USING CONSERVATION TILLAGE
TO REDUCE GREENHOUSE GAS EMISSION IN NORTHERN CHINA

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ABSTRACT

Using GXH-3010E1 CO_2 infrared analytical instrument linked with close chamber, effects of different tillage and residue management on CO_2 emission are researched in northern China. Results showed: conservation tillage can reduce CO_2 emission, Controlled traffic can reduced 9.7L/hm^{2}a fuel consumption than that of random traffic,which means reduction od CO2, the more tiilage, the more CO2 emission from soil.

Key word: conservation tillage; residue management; controlled traffic; soil CO_2 flux

INTRODUCTION

Tillage is assumed to have a major influence on soil C emissions, tillage induced soil C loss has been shown to be important especially in the short-term periods, there are many report about soil tillage accelerates organic C oxidation releasing high amounts of CO2 to the atmosphere in a few weeks (Ellert and Janzen, 1999; Prior et al., 2000; La Scala et al., 2006). La Scala et al (2008) regard that the soil CO2 flux in tilled plots can be described as result of a natural plus a tillage-induced emission.

Whereas, there are some seasonal monitoring of CO2 fluxes from soils under contrasting tillage regimes suggests that similar amounts of CO2 are emitted from no-tillage and conventional tilled systems. For example, Hendrix et al(1998) reported that fluxes were slightly greater in no-tillage plots than in conventional tilled plots in Georgia; Franzluebbers et al(1995) reported that annual soil CO2 fluxes from various cropping systems in Texas were not significantly different or up to 23% greater in no-tillage compared to conventionally disked systems. B.H.Ellert and H.H.Janzen's(1999) study suggested that the short-term influence of soil tillage on the transfer of soil C to atmospheric CO2 is small in Canadian Prairies. Roberts and Chan (1990) used simulated tillage techniques in laboratory studies to examine the importance of tillage-induced increase in soil respiration as a mechanism for organic matter loss. They concluded that the increase in microbial respiration due to tillage was probably not a major factor leading to losses of soil organic matter in soils under intensive cultivation.

As a measure of soil and water conservation, conservation practices were widely adopted by farmers in the world. some area farmers has been adoption controlled traffic (e.g. Australia), and it has been vigorously advocated in both the USA and Europe (Tullberg, et al.2007).Furthermore, there is a rising interest in the impact of conservation tillage practices on carbon sequestration in recent years (Deen et al, 2003), research indicated that agriculture can act both as a sink and a source (Paustain et al., 1997; Lal et al., 1998), realizing that the use of conservation practices by agriculture could decreased the net emission of carbon dioxide in many areas (Noel et al, 2000; Wan and Lin, 2004; Nobuhisa Koga et al, 2003; Reicosky et al, 1999). Conservation tillage retain more plant residue on the soil surface and have greater near-surface soil C contents than conventional tillage, especially, in cool, humid climate condition, the decomposition of plant residue is slower in conservation tillage as a result of reduced soil-residue contact compared with residue that is completely incorporated by conventional tillage (Drury et al 2006).

The objectives of these studies were to quantify the effect of residue management and tillage compaction on soil CO2 fluxes and determine whether controlled traffic can decrease soil CO2 emission.

MATERIALS AND METHODS

2.1 Study Site And Experimental Design

Site one: Wuchuan county, Inner Mongolian, in the north of China(111°42′N, 41°12′E), semi-arid and agro-pastoral region with mean annual precipitation of 300-350 mm(55.7% as rain from July to August), pan evaporation of 1848.3mm and annual temperature of 2.4℃. The experimental field was planted with spring wheat, the field was divided into four treatments after the autumn of 2007: (1) No-till with residue cover, (2) No-till without residue cover, (3) Plowed with residue reutrn to the soil,(4)Plowed without residue Four replicates. Basic soil and residue properties are summarized in Table 1.

