Acta Agronomica Óváriensis Vol. 63. Különszám

THE EFFECT OF TILLAGE TO QUANTIFY OF CARBON DIOXIDE EMISSIONS FROM THE SOIL

JÁN HECL – BOŽENA ŠOLTYSOVÁ – IGOR DANIELOVIČ
National Agricultural and Food Centre − Agroecology Research Institute in Michalovce, Slovakia

SUMMARY

Quantification of CO_2 emissions was tested in the years 2016 - 2018 on gleyic fluvisol in Milhostov at the grain maize. Maize was grown in two soil protection technologies (reduced tillage, direct sowing without tillage, resp. no-tillage), which were compared with conventional tillage with ploughing. The field experiment was established as a rotation of four crops: grain maize, spring barley, soybeans, winter wheat. Soil CO_2 emissions were measured at each tillage. Every year, in the monitored years higher CO_2 emissions were found in conventional tillage (average 0.166 g m^{-2} h^{-1}) and lower at reduced tillage (average 0.157 g m^{-2} h^{-1} – reduced tillage. resp. average 0.153 g m^{-2} h^{-1} direct sowing). From the point of view of the year a higher emission of carbon dioxide from the soil was found in 2016 (average 0.184 g m^{-2} h^{-1}), lower in 2017 (average 0.152 g m^{-2} h^{-1}) and the lowest in 2018 (average 0.142 g m^{-2} h^{-1}). The differences in CO_2 emissions found between tillage and reduced tillage and direct sowing were statistically insignificant.

Keywords: Gleyic Fluvisols, CO_2 emissions, tillage, maize

INTRODUCTION

It is generally known that global climate change caused by anthropogenic emission of greenhouse gases is the most important environmental problem in human history. On the intensity of the greenhouse effect has significant influence the content of CO_2 in the atmosphere, which is increasing mainly by burning fossil fuels. Less well known is the fact that tillage and farming methods in agriculture also contribute to the increase in CO_2 concentrations in the atmosphere. In the last two decades the study of the CO_2 content of the atmosphere has become the subject of worldwide research, because its increasing concentration intensifies the greenhouse effect. There is a warming and climatologists are talking about climate change and its influence on all components of human activity including agriculture.

Carbon dioxide is one of the most important gases in the soil, where its concentration is 10 to 100 times higher than in the atmosphere. It is produced in the soil by two main processes - microbiological degradation of organic matter and respiration of the plant root system. This CO_2 production is very variable and depends on many external factors, but also on the properties of the soil profile. Soils are the largest terrestrial pool of carbon (C) storing 2344 Pg C (1 Pg = 1 billion tonnes) of soil organic carbon (SOC) in the top 3 m. Tillage also affects soil organic carbon stock. Tilling changes the balance between organic carbon put into the soil by plants and rendered available for soil micro-organisms and carbon output as greenhouse gases due to organic matter decomposition. Soil tillage is estimated to have decreased SOC stocks by two-thirds from pre-deforestation levels (Lal. 2003). Agricultural systems contribute to carbon emissions through many mechanisms, but on the other hand, through soil protection technologies they become potential carbon sinks in the soil. Land managed by soil protection technologies can accumulate significantly more carbon than its losses. The reduction of CO_2 emissions from the soil is caused and influenced by the reduction of the intensity of manipulation with the surface layer of the soil the preservation of new organic matter in the soil and at the same time by reduction of the extent of oxidation processes affecting organic matter in the soil.

The aim of the paper was to quantify carbon dioxide emissions from the soil of grain maize grown in different tillage methods.

MATERIAL AND METHOD

The issue was solved in the years 2016 - 2018 at the experimental workplace of the National Agricultural and Food Centre - Research Institute of Agroecology Michalovce, which is located in Milhostov. The Milhostov experimental workplace is located in the central part of the East Slovakian lowlands at an altitude of 101 m (48 ° 40′ N; 21 ° 44′ E), northwest of the district town of Trebišov.

There are gleyic fluvisols, which arose as a result of long-term exposure of groundwater and surface water on very heavy alluvial sediments with adverse physical and physic-chemical properties. The problem was solved in experiments with different tillage. The field experiment included two soil protection technologies (reduced tillage - RT and no-tillage resp. direct sowing - NT), which were compared with conventional tillage with ploughing – CT.

The field experiment was established as a rotation of four crops: grain maize, spring barley, soybeans, winter wheat. Soil CO_2 emissions were performed at each tillage. During the monitoring period, five measurements of CO_2 emissions from the soil were performed annually on grain maize.

