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# Nutrient dynamics within drainage ditches under recent, medium, and long-term drainage in the Black soil zone of southeastern Saskatchewan

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ABSTRACT

Surface drainage ditches improve drainage and reduce in-field flooding, but have been implicated in loss of nutrients and reduction of downstream water quality. However, ditches may also assist in minimizing off-site nutrient losses via within-ditch nutrient cycling and retention. Drainage has been increasing in the sub-humid regions of the Prairie Pothole Region, but little work has been done to examine the nutrient dynamics associated with drainage under these climatic conditions. Therefore, the objectives of this study were to characterize within-ditch nutrient pools and processes as a function of drainage duration: recent (7–15 years), medium (20–34 years), and long-term (36–50 years). Pools and processes included: 1) soil organic (SOC) and inorganic (SIC) C and water-extractable organic carbon (WEOC); 2) macronutrient (N and P) concentrations by depth, within and adjacent to drainage ditches; and 3) within-ditch nutrient (N and P) storage, cycling, and release. Results indicated greater SOC storage in the ditch-slope (MS) and greater P storage within-ditch (D), and that nutrient storage, cycling, and release varied with the drainage ditch age. In particular, relative to medium (MD) and long-term drained (LD) sites, recently drained sites (RD) had lower potential N mineralization and nitrification, and higher P desorption, which suggested less potential N loss, but greater potential P loss. Overall, these results provide a basis for considering age-specific management practices and essential information to make agricultural drainage more sustainable.



## 1. Introduction

Agricultural drainage is widely used throughout the world to increase land available for farming (Beauchamp, 1987; Kinsman-Costello et al., 2014). Drainage, whether surface or subsurface, involves installation of drainage ditches that transport excess water, containing nutrients, downstream. As a result, drainage is a large contributor of N and P loading to downstream waterbodies having a negative effect on water quality (Guo and Ma, 2011; Kinsman-Costello et al., 2014; Ye et al., 2014). Previous drainage research has focused primarily on water quality issues (Montagne et al., 2009), with relatively little emphasis on how drainage might affect nutrient dynamics and other soil properties of the land, despite the fact that nutrient export in drainage water depends on both macro-climate and soil properties (Randall and Goss, 2008).

Ditch soil has the ability to behave as a source or sink of N and P as a result of various factors such as nutrient availability, sorption/desorption characteristics, and aerobic/anaerobic conditions (Andersson et al., 2015; Smith et al., 2015; Withers et al., 2005). Previous studies have examined N (Strock et al., 2007) and P (Dunne et al., 2007) cycling within ditches. Studies have also identified various within-ditch management practices that have potential to reduce N and P losses, such as the use of soil amendments (e.g., calcium carbonate that can bind with P) and controlled drainage (Dunne et al., 2007; Kleinman et al., 2015). However, nutrient cycling and the success of management practices vary across studies and are site specific (Kleinman et al., 2015). Since most of these studies were completed in warmer, more humid regions, such as the Midwestern US and Ontario, Canada, there is need to determine how drainage specifically affects within-ditch nutrients in the semi-arid to sub-humid northern Prairie Pothole Region (PPR; Fig. 1A).

The PPR, which spans the southern portion of the Prairie provinces of Canada and down into the northern United States (Fig. 1A), has an undulating to hummocky landscape containing millions of small wetlands scattered across prime agricultural land. These wetlands are typically inundated in the spring following snowmelt and dry up throughout the growing season (Brunet and Westbrook, 2012; van der Kamp and Hayashi, 2009). However, since 2010 to time of writing, there has been increased flooding and excess soil moisture in southeast Saskatchewan (Bedard-Haughn, 2009; Brimelow et al., 2014; Johnson et al., 2010). Furthermore, the northern Prairie region is expected to experience warmer and wetter conditions in the future. Historical data indicates Prairie temperature has increased by 1.6 °C (Bonsal et al., 2012) and precipitation across the whole PPR has increased by 9% over the

