

## STATE OF THE ART IN THE HUNGARIAN FIELD RESEARCH: THE EFFECT OF TILLAGE ON CO<sub>2</sub> EMISSION

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### Abstract

There are many methods used by researchers to measure CO<sub>2</sub> flux after different tillage tools and methods. Our research was made to measure the effect of different tillage methods on the CO<sub>2</sub> flux from soil and to evaluate the effect of conservation tillage tools on CO<sub>2</sub> emissions. Beside of these the research aim is to exactly determine the CO<sub>2</sub> emission savings of conservation tillage methods.

Our research has shown that the use of the environment-oriented, mulch-tillage methods can play a major role in reducing of greenhouse gas emissions by increasing the rate of organic matter oxidation.

Our objectives were to develop a reliable and method to measure the short, intermediate and seasonal effect of different tillage methods on the CO<sub>2</sub> flux after tillage.

### Introduction

Carbon dioxide flux from soil is an important factor in the increasing of the concentration of greenhouse gases in the atmosphere. Any increase in soil carbon has important benefits for the sustainability and productivity of the agro ecosystem. CO<sub>2</sub> is one of the most important greenhouse gases, because increase in its concentration causes about 50% of the total radiative forcing (Rodhe, 1990).

Improved agricultural practices have great potential to increase carbon sequestration and decrease the net emission of carbon dioxide and other greenhouse gases, but available information has not been synthesized in a form that policy makers and land managers readily can use to mitigate CO<sub>2</sub> emissions in relation to the potential greenhouse effect.

Intensive agricultural production systems that include intensive tillage result in soil degradation and erosion that impacts soil, water, and air quality. The effects of conservation tillage and residue interactions on greenhouse gas fluxes and soil carbon should be evaluated. Soil scientists have studied the dynamic nature of soil carbon from an agronomic perspective, but not from an environmental context. Thus, more information is needed to advance the current understanding of how agricultural production systems can be modified to enhance environmental quality.

We need direct measurements to quantify CO<sub>2</sub> flux as affected by agricultural management practices. 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. (Jori, 2004)

Limited measurements are available on CO<sub>2</sub> evolution immediately after tillage in the field. 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<sub>2</sub> or N<sub>2</sub>O one hour after closure is measured. This change is a result of net emission from the soil and enables gas flux to be determined, using both manual and automated closed chambers. (Jori et al., 2004) The manual chambers (Clayton et al., 1994.) 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 analyzed in the laboratory by gas chromatography.

The CO<sub>2</sub> flux from the tilled soil surfaces was measured using a large portable chamber described by Reicosky, (1990), and Reicosky and Lindstrom (1993). Measurements for CO<sub>2</sub> flux were initiated within 5 min of the last tillage pass. Briefly, the chamber (volume of 3.25 m<sup>3</sup> covering a horizontal land area of 2.67 m<sup>2</sup>) 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-s intervals for a period of 80 s to determine the rate of CO<sub>2</sub> and water vapor increase. After the appropriate lag times, data for a 30-s period was used to convert the volume concentration of water vapor and CO<sub>2</sub> to a mass basis then linearly regressed as a function of time to reflect the rate of CO<sub>2</sub> and water vapor increase within the chamber expressed on a unit horizontal land area basis.

Environment-friendly CO<sub>2</sub> conservation tillage practices were described in Hungary by Birkás (2002). She pointed on importance of controlling microbiological activity and improving sustainable soil protection. Tillage CO<sub>2</sub> emission investigations made by domestic researchers are using similar measuring techniques as described by foreigner studies.

Jóri and Gyuricza (Jóri 2004) grounded short term measurement techniques by using low volume closed chamber with different instrumentation. Tóth and Koós (2006) were investigating the differences of soil CO<sub>2</sub> flux of experimental field with six different tillage treatment plots. They used cylindrical sampling chambers, samples were taken from the chambers with needle. Zsembeli and Kovács (2007) used 18 liter and later 2,8 liter chambers with metal frame and water isolation. They pointed on the close correlation between the intensity of CO<sub>2</sub>-emission and the structural state and organic matter content of the soil.

