Available online at www.sciencedirect.com
SCIENCE DIRECT®
Soil & Tillage Research 89 (2006) 78–85
Soil & Tillage Research
www.elsevier.com/locate/still

Management effects on soil CO_2 efflux in northern semiarid grassland and cropland

A.B. Frank *, M.A. Liebig, D.L. Tanaka

USDA, Agricultural Research Service, Northern Great Plains Research Laboratory, Box 459, Mandan, ND 58554, USA

Received 13 October 2004; received in revised form 16 June 2005; accepted 24 June 2005

Abstract

Soil respiration is a process influenced by land use, management practices, and environmental conditions. Our objectives were to evaluate relationships between management-induced differences in soil organic carbon (SOC) and soil CO_2 efflux from continuous no-till spring wheat (*Triticum aestivum* L.), spring wheat-fallow under no-till, and a native mixed-grass prairie with grazing near Mandan, ND. A Werner–Sen–Chama soil complex (Entic Haplustoll, Typic Haplustoll, and Typic Calciustoll) was present at the grassland site and a Wilton silt loam (Pachic Haplustoll) at the cropping sites. Soil chambers were used to measure soil CO_2 effluxes about every 21 days starting 14 May 2001 to 1 April 2003. Soil water and soil temperature were measured at time of CO_2 efflux measurements. Soil organic carbon, microbial biomass carbon (MBC), and above and belowground plant biomass were measured in mid-July each year. Root biomass to 0.3 m depth of the undisturbed grassland was significantly greater (12.3 Mg ha^{-1}) than under continuous wheat (1.3 Mg ha^{-1}) and wheat-fallow (0.3 Mg ha^{-1}). Grassland SOC content of 84 Mg ha^{-1} to 0.3 m soil depth was 1.2 times greater than continuous wheat and 1.3 times greater than wheat-fallow. The MBC of the grassland was 2.2 Mg ha^{-1}, or 3.6 times greater than continuous wheat and 7.2 times greater than wheat-fallow treatments. Soil CO_2 efflux averaged 2.8 g CO_2–C m^{-2} day^{-1} for grassland, compared to 1.9 g CO_2–C m^{-2} day^{-1} for wheat fallow and 1.6 g CO_2–C m^{-2} day^{-1} for continuous wheat treatments. Although these CO_2 efflux rates were based on measurements made at intervals of about 21 days, the differences among treatments with time were rather consistent. Differences in soil CO_2 efflux among treatments could be attributed to differences in SOC and MBC, suggesting that land use plays a significant role in soil CO_2 efflux from respiration.
Published by Elsevier B.V.

Keywords: Soil respiration; Soil organic carbon; Microbial biomass; No-till; Wheat

1. Introduction

Land use influences soil organic carbon (SOC) content. Conversion of grasslands in the Great Plains of the USA to cultivated cropland has resulted in loss of 15–30% of soil organic matter (Davidson and Ackerman, 1993). Adoption of minimum- and no-till

Abbreviations: C, carbon; MBC, microbial biomass carbon; SOC, soil organic carbon

* Corresponding author. Tel.: +1 701 667 3007; fax: +1 701 667 3054.
E-mail address: franka@mandan.ars.usda.gov (A.B. Frank).

0167-1987/$ – see front matter. Published by Elsevier B.V.
doi:10.1016/j.still.2005.06.009

practices has partly reversed the trend in SOC losses observed under conventional tillage using moldboard plow (Fortin et al., 1996; Dao, 1998; Curtin et al., 2000). In tillage systems, residue management affects soil CO_2 efflux by altering soil temperature and water content, both of which affect microbial population and activity (Doran, 1980; Rochette et al., 1991; Fortin et al., 1996). Soil carbon (C) loss in a conservation tillage system, where soil erosion is nonexistent, is almost entirely the product of root and microbial respiration. Grassland often contains higher amount of SOC than cultivated cropland mainly due to the absence of disturbance and an extensive fibrous root system.

