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Soil physical quality varies among contrasting land uses in Northern Prairie regions

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ABSTRACT

Conversion of native grassland to other agricultural land uses can alter soil properties such as organic matter, but little is known about how this impacts soil physical quality indicators in the mixedgrass and aspen parkland natural subregions of the Canadian prairies. This study evaluated soil physical properties in three land use systems (native grasslands, introduced pastures and annual croplands) at seven sites across south-central Alberta, Canada. Hydraulic conductivity (K), pore size fractions and S-index were derived from moisture retention curves measured using a HYPROP system. Fractal aggregation was determined from the mass-diameter relationship of soil aggregates (0.25–8 cm diameter) using 3D laser scanning. All our results, except for K, showed a consistent trend of soil quality differences in the following ranking: native grassland > introduced pasture > annual cropland. Relative to croplands, introduced pastures led to an increase from 9 to 12% in medium-size pores (as median volume fraction of 9–50 μm diameter), whereas this pore fraction in native grassland was 19% ($Ps < 0.001$). The S-index also detected clear differences in soil quality among land uses, ranging from very low values in annual cropland (0.020), to intermediate in introduced pasture (0.033), and the greatest in native grassland (0.048). Similarly, native grassland had the most frequent and significant fractal aggregation results, indicating a well-developed hierarchical soil structure under native grassland. Certain dynamic soil properties were associated with inherent soil properties; for example, water content at saturation and K were both correlated with clay content (correlation coefficients $\geq$ 0.89*). Our results suggest that S-index, fractal aggregation and medium-size pore abundance are robust soil physical quality indicators sensitive to contrasting agricultural land uses in northern temperate prairies.

1. Introduction

Concerns about increasing land degradation and the associated loss of long term productivity substantiate the need to improve agroecosystem management to maintain underlying soil quality (Shahab et al., 2013). Agricultural landscapes can provide a wide range of ecosystem services (i.e., flood mitigation, carbon sequestration, biodiversity conservation, food and biomass production) (Franzluebbers et al., 2014; Naidoo et al., 2008; Shukla et al., 2006), and earlier research has emphasized the importance of soil quality on maximizing these services (Andrews et al., 2004). Developing indicators of soil quality can inform land stewardship and improve sustainability (Andrews et al., 2002; Karlen et al., 2014). It has been difficult to characterize soil quality across agricultural landscapes due to broad edaphic and climatic variability. Additionally, land use management has been shown to impact soil quality by altering the dynamic properties of soil such as variations in pore-size fractions which govern water flow and storage capacity (Bodhinayake and Si, 2004; Zhou et al., 2008).

Soil quality can be characterized by selecting properties that are known to be sensitive to management effects, and hence are useful indicators of ecosystem performance and function (Karlen et al., 2001). In the case of soil physical properties, insightful quality indicators are those related to soil aggregation, structure, macroporosity and associated processes such as water movement and air

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exchange (Reynolds et al., 2009; Shahab et al., 2013). These physical properties and functions largely integrate the chemical and biological components and responses of soil to management, as well as their associated plant productivity (Dexter 2004; Shukla et al., 2006). Quantification of soil quality has been lacking and remains a key goal in agricultural management; new soil health

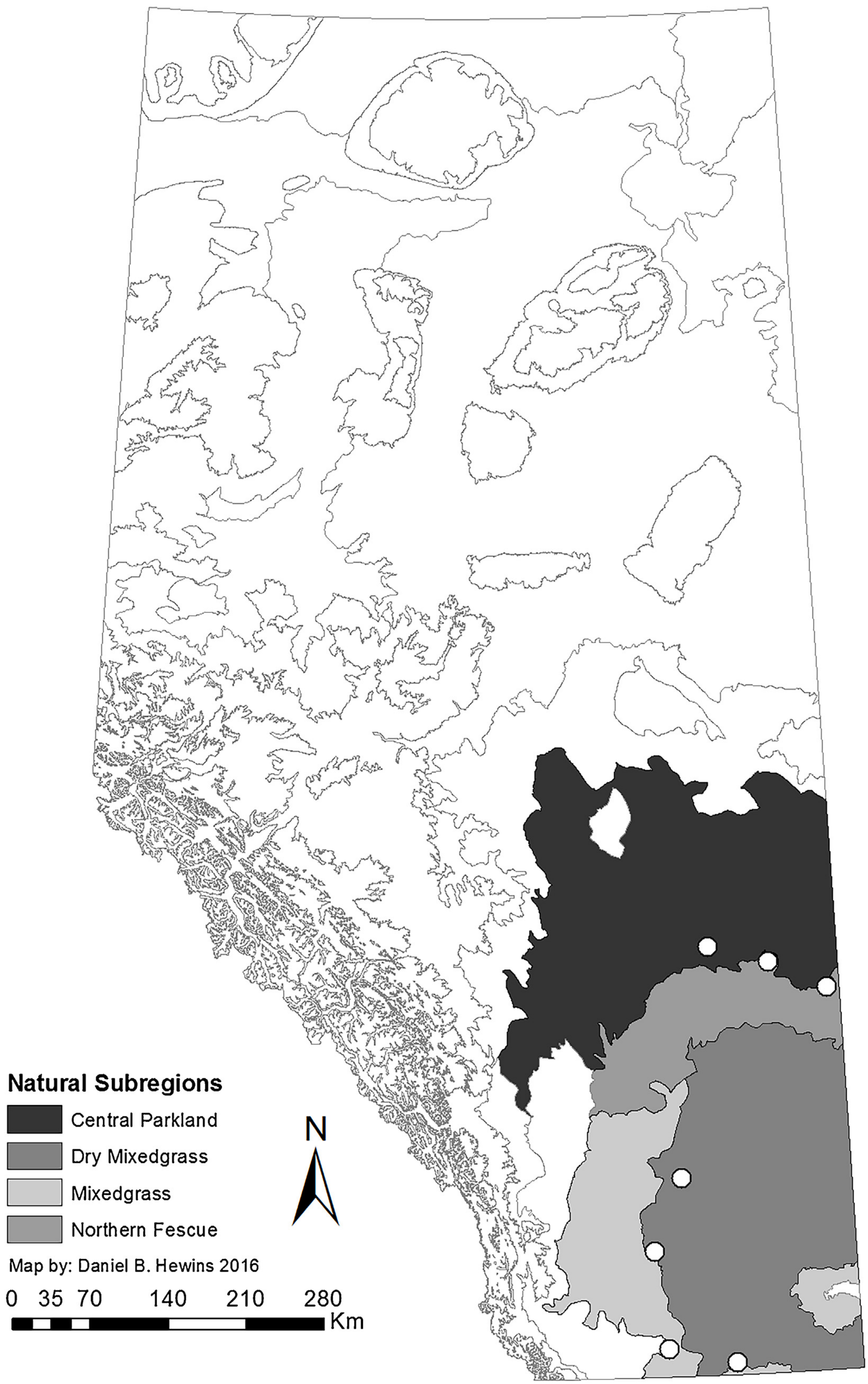

Fig. 1. Location of experimental sites as open circles within the mixedgrass and parkland natural sub-regions in south-central Alberta, Canada.