### Materials and methods

Aim of the studies was to examine the short and intermediate term and the seasonal influence of tillage on soil CO<sub>2</sub> emission.

Our aim was to determine the difference in the effect of conventional and conservation tillage methods on the CO<sub>2</sub> flux from soil. Reducing soil CO<sub>2</sub> emission to keep soil carbon has important benefits for the sustainability and productivity of the agro ecosystem. The adequate use of low emission tillage systems has the potential to increase soil productivity and profitability of farming systems by increasing yields or reducing production.

#### *Short term study description:*

Short term studies were made on different fields with different treatment operations. Study conditions are summarized in Table 1.

#### *Intermediate study description:*

Intermediate study was conducted on clay loam soil at Enying Ltd. Farm. The study was initiated on 15. August 2004 9:00am and finished on 16. August 2004 2:00pm. The intermediate influence of tillage on soil CO<sub>2</sub> evolution was assessed by recording 2 series of successive measurements. Each series included a pre-tillage measurement to assess „reference” flux uniformity, followed by two different past-tillage measurement to compare fluxes along tilled and undisturbed plots. Plots were set out on wheat stubble. For the tillage treatment commercially available Kverneland BB115 plough and Kuhn Optimizer compact disc harrow were used (Table 2).

Table 1. Conditions of short term studies

No.	Operation/ Date		Field	Weather condition	Machine	Working depth, cm
1.	Stubble mulching on wheat stubble 07.15.2003		Enying "S4"-field	Dry, sunny, 28°C	Rába-IH disc harrow+ Güttler roller	14-16
					Komondor mulch tiller	14-16
					Kverneland CLE chisel plough	24-26
2.	Primary tillage on corn stubble	09.23.2003	Enying "S10"-field	Dry, windy, 20°C	Rába-IH disc harrow+ Güttler roller	19-21
		Kverneland BB 115 plough			24-26	
	10.16.2003	Dry, windy, 16°C		Kverneland CLE chisel plough	33-37	
3.	Secondary tillage on corn field 04.29.2004		Enying "S10"-field	Dry, windy, 23°C	Syncrogerm 6M seedbed maker on primary tillage plots	9-11
4.	Stubble mulching on raps stubble 06.06.2007		Hosszúvíz "A1"-field	Dry, sunny, 26-28°C	Pöttinger Synkro field cultivator + Pöttinger Lion rotary harrow	16-18
					Pöttinger Synkro field cultivator	22-25
5.	Stubble mulching on what stubble 14.07.2007		Mesztegnyő "H1"-field	Dry, sunny, 25-28°C	Middle-deep loosener	38-45
					Pöttinger Synkro field cultivator	22-25
					Pöttinger Synkro field cultivator + Pöttinger Lion rotary harrow	16-18
					Symba X-press disc harrow	18-22
6.	Stubble mulching on wheat stubble 15.07.2007		Hosszúvíz "A1"-field	Dry, sunny, 28-31°C	Symba X-press disc harrow	18-22
7.	Primary tillage on wheat stubble 08.09.2011		Mesztegnyő "T1"-field	Dry, sunny, 28-31°C	Middle-deep loosener	38-42
8.	Stubble mulching on sunflower stubble 09.17.2011		Mesztegnyő "T1"-field	Dry, sunny, 25-28°C	Pöttinger Synkro field cultivator	14-16

Table 2. Site and treatment specification of the intermediate study

No.	Operation/ Date	Field	Weather condition	Machine	Working depth, cm
1.	Stubble mulching on wheat stubble 07.15.2003 - 07.16.2003	Enying "S4"	Dry, sunny, 28°C	Kuhn Optimer compact disc harrow	12-14
				Kverneland BB115 plough	24-26

#### Seasonal study description:

Seasonal effect of the different primary tillage was observed by analyzing the data of Enying Ltd. Farm "S10" field. Data of CO<sub>2</sub> flux after stubble mulching on three different plots were recorded at 09.23.2003 and seasonal effect was observed by collecting CO<sub>2</sub> flux data of the plots after seedbed preparation at 04.29.2004.