Table 1 Summary of soil (0-20cm depth) and surface residue properties (mean and standard deviation) on treatment plots

Soil cover	Tillage	Residue,DM (kg/ ha)		Residue,N (g/ kg)		Residue,C (g /kg)		Soil, N (g /kg)		Soil organic matter (g /kg)	
			±sd		±sd		±sd		±sd		±sd
Residue cover	Conventional Tillage	760	280	3.9	0.25	405	13.4	0.64	0.28	12.5	6.7
	No tillage										
No cover	Conventional tillage	-	-	-	-	-	-	0.58	0.19	9.2	2.8
	No tillage										

Site two: Daxing district, Beijing (39°45′N, 116°20′E). Mean annual precipitation of 568.9 mm and annual temperature of 11.5℃. Farmign system is double crops of wheat and maize. Two treatments were designed. One is conservation tillage with controlled traffic, another is conservation tillge with random traffic. No crops on the traffic lanes.

Site three: The Ecological Station of the Chinese Academy of Sciences, Luancheng, Hebei

Province(37° 50′N, 114° 40′E). Average annual rainfall is about 550mm, average annual temperature is 12.5 °C with 196 frost free days. Cropping system is also double crops of wheat and maize. In June, wheat is harvested, and maize planting; in September, Maize harvest, and wheat sowing.Three treatments were tried: (1) conventional tillage, namely plough (CK); (2) rotary tillage (RT); (3) no tillage (NT).

2.2 Measurement of Soil CO2 Emissions, Soil Moisture And Soil Temperature

CO_2 flux from the soil surface was measured with GXH-3010E1 CO_2 infrared analytical instrument, the instrument has been described by Yu and Sui (2007). The instrument linked with closed chamber which covered a surface area of $0.04m^2$ and had a volume of $0.024m^3$. with the electric fan running, the chamber was lowered over the treatment surface with its bottom support frame inserted into the soil approximately 20mm.(Fig.1) CO_2 concentration were measured at 10 second intervals over 2 minutes period and stored on a laptop compute, three measurements in the same area were made and averaged.

Fig 1 GXH-3010E1 CO_2 infrared analytical instrument.

Prior to tillage and before measuring soil respiration, soil(0-20cm depths) were sampled and weighed from all treatments, after dried at 105℃ for 8h, the soil were weighed again to determine soil water content(g kg-1) , the same operation which measured soil water content was done after tillage practice. Soil temperature was measured at surface, 10, 20cm in each of the treatments used thermocouples.

2.3 Data Analysis

The SPSS analytical software package was used for statistical analyses. Mean values were calculated for each measurement, and ANOVA was used to assess the effects of conservation tillage on wind erosion. In case of significant F-values ($P<0.05$), multiple comparisons of annual mean values were made on the basis of least significant difference (LSD).

RESULTS AND DISCUSSION

3.1 Site One Result

3.1.1 Tillage and residue effect

Tillage can induced soil CO_2 flux and lead to the loss of soil carbon .CO2 was measured 6 days after plowed, the results shows, CO_2 flux are 135% and 70% more in ploughing field respectively for residue cover and no cover plots. Reicosky(2002) observed substantial short-term losses of CO_2 immediately after moldboard tillage of mineral soils, with continued flux for at least 40 days. In agro-pastoral regions in northern China, soil organic matter at low level at the experiment site, just 12.5g/kg and 9.2g/kg at residue cover and no cover field, respectively (Table 1). Meanwhile, few residues leave the filed as low crop production at 2007, the residue dry matter is 760kg/ha, 58% less than general production. These may the reason that continued high soil CO_2 flux no more than six days.

Before tillage, residue cover field soil CO_2 flux is 23.52g/m^{2}d, the no cover field soil CO_2 flux is 42.72g/m^{2}d. When the soil inverted and fractured, it causes an immediate loss of trapped CO_2, deep tillage can also incorporates plant residues and aerates the soil thus enhancing microbial oxidation (Reicosky and Lindstrom, 1995), after soil tillage, the soil CO_2 flux reached to 47.14 g/m^{2}d and 82.49g/m^{2}d in residue cover field and no cover field, respectively(Table2). During the measurement six days, the CO_2 flux of residue cover field higher than that of no cover field.