Terms measured 2016: 1. – 15.5.; 2. – 22.6.; 3. – 7.7.; 4. – 21.7.; 5. – 8.9.

Terms measured 2017: 1. – 29.5.; 2. – 28.6.; 3. – 19.7.; 4. – 22.8.; 5. – 25.9.

Terms measured 2018: 1. – 24.5.; 2. – 26.6.; 3. – 19.7; 4. – 9.8.; 5. – 27.9.

At the given dates on each variant 5 measurements were performed at three-minute intervals in three replicates. COMT 500 instruments were used for measurement.

Figure 1: Measurement of CO_2 emissions at grain maize

RESULTS AND DISCUSSION

The average amounts of carbon dioxide emissions from the soil under the grain maize are presented in *Table 1*. The results are recalculated with respect to the amount of emissions at the beginning and at the end of the measurement, the incubation time, the air temperature at the beginning and at the end of the measurement, the volume of the incubation vessel and the measured area and are presented in g m^{-2} h^{-1}. Every year in the monitored years higher CO_2 emissions were found in conventional tillage (average 0.166 g m^{-2} h^{-1}) and lower at reduced tillage (average 0.157 g m^{-2} h^{-1} – reduced tillage, resp. average 0.153 g m^{-2} h^{-1} direct sowing).

Table 1: CO_2 emissions [g.m^{-2}.h^{-1}] at grain maize

Term	**CT**			**RT**			**NT**		
	2016	**2017**	**2018**	**2016**	**2017**	**2018**	**2016**	**2017**	**2018**
1.	0.165	0.150	0.099	0.176	0.164	0.104	0.174	0.122	0.079
2.	0.183	0.181	0.196	0.170	0.188	0.192	0.162	0.167	0.215
3.	0.176	0.159	0.191	0.170	0.164	0.185	0.153	0.173	0.186
4.	0.244	0.174	0.151	0.221	0.178	0.139	0.223	0.157	0.145
5.	0.228	0.106	0.097	0.141	0.112	0.059	0.173	0.083	0.086
average (year)	0.199	0.154	0.147	0.176	0.161	0.136	0.177	0.140	0.142
average (tillage)	0.166			0.157			0.153		

CT – conventional tillage, RT – reduced tillage, NT – no-tillage resp. direct sowing

From the point of view of the year a higher emission of carbon dioxide from the soil was found in 2016 (average 0.184 g m^{-2} h^{-1}), lower in 2017 (average 0.152 g m^{-2} h^{-1}) and the lowest in 2018 (average 0.142 g m^{-2} h^{-1}).

Table 2: CO_2 emissions [g.m^{-2}.h^{-1}] at different tillage

Crops	**tillage**	**2016**	**2017**	**2018**
Grain maize	CT	0.199	0.154	0.147
	RT	0.176	0.161	0.136
	NT	0.177	0.140	0.142
	average	0.184	0.152	0.142

CT – conventional tillage, RT – reduced tillage, NT – no-tillage resp. direct sowing

Average air temperature and total amount of precipitation at the experimental locality and their comparison with the long-term normal for the years 1981 – 2010 (*Danilovič et al*. 2017) are presented in *Table 3.*

Table 3: Average air temperature [ºC] and total amount of precipitation [mm]

Month	Air temperature [ºC]				Total amount of precipitation[mm]			
	LT[ºC]	2016	2017	2018	LT[mm]	2016	2017	2018
IV.	14.5	10.4	11.6	9.7	41	13	46	28
V.	15.5	15.8	16.2	18.4	66	66	52	80
VI.	18.4	20.5	20.3	20.3	67	36	87	106
VII.	20.4	21.5	20.4	22.2	77	100	75	25
VIII.	19.8	19.6	21.4	23	66	89	48	52
IX.	14.8	17.2	15.1	16.9	57	46	60	27
average - sum	16.6	17.7	17.2	19.2	374	350	368	318

LT - long-term

From the point of view air temperature the vegetation period of 2017 was warm, in 2016 very warm and in 2018 extraordinary warm. From the point of view precipitation (vegetation period identical to the CO_2 measurement period), we can evaluate the years 2016 and 2017 (93.5 % of the long-term normal, resp. 98.4 % of the long-term normal) as normal and the vegetation period of 2018 was dry (85 % of the long-term normal). Weather especially temperature and precipitation significantly influence the overall carbon sequestration in the soil and its subsequent release *(Suddick et al.* 2010).

