16th IFOAM Organic World Congress, Modena, Italy, June 16-20, 2008
Archived at http://orgprints.org/view/projects/conference.html

Carbon sequestration in organic and conventional managed soils in the Netherlands

Sukkel, W.[1], Geel, W. van[1] & Haan, J.J. de[1]

Key words: organic matter, carbon sequestration, farm management, organic agriculture

Abstract

Next to other important agronomic and ecological aspects, the organic matter sequestration in the soil plays an important role in the CO_2 balance. Based on detailed farm registrations, the input of effective organic matter and the changes in carbon sequestration in the soil was calculated for a large number of organic and conventional farms in the Netherlands. Results show that both organic and conventional management resulted in a decrease of the pool of organic carbon in the soil. The average decrease for the conventional management was 401 kg ha^{-1} $year^{-1}$ and for the organic management 261 kg ha^{-1} $year^{-1}$. The input of effective organic matter in the soil was significantly higher in organic than in conventional farms. Animal manure was the main contributor to this difference.

Introduction

Changes in the organic matter in the soil are crucial for agronomic aspects like nutrient dynamics, structure and water storage capacity as well as for the environmental performance of a farming system like biodiversity, nitrate leaching and recently in focus, carbon storage in the soil. Organic matter in soils acts as a large carbon sink and plays an important role in the CO_2 balance. This paper will deal with the changes of the organic matter in the soil under current organic and conventional management practices in the Netherlands.

Materials and methods

Data for the calculation of the changes in soil organic matter were obtained from detailed farm registrations of 101 organic and 85 conventional farms in the Netherlands divided in three regions: Central clay, South-west clay and South-east sand. Each region represents a group of farms on a similar soil type and under similar climate conditions. Data were registered in the period 1998 to 2006. From every farm there were 1 to 4 years of registered data available. Both the amount and type of organic matter input were registered including crop residues and green manures.

From the data an average organic matter input and the so called effective organic matter input were calculated for organic and conventional farms in a certain region. The effective organic matter is defined as the organic matter that is still available one year after incorporation in the soil. For every type of organic matter, standard data are used for the remaining percentage of organic matter after one year of incorporation in the soil.

[1] Wageningen University and Research Centre, dep. Applied Plant Research. Edelhertweg 1, 8219 PH, Lelystad, The Netherlands, E-Mail: wijnand.sukkel@wur.nl

To predict the effect of different organic matter management strategies on organic and conventional farms, the decomposition model of Janssen (1996) was used. This model describes the decomposition of organic matter or carbon (C) in the soil as:

$$Y_t = Y_0 \cdot EXP\ (\ 4.7\ ((a + t \cdot f_{temp})^{-0.6} - a^{-0.6}\ )\ )$$

Where Y_t = remaining amount of OM after t years; Y_0 = initial amount of fresh organic matter added to the soil; t = number of years after application; f_{temp}= correction factor for temperature (f_{temp}= 1 when average temperature is 9 ^oC); a = initial age of the organic material.

The increase of organic matter in the soil caused by the yearly input on the one hand and the loss of the present soil organic matter (SOM) on the other hand, were calculated separately. The a-value is based on the type of organic matter that is incorporated in the soil and can be derived from the humification rate of the incorporated organic matter in the first year. For this study an average a-value was calculated per region and farm type, based on the average organic and effective organic matter input per region and farm type and this value was used in the model. The decomposition rate of the present SOM of the involved farms is unknown. From results of long-term experiments in the Netherlands by Kortleven (1963) an average a-value for SOM of 16 was determined (Janssen, 2002). From a long-term pot experiment with 36 Dutch soils Wadman & De Haan (1997) found a-values ranging from 14 to 50. On two different sand locations in the south east of the Netherlands Postma & van Dijk (2004) found a-values of 16 and 19. According to Van Veen & Kuikman (1990) finer, clayey soils show on average slower decomposition rates and a higher retention of organic matter than coarse, sandy soils. To calculate the carbon loss of the involved farms for this case an a-value of 21 is used for the clay soil regions and of 16 for the south east sand region. The a-values correspond with a decomposition of the soil organic matter of 2% respectively 3% between t_o en t_1. For all calculations the average year temperature in the region is used for the calculation of the correction factor f_{temp}.