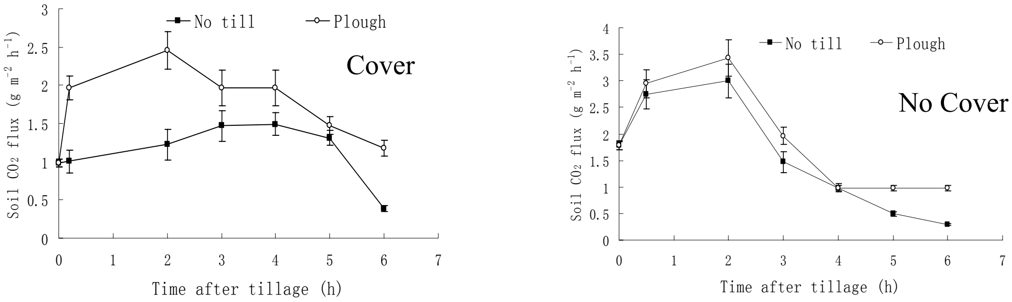

Fig.2. The effect of tillage on soil CO_2 flux afterploughing.

CO_2 flux was greater after than before tillage, regardless of residue cover. soil CO_2 flux dramatically increased especially at the immediately following tillage (Fig.2).Mean CO_2 flux values measured within 10min after plough were 1.96 and 1.07 times greater than those for no till in the residue cover and no cover fields, respectively. Average soil CO_2 of Six days was 19.64 and 19.65g/m^{2}d on the residue cover and no cover fields, respectively. Ploughing with residue cover can significantly increase soil CO_2 flux by 135% compared to that without cover.

Table 2 Soil CO_2 flux (g/m^{2}d) of different treatments measured, May 2008.

Days after plow	Tillage	No cover	Residue cover
0	No tillage	35.36	23.57
	Conventional tillage	82.49	47.14
	$Lsd_{tillage}=4.09$; $Lsd_{cover}=4.09$;$Lsd_{tillage\times cover}=5.79$		
1	No tillage	17.68	11.79
	Conventional tillage	29.47	35.35
	$Lsd_{tillage}=1.37$;$Lsd_{tillage\times cover}=1.94$		
2	No tillage	11.79	23.57
	Conventional tillage	17.68	47.14
	$Lsd_{tillage}=1.45$; $Lsd_{cover}=1.45$;$Lsd_{tillage\times cover}=2.05$		
3	No tillage	11.82	23.58
	Conventional tillage	23.58	41.25
	$Lsd_{tillage}=1.93$; $Lsd_{cover}=1.93$;$Lsd_{tillage\times cover}=2.73$		
4	No tillage	29.47	23.57
	Conventional tillage	29.46	64.82

	$Lsd_{tillage}=0.44$; $Lsd_{cover}=0.44$;$Lsd_{tillage\times cover}=0.89$		
5	No tillage	11.79	11.78
	Conventional tillage	17.68	41.25
	$Lsd_{tillage}=1.99$; $Lsd_{cover}=1.99$;$Lsd_{tillage\times cover}=3.61$;		

In the experiments, tillage and tillage×cover interaction give significant effect on soil CO_2 flux (Table2). For lack of rainfall and irrigation at 2007, the crop productions of the experiment area are lower than common year, these may be the reason that no differences of soil CO_2 fluxes were found between residue cover and no cover fields..

3.1.2 Cumulative fluxes

For both fields, six day cumulative soil CO_2 flux measured after tillage. All the pattern of cumulative CO_2 flux followed lines increase (Fig.3). During the measured period, the average soil CO_2 flux is about 20g/m^{2}d no tillage fields. The average soil CO_2 flux is about double of no tillage. In the residue cover fields, the soil CO_2 flux reached 46 g/m^{2}d , and the no cover fields reached 34 g/m^{2}d. These result like Russ et al (2007) measurement used small chamber at Everglades Research and Extension Center, University of Florida.