Álvaro-Fuentes et al. (2008) investigated tillage impact on CO_2 emissions from soils in a semiarid climate attributed the observed large difference between tillage and no-tillage to differences in soil water availability. At humid sites high soil moisture favour high decomposition rates resulting in small differences between tilled and untilled soils, while large differences develop in arid climates with much lower soil water content (*Fortin et al*. 1996; *Feiziene et al.* 2011). This supports the idea that the soil response to tillage is affected by climate thresholds (*Franzluebbers and Arshad.* 1996). This fact was not confirmed in our experiment, because 2018 was the driest year, but the difference in CO_2 emissions between tillage soil and no-tillage soil was not significant (5.4 %). Our results showed that in 2016 the amount of CO_2 emissions from no-tillage soil (average of RT and NT variants) was 11.3 % lower compared with soil tillage. By analogy a lower amount of carbon dioxide emissions was on no-tillage variants in 2017 (by 2.3 %), resp. in 2018 (by 5.4 %) compared to tillage variants. *Khatab et al*. (2016) evaluated 46 works dealing with the CO_2 emissions from soil and found that tillage emitted 27 % more CO_2 than no-tillage in arid climates; while for pairs in humid climates tillage emitted 16 % more CO_2 than no-tillage. In clayey soils the differences between tillage and no-tillage were much smaller with tilled soils emitting 9 % more CO_2 than untilled soils. Our results confirm their findings, because the soils of our experiment are heavy (gleyic fluvisols) and the differences in CO_2 emissions between tillage and no-tillage soil were statistically insignificant. The contents of soil organic carbon in the experiment (*Table 4*) with different tillage systems were quite balanced and ranged from 14.02 - 17.93 g kg^{-1}. Slightly higher contents of soil organic carbon were recorded on reduced and no-tillage variant. According to a study by *Khataba et al.* (2016), soils with a content of soil organic carbon in the range of 10 - 30 g kg^{-1} tilled soils emitted an average 17 % more CO_2 than untilled ones. In our case the values are slightly lower, as the variant with reduced tillage and no-tillage emitted by 2.3 - 11.3 % less CO_2 than in the tillage variant.

Table 4: Content of the soil organic carbon on experimental variants [g kg^{-1}]

Year	CT	RT	NT
2016	15.67	16.72	16.71
2017	14.02	14.72	15.24
2018	16.80	17.59	17.93
average	15.50	16.34	16.63

CT – conventional tillage, RT – reduced tillage, NT – no-tillage resp. direct sowing

CONCLUSIONS

In a three-year trial experiment statistically insignificant differences in CO_2 emissions were found between tilled and no-tilled soil. In individual years 2.3 - 11.3 % less carbon dioxide was emitted from no-tilled soils than tilled soils. Our results indicate that improved agronomic practices include minimal tillage can also bring side benefits in the form of reduced greenhouse gas emissions and improved carbon sequestration. Carbon sequestration in the soil can make a significant contribution to mitigating the negative effects of climate change in the future.

A TALAJMŰVELÉS HATÁSA A TALAJBÓL SZÁRMAZÓ SZÉN-DIOXID KIBOCSÁTÁSÁRA ÉS MENNYISÉGI MEGHATÁROZÁSÁRA

HECL JÁN – ŠOLTYSOVÁ BOŽENA – DANIELOVIČ IGOR

Nemzeti Agrár- és Élelmiszeripari Központ - Agroökológiai Kutatóintézet, Michalovce, Szlovákia

ÖSSZEFOGLALÁS

A CO_2-kibocsátás mennyiségi meghatározását a 2016-2018-as években Milhostovban a szemes kukoricánál glejes öntéstalajon vizsgáltuk. A kukoricát két talajvédelmi technológiával (csökkentett talajművelés, közvetlen vetés talajművelés nélkül, illetve talajművelés nélküli vetés) termesztették, amelyeket összehasonlítottuk a hagyományos szántással történő talajműveléssel. A szántóföldi kísérletet négy kultúra vetésforgójaként alakítottuk ki: szemes kukorica, tavaszi árpa, szója, őszi búza. A talaj CO_2-kibocsátást minden talajművelésnél megmértük. A megfigyelt években magasabb CO_2-kibocsátást mértünk a hagyományos talajművelésnél (átlagosan 0,166 g m^{-2} h^{-1}) és alacsonyabb a csökkentett talajművelésnél (átlagosan 0,157 g m^{-2} h^{-1} - csökkentett talajművelés, illetve átlagosan 0,153 g m^{-2} h^{-1} közvetlen vetés). Az évjárat szempontjából 2016-ban magasabb (átlagosan 0,184 g m^{-2} h^{-1}), 2017-ben alacsonyabb volt a talajból származó szén-dioxid-kibocsátás, (átlagosan 0,152 g m^{-2} h^{-1}) és a legalacsonyabb 2018-ban (átlagosan 0,142 g m^{-2} h^{-1}). A talajművelés, a csökkentett talajművelés és a közvetlen vetés között a CO_2-kibocsátásban talált különbségek statisztikailag nem igazoltak.

