Carbon input and soil carbon dioxide emission affected by land use and management practices

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Abstract
Land use and management practices may influence carbon inputs and soil CO_2 emissions, a greenhouse gas responsible for global warming. C inputs and soil CO_2 emissions were monitored from crop and grassland with various irrigation and cropping systems from 2006 to 2008 in western North Dakota, USA. Treatments were two irrigation systems (irrigated and non-irrigated) and six cropping systems [conventional-tilled barley with N (CTBFN), conventional-tilled barley with no N (CTBON), no-tilled barley-pea with N (NTB-PN), no-tilled barley with N (NTBFN), no-tilled barley with no N (NTBON), and no-tilled Conservation Reserve Program (grassland) (NTCRP)]. Crop residue C was greater in irrigated than in non-irrigated systems and greater in CTBFN and NTBFN than in other cropping systems. Soil CO_2 flux varied with time of measurement in various irrigation and cropping systems. Total CO_2 flux from May to October was greater in irrigated than in non-irrigated systems and greater in NTCRP than in other treatments. Differences in crop C inputs, root and soil respiration, and soil temperature and water content can result in variations in CO_2 emissions among management practices and land use.

Key Words
Carbon dioxide, cropping system, irrigation, nitrogen fertilization, residue carbon, tillage.

Introduction
Emission of CO_2 from soils under cropland and grassland contributes a significant source of greenhouse gas responsible for global warming (Duxbury 1994). The emission occurs due to root and soil respiration and organic matter mineralization (Curtin *et al.* 2000; Sainju *et al.* 2008). In contrast, soil is also an important sink of atmospheric CO_2 which is absorbed by plant biomass through photosynthesis and converted into soil organic matter after the residue is returned to the soil (Lal *et al.* 1995). Management practices, such as irrigation, tillage, cropping system and N fertilization can alter crop residue C inputs, nutrient dynamics, and soil temperature and water contents that influence soil surface CO_2 emissions (Curtin *et al.* 2000; Al-Kaisi and Yin 2008; Sainju *et al.* 2008).

Materials and methods
The experiment was conducted in western North Dakota in a sandy loam soil. Treatments consisted of two irrigation systems (irrigated and non-irrigated) as main plot and six cropping systems (CTBFN, CTBON, NTB-PN, NTBFN, NTBON, and NTCRP) as split-plot treatments in a randomized block design with three replications. Malt barley and pea were planted in April and harvested in October. The NTCRP treatment consisted of mixed alfalfa and grasses (crested wheatgrass and western wheatgrass) that were self regenerated. Plant biomass was measured from two 0.5 m^2 areas and crop grain yield was determined with a combine harvester. After harvesting grains in croplands, biomass residue (stems + leaves) were returned to the soil. In NTCRP treatment, grass biomass was allowed to self recycle in the soil. Soil surface CO_2 flux was measured from 9 A.M. to 12 A.M. every week from April to October, 2006 to 2008, with an Environmental Gas Monitor chamber containing an infrared CO_2 analyzer attached to a data logger (PP System, Haverhill, Massachusetts, USA). The chamber was placed at the soil surface for 2 min in each plot until CO_2 flux measurement was recorded in the data logger. At the time of measurement, soil temperature at the 0-15 cm depth was measured with a probe attached to the data logger and soil water content was determined gravimetrically by collecting field-moist soil sample and oven drying at 105^{o}C.

Results and discussion
Crop residue C differed significantly among treatments (Table 1). Under irrigated condition, residue C was greater in CTBFN than in other cropping systems, except in NTBFN. Under non-irrigated conditions, residue C was greater in CTBFN, CTBON, and NTBFN than in NTBON and NTCRP. Averaged across cropping systems, residue C was greater in irrigated than in non-irrigated systems. Similarly, averaged across

Table 1. Effect of irrigation and cropping system on crop residue C input averaged across years.