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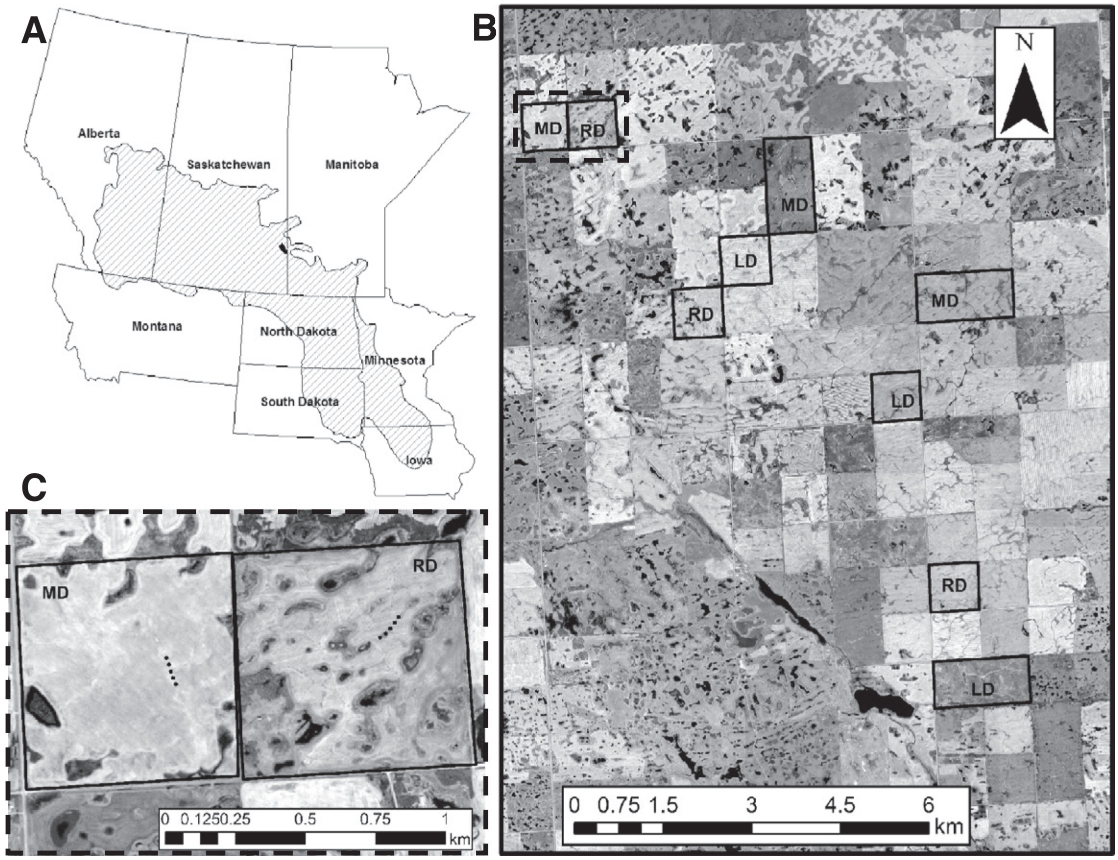


**Fig. 1.** A) The Smith Creek Watershed (indicated in black) in southeastern Saskatchewan where the study area was located. The shaded area represents the Prairie Pothole Region. B) The nine sites of different drainage durations (RD = recent, MD = medium, LD = long-term) that were selected. C) A close up view of a medium and recent drained site. The dots represent the points sampled along the selected ditch.

20th century (Millet et al., 2009; and Johnson et al., 2010). Consequently, the frequency and intensity of drainage installation have been increasing, highlighting the need for better understanding of nutrient dynamics to maximize productivity and minimize downstream water quality risk. In addition, there is a need to determine whether these dynamics change over time.

The aim of our study was to better understand ditch nutrient storage and dynamics as a function of drainage duration within the Smith Creek Watershed in the Black soil zone (based on the Canadian System of Soil Classification (Soil Classification Working Group, 1998)) of southeastern Saskatchewan. Objectives of this study were to: 1) determine if within-ditch soil carbon characteristics (quantity and quality) changed with drainage duration; 2) quantify macronutrient (N and P) pools by depth for both mid-ditch and ditch-slope soils; and 3) measure how the storage, cycling, and release of within-ditch N and P varied as a function of duration of drainage.

## 2. Materials and methods

### 2.1. Site description

The study area was located in the northern section of the Smith Creek watershed (50°50′4″N 101°34′48″W) in southeast Saskatchewan, Canada (Fig. 1). Climate is semi-arid, with mean temperature of −17.9 °C in winter and 17.8 °C in summer (Brunet and Westbrook, 2012). Mean annual precipitation (1981–2010) is 449 mm (Government of Canada, 2016). This watershed was of interest due to previous hydrological research and the extensive drainage that has occurred in this area. The wetland density here is high (average 20 wetlands $km^{-2}$) and, over the past 50 years, more than half of the wetlands have been drained (Brunet and Westbrook, 2012; Pomeroy et al., 2014). Surface drainage is the common type of drainage installed here; open ditches are used to connect wetlands and move water downstream. Based on the Canadian System of Soil Classification (Soil Classification Working Group, 1998), upland soils are dominated by the Chernozemic Order and depressions by the Gleysolic Order. The Chernozemic order is approximately equivalent to Haplic Calcisols or Calcic Chernozems, and the Gleysolic Order to Mollic Luvic or Mollic Gleysols according to the World Reference Base (IUSS Working Group, 2006).

### 2.2. Soil sampling

In fall 2014, nine sites were selected and grouped into drainage categories based on drainage duration: recently drained (RD) (7–15 years), medium drained (MD) (20–34 years), and long-term drained (LD) (36–50 years) (Fig. 1B). These sites were selected with the use of air photos and soil maps. The sites had a similar historical land use (cropped) and parent material (glacial till). Within each site, a 100 m segment of ditch was selected; this segment was representative of ditches within the field in its slope contouring (steep/gentle). In each segment, three to five sampling locations were selected (total: 37 sampling locations) (Fig. 1C). The initial goal was to sample five per segment, but this was reduced to three due to weather constraints. All ditches were gently sloping (0–5% slope), u-shaped, cultivated (seeded through), and had no standing water at the time of sampling. One within-ditch (mid-ditch, D) sample was taken from the bottom of ditch, and the paired ditch-slope (MS) sample was taken 5 m upslope of the D sample. Soil