Int. Agrophysics, 2008, 22, 287-290

INTERNATIONAL
Agrophysics
www.international-agrophysics.org

Emission of greenhouse gases and soil organic matter balance in different farming systems**

J. Stalenga and A. Kawalec*

Osiny Experimental Station, Department of Systems and Economics of Crop Production, Institute of Soil Science and Plant Cultivation, National Research Institute (IUNG-PIB), Czartoryskich 8, 24-100 Puławy, Poland

Received May 27, 2008; accepted June 3, 2008

A b s t r a c t. Estimation of the influence of different farming systems on emission of greenhouse gases (methane and nitrous oxide) was the aim of the research. The research was conducted on the basis of a special field experiment established in 1994 in the Experimental Station in Osiny in which different crop production systems are compared, and in a group of 20 organic farms organic farms located in the central part of Poland. For the first object the analysis of nitrous oxide emission and soil organic matter balance was done for 1996-2007, whereas for the second one CH_4 and N_2O emission and potential of sequestration of CO_2 in soil organic matter was done for 2004-2005.

Organic farming system was characterized by significantly lower nitrous oxide emission in comparison to other systems. There was no distinct difference in CH_4 emission between compared systems. In the organic farms, total CH_4 and N_2O emission expressed in GWP units amounted to 1623 points and this was 22% less than the average value for the Kuyavian-Pomeranian voivodeship. Balance method showed that organic system has a great potential in sequestration of CO_2 in soil organic matter in comparison to integrated and conventional systems. However, measurements of humus content in soil did not confirm that observation.

K e y w o r d s: organic farming, greenhouse gases, methane, nitrous oxide

INTRODUCTION

Agriculture, like other human activities, is a source of emission of greenhouse gases, mainly CO_2, CH_4, and N_2O. The rate of this emission increases year by year as a result of increase of total crop and animal production all over the world. Nalborczyk *et al*. (1996) showed that the level of emission of particular greenhouse gases significantly depends on the type of farm and system of farming.

At the same time agriculture has a great potential to absorb huge amounts of CO_2 in crop biomass and its retention in soil humus. In consequence agriculture may significantly mitigate the greenhouse effect (Hepperly *et al*., 2007).

Evaluation of the effect of different crop production systems on the rate of nitrous oxide and methane emission and soil organic matter balance was the aim of the research work.

MATERIALS AND METHODS

The research was conducted on two independent objects. The first one was a special field experiment established in 1994 in the Experimental Station in Osiny (Lublin voivodeship) in which different crop production systems (ecological, integrated and conventional) are compared. The analysis was done for the period of 12 years (1996-2007). For this object only the rate of nitrous oxide emission and soil organic matter balance were taken into account in the research.

The second object was a group of 20 organic farms located in a close distance from each other in the central part of Poland (18 farms were from Kuyavian-Pomeranian and 2 farms from Warmian-Masurian voivodeship). Evaluation of greenhouse gases emission (CH_4, N_2O) and potential of sequestration of CO_2 in soil organic matter of theses farms was done for 2004-2005.

Both the process of enteric fermentation and manure management were taken into account in assessment of CH_4 emission. Calculations of its emission from enteric fermentation were done only for farms with cattle keeping, because just this group of farm animals is the most important source

*Corresponding author's e-mail: stalenga@iung.pulawy.pl
**The work was done under Programme of the Scientific Network, AGROGAS Project 'Reduction of greenhouse gas and ammonia in agriculture', contract No. 17/E-164/SN-019/2007.

of this greenhouse gas. The following values of CH_4 emission from this process for particular farm animals (in kg/unit/year) were assumed: 94 – cows; 47.3 – other cattle (Olendrzyński *et al*., 2007). CH_4 emission from manure management was calculated on the basis of data on manure production in a farm. There was 25% of dry matter in manure, of which 20% of this matter can undergo fermentation. Efficiency of methagenesis for manure was assumed on the level of 0.3 mol per 1 kg of fermented substance (1 mol of CH_4 = 16 g of CH_4) (Nalborczyk *et al*., 1996).

