DUTCH (ORGANIC) AGRICULTURE, CARBON SEQUESTRATION AND ENERGY PRODUCTION.

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Abstract
Carbon sequestration in soils is often mentioned in the discussions about climate changes. In this paper the opportunities for carbon sequestration in Dutch agriculture are discussed at farm and national level. Farm internal carbon sources are already completely used in livestock farming. The effect under arable conditions is limited in time and very limited compared to national CO2 emission. External sources are scarce. Energy production out of crop residues and manure via biogas installations is possible but the overall impact is again very limited. The effect of this biogas pathway on soil organic matter quantity and quality is not yet known. Organic arable farmers do already have a higher soil organic matter content than conventional farmers, partly due to external carbon sources. This puts them in a leading position. The disadvantage is that it is more difficult for them to do a next step in increasing soil organic matter.

Introduction

In discussions about climate change, carbon sequestration in agricultural soils (Hepperly et al 2007) and energy production out of energy crops or crop residues (Möller et al 2008), are frequently mentioned as contributions from agriculture to minimize these changes. Within these discussions organic agriculture is sometimes mentioned showing a positive or less negative impact than conventional agriculture. The results of a comparison between organic and conventional agriculture and the results of an absolute net greenhouse gas balance of any agricultural system will strongly depend on the national, regional or even local conditions. For this reason, it is difficult to claim an overall effect.
In the following text we describe the situation in the Netherlands with three questions as guiding principles:

- To what extent could agricultural soil play a role in soil carbon sequestration in the Netherlands?
- Could agriculture become an energy producer without increasing the risk of insufficient organic matter input for maintaining soil fertility?
- Is organic farming as a system favorable above conventional farming with respect to carbon sequestration and energy production?

Method

A recent publication about soil organic matter (SOM) in four regions in the Netherlands (Hanegraaf et al 2007) states that SOM in both arable and grass areas is not declining. Data from the Central Agency for Statistics (Centraal Bureau voor de Statistiek 2007) were used for national arable and grassland areas. For estimating the decay of organic matter (OM) we used the national standard table for 'effective organic matter' (EOM) (Koopmans & van der Burgt, 2001). EOM is defined as the part of total OM which is, one year after application, not yet decomposed, thus contributing to SOM in the long term. The OM decay algorithm of Janssen (1984) in

the NDICEA model (van der Burgt et al, 2006) is used to estimate OM decomposition. We assumed that an increase of 0.2% (in case of arable land, from 1.8 to 2.0% SOM) would increase overall soil fertility and could in 'normal' agricultural practice be realized in 10 years without causing negative side-effects (P surpluses, N leaching). For estimations of the availability of OM (manures and composts) for carbon sequestration purpose, data from CBS (Centraal Bureau voor de Statistiek 2007) and the Association of compost producers (Vereniging Afvalbedrijven 2007) were used.
For calculations of the soil carbon we assumed that 58% of SOM is carbon, that the topsoil in arable farms is 25 cm and that the soil density is 1.35 gram cm^{-3}. For organic matters applied to the soil we assumed an average C-content of 45%.

Results and discussion

Arable land.

The actual average SOM content of arable land in four regions in the Netherlands with sandy soils is 1.8% (Hanegraaf et al, 2007) and is supposed to be stable during the last two decades. That means that in this area the actual average farm management is able to maintain 1,8% of soil organic matter, being 60,750 kg organic matter or 35,235 kg carbon per hectare. To increase this by 0.2%, 392 kg carbon should additionally be sequestered each year during ten years. To reach this, 392 * (1/0,45) = 870 kg EOM per hectare is needed. Additionally, extra carbon is needed to maintain the increased SOM level. After ten years this 'extra' has increased to 15% of the additional gift (NDICEA model calculation), so135 kg EOM.
A dosage of 870 kg EOM (1st year) up to 1005 kg (10th year) is reasonable at first sight. This can be realized, for example, by applying 8.3 (up to 9.6 in the 10th year) tons of compost with 22% OM and half of the OM being dissimilated in the first year (11 % EOM). Purchased compost at farm level is an external source of carbon; internal sources can be used too. Changes in the crop rotations can contribute to a minor degree, but cumulative it can be substantial. For example, a successful green manure crop *added* in the rotation (one in four years) might add 900 * (1/4) = 225 kg EOM per hectare and year.
Straw incorporated in the soil (once in four years) *instead of selling* brings the same amount. A cereal crop (with the straw put into the soil) *instead of a vegetable crop* (once in four years) will add 300 to 400 kg EOM. *Replacing* an artificial fertilizer application by 20 tons of cow slurry brings 600 kg EOM, so 150 kg if done once in four years, being an external carbon source for arable farms.
So far, considering the theme at field or farm level, this increase of 0.2% in ten years could indeed be accomplished with internal and/or external carbon sources. At national level the total area of arable land is about 1,000,000 hectares (Centraal Bureau voor de Statistiek 2007). At this level the situation is completely different. Compost, being an external source at farm level, is an internal source at national level. If the increase is to be realized with compost only, the need is 8.3 million tons per year. Total Dutch compost production at the time is 1,5 million tons per year (Vereniging Afvalbedrijven 2007) and this is already used in or outside agriculture for soil improvement. Other organic matter sources are not easily available.
If realized completely with internal carbon sources, which is possible but not very realistic, 3,920 kg carbon per hectare is sequestered after ten years. For 1,000,000 hectares this is 3.9 million ton carbon or 14.4 million ton CO_2, thus 1.4 million ton per

