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Effects of drainage duration on mineral wetland soils in a Prairie Pothole agroecosystem

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ABSTRACT

Recent flooding of agricultural land in the northern Prairie Pothole Region – coupled with intensification of agriculture – has resulted in renewed efforts to drain Prairie Potholes. Drainage is used to improve growing conditions and increase the amount of land that can be cultivated. The aim of this study was to determine if duration of agricultural drainage improved growing conditions and nutrient availability, by measuring physical (i.e. structure and bulk density) and chemical properties (i.e. C, N, and P). Forty-two wetlands and paired midslopes were selected in the Prairie Pothole Region in the Black soil zone of southeastern Saskatchewan. Drainage duration of wetlands ranged from 0 to 50 years. Results suggest drainage does improve growing conditions and nutrient availability for agricultural production, but these changes vary across wetlands drained for different durations of time. Compared with undrained soils, changes were greatest in soils drained from 20 to 34 years, but decreased after 36 years becoming more similar to cultivated midslope positions. Some drainage benefits include increased nitrification and greater available PO_4^{-3} at a depth of 0–15 cm. Phosphorus sorption decreased with drainage duration and P desorption increased in soils drained from 7 to 34 years. This could result in greater available N and P for crop uptake, but could also lead to greater nutrient losses. Additionally, bulk density increased and microaggregates decreased with drainage duration. Compared with undrained soils, drainage did not have a significant effect on macroaggregates, soil organic carbon, water extractable organic carbon, light fraction, total N, NO_3^-, and mineralization. It is likely other agricultural practices used in conjunction with drainage, such as tillage, fertilizer additions, and crop removal, are affecting how these soil properties change over time. The resulting quantitative data from this study provides an excellent resource for planning management strategies to improve nutrient use efficiency and reduce losses to the environment.

1. Introduction

The Prairie Pothole Region (PPR) is a valuable agricultural region covering the southern half of Saskatchewan and extending into Alberta, Manitoba, and the United States (Fig. 1; Cortus et al., 2009). One of the distinguishing characteristics of the PPR is its millions of small mineral wetlands, also known as sloughs or potholes, located within depressions of the hummocky landscape. Potholes provide many ecological services such as wildlife habitat, flood control, improved water quality, groundwater recharge, and carbon sequestration (Bedard-Haughn et al., 2006; Euliss et al., 2006; Neuman and Belcher, 2011). These wetlands are usually hydrologically connected only during spring following snowmelt, when they fill up and then spill into another nearby wetland (Spence, 2007; van der Kamp and Hayashi, 2009). Over the course of a growing season many of the smaller wetlands dry up and may even be cultivated during drier years. However, since 2010, northern and eastern Saskatchewan Prairies have been experiencing a wet period where these wetlands are remaining wetter for longer periods, expanding in size, and encroaching onto valuable farmland.

Saturated soils are unfavourable for plant growth due to anoxic conditions, restricted root growth, reduced nutrient availability, and increased salinity (Bedard-Haughn, 2009; Nangia et al., 2013). Waterlogged soils are also difficult to navigate large agricultural equipment through, which can delay seeding. Agricultural drainage is a common management practice used in more humid

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regions of the world to improve soil for crop production (Kleinman et al., 2015; Madramootoo et al., 2007; Montagne et al., 2009; Nangia et al., 2013). Drainage removes excess water from the soil creating aerobic conditions and warmer soil temperatures, which can increase decomposition. This has potential to change key soil fertility related physical and chemical properties, such as structure, bulk density, infiltration, and nutrient availability, ultimately increasing crop yields (Ewing et al., 2012; Hundal et al., 1976; Streeter and Schilling, 2015; Sullivan et al., 1998). Saturated soils and agricultural intensification in Saskatchewan have resulted in renewed efforts by farmers to drain wetlands (Brunet and Westbrook, 2012; Dumanski et al., 2015).

The common drainage method used in southeastern Saskatchewan is surface drainage since it is the most ideal for flat areas with a low hydraulic conductivity and for draining scattered depressions. Surface drainage is also less costly than subsurface tile drainage (Bedard-Haughn, 2009; Cortus et al., 2009; Fangmeier et al., 2006; Robinson and Rycroft, 1999). Surface drainage involves excavating open ditches between isolated wetlands to move water from one wetland to the next (Brunet and Westbrook, 2012). Unlike subsurface drainage that removes water from throughout the soil profile, surface drainage only removes water from the uppermost soil (Bedard-Haughn, 2009).