The following sources of N_2O emission were taken into account: manure/compost management, biological nitrogen fixation and synthetic fertilizers (only for conventional farms). It was assumed that 1.15% of total N content in manure is lost as N_2O and that about 1% of symbiotically fixed nitrogen is denitrified to N_2O (Emission of greenhouse gases in Poland, 1994). For synthetic nitrogen fertilizers it was assumed that 0.9% of total N content in a fertilizer is lost in the form of nitrous oxide (Olendrzyński *et al*., 2007).

Emission of N_2O and CH_4 was expressed in CO_2 equivalent using special values of Global Warming Potentials (GWP) (Olendrzyński *et al*., 2007).

Special indexes of reproduction and degradation of soil organic matter were taken into account in evaluation of the effects of crop production systems on the content of soil organic matter and on potential of sequestration of CO_2 in soil (Kundler *et al*., 1981). Measurements of humus content in soil were compared with the results of the above mentioned balance method.

RESULTS AND DISCUSSION

Emission of N_2O in the organic crop production system was more than two times lower than in two other systems (Table 1). The ban of mineral nitrogen was the main factor that considerably reduced the concentration of easily available mineral nitrogen in soils and thus N_2O emissions in organic farming. Furthermore, diversified crop rotations with green manure improve soil structure and diminish emissions of nitrous oxide, and additionally soils managed organically are more aerated and have significantly lower mobile nitrogen concentrations.

In literature there are studies showing that emissions of N_2O from organic grass-clover leys were considerably lower than from conventional grass. In the study by Petersen *et al.* (2006), lower emission rates for organic compared to conventional farming were found for five European countries. In a long-term study in southern Germany, Flessa *et al*. (2002) also found reduced nitrous oxide emission rates in the organic farm, although yield-related emissions were not reduced. However, some authors show (Ball *et al*., 2002) that some N_2O emissions from organic arable systems are higher than from conventional systems, particularly in the first year after ploughing out ley.

Soil organic matter balance (taking into account crop rotation and manure/compost management) in the organic system was positive and amounted to 1.9 t ha^{-1} $year^{-1}$ (Table 2). This confirms high potential of organic system in sequestration of CO_2 in soil organic matter. Very positive soil organic

T a b l e 1. Emission of pure N_2O and in CO_2 equivalent (kg ha^{-1}) in different crop production systems (1996-2007)

Source of emission	Emission expressed in N_2O			Emission expressed in CO_2		
	Organic	Conventional	Integrated	Organic	Conventional	Integrated
Synthetic fertilizers	-	1.29	0.64	-	400	198
Manure/compost management	0.24	-	0.30	74	-	93
N-fixing crops	0.20	-	0.13	62	-	40
Total	0.44	1.29	1.07	136	400	332

T a b l e 2. Soil organic matter balance (t ha^{-1}) in different crop production systems (1996-2007)

Specification	Influence of crop rotation	Influence of organic fertilizers	Influence of ploughed straw	Balance
Organic system (ECO)	1.46	0.44	-	1.90
Conventional system (CON)	-1.59	-	0.73	-0.86
Integrated system (INT)	-2.11	0.55	0.32	-1.24

matter balance in the organic farms was a result of 40% share of fodder crops in the cropping system. Whereas, in two other systems a negative balance was noted and it was a consequence of high share of cereals and other crops influencing negatively soil organic matter balance in the cropping system.

High dynamics of changes of humus content during the period of 12 years in 3 systems was observed (Fig. 1). In general, a little decrease of its content was observed for all the systems, however in organic and integrated systems this decrease was higher than in the conventional one. Actual humus content depended on the value measured at the beginning of the analysed period.

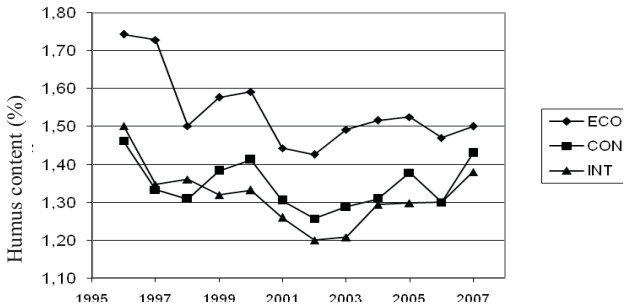

Fig. 1. Changes of humus content in different crop production systems (1996-2007).