Results and discussion

It shows in figure 1 that the main contributions to the input of effective organic matter are made by the input of crop residues (roots, stubble etc.) and by the input of animal manure. Animal manure is available in abundance in the Netherlands. The main difference between organic and conventional management is the amount of input of animal manure, vegetable manure (mainly compost) and green manure.

Table 1 depicts the results of the model calculations. It shows that both with the conventional and the organic management the amount of carbon in the soil is decreasing in the course of the coming 25 years. However the organic management loses on average 140 kg of carbon per year less than the conventional management.

A critical comment on the better performance of the organic management is that in the Netherlands the majority of the applied animal manure on organic farms is still coming from conventional farms. So it derives part of its better performance in carbon losses from the conventional sector.

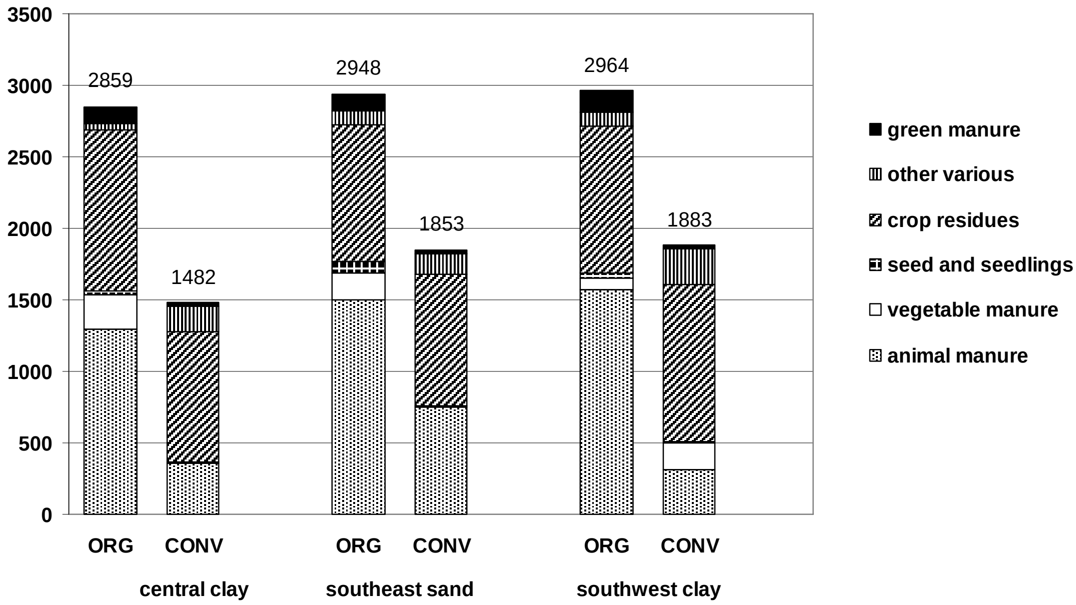

Figure 1: Input and origin of effective organic matter (kg ha^{-1} year^{-1}) per group of farms in a region.

Tab. 1: Average percentage of organic matter (o.m.) in the soil and calculated changes in sequestered carbon in the soil per group of farms.

