INTENSIVE TILLAGE AS A MECHANISM FOR CO_2 EMISSION FROM AGRICULTURAL SOILS

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ABSTRACT

Agricultural ecosystems can play a significant role in production and consumption of greenhouse gases, specifically, carbon dioxide (CO_2). Information is needed on the mechanism and magnitude of gas generation and emission from agricultural soils with specific emphasis on tillage mechanisms. This work reviews effect of different tillage methods on the short-term CO_2 and H_2O vapor flux from clay loam soils high in soil organic carbon (C) in the northern corn belt of the U.S. [*Reicosky and Lindstrom*, 1993, 1995; *Reicosky*, 1997, 1998]. The soil CO_2 flux was measured one minute after the tillage using a large, portable chamber as described by *Reicosky and Lindstrom* [1993]. The four tillage methods were moldboard plow (MP) only, moldboard plow plus disk harrow twice, disk harrow and chisel plow using standard tillage equipment following a wheat (T. Aestivum L) crop compared with no tillage (NT). The CO_2 flux was measured with a large portable chamber commonly used to measure crop canopy gas exchange initiated within one min. after tillage and continued intermittently for 19 days. The C released as CO_2 during the 19 days following the moldboard plow, moldboard plow plus disk harrow, disk harrow, chisel plow and not tilled treatments would account for 134%, 70%, 58%, 54% and 27% respectively of the carbon in the current year's crop residue. *Reicosky* [1998] determined the impact of strip tillage methods on CO_2 and H_2O loss after five different strip tillage tools and no-till. The highest CO_2 fluxes were from the moldboard plow and subsoil shank tillage. Fluxes from both slowly declined as the soil dried. The least CO_2 flux was measured from the no-till treatment. The other forms of strip tillage were intermediate with only a small amount of CO_2 detected immediately after the tillage operation. These results suggest that the CO_2 fluxes appear to be directly and linearly related to the volume of soil disturbed. The narrower and shallower soil disturbance caused less CO_2 and H_2O loss suggest that the volume of soil disturbed must be minimized to reduce C loss and impact on soil and air quality. The short-term CO_2 loss five hours after four conservation tillage tools was only 31% of that of the moldboard plow. The moldboard plow lost 13.8 times as much CO_2 as the soil area not tilled while different conservation tillage tools lost only 4.3 times. The smaller CO_2 loss following conservation tillage tools is significant and suggests progress in developing conservation tillage tools that can enhance soil carbon management [*Reicosky*, 1997].

Much of the previous research reviewed on tillage-induced C losses used a dynamic chamber that may affect natural CO_2 fluxes due to the "chamber effect". Concern for possible "chamber effects" on soil gas fluxes led to a study to qualitatively evaluate tillage-induced CO_2 loss from a plowed line source without using the portable dynamic chamber. Pressure fluctuations associated with turbulent mixing required for sampling uniformity and the tillage-induced change in soil air permeability brings uncertainty to the meaning of soil gas fluxes measured with dynamic chambers *Reicosky* [2003]. The tillage-induced change in soil properties led to short-term CO_2 losses that were higher than those from undisturbed soil. Changes in surface soil properties caused by tillage combined with the aerodynamic pressure forces associated with natural wind movement over the soil can result in substantial CO_2 loss. The large differences in CO_2 and H_2O loss between MP and NT treatments were likely caused by tillage in combination with wind speed effects in the chamber. *Denmead and Reicosky* [2003] compared chamber measurements of soil CO_2 flux after tillage with those calculated simultaneously by novel, non-disturbing, micrometeorological techniques suitable for small treated areas. Three meteorological techniques were employed: one using a line-source solution, one using a solution for a semi-infinite strip, and one using a backward Lagrangian stochastic model. Inputs were measurements of wind speed and gas concentrations on upwind and

downwind edges of the treated area at 0.2m above the surface. Chamber and micrometeorological measurements were made for 1h before and 2h after plowing. There was good quantitative agreement between all three micrometeorological methods for both CO_2 and H_2O vapor fluxes, but the agreement between them and the chamber was variable, depending on the wind speed. All methods agreed at a wind speed (at 0.25m) of 2.27 m s^{-1}, but the chamber gave higher fluxes when the wind speed was less than that value and lower fluxes above it. Interestingly, the "wind" speed within the chamber is a constant 2.2 m s^{-1}. Wind speed has a large effect on gas fluxes from the tilled soil, particularly in the early stages of the emission. It is suggested that the micrometeorological techniques employed in this study provide attractive alternatives to chambers or could be used to calibrate "chamber effects".

Further investigation evaluated the effect of no till, deep plowing and wind speeds on the soil CO_2 concentration in muck soils. Miniature infrared gas analyzers were installed at 30 cm in muck soil plowed and not tilled. Loosening the soil with the Harrell Switch Plow (HSP) to 42 cm resulted in a very rapid decline in CO_2 concentration as a result of "wind-induced" gas exchange from the soil surface. Higher wind speeds during mid-day resulted in a more rapid loss of CO_2 from the HSP than from the NT plots that appeared independent of barometric pressure fluctuations. The subtle temporal trend in the NT plots was similar, but much lower in magnitude. Tillage-induced change in soil air permeability enabled wind speed to affect the gas exchange and soil CO_2 concentration at 30 cm, literally drawing the CO_2 out of the soil resulting in a rapid decline in the CO_2 concentration and likely a subsequent increase in the oxygen concentration. Carbon dioxide concentrations in the NT plots averaged about 3.3% CO_2 while the average concentration in the plowed plots was about 1.4% at the end of the study. Wind and associated aerodynamic pressure fluctuations have a definite effect on gas exchange from soils, especially tilled muck soils with very low bulk densities and high soil air permeabilities.

While the short-term tillage-induced CO_2 release measured with a large portable chamber may be open to question providing only relative differences between tillage methods, the absolute CO_2 fluxes are strongly controlled by tillage-induced changes in soil physical properties and aerodynamic forces causing gas exchange. The short-term cumulative CO_2 loss was related to the soil volume disturbed by the tillage tools. The smaller CO_2 loss from strip tillage and conservation tillage tools was significant and suggests progress in equipment development for enhanced soil C management. Conservation tillage reduces the extent, frequency and magnitude of mechanical disturbance caused by the moldboard plow and reduces the large air-filled soil pores to slow the rate of gas exchange and C oxidation. The results demonstrated a need for better understanding of chamber effects, improved soil management and policies that favor less intensive tillage to minimize C loss and increased C sequestration in agricultural production systems.

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