In the investigated group of organic farms with cattle keeping, average CH_4 emission in the period 2004-2005 amounted to 72.3 kg ha^{-1} $year^{-1}$ and it was 12 kg less than the average value in the Kuyavian-Pomeranian voivodeship (Table 3). This difference was mainly a consequence of a significant drop of cattle density in the organic farms in 2005 in comparison to the former year when it was on the same level as for the whole voivodeship. In general, methane emission is more connected with cattle density in a farm than with the farming system.

Emission of N_2O in the investigated organic farms was about 3 times lower than the average value for the voivodeship and amounted to 0.34 kg ha^{-1} $year^{-1}$ (Table 4). The reason has already been explained above. In the analyses, emission of N_2O connected with industrial processes of production of some synthetic nitrogen fertilizers was not taken into account.

Some authors (Olesen *et al*., 2006) show that the greenhouse gases (GHG) emissions at farm level could be related to either the farm N surplus or the farm N efficiency. In other own research (Kuś *et al*., 2005) conducted in this group of farms significantly lower nitrogen surpluses were noted for organic farms in comparison to conventional farming in this region.

Soil organic matter balance in the investigated organic farms was positive and amounted to 1.07 t ha^{-1} $year^{-1}$. High share of fodder crops in the cropping system and a relatively high stocking rate influenced this result. Whereas, a slighty negative (-0.02 t ha^{-1} $year^{-1}$ balance in the conventional farms in Kuyavian-Pomeranian voivodeship was a consequence of

Table 3. Emission of pure CH_4 and in CO_2 equivalent (kg ha^{-1}) in the investigated organic farms and in conventional farms in Kuyavian-Pomeranian voivodeship in 2004-2005

Specification	Emission in CH_4		Emission in CO_2 eq.	
	Organic	Conventional	Organic	Conventional
Enteric fermentation*	70.5	82.5	1480	1732
Manure management	1.8	1.6	38	34
Total	72.3	84.1	1518	1766

*Only farms with cattle keeping.

Table 4. Emission of pure N_2O and in CO_2 equivalent (kg ha^{-1}) in the investigated organic farms and in conventional farms in Kuyavian-Pomeranian voivodeship in 2004-2005

Specification	Emission in N_2O		Emission in CO_2 eq.	
	Organic	Conventional	Organic	Conventional
Synthetic fertilizers	-	0.84	-	260
Manure management	0.12	0.09	37	28
N-fixing crops	0.22	0.08	68	25
Total	0.34	1.01	105	313

72% share of cereals in the cropping system, a very low share of fodder crops (7.6%), and additionally significantly lower than in the organic farms stocking rate (67 LU/100 ha of UAA).

Sequestration of CO_2 in soil organic matter seems to be one of the most promising tools for mitigating the greenhouse effect in agriculture. The results of many researchers (Marriott and Wander, 2006; Niggli *et al.*, 2008; Pimentel *et al*., 2005) show that the enhanced soil fertility in organic farming leads to stabilization of soil organic matter and in many cases to sequestration of carbon dioxide into the soils.

It is estimated that, under Northern European conditions, conversion from conventional to organic farming would result in an increase of soil organic matter of 100 to 400 kg per hectare annually during the first 50 years. After 100 years, a steady state *ie* a stable level of soil organic matter, would be reached (Foereid and Høgh-Jensen, 2004).

Results of own research showed that organic farming had such a potential, however significant effects may be visible only when good agricultural practices for reproduction of soil organic matter will be implemented on a wide scale.

CONCLUSIONS

1. Organic farming system was characterized by significantly lower nitrous oxide emission in comparison to other systems.