#### Instrumentation

Soil CO<sub>2</sub> fluxes were measured in situ in earlier studies the INNOVA 1312 Multi Gas Monitor (Fig.1.) were used. Because of the high cost of INNOVA system for the latter studies –after a field validation process – a TESTO 535 CO<sub>2</sub> tester was regularly used. (Fig.2.)

The sampling was taken by using closed sampling chambers, which were continuously developed on the basis of former studies experiences. Earlier studies were made using 8 litre polyethylene sampling chamber (Fig.2.), later to extend CO<sub>2</sub> flux sampling

stability, the 27 litre polycarbonate chambers, with air circulation (Fig.3.) were used. Sampling was made on every plot on minimum three random places (Fig.4.). The chambers were emptied after each measurement. Proposed repetition of gas exchange measurements (Table 3.) was specified by the supposed intensity of CO<sub>2</sub> flux. Specification of measure process was made to make different studies comparable. Air CO<sub>2</sub> concentration and temperature and also the soil temperature was measured and registered, to determine the exact value for soil CO<sub>2</sub> flux and the relations between these characteristics.

Table 3. Optimal measure cycle of CO<sub>2</sub> measurements

Measure time	Measure cycle duration
Short term measurements	
0-90 min	15 min
90-240 min	30 min
Intermediate measurements	
0-4 hour	40 min
4-9 hour	60 min



Figure 1. INNOVA 1312 Multi Gas Monitor

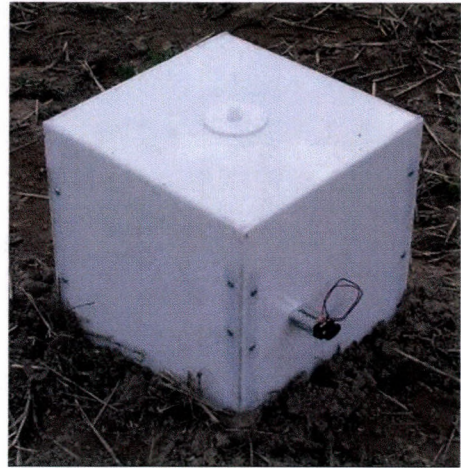


Figure 3. The 27 liter portable chamber



Figure 2: TESTO 535 CO<sub>2</sub> tester and 8 liter portable chamber



Figure 4. Portable chambers on the test field

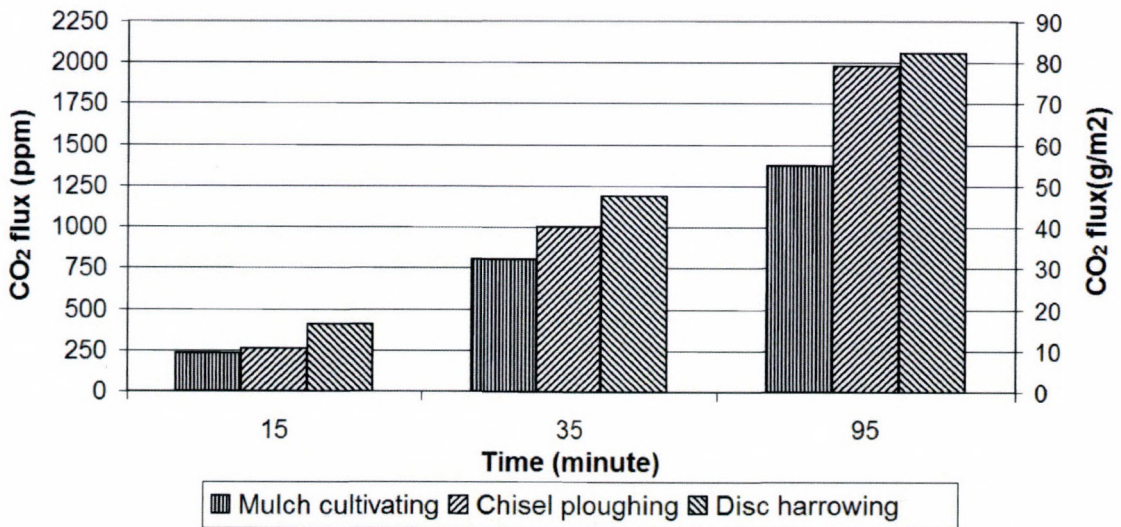


Figure 5. CO<sub>2</sub> flux versus time after stubble mulching (1. study)

