7. Quantification and selection of measures to increase carbon stocks in agriculture.

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Introduction

The discussion was focussed on:
1. Identification of relevant actual and potential sinks for carbon dioxide in the Netherlands.
2. Identification of measures that may enhance these sinks.
3. What are the available methods to estimate sink-size and rate of change?
4. What are the data needs to quantify the sink-strength on a yearly basis?
5. What is the uncertainty in these estimates?
6. What is needed to reduce uncertainties in this field? For which period?

Measures that address sink-size

The participants identified some 30 measures that have an impact on sink-strength in agriculture and nature in the Netherlands. Most of these measures are not really new, some may have been abandoned in the past due to agricultural policies, few were real innovations. The participants then discussed on the criteria to select the most promising sink enhancements. There was agreement on the following criteria:

1. feasibility (both from a technical point of view and from a socio-economic and an acceptability point of view),
2. the stock should be extensive,
3. the potential sink should be of some size,
4. measures to accomplish this sink enhancement should be realistic and manageable

With these criteria the participants selected the 7 most promising measures that have a large sink potential in the Netherlands and are feasible under present socio-economic circumstances. There may very well be more potential measures, but some of these seem hard to realize on the short term (<5 years) when a change of the function of the land is involved (e.g. from agriculture to wetland and e.g. from agriculture to forest). However, they may become feasible at the medium (5-10 years) or long term (>10 years).
We have presented our results in Table 1.

Table 1: Promising measures to enhance the soil carbon in agriculture in the Netherlands around 2000

Measure	Feasibility	Data availability	Who owns the data	Uncertainty	Research needs
1. Increase of soil C in permanent grassland	+	+/-	ALTERRA Experimental farms	10-50%	Measurements in pilots
2. Groundwatertable manipulation in peatmeadows	-	+/-	ALTERRA VU.	10-50%	Measurements in pilots
3. Reduction of tillage	+	+ arable land	Experimental farms	10-50%	Measurements in pilots
4. Crop rotation and residue management	+	+	TAGA-archive ALTERRA RUG	>50%	Measurements in pilots
5. Set aside	+	Abroad, USA	Wageningen	>70%	Measurements in pilots
6. Animal manure management	+	+	Wageningen	10-15%	
7. Other organic waste management	+	+	Wageningen VAM	10-50%	Dose-effect measurements

1. Increase of soil carbon in permanent grassland

The measure is to ask farmers not to plow their meadows anymore and not to re-seed every few years and to return to "permanent grassland" instead of including grass in a crop rotation scheme. The feasibility (technical and acceptance) is high in alternative farming. The feasibility (acceptance) in regular farming will be lower as it restricts the freedom of individual farmers. When legumes such as clovers enter the meadows, the nutritious value will be acceptable. Measurements are needed, as we do not yet know what the rate of carbon sequestration is from a situation with tillage each few years to a no tillage situation.

2. Groundwater table manipulation in peat meadows

The measure is meant to restore the accumulation of organic matter and to enhance peat growth. The measure will reduce the oxidation of peat and reduce the emission of CO_2 by elevating the water table. In general, this will reduce the productivity and limit the agricultural use. Ultimately, agricultural activities are not possible in natural, wet grasslands. An unwanted side effect of rising the watertable is the methane emissions from the new wetland areas. This measure is only feasible if the net effect on global warming is positive, that is, no net emissions. Research is needed because that is unknown as yet. Currently, the feasibility of the measure is low because this often means a change of land use from agriculture to nature and it is not likely that this will take place on a large scale at the short-term. Although in the Netherlands we have many peat soils these are now sources of CO_2 as no active peat formation takes place since the large scale lowering of the groundwater table for agriculture has started after 1950. Oxidation of peat takes place upon lowering the groundwater table. Therefore most peat meadows are sources of CO_2 in the Netherlands. Much information is available in the Netherlands, notably at Alterra in Wageningen on the oxidation and subsidence of peat soils after lowering of the groundwater table. However, no

information is available on the carbon sequestration potential after restoration. A point of concern is that the water quality has changed since 1950 and due to agricultural activities nutrient have accumulated. Measurements are needed to learn more about the reaction of oxidized peat soils upon wetting with different water types, including eutroficated water. Some pilot studies by the Free University have started recently in the Horstermeer Polder and in the polders near the Naardermeer.