Soil respiration is the process whereby CO_2 evolves from the soil surface from metabolic activity of soil microbes and roots. Reduction in soil disturbance greatly reduces soil respiratory C efflux (Rochette et al., 1991; Fortin et al., 1996; Reicosky, 1997; Dao, 1998; Curtin et al., 2000; McGinn and Akinremi, 2001) and along with C supply are the major factors determining the magnitude of soil respiration (Carpenter-Boggs et al., 2003; Lohila et al., 2003; Wang et al., 2003). Tillage practices alone strongly affect soil CO_2 efflux. Examples include: comparisons of no-till and conventional tillage to permanent grass fields showed about 50% lower soil respiration in the tillage treatments and about 50% greater microbial biomass in the grass fields (Carpenter-Boggs et al., 2003); soil CO_2 efflux during a 60-day period following a wheat crop (*Triticum aestivum* L.) was twice as great under moldboard plow tillage than no-till (Dao, 1998); small grain cropping systems in eastern Canada had soil CO_2 efflux rates 75 g C m^{-2} $year^{-1}$ greater under conventional tillage than no-till (Fortin et al., 1996); and soil CO_2 efflux was lower under continuous cropping than in a crop-fallow system under no-till due to slower decomposition of residues near the soil surface and reduced soil temperatures (Curtin et al., 2000).

Soil CO_2 efflux rates may also vary with crop species used. Daily soil respiration rates under barley (*Hordeum vulgare* L.) were nearly twice that of fallow; a result attributed to the presence of roots and higher microbial activity under barley than fallow (Akinremi et al., 1999). Soil CO_2 efflux from grasslands is generally greater than for annual crop systems. A comparison study of two grassland sites and a sorghum crop showed CO_2 efflux of 450 g C m^{-2} $year^{-1}$ from bermudagrass [*Cynodon dactylon* (L.) Pers] and 650 g C m^{-2} $year^{-1}$ from native prairie compared to 60 g C m^{-2} $year^{-1}$ from sorghum [*Sorghum bicolor* (L.) Moench] (Dugas et al., 1999). Grazing also influences soil CO_2 fluxes. A grazed mixed-grass prairie had higher efflux rates (4.3 g C m^{-2} day^{-1}) than a non-grazed mixed-grass prairie (3.5 g C m^{-2} day^{-1}) (Frank et al., 2002). Recapture of CO_2 by crops is important to net ecosystem C loss as shown when soil respiration from a corn (*Zea mays* L.) field was equivalent to about 30% of net CO_2 assimilation from photosynthesis during the growing season (Rochette and Flanagan, 1997).

There is a need to better understand seasonal respiratory CO_2 losses from soils that differ in management-induced SOC. More information is needed on rates of CO_2 efflux during the dormant period for grassland and non-crop period for cropland. Such understanding will provide information on how management practices influence net C exchange, and therefore, their role to mitigate, or contribute to, the greenhouse effect. Accordingly, we sought to evaluate soil CO_2 efflux over two crop years for a Northern Great Plains semiarid mixed-grass prairie, and continuous wheat and wheat-fallow cropping systems under no-till management. The primary objectives of this study were to (1) determine the seasonality and rates of soil CO_2 efflux from sites differing in management and SOC and (2) identify relationships of biotic (plant biomass, SOC, and microbial biomass carbon (MBC)) and abiotic (SWC and soil temperature) factors governing soil respiration.

2. Materials and methods

2.1. Site description

Study sites were located at the USDA, Agricultural Research Service, Northern Great Plains Research Laboratory at Mandan, North Dakota, USA (latitude 46°46′N, longitude 100°55′W; elevation 518 m; mean annual precipitation 404 mm; mean daily air temperature 5 °C). Treatments were a 40 ha grazed mixed-grass prairie (grassland), 0.5 ha continuous spring wheat with no-till management, and 0.5 ha spring wheat-fallow with no-till management. The two cropping sites were located approximately 3 km west of the grassland site.