Short-Term Study of Tillage Induced Soil CO_2 Loss

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Abstract— The aim of our research was to measure the effect of different primary tillage methods on the CO_2 flux from soil and to evaluate the effect of conservation tillage tools on short-term CO_2 emissions. The field test was conducted on clay loam soil corn field. The three tillage treatment included moldboard plough, heavy disc harrow, chisel plough and no till.

Moldboard plough had the roughest soil surface and the highest initial CO_2 flux and maintained the highest flux throughout the study. The moldboard ploughing caused most CO_2 loss than the less intense tillage like chisel ploughing, mulch cultivating or disc harrowing. The fall, primary tillage caused more CO_2 than spring seedbed making tillage apparently related to preceding seasonal microbial activity.

This result supports increased adoption of new and improved forms of conservation tillage equipment and offer a significant potential to preserve or to increase soil C levels and to decrease the carbon dioxide in the atmosphere.

Keywords— CO2 flux, tillage, climate change, greenhouse gases, tillage processes

I. Introduction

The concentration of greenhouse gases in the atmosphere has increased steadily since about 1850. A substantial part of the total increase so far has been attributed to deforestation, conversion on farmland, and other agricultural activities [1]. CO_2 is the most important greenhouse gas, because increase in its concentration causes about 50% of the total radiative forcing [2]. The concentration of CO_2 in the atmosphere was about 280 ppm in about 1850 and 365 ppm in 1996, and it is increasing at the rate of 0.5 %/yr. If this trend continues, CO_2 concentration can reach up to 1000 ppm till the end of the 21st century [3].

Improved agricultural practices have great potential to increase carbon sequestration and decrease the net emission of carbon dioxide and other greenhouse gases, but policy makers have not widely recognized this potential. Since the 1980s, considerable scientific information has been collated about the potential of agricultural lands to sequester C [4–7]. But the available information has not been synthesized in a form that policy makers and land managers readily can use to mitigate CO_2 emissions in relation to the potential greenhouse effect.

There is a definite need for information on the impact of tillage on CO_2 from soil and how farming practices can be managed to minimize impact on global climate change.

Information is needed on both the short-term effect of agricultural management decisions and the long-term effects, as they may affect global climate change. Direct evidence on the effect of tillage method on CO_2 flux rates is limited.

Over the past two decades, conservation tillage has evolved primarily for erosion control. However, recent concern for global climate change reemphasizes the importance of conservation tillage and how it can be implemented on many soils to help reduce soil C losses. While tillage and cultivation result in loss of soil C and nitrogen [8,9], the direct influence of tillage on CO_2 flux is varied and highly interactive. Variation in the soil CO_2 flux can result from the interaction of many factors. Soil loosening should improve accessibility of oxygen necessary for organic matter decomposition and respiration resulting in CO_2 release.

Gas fluxes were measured using closed chamber system. The atmosphere immediately above the soil surface is enclosed by the chamber and the change in concentration of CO_2 or N_2O one hour after closure is measured. This change is a result of net emission from the soil and enables gas flux to be determined. There are gas sampling techniques developed using both manual and automated closed chambers. The manual chambers [10] were cylinders of diameter 0,4 m, pushed into the soil to a depth of 50 mm and with the head space enclosed with an aluminium lid. Gas samples were taken in syringes or aluminium sampling tubes and subsequently analysed in the laboratory by gas chromatography. In order to assess the effects of no-till drill slits on N_2O flux, small manual chambers were pushed into the soil to a depth of 30 mm so as either to enclose a drill slit or the area between drill slits. These chambers were enclosed by close-fitting plastic caps, containing an injection port. The automatic chambers (0.7 x 0.7 m) have automated a lid closing and sampling system which allows the remote collection of gas samples at programmed time intervals. Samples are collected by pumping into one of 24 isolated copper loops, attached to two rotary valves. The entire valve/loop assembly is removed, transported to the laboratory for automated gas chromatographic analysis and replaced by a duplicate in order to preserve continuity of sampling. Gas diffusivity was measured in situ in the tillage experiment by measuring the rate of escape of Freon from a chamber enclosing the soil surface [11].

Reference [12] describes a large portable chamber to measure CO_2 flux from the tilled soil surfaces. Measurements for CO_2 flux were initiated within 5 min of the last tillage pass. Briefly, the chamber (volume of 3.25 m3 covering a horizontal land area of 2.67 m2) with mixing fans running was moved over the tilled surface until the chamber reference points aligned with plot reference stakes, lowered and data rapidly collected at 2 seconds intervals for a period of 80 second to determine the rate of CO_2 and water vapour increase. After the appropriate lag times, data for a 30 second period was used to convert the volume concentration of water vapour and CO_2 to a mass basis then linearly regressed as a function of time to reflect the rate of CO2 and water vapour increase within the chamber expressed on a unit horizontal land area basis.