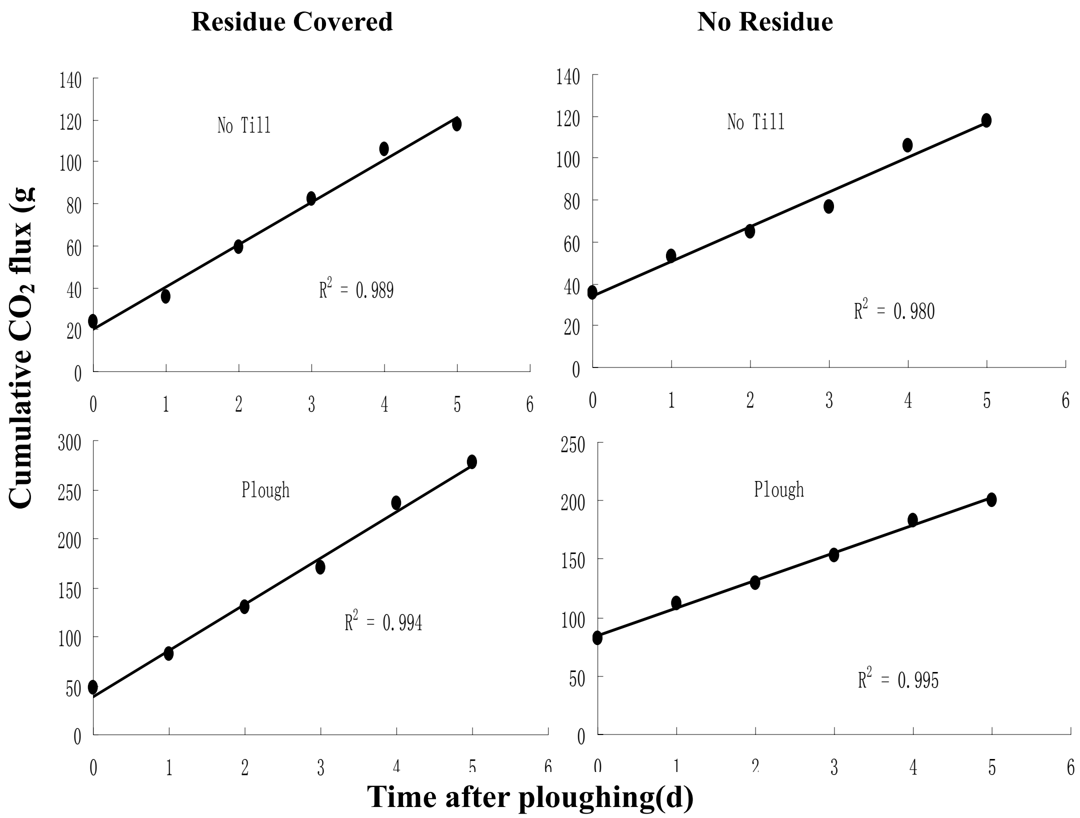

Fig.3. The effect of tillage on Cumulative CO2 flux.

No cover fields were plough at autumn of 2007. Tillage can loosed surface soil, so the soil bulk density of no cover was 13.2% less than that of residue cover field. After tillage, the soil bulk density of no cover and residue cover reached the same amount at 10cm, and the after was

28.5% and 19.2% less than that of before in the residue cover field and no cover field, respectively(Table 2). Small soil bulk density denote that great soil air filled porosity, Russ et al(2007) regard that greater air filled porosity may the reason that the no cover field CO_2 flux immediately following plough tillage tended to be greater than residue cover field.