Cropping system†	Irrigation (Mg C/ha)		
	Irrigated	Non-irrigated	Mean
CTBFN	2.42aA‡	1.72aB	2.07a
CTBON	1.31cA	1.40aA	1.36c
NTB-PN	1.88bA	1.35abB	1.61b
NTBFN	2.25abA	1.63aB	1.94a
NTBON	1.01cA	0.98bcA	0.99d
NTCRP	1.12cA	0.69cB	0.90d
Mean	1.67A	1.29B	
Contrasts			
Till vs. no-till			0.25*
N fertilization vs. no N fertilization.			0.83***
Cont. barley vs. barley-pea in no-till			0.33*
Cropping vs. grasses in no-till			0.69***

irrigation system, residue C was greater in CTBFN and NTBFN than in other cropping systems. Residue C was greater with tillage than with no-tillage, greater with N fertilization than without, greater with continuous barley than barley-pea, and greater with crops than with grasses. Soil surface CO_2 flux varied with measurement dates from April to October 2007 among cropping systems (Figure 1). The flux was normally greater with NTCRP than with other cropping systems from April to July. Greater fluxes in all cropping systems were observed immediately following substantial rainfall in June and July (Figure 2), a result of increased microbiological activity due to increased soil water content and temperature (Figure 1). Similar results were obtained in 2006 and 2008. The flux was also greater with irrigation than without at most measurement dates, probably due to increased water availability.

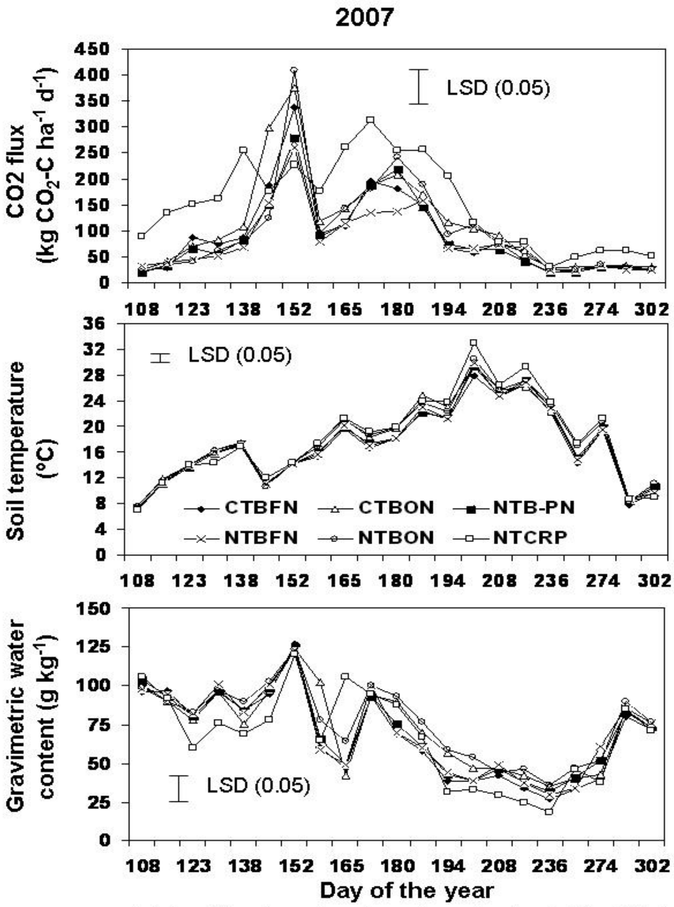

Figure 1. Effect of cropping system on soil surface CO_2 flux and soil temperature and water content at the 0-15 cm depth in 2007. CTBFN, conventional-tilled malt barley with 67 to 134 kg N/ha; CTBON, conventional tilled malt barley with 0 kg N/ha; NTB-PN, no-tilled malt barley-pea rotation with 67 to 134 kg N/ha applied to malt barley; NTBFN, no-tilled malt barley with 67 to 134 kg N/ha; NTBON, no-tilled malt barley with 0 kg N/ha; and NTCRP, no-tilled Conservation Reserve Program.