Information is needed on the short-term impacts of various tillage methods on C flow and dynamics within an agricultural production system. Our objective was to measure the effect of different tillage methods on the CO_2 flux from soil. Any increase in soil carbon has important benefits for the sustainability and productivity of the agro ecosystem. Many of the land management practices that favor carbon accumulation, like conservation tillage also prevent erosion thereby improving air and water quality. This has the potential to increase soil productivity and profitability of farming systems by increasing yields or reducing production.

II. MATERIALS AND METHODS

A. Site description

This work was conducted on clay loam soil with high humus content in Enying (county Fejer), Hungary (Table 1.).

TABLE I
SITE SPECIFICATION

No. of measurement	Operation	Weather condition
1.	Stubble mulching on wheat stubble	Dry, sunny, 28°C
2.	Primary tillage on corn stubble	Dry, windy, 20°C
3.	Secondary tillage on corn field	Dry, windy, 23°C

B. Study description

The first study area was planted to winter wheat on last decade of October and harvested on first decade of July. The short–term influence of tillage on soil CO_2 evolution was assessed by recording 2 series of successive measurements. Each series included a pre-tillage measurement to assess „base line" flux uniformity, followed by three different past-tillage measurement to compare fluxes along tilled and undisturbed plots.

The second study area was planted to corn on last decade of April and harvested on last decade of September. The short-term influence of primary tillage on soil CO_2 evolution was assessed by recording 2 series of successive measurements to compare fluxes using different equipments.

The secondary tillage treatment was done on primary tilled area at spring time using a seedbed maker machine (Table 2).

TABLE III
TREATMENT SPECIFICATION

No. of measurement	Operation	Machine	Working depth, cm
1.	Stubble mulching	Rába-IH disc harrow+ Güttler roller	15
		Komondor mulch tiller	15
		Kverneland CLE chisel plough	25
2.	Primary tillage	Rába-IH disc harrow+ Güttler roller	20
		Kverneland BB 115 plough	25
		Kverneland CLE chisel plough	35
3.	Secondary tillage	Syncrogerm 6M seedbed maker	10

For the tillage treatment commercially available tillage implements were used (*Fig. 1-5.*). The tractor with tillage implement made a pass through the plot and within one minute the portable chamber was moved over the measurement area and gas exchange measurement completed. A series of two measurements were made to get the initial flux of CO_2 immediately following tillage. The gas exchange measurements were repeated on a regular cycle so that each of measurement areas was visited at least once a quarter (half) hour for up to three hours after initial tillage.

Fig. 1 Rába-IH disc harrow + Güttler roller

Fig. 1 Komondor mulch tiller

Fig. 3 Kverneland CLE chisel plough

Fig. 4 Kverneland BB 115 plough

Fig. 5 Syncrogerm 6M seedbed maker

C. Instrumentation

Soil CO_2 fluxes were measured in situ using an INNOVA 1312 Multi Gas Monitor with closed chamber system (*Fig. 6.*). Conical shaped, 8 liter volume polyethylene sampling chamber were used to measure soil CO_2 flux (*Fig. 8.*). Chambers were installed by penetrating them into the soil to separate chamber air from the atmosphere. The atmosphere immediately above the soil surface is enclosed by the chamber and the change in concentration of CO_2 every 15(30,60) minutes after closure measured. This change is a result of net emission from the soil and enables gas flux to be determined. Because of the high cost of INNOVA system for the second and third study –after a field validation process – we used the TESTO 535 CO_2 tester (Fig. 7.).

Fig. 6 INNOVA 1312 Multi Gas Monitor

Fig. 7 TESTO 535 CO_2 tester

Fig. 8 CO_2 chambers on the test field

III. **RESULT AND DISCUSSION**

A. Stubble mulching

The CO_2 flux as a function of time for each tillage treatment in the first 2 hours can be compared on Fig. 9.

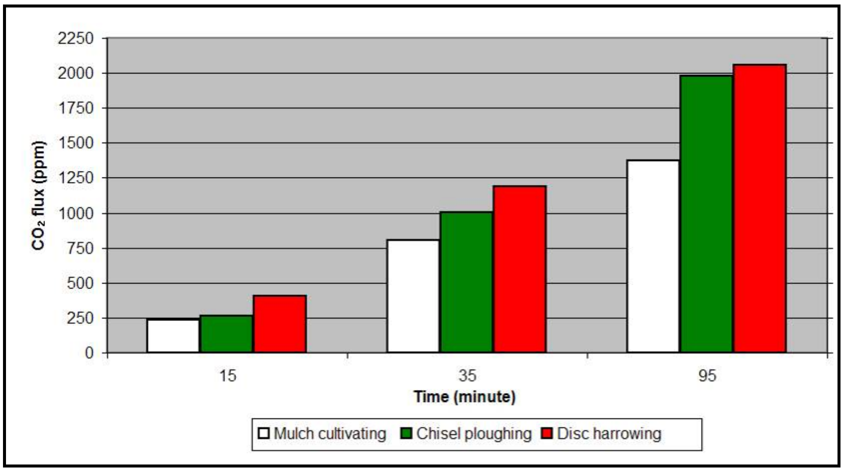

Fig.9: CO_2 flux versus time after stubble mulching

Immediately after tillage was not observed significant differences. The CO_2 flux measured during 85-105 minutes shows some advantages for mulch tiller where the rear part (spring loaded crumbler) of the machine was effective.