year. Total CO_2-emission in the Netherlands in 2006 was 210 million tons (Milieu & Natuur Compendium 2008).The yearly sequestration would be 0.7% of total emissions, during ten years only.

Grassland

In grassland, due to a year-round production potential and a high organic matter turn-over into the soil, an average of 4.3% OM was measured (Hanegraaf et al 2007), so considerably higher than arable land. On the average, out of an agronomic point of view there is no reason to increase soil organic matter content in grassland production systems. If nevertheless desired, this can only be done by farm-external sources of carbon since most internal sources - the grass crop itself and the manure from the herd – are used already. As mentioned before, there are no substantial external sources of carbon – organic materials – available.

Energy production out of crop residues and manure

Crop residues and manure can be applied to the soil, contributing to maintain or increase SOM. It can also first be used for energy production in biogas installations and then applied to the soil, meanwhile increasing the nitrogen use efficiency of the system (Möller et al 2008, van der Burgt 2008). As far as known, the easily decomposable carbon components will be decomposed in the biogas installation as well as in the soil when directly applied. There might be minor quantitative differences in EOM between both pathways, but this is not known yet. There might also be qualitative differences in effects on soil life. This also is not known so far, nor are known the consequences for soil fertility in the long term.

We assume that in arable farming at the average 2,000 kg organic matter is available in above-ground crop residue (straw production kept out of consideration) with 45% carbon. This is 720 million kg carbon. Annual manure production in the Netherlands is 70 million tons with an assumed average C-content of 40 kg per ton, containing 2,800 million kg C. If we assume that 1 kg carbon in organic matter can produce 0.1 m^3 gas, the (unrealistic) maximum use of all crop residues and all manures would produce 280 million m^3 gas. Annual gas consumption in the Netherlands is 21,000 million m^3. This means that a (unrealistic) maximum of 1.3% equivalence of the national gas consumption could be produced by biogas installations.

Organic agriculture

Organic grassland is supposed to have the same SOM content as conventional grassland. Organic arable land has on average a higher SOM content than conventionally cultivated arable land. This higher level can not be explained by a lower decomposition rate. It can partly be explained by a higher internal input (green manures, clover grass in the rotation, cereals in the rotation, but lower yields and therefore maybe lower crop residues act contradictory) and partly by a higher external input: manures from conventional farms and purchased composts. So organic agriculture, due to its emphasis on soil fertility and SOM, is already to a certain degree using the soil for carbon sequestration. As far as this is done with internal carbon this is indeed an organic system property. As far as it is realized by input of external sources it is not a system property. For organic farmers, because of their higher starting point, it will be more difficult to increase the SOM content with internal carbon sources than for their conventional neighbors. The potential energy production out of organic crop residues compared to conventional systems is uncertain: it might be higher due to more green manures and clover grass or alfalfa in the rotation, and it might be lower due to lower crop residue yields in general.

Conclusion

In the Netherlands, at farm level, an increase in SOM content with internal or external carbon sources is possible for arable farms. The effect is limited in time (once a higher level is reached, the increase is topped off and is unnecessary out of agronomic point of view) and quantitatively very limited compared to total national CO_2 emission. For grasslands an increase of organic matter is out if the question: there is no agronomic need and all farm internal carbon sources are used already. Additional external carbon sources are scarce.
Organic farming, especially arable farmers, have a 'plus' that they have already put additional carbon into their soils, but this is only partly a system property and another step in increasing SOM will be difficult. Nevertheless carbon sequestration might be mentioned as a positive factor for individual farmers or organic farming as a whole. Energy production might have the same role: a very limited effect, but an interesting object for positive positioning of organic agriculture.

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