2. There was no distinct difference in CH_4 emission between compared systems.

3. In the organic farms, total CH_4 and N_2O emission expressed in GWP units amounted to 1623 points and this was 22% less than the average value for the Kuyavian-Pomeranian voivodeship.

4. Balance method showed that organic system has a great potential in sequestration of CO_2 in soil organic matter in comparison to integrated and conventional systems. However, measurements of humus content in soil did not confirm that observation.

REFERENCES

Ball B., Scott A., Mc Taggart I.P., and Watson Ch.A., 2002. Greenhouse gas emissions from soils under organic management. Proc. Conf. UK Organic Research, March 26-28, Aberystwyth, UK.

Emission of greenhouse gases in Poland (in Polish), **1994.** Report Ministry of Environment Protection, Warsaw, Poland.

Flessa H., Ruser R., Dörsch P., Kamp T., Jimenez M.A., Munch J.C., and Beese F., 2002. Integrated evaluation of greenhouse gas emissions (CO_2, CH_4, N_2O) from two farming systems in southern Germany. Agric. Ecosys. Environ., 91, 175-189.

Foereid B. and Høgh-Jensen H., 2004. Carbon sequestration potential of organic agriculture in northern Europe – a modelling approach. Nutr. Cycl. Agroecosyst., 68(1), 13-24.

Hepperly P., Seidel R., Pimentel D., Hanson J., and Douds D.D., 2007. Organic farming enhances soil carbon and its benefits. In: Soil Carbon Management, Economic, Environmental and Societal Benefits. (Eds A. Kimble, C. Rice, M. Read, F. Mooney, A. Follet, and A. Lal). CRC Press, Boca Raton, FL, USA.

Kundler P., Eich D., and Liste J., 1981. Mehr tun als nur ersetzen: Verstärkte Zufuhr organischer Substanz zum Boden – Wesentliche Voraussetzungen für einen hohen Leistungsanstieg in der Pflanzenproduktion. Neue Deutsche Bauernzeitung, 22(36), 8-9.

Kuś J., Kopiński J., Madej A., and Stalenga J., 2005. Comprehensive evaluation of the organic farms in the Brodnica region (the Kuyavian-Pomeranian voivodeship) Part 1. In: Comprehensive evaluation of selected organic farms in the kujawsko-pomorskie region and organic food chain. BERAS Project Report, IUNG-PIB Press, Puławy, Poland.

Marriott E.E. and Wander M.M., 2006. Total and labile soil organic matter in organic and conventional farming systems. Soil Sci. Soc. Am. J., 70, 950-959.

Nalborczyk E., Łoboda T., Pietkiewicz S., Siudek T., Machnacki M., and Sieczko L., 1996. Emission of greenhouse gases in Polish agriculture and possibilities for its reduction. Part II. Greenhouse gases balance in different farms specialised in crop production (in Polish). Expert Opinion, SGGW Press, Warsaw, Poland.

Niggli U., Schmid H., and Fliessbach A., 2008. Organic Farming and Climate Change. Int. Trade Centre (ITC) Press, Geneva, Suisse.

Olendrzyński K., Kargulewicz I., Skośkiewicz J., Dębski B., Cieślińska J., Olecka A., Kanafa M., and Kania K., 2007. Greenhouse gases emission inventory for 2005 (in Polish). Institute of Environment Protection Press, Warsaw, Poland.

Olesen J.E., Schelde K., Weiske A., Weisbjerg M.R., Asman W.A.H., and Djurhuus J., 2006. Modelling greenhouse gas emissions from European conventional and organic dairy farms: Agric. Ecosys. Environ., 112, 207-220.

Petersen S.O., Regina K., Pöllinger A., Rigler E., Valli L., Yamulki S., Esala M., Fabbri C., Syväsalo E., and Vinther F.P., 2006. Nitrous oxide emissions from organic and conventional crop rotations in five European countries: Agriculture, Ecosys. Environ., 112, 200-206.

Pimentel D., Hepperly P., Hanson J., Douds D., and Seidel R., 2005. Environmental, energetic, and economic comparisons of organic and conventional farming systems. BioSci., 55(7), 573-582.