Region	Type	No of farms	%soil o.m.	Carbon change (kg ha^{-1} year^{-1})		
				increase	loss	net change
central clay	organic	22	4.0	320	670	-351
	conv.	17	3.4	138	589	-451
southeast sand	organic	38	3.0	339	659	-320
	conv.	34	2.9	174	640	-465
southwest clay	organic	41	2.4	326	437	-111
	conv.	34	2.6	176	463	-287
total	organic	101	3.1	328	589	-261
total	conv.	85	3.0	163	564	-401

The decomposition of organic matter may better be described by the model of Yang (Yang and Janssen, 2000). However this model uses two parameters for the decomposition rate and the values of these parameters for different types of organic matter are unknown yet. Furthermore the used Janssen model, does not account for soil properties affecting the decomposition rate of the organic matter such as texture.

The result of the calculated net change of soil carbon largely depends on the decomposition of the present SOM (for this case the setting of the a-value). When the a-value is changed into 18 or 30 for clay soils and 13 or 25 for sand soils, the average net change of soil carbon varies from -360 to -71 kg ha^{-1} year^{-1} for the organic farms and from -496 to -219 kg ha^{-1} year^{-1} for the conventional farms.

The net decrease of organic carbon in the soil on arable land is confirmed in several studies. Vleeshouwers & Verhagen (2002) come to the same conclusion for the European arable soils. Although their estimation of net carbon losses are almost double the values found in this study. In long-term comparisons of farming systems in the Netherlands on southeast sand and central clay soil organic matter content declined as well for the conventional as for the biological farming systems (Dekking, 2003; Van Geel & De Haan, 2007). The inputs of effective organic matter were comparable to the amounts mentioned in figure 1 for the two regions and farm types. Pimentel et al. (2005) however measured a net increase of organic carbon in the soil for both organic and conventional agriculture. The results concerning the additional carbon sequestration in organic soils compared to conventional soils correspond with the study of Freibauer et al (2004). Freibauer (2004) concludes that organic farm management could sequester between 0 to 500 kg of organic carbon per hectare per year more than conventional agriculture.

Conclusions

Field experiments as well as model calculations show that with the current farm management in practice on Dutch arable farms the amount of organic carbon stored in the soil decreases, both in organic as well and in conventional managed soils. However the decrease with the organic management is lower than with conventional management.

References

Dekking, A. (2003). Organische stof verdient meer aandacht. Ekoland 12: 18-19.

Freibauer, A., M.D.A. Rounsevell, P. Smith & J. Verhagen. (200. Carbon sequestration in the agricultural soils of Europe. Geoderma 122: 1-23.

Janssen, B.H. (1996).Nitrogen mineralization in relation to C:N ration and decomposability of organic materials. Plant & Soil 181, p. 39-45.

Janssen, B.H. (2002). Organic Matter and Soil Fertility. Lecture notes J 100-225, edition 2002, Wageningen Agricultural University, 247 pp.

Kortleven, J. (1963). Kwantitatieve aspecten van humusopbouw en humusafbraak. PhD thesis, Wageningen Agricultural University, 109 pp.

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

Postma, R. & T.A. van Dijk (2004). Organische stofopbouw en N-mineralisatie op kernbedrijven; verfijning model Minip. Report OV0414,Telen met Toekomst, 32 pp.

Van Geel, W. & J. de Haan (2007). Effecten van organische-stofbeheer in Nutriënten Waterproof op het organische-stofgehalte en de koolstofopslag in de bodem. Praktijkonderzoek Plant & Omgeving, Lelystad, 27 pp.

Van Veen, J.A. & P.J. Kuikman (1990). Soil structure aspects of decomposition of organic matter by micro-organisms. Biogeochemistry 11: 213-233.

Vleeshouwers, L.M. & A. Verhagen. (2002) .Carbon emission and sequestration by agricultural land use: a model study for Europe. Global Change Biology 8, 519-530.

Wadman, W.P. & S. de Haan (1997). Decomposition of organic matter from 36 soils in a long-term pot experiment. Plant and Soil 189: 289-301.

Yang, H.S. & B.H. Janssen (2000). A mono-component model of carbon mineralization with a dynamic rate constant. European Journal of Soil Science 51, p 571-529.