Evaluation of the trends of measured data has shown that except the moldboard plow, immediately after tillage was not observed significant differences. The CO<sub>2</sub> flux measured after 60 minutes shows some advantages for mulch tiller where the rear part (spring loaded crumbler) of the machine was effective.

*Intermediate influence:*

Analyzing the intermediate (Fig.6.) emission of soil CO<sub>2</sub> has shown that short (e.g.3-5hours) measurement data can be extrapolated to calculate intermediate emission data considering soil temperature, moisture content and tillage intensity.

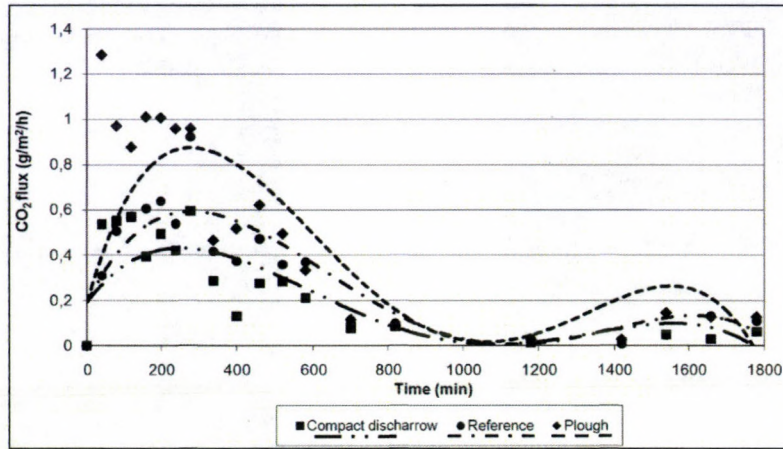


Figure 6. Intermediate (30 hour) emission of CO<sub>2</sub> after tillage

*Seasonal influence:*

The CO<sub>2</sub> flux as a function of time for each primary tillage treatments in October, in the first 1,5 hours can be compared on

Fig. 7. In the case of chisel ploughing the emission was measured along the shank and between of them and was counting an average for the whole field.

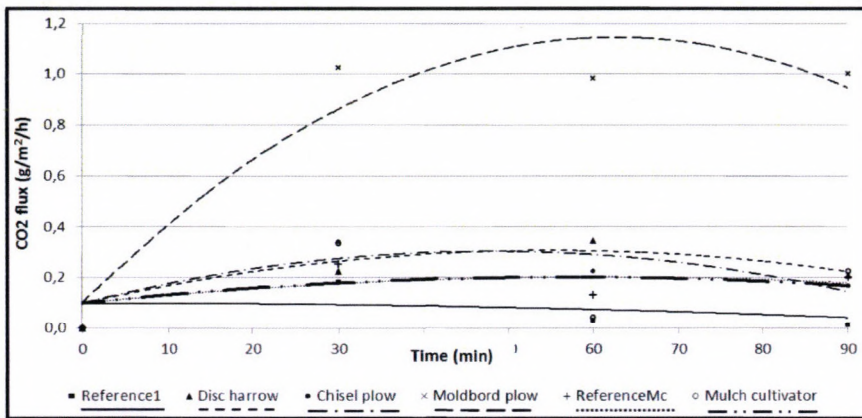


Figure 7. CO<sub>2</sub> flux versus time after different primary tillage operations (2. study)

The higher CO<sub>2</sub> 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.

The CO<sub>2</sub> flux after seedbed making in spring as a function of time for each primary tillage pre-treatment in the first 90 minutes can be compared on Fig. 8.