3.2 Site Two Result

The CO_2 emission were significantly different at crop zone between the random traffic and controlled traffic when utilize opaque close chamber measurement, the CO_2 flux were considerably larger for controlled traffic(95.04±6.79g/m^{2}d)than for random traffic(50.91±7.57g/m^{2}d), however, the CO_2 emission were not significant different between the random traffic and controlled traffic when utilize transparent close chamber measurement (Fig.4).

Carbon dioxide is produced in soil as a result of decomposition of organic material by micro organisms and root respiration, effects of traffic on CO_2 fluxes measured using opaque and transparent chamber, meanwhile, there were growth crop in chamber, for this reason, CO_2 flux also include crop respiration within opaque chamber and photosynthetic fixation within transparent chamber, so, the CO_2 concentration of transparent chamber is decrease. Root length density and root dry weight can express below ground plant biomass to some extent, root derived respiration is proportional to both, above and below ground plant biomass(Graine et al, 2001; Hill et al, 2004). At crop zone, controlled traffic can increased root dry weight and root length density compared with random traffic, these may the reason that controlled traffic increased CO_2 flux compare with random traffic.

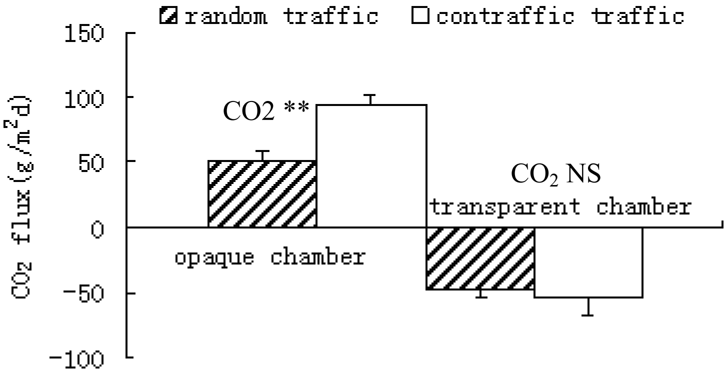

Fig.4 Effects of traffic on CO2 flux under opaque chamber and transparent chamber at crop zone.

The CO_2 emission of inter row and traffic zone just from soil respiration and root respiration, there are no significant difference between random traffic and controlled traffic at inter row, whereas, they are all significant higher than traffic zone (Fig 5).these results agree with Pengthamkeerati et al (2005) reported that soil CO_2 released was significantly reduced with increasing soil bulk density.

As expected, soil CO_2 flux was

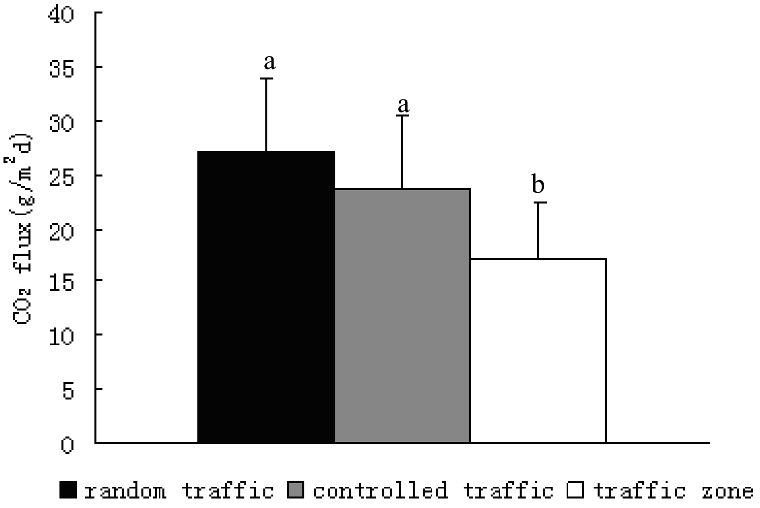

Fig 5 soil respirations at different zone. low case letter indicate significant (P<0.05).

significantly decreased in vehicle traffic soils than no traffic, this indicates soil compaction had a positive effect on soil CO_2 flux compaction, which results in increased soil bulk density, can limit gas transport and limit soil aeration that may reduce soil microbial activity (Pengthamkeerati et al ,2005).

