et al., 2006; Palta et al., 2013). Usually, denitrification occurs when O_2 concentrations are < 0.2 mg L^{-1} and N_2 is the primary end product (Seitzinger et al., 2006). However, N_2O production relative to N_2 increases during denitrification if soil NO_3^- is elevated because NO_3^- is a preferred electron acceptor over N_2O. The denitrification process is also closely related to other parameters, such as soil C:N ratio, pH, and soil moisture (Ullah et al., 2005; Ruser et al., 2006; Morse et al., 2012; Hunt et al., 2014).

Wetlands have demonstrated high efficiency in removing nutrients, especially nitrate-nitrogen, from waters (Lowrance et al., 1997; Mayer et al., 2007; Ducey et al., 2015). In the United States (U.S.), about 53% of wetlands have been converted to other land use types over the past 100 years (Dahl, 1990). Large areas of wetlands have been drained and used as arable lands for crop cultivation (Johnston, 1994). Conversion of wetland to agricultural land substantially changes soil moisture conditions through fill, surface or sub-surface drainage (i.e., open ditches or tile drains), and/or high water consumption by agricultural plants (Blann et al., 2009; Murray et al., 2009; Li et al., 2016a; Li et al.,

* Corresponding author.
E-mail address: greg.mccarty@ars.usda.gov (G.W. McCarty).

http://dx.doi.org/10.1016/j.geoderma.2017.09.003
Received 21 February 2017; Received in revised form 31 August 2017; Accepted 3 September 2017

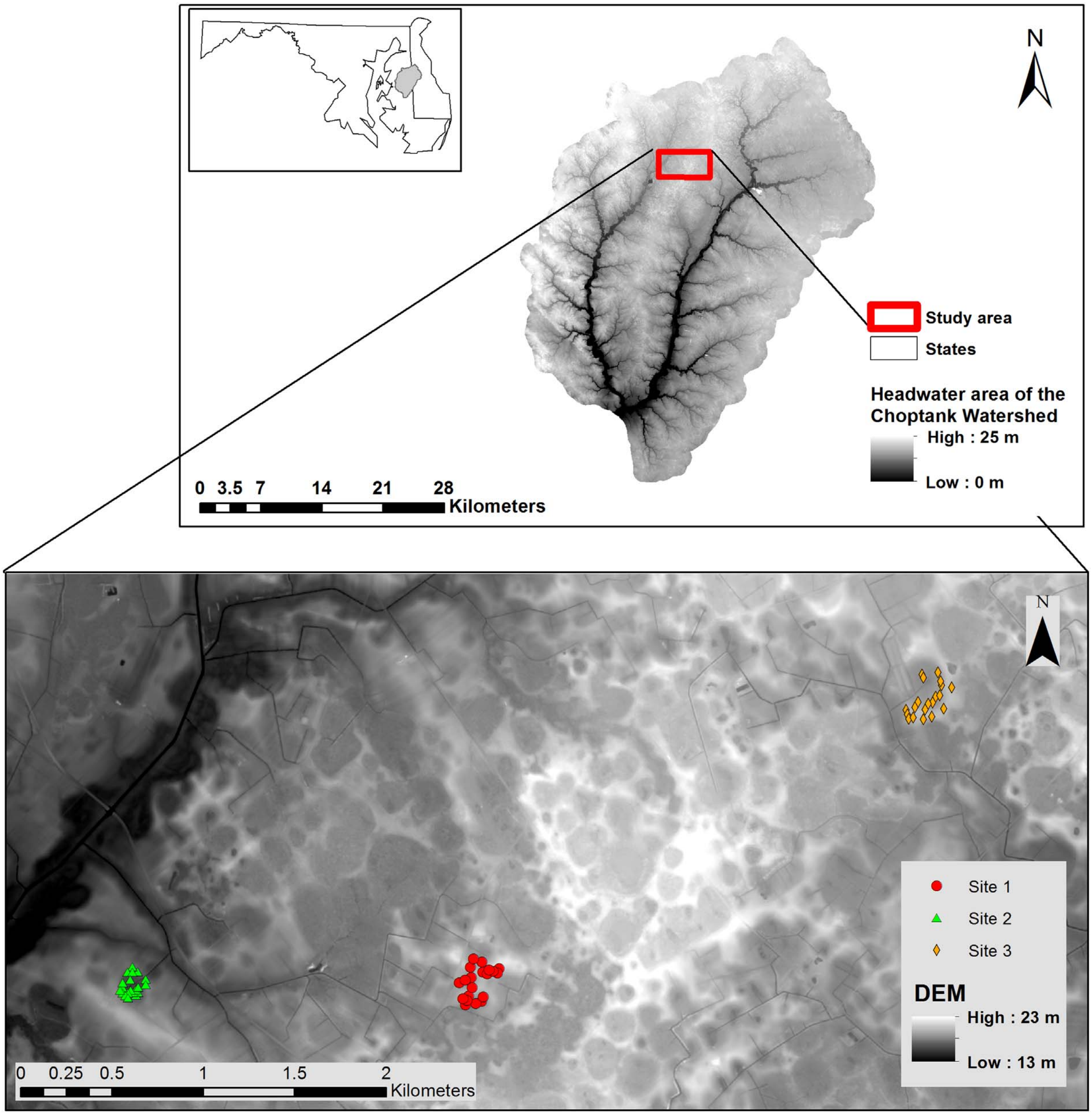

Fig. 1. Location of the study areas.

2017). Unlike hydric soils in wetlands that are usually in a state of low oxygen content (Mitsch and Gosselink, 2015), top soils in most agricultural lands are under aerobic conditions (Blann et al., 2009; Munch and Velthof, 2006). Extent of anaerobic conditions in agricultural land depends on multiple factors, including precipitation, irrigation, and soil texture, which influence soil volumetric water content (Munch and Velthof, 2006). Denitrification rates tend to be site- and time-specific due to variations in hydrologic conditions (Dobbie et al., 1999; Ruser et al., 2006).

In addition to soil properties, such as soil organic matter and soil moisture, the effect of topography on denitrification has received increasing attention because it may affect denitrification by controlling soil water saturation, texture, and biogeochemistry (Shaftel et al., 2012; Duncan et al., 2013; Anderson et al., 2014, 2015). Topography is often depicted using digital elevation models (DEMs), which can be generated using multiple data sources. One relatively new and rapidly developing data source is Light Detection and Ranging (LiDAR). Compared to traditional, non-LiDAR derived DEMs, data from LiDAR often provide more detailed and more accurate topographic information (Coren and Sterzai, 2006; Glenn et al., 2006).

Topographic metrics derived from DEMs have been developed to understand spatial-dependent processes in response to landscape morphology. Several studies have employed either topographic position or topographic wetness index (TWI) to investigate spatial variation in denitrification (Hunt et al., 2007; Duncan et al., 2013; Anderson et al., 2014, 2015). However, a single topographic attribute is not enough to obtain a robust understanding of topographic effects on denitrification (Florinsky et al., 2004). Based on the spatial scope of variables, there are three main groups of topographic attributes, including local topographic characteristics (surface geometry of a studied point), non-local topographic variables (relative position of a studied point on the surface), and combined topographic characteristics (local and nonlocal variables) (Florinsky, 1998). Topographic openness is a non-local topographic index which presents an angular surface measure and represents the topographic dominance or enclosure of any location in an irregular surface (Yokoyama et al., 2002; Smith and Clark, 2005;