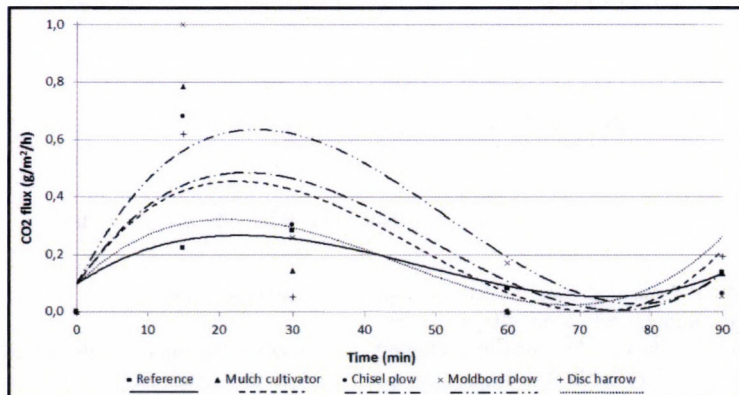


Figure 8. CO<sub>2</sub> flux versus time on different primary tillage plots after secondary tillage (2. study)

The long-term (seasonal) effect of the different primary tillage was observed after seedbed preparation. All conservation tillage implements produced less CO<sub>2</sub> than 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<sub>2</sub> loss.

*Results in practice:*

To utilize the results of the investigation of CO<sub>2</sub> emission of tillage practices, there is a need to develop special tillage

machines which are suitable to satisfy the requirements of low emission tillage practices. There are several manufacturers who produce machines which can be used to lower the CO<sub>2</sub> emission of tillage, but Hungarian field conditions make necessary to cooperate with domestic companies to develop the adequate machines.



Figure 9. SX MulchMaster cultivator



Figure 10. SX disc ripper



Figure 11. SX 480D Air Seeder

Our effort of the past years to develop these machines for Hungarian field conditions was succeeded as the three basic machines (mulch cultivator(Fig.9.), mulch loosener (Fig.10.) and mulch seeder(Fig.11.)) of the low carbon loss tillage practice were getting started production. The results of CO<sub>2</sub> emission studies were put in practice with these machines thus the comprehensive spread of low CO<sub>2</sub> emission tillage practices can be started.

**Conclusions**

There is a great need to determine exactly the amount of tillage induced CO<sub>2</sub> loss of different tillage practices, to have enough information to determine correctly the CO<sub>2</sub> savings of conservation tillage methods. Studies in the past years were pointed on the importance of correct measurement techniques.

Investigated the results the study has shown that the developed sampling chamber and measurement method is suitable to determine adequate soil CO<sub>2</sub> emission of different soil types and treatments.

The examination of only the short term influence of tillage on soil CO<sub>2</sub> emission can lead to faulty implications because the cognition of the duration of initial high emission is unavoidable.

Naturally like of measurements are very important. The cumulative method, where the emitted CO<sub>2</sub> is collected for hours or longer in the same chamber covering the same area of soil surface, according to our measurements can change the natural environment of soil under the sampling chamber. Therefore to get correct results of longer investigations, the method with ventilated sampling chambers have to be used, where the chambers were emptied after each measurement and the sampling is followed on a new place on the test plot where the surface was undisturbed after the treatment. Studies have shown that there are high variances between the results of cumulated and ventilated measuring methods of long term measurements. It is also important to use chambers with larger basic area and higher volume-area coefficient to get more reliable results by long term measurements.

Measuring long term effect of CO<sub>2</sub> flux by every commercially available tillage machine is not an effective method. Short term measurements (3-6 hours) are suitable to determine the initial emission after tillage and this information is useful to the relatively exact estimation of the long term effect.

The weather condition, first of all the temperature has a great influence on the soil CO<sub>2</sub> flux. Below 10°C has no significant differences between the different tillage methods

Summarized the results were getting from the field research of different tillage treatments the following conclusions can be drawn:

– 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<sub>2</sub> 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<sub>2</sub> fluxes : moldboard plough, chisel plough, heavy disc harrow and mulch tiller,  
– The results suggest that selection of primary tillage implement that maintains surface residue and minimizes soil disturbance could help CO<sub>2</sub> loss.

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