3. Reduction of tillage

It is not well known in the Netherlands what the effect of reducing or abandoning tillage is on soil carbon. Information is available of effects of tillage on soil carbon under arable land, not under grassland. Loss of carbon is measured under different crops and different tillage regimes by the Instituut voor Bodemvruchtbaarheid in Haren. Information is now in Alterra in Wageningen. Measurements are needed in pilots to establish the rate of increase of soil carbon after reduction of tillage and to astablish an expected maximum sequestration of carbon in the soil.

4. Crop rotation and residue management

It is well known for each crop how much carbon is taken off the land and how much is left on the land from residues. Information is available from experimental farms of the former IB, now Alterra in Wageningen. Information can also be found at the Praktijkonderzoek Rundveehouderij and the Praktijkonderzoek Akkerbouw en Vollegrondsgroenten of Wageningen University. It is unknown at what rate and to what limit rotations and residue management can enhance the soil carbon. Measurements in pilots are needed.

5. Set aside

The measure is to take land out of agricultural production for nature development or as a permanent set aside. The soil organic carbon will increase over time. The data on soil organic carbon can be found in the Wageningen University and Research Center, at the Alterra research institute and at the laboratory of Soil Science and Geology.
Soils that are formed under natural vegetation can be characterized by their genoform which includes a characteristic stock of soil organic carbon. Under agriculture these soils loose part of their soil organic carbon stock, which results, together with other changes, in a certain phenoform. Once a soil is taken out of agricultural production, the soil organic carbon stock will start to build up again under succession stages of natural vegetation. The difference between carbon content of the phenoform and the genoform is a potential carbon sink. Since 1990 many hectares of agricultural land have been taken out of production and it is the intention of the Dutch government to continue this policy. An example (Hoosbeek): Sink rate of CO2 (pheno- to genoform) = 15 ton CO2/ha/yr (during first 30 years of 100 year period). When 5000 ha is taken out of agricultural production each year, starting in 1991, then in the first year (1991) the sink was 0.075 Mt CO2. Each following year the sink will increase by 0.075 Mt CO2. The sinks to be reported for the years 2000, 2010, 2020 are then respectively 0.75, 1.5 and 2.25 Mt CO2. These sinks are estimated averages and would need to be established more accurately for the major soil types in the Netherlands. No experiments are known from the Netherlands where any build-up of carbon in the soil after abandonment is measured.

6. Animal manure management

Because of the high input agriculture in the Netherlands and the large amount of animals we have plenty manure. This is achieved through large imports of animal feeds from different parts of the world. The manure surplus has led to over-fertilization of fields and to high nitrate levels in the groundwater. However, improved animal manure management may lead to

build-up of soil carbon. Manure fermentation could be used to stabilize the manure and simultaneously recover methane for energy. Fermentation of manure with other organic wastes can even enhance the methane yield. This however increases the risk of contaminating the residues and residue treated soils with heavy metals. Therefore, manure certification is required for a safe disposal on the land. It is expected that manure slurry is not enhancing the soil carbon very much. Solid manure with a high straw content is expected to be more beneficial for the soil carbon. Both manure slurries and manure mixed with straw will increase the soil carbon but the literature is ambiguous on the quantification of this effect.

7. Organic waste management

In 1990 14 million ton waste was landfilled with an organic carbon content of 110 kg per ton. If it is assumed that half of this amount is dissimilated to form landfill gas (with methane and carbon dioxide), then the other half stays in the landfill for a very long period of time. In 1990 thus 2.8 million-ton CO_2 was sequestered. The feasibility to dump organic waste in landfills is low because of the ban on landfilling of combustible organic waste since 1994. However still large amounts of organic carbon end up in the landfills as part of other waste streams. Sewage sludge was used on the land until 1980. Because the high content of heavy metals this is no longer allowed. All combustible organic waste including sewage sludge is now used for energy purposes in waste incinerators. Since 1995 wood waste is used in power generation as well. Part of the recycled organic waste is composted by the VAM. This compost is used to enhance soil carbon. Measurements are needed to ensure the build up of carbon in the stable humus.

General discussion

It was striking that there was so little knowledge and so much uncertainty about the potentials and possibilities to enhance the soil carbon. One of the reasons for this may be that research always has focussed on increasing the production and not on the soil carbon change related to land use and land use change. Still those who were present expressed the feeling that it must be possible to produce data within half a year with a certain degree of reliability in order to set an example of how to report these kind of data. Then from year to year the reliability of the data will increase through new experimental research and an adequate monitoring and evaluation program. The realization of such a program will be accomplished within 3 to 5 years.