The greatest concerns regarding agricultural drainage are effects on water quality and downstream flooding. Drainage water can transport nutrients (i.e. N and P), salts, sediment, and bacteria that can contaminate drinking water, put stress on fish communities, and contribute to eutrophication. Eutrophication leads to hypoxia, toxic algae blooms and disruption to recreational use of water (Bedard-Haughn, 2009; Haygarth et al., 2013; Kleinman et al., 2015; Montagne et al., 2009; Randall and Goss, 2008; Tan and Zhang, 2011; Westbrook et al., 2011). Additionally, drainage can increase magnitude and frequency of flood events (Brunet and Westbrook, 2012; Dumanski et al., 2015). As a result of these concerns, the main focus of drainage research in Saskatchewan and globally has been on the water aspect of drainage. Research focusing on how drainage specifically affects soil physical and chemical properties is limited, and studies looking at long term effects of drainage are almost nonexistent (Bedard-Haughn, 2011; Montagne et al., 2009). Since drainage is used to improve soil fertility and agricultural production, research on how drainage directly affects soil properties is a knowledge gap that needs to be filled. Not only would this information be beneficial for determining if drainage is a suitable management practice for long-term soil quality, but it would also be beneficial for developing management strategies that could help minimize negative impacts associated with drainage.

Drainage research in Saskatchewan is limited and research from more humid areas of the PPR is not directly applicable due to different climate, drainage type (i.e. surface drainage), unique hydrology, and soils of the semi-arid to sub-humid PPR. Agricultural drainage is necessary in these regions and, given that low-lying areas tend to have higher nutrient and organic matter concentrations than surrounding uplands, drainage may create some of the best agricultural land. Since these wetland soils are so different from upland soils, understanding how drainage may change these poorly drained soils in comparison to upland soils is important from a management perspective and can help improve nutrient planning. The objectives of this study were to: (1) determine how drainage affects physical and chemical properties in the Black Soil Zone of Saskatchewan over time; and (2) determine if these drained soils become more similar to upland (midslope) soils in terms of properties and nutrient dynamics.

2. Materials and methods

2.1. Site and sampling design

Research was conducted in the Smith Creek Watershed (50°50′4″N 101°34′48″W), approximately 60 km southeast of Yorkton, Saskatchewan in the PPR (Fig. 1). The average wetland density is approximately 20 wetlands per km^2 (Brunet and

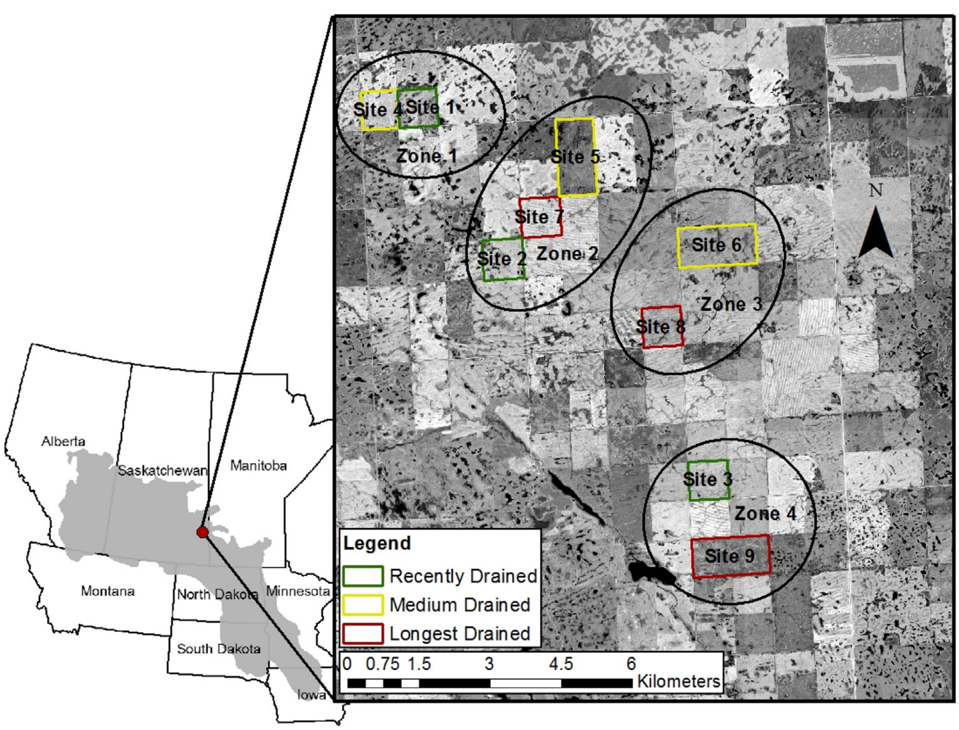

Fig. 1. Location of sites within the study area in the northern portion of the Smith Creek Watershed. The recently drained sites range in drainage duration of 7–15 years, medium drained: 20–34 years and longest drained: 36–50 years. Undrained wetlands were selected for each zone, except for zone 3 where no undrained wetlands remain.