3.3 Site Three Result

Emissions followed similar patterns initially, increasing towards the wheat filling stage in early summer (Fig6). Despite the similarity in pattern, the absolute values of emissions differed between tillage treatments and were always higher on CK and RT than NT. Differences of CO_2 emissions developed over the summer after wheat harvest. On CK, emissions remain on a similar level throughout the early part of the maize growing season before gradually increasing with plant development. On RT and NT on the other hand, wheat harvest is associated with a clear decline in emissions. Subsequently, values increase with maize growth, but remain below the values of CK. Emissions decline again after harvest, followed by short peaks associated with tillage in October on CK and RT. As a consequence, daily soil CO_2 emissions for CK, RT, and NT averaged 11.30g m^{-2}, 9.63 g m^{-2} and 7.99 g m^{-2}, respectively. Peak emissions during this later stage were approximately twice as high on CK and RT as NT.

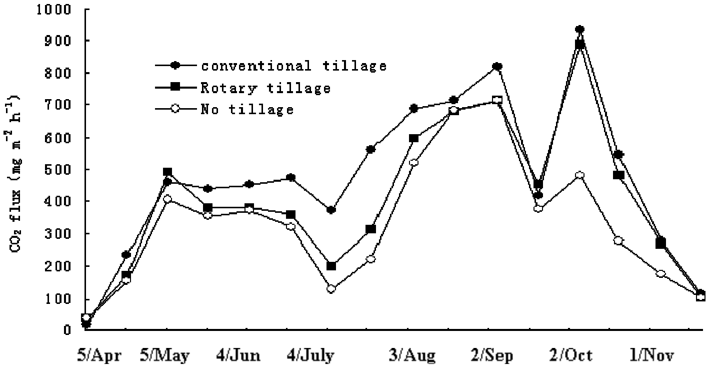

Figure.6 Mean CO_2 flux over the period studied

CONCLUSION

1. At the low soil organic matter region, soil tillage is the main factor which influences soil CO2 flux, when the soil organic matter reached certain high level, plant residue will lead some effect on soil CO2 emission.

2.The proportion of residue returned to field should be shifted according to the amount of the soil organic matter. For the agro-pastoral regions of northern China, its soil organic matter remain low level, there are many capacity to store C through agriculture management especially conservation tillage. Paustian et al(2000).regard that Agricultural soils can however actually serve as a significant C sink, rather than a C source, at least until the maximum capacity to store C is achieved, if improved residue management and reduced tillage systems are adopted.

3.Tillage gives big effect of CO2 emission. Daily soil CO_2 emissions for CK, RT, and NT averaged 11.30g m^{-2}, 9.63 g m^{-2} and 7.99 g m^{-2}.

4. No significant difference of CO2 emission between controlled traffic and random traffic fields, these didn't imply that controlled traffic can't reduce CO_2 emission. For the CO_2 emission is largely the result of burning fossil fuels in arable land (Robertson, et al. 2000),

controlled traffic can reduce CO_2 flux through largely reducing fuel consumption. Conservation tillage can reduce about 9.7L/hm^{2}a of fuel consumption, equal to If the emission of 2.75Kg CO_2 per L fuel consumption (Nobuhisa Koga et al 2003), the CO_2 flux is 87.7kg/ha in controlled traffic and 114.4kg/ha in random traffic. So, if the farmers of northern China adopted controlled traffic, a reduction in the total annual amount of CO_2 released by soil tillage for the additional 10^4t or 2.3% could be expected, meanwhile, if the conventional tillage change to controlled traffic, the CO_2 release will be more reduction.

5.If carbon bargain price reach 30-40EUR/t(44.2-59dollar/t), conservation tillage can reduce CO2 more than 20kg/mu than conventional tillage, euqal to about US$15/ha.

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