B. Primary Tillage

The CO_2 flux as a function of time for each tillage treatment in the first 2,5 hours can be compared on Figure10. In the case of chisel ploughing the emission was measured along the shank and between of them and was counting an average.

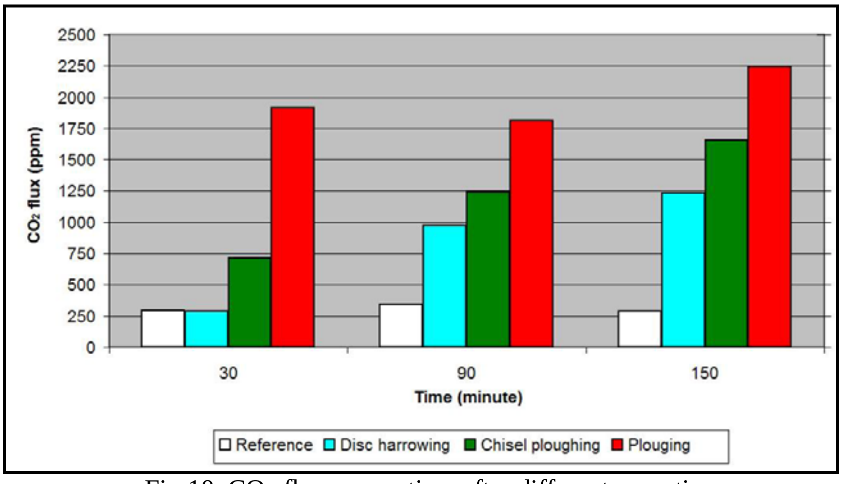

Fig.10: CO_2 flux versus time after different operations

The higher CO_2 fluxes were related to depth and intensity of soil disturbance that resulted in a rougher surface and larger voids. The initial fluxes were relatively large from the moldboard plough surface and the increasing was not high. The fluxes from the chisel plough and disc harrow surface showed a similar trend.

C. Secondary tillage

The CO_2 flux after seedbed making as a function of time for each primary tillage pre- treatment in the first 2 hours can be compared on Figure11.

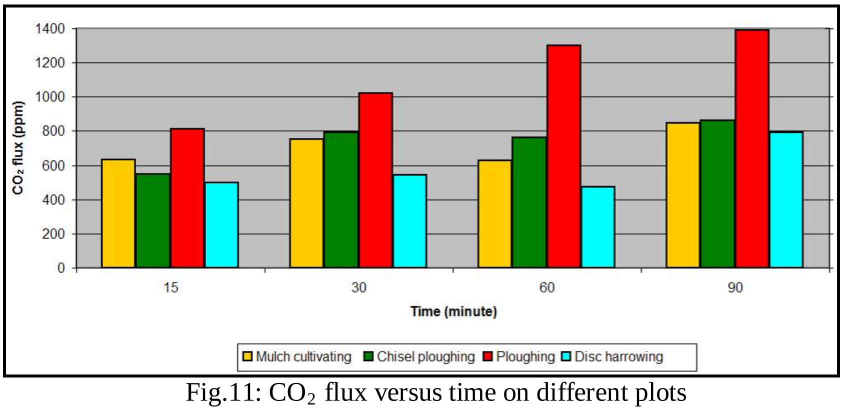

Fig.11: CO_2 flux versus time on different plots

The long-term (seasonal) effect of the different primary tillage was observed after seedbed preparation. All conservation tillage implements produced less CO_2 then the moldboard plough. Because of the conservation tillage implements were primary designed to leave crop residue on the surface they can have a second beneficial effect that results in less CO_2 loss.

IV. CONCLUSIONS

Summarized the results were getting from the field research the following conclusions can be drawn:

- The methods and tools using for measuring of CO_2 emission need further developments to increase the accuracy of field measurement,
- The weather condition, first of all the temperature has a great influence on the soil CO_2 flux. Below 10^oC has no significant differences between the different tillage methods,
- The intensive tillage, like moldboard ploughing that disturbs the soil to depths and leaves the surface rough can result in essential carbon loss, because the plough not only fractures and opens the soil which can allow fast CO_2 and oxygen exchange, but also incorporates residue into the soil which feeds a microbial population explosion. In the case of conservation tillage, most residues are left on the soil surface, so a small portion is in closed contact with the soil moisture and can be available to microorganisms,
- The order of different primary tillage implement by measured CO_2 fluxes : moldboard plough, chisel plough, heavy disc harrow and mulch tiller,
- Based on the soil carbon dioxide emission after tillage of the studied tillage operations (moldboard plough, chisel plough, heavy disc harrow, mulch tiller) moldboard ploughing has the worst effects on climate change.
- These results suggest that selection of primary tillage implement that maintains surface residue and minimizes soil disturbance could help CO_2 loss.

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