Kulcsszavak: glejes öntéstalaj, CO_2-kibocsátás, talajművelés, kukorica

ACKNOWLEDGEMENTS

This publication was supported by the Operational Programme Integrated Infrastructure within the project: Sustainable smart farming systems taking into account the future challenges 313011W112 cofinanced by the European Regional Development Fund.

LITERATURE

Álvaro-Fuentes, J. – López, M. – Arrúe, J. - Cantero-Martínez. C. (2008): Management effects on soil carbon dioxide fluxes under semiarid Mediterranean conditions. Soil Sci. Soc. Am. J. 72, 194-200.

Brázdil, R. et al. (1996): Impacts of a Potential Climate Change on Agriculture of the Czech Republic Country Study of Climate Change for the Czech Republic. Element 2. Národní klimatický program ČR. svazek 21. Praha. Český hydrometeorologický ústav. 146 s. ISBN 80-85813-31-9.

Danilovič, M. – Hlavatá, H. – Šoltysová, B. (2017): Criteria for abnormality evaluation of selected weather parameters in the Slovak Republic. Agriculture (Poľnohospodárstvo). 63, (2) 86-91 ISSN 1335-2415. DOI: 10.1515/agri-2017-0005.

Feiziene, D. – Feiza, V. – Kadziene, G. – Vaideliene, A. – Povilaitis, V. - Deveikyte, I. (2011): CO_2 fluxes and drivers as affected by soil type. tillage and fertilization. Acta Agr. Scand. Section B-Soil Plant. 62, 311-328.

Fortin, M, C. – Rochette, P.- Pattey, E. (1996): Soil carbon dioxide fluxes from conventional and no-tillage small-grain cropping systems. Soil Sci. Soc. Am. J. 60, 1541-1547

Franzluebbers, A. – Arshad, M. (1996): Soil organic matter pools with conventional and zero tillage in a cold. semiarid climate. Soil Till. Res. 39, 1-11.

Frier, N. - Chadwick O, A. - Trumbore S, E. (2005): Production of CO_2 in Soil Profiles of a California Annual Grassland Ecosystems. 8, (4). 412-429.

Jobbágy, E, G. – Jackson, R, B. (2000): The vertical distribution of soil organic carbon and its relation to climate and vegetation. Ecol. Appl. 10, 423–436.

Pauline, Ch. – Philippe, C. – Vincent, Ch. (2016): No-tillage lessens soil CO_2 emissions the most under arid and sandy soil conditions: results from a meta-analysis. Biogeosciences. 13, 3619-3633

Krištof, K. – Šíma, T. – Nozdrovický, L. – Findura, P. (2014). The effect of soil tillage intensity on carbon dioxide emissions released from soil into the atmosphere (2014). In: Agronomy research 12, (1).115-120.

Lal, R. (2003): Global potential of soil carbon sequestration to mitigate the greenhouse effect. Crit. Rev. Plant Sci. 22, 151-184.

Lavelle, P. – Spain, A,V. (2001): Soil Ecology. Kluwer Academic Publishers. New York. 613p.
ISBN-13 978-0-306-48162-8 (e-book)

Rastogi, M. – Singh, S. – Pathak, H. (2002): Emission of carbon dioxide from soil. Curr. Sci. 82, 510-517.

Suddick, E, C. et al. (2010): The Potential for California Agricultural Crop Soils to Reduce Greenhouse Gas Emissions. A Holistic Evaluation (Book). Advances in Agronomy. 107, (C) 123-162.

A szerző levélcíme – Address of the author:

Ján Hecl – Božena Šoltysová – Igor Danielovič
NPPC – Agroecology Research Institute Michalovce, Špitálska 1273, 071 01 Michalovce, Slovakia
e-mail: jan.hecl@nppc.sk