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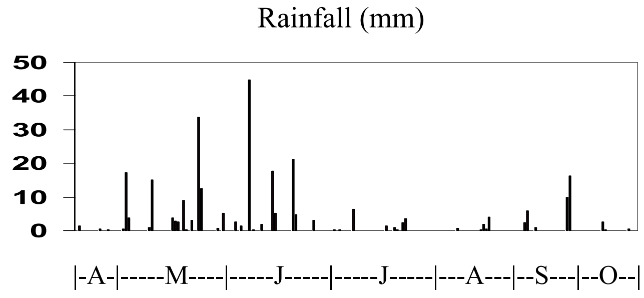

Figure 2. Rainfall distribution during measurement dates in 2007 (total rainfall from May to October 2007 = 278 mm).

Total CO_2 flux from April to October was greater in NTCRP than in other cropping systems in all years (Table 2). The flux was lower in NTBFN and NTB-PN in 2 out of 3 years. Tillage increased the flux compared with no-tillage in 2 out of 3 years but N fertilization decreased the flux compared with no N fertilization in 1 out of 3 years. The greater CO_2 flux but lower or similar soil water content in NTCRP than in other cropping systems (Table 2, Figure 1) suggests that grass roots in their undisturbed condition continued to respire from April to July when crops were still growing. Although C inputs from aboveground residue was lower in NTCRP than in other cropping systems (Table 1), belowground (root) residue was considered to be greater with grasses than with crops. As a result, increased root respiration and mineralization of belowground residue could have increased CO_2 flux in NTCRP. In croplands, assuming root growth was similar to aboveground growth; increases in crop residue C did not always increase CO_2 flux. Rather flux was greater with CTBON than with other treatments, probably due to tillage (Curtin *et al.* 2000). Nitrogen fertilization has been known to decrease CO_2 flux (Al-Kaisi and Yin 2008).

Table 2. Effect of irrigation and cropping system on soil surface CO_2 flux at the 0- to 15-cm depth from 2006 to 2008.

Irrigation	Cropping system†	Soil surface CO_2 flux ($kg\ CO_2$-C/ha/d)		
		2006	2007	2008
Irrigated		132a‡	118a	148a
Non-irrigated		88b	91b	111b
	CTBFN	96c	93cd	131bc
	CTBON	112b	112b	147b
	NTB-PN	96c	87d	116cd
	NTBFN	96c	82d	118cd
	NTBON	100bc	101bc	110d
	NTCRP	161a	153a	161a
<u>Contrasts</u>				
Till vs. no-till		12	22*	49***
N fertilization vs. no N fertilization.		-19	-38**	-8
Cont. barley vs. barley-pea in no-till		2	5	-2
Cropping vs. grasses in no-till		-64***	-63***	-46**

† Cropping systems are CTBFN, conventional-tilled malt barley with 67 to 134 kg N/ha; CTBON, conventional tilled malt barley with 0 kg N/ha; NTB-PN, no-tilled malt barley-pea rotation with 67 to 134 kg N/ha applied to malt barley; NTBFN, no-tilled malt barley with 67 to 134 kg N/ha; NTBON, no-tilled malt barley with 0 kg N/ha; and NTCRP, no-tilled Conservation Reserve Program.
‡ Numbers followed by different lower case letters within a column and upper case letter within a row in a set are significantly different at $P \leq 0.05$ by the least significant difference test.
*, **, and *** Significant at $P \leq 0.05$, 0.01, and 0.001, respectively.

Conclusions

Aboveground residue C input did not increase CO_2 emissions in croplands due to interaction of cropping system with tillage and N fertilization. Similar findings were observed in grassland. Increased root respiration probably increased CO_2 emission in grassland compared with cropland. Regardless of cropping systems, the emissions were greater with irrigation than without. For reducing CO_2 emission from croplands, no-tilled continuous cropping with recommended rates of N fertilization can be used.

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