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Synthesis

Land Management History of Canadian Grasslands and the Impact on Soil Carbon Storage

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Abstract

Grasslands represent a large potential reservoir in storing carbon (C) in plant biomass and soil organic matter via C sequestration, but the potential greatly depends on how grasslands are managed, especially for livestock and wild animal grazing. Positive and negative grazing effects on soil organic carbon have been reported by various studies globally, but it is not known if Canadian grasslands function as a source or a sink for atmospheric C under current management practices. This article examines the effect of grassland management on carbon storage by compiling historical range management facts and measurements from multiple experiments. Results indicate that grazing on grasslands has contributed to a net C sink in the top 15-cm depth under current utilization regimes with a removal rate of CO_2 at 0.19 ± 0.02 $Mg \cdot C \cdot ha^{-1} \cdot yr^{-1}$ from the atmosphere during recent decades, and net C sequestration was estimated at 5.64 ± 0.97 $Mg \cdot C \cdot ha^{-1}$ on average. Naturalization of 2.3 M ha of previously cultivated grasslands in the 1930s has also led to C sequestration in the Canadian prairies but has likely abated as the pool has saturated. Efforts made by researchers, policymakers, and the public has successfully led to the restoration of the Canadian prairies to a healthier state and to achieve considerable C sequestration in soils since their severe deterioration in the 1930s. In-depth analysis of management, legislation, and agricultural programs is urgently needed to place the focus on maintaining range health and achieving more C storage in soils, particularly when facing the reduced potential for further C sequestration.

Key Words: Canadian grazing grasslands, cultivation abandonment, grassland carbon restoration, grassland deterioration, naturalized grasslands, soil carbon sequestration

INTRODUCTION

Carbon dioxide concentration in the atmosphere has increased by 100 $\mu mol \cdot mol^{-1}$ during the last 150 yr (Morgan et al. 2004), which has contributed to climate change in the last century (Woodwell et al. 1995). Natural and managed ecosystems, however, offer opportunities to mitigate CO_2 release due to the vast potential of C storage in soil given their large geographic distribution (Bagchi and Ritchie 2010). It has been estimated that adopting improved land management practices has the potential to offset up to one-third of global greenhouse gas emissions annually (Lal 2004). Carbon sequestration can also provide a positive feedback to the ecosystem through improved soil quality and reduced soil erosion (Derner and Schuman 2007).

Grasslands represent the largest land resource in the world, occupying 40% of the earth's land surface (Wang and Fang 2009) and storing over 10% of terrestrial biomass C and nearly 30% of the global soil organic carbon (SOC) stock (Scurlock and Hall 1998). Many grassland areas have suffered losses of SOC over recent decades due to intensive grazing and agricultural use and thus may have a large potential to sequester lost C back into the soil (Reid et al. 2004). Schlesinger (1997) reported that grasslands globally sequester C in soil at a rate of $0.5\ Pg \cdot C \cdot yr^{-1}$. Although the rate is far lower than in improved croplands and pastures, the contribution of grasslands in terrestrial C storing accounts for a significant C sequestration given the large area of land resources and minimal requirement of inputs (Derner and Schuman 2007). Grasslands C sequestration can be influenced by many factors, such as biome composition, climate change (Conant et al. 2001), and management practices (Jones and Donnelly 2004). Grazing has been treated as a major influence on grassland C sequestration due to the expansive use of this practice and the large potential to store SOC globally (Olff et al. 2002).

Originally, the natural grasslands of Canada covered about 61 500 000 ha, which extended across broad areas of Alberta, Saskatchewan, and southern Manitoba (Clayton et al. 1977). At present, residual grasslands occupy only less than 11 000 000 ha, and their distribution is highly geographically fragmented (Statistics Canada 1991–2011). Fifty million hectares of the original natural grassland have been cultivated with wheat and other crop production and urban expansion. The primary use of the remaining natural grasslands is for the grazing of domestic livestock and wildlife. Other natural grasslands are conserved by the Crown and through pasture maintenance, national parks, and military installations, which are estimated to represent 1 540 000 ha in total (McCartney and Horton 1999).

The initial cultivation of grasslands resulted in large losses of SOC. Studies have reported that between 20% and 60% of

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