EMISSION OF CO_2 FROM AGRICULTURAL PEAT SOILS IN THE NETHERLANDS AND WAYS TO LIMIT THIS EMISSION[1]

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Summary
A method to calculate CO_2 emissions from subsidence was developed. Empirical relationships between ditchwater and groundwater levels and subsidence were derived based on monitoring results collected during more than 30 years. With these relationships, data from the Dutch Soil Database and water management databases we calculated that the annual CO_2 emission of Dutch agricultural peat soils is 4.25 Mton. High ditchwater levels is a way to diminish oxidation and so CO_2 emission of peat soils but will make the traditional dairy farming on peat soils economically impossible. Subsurface irrigation by submerged drains is investigated as a promising alternative.
Keywords: subsidence, GHG emission, conservation, ditchwater level, groundwater level

Introduction

According the United Nations Framework Convention on Climate Change the Netherlands has to report emissions of greenhouse gases periodically to the UNFCCC secretariat in Bonn in a national inventory. This should be based on internationally comparable methodologies, be public and transparent, include all sources and removals by sinks of all greenhouse gases. A specific source mentioned by the International Panel on Climate Change (IPCC) is the CO_2 emission caused by agricultural use of organic soils. This was not reported according to international standards and partly missing in the National Inventory Report for the Netherlands. Therefore the objective of this research was the development of an international accepted method to calculate CO_2 emissions by agricultural use of peat soils.

In a review Kasimir-Klemedtsson et al (1997) compared three methods to determine greenhouse gas emissions from farmed organic soils: (a) estimates from subsidence rates; (b) by modeling using precipitation and temperature as input variables; and (c) by measuring CO_2 emissions. Method (c), the direct measurement of the CO_2 emission with closed chambers is complicated by the soil respiration of fresh organic matter. In their comparison between methods (a), (b) and (c) Kasimir-Klemedtsson et al (1997) assumed a soil respiration of fresh organic matter of 38%. A further complication is that CO_2 emissions vary very strongly in time and require more or less continues measurements during the whole year. Nevertheless direct CO_2 emission measurement is a widely used technique and a lot of data is collected in this way. Method (b) is based on an empirical relationship between the subsidence by oxidation and the annual precipitation divided by the annual mean temperature (Eggelsman, 1976). The CO_2 emission calculated by this method proved to be unrealistically high and much higher than calculated with the methods (a) and (c) (Kasimir-Klemedtsson et al., 1997). Method (a), the calculation of the CO_2 emission based on the subsidence of peat soils is a robust method, because the subsidence is usually measured over many years (sometimes decades) and is in a long-term perspective mainly caused by a summation

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of oxidation and so CO_2 emission. Subsidence of drained peat soils is caused by oxidation of the organic matter of the peat soil, consolidation of the peat layer and permanent shrinkage of the upper part of the peat soil above the groundwater level. To calculate the CO_2 emissions the fraction subsidence due to oxidation of organic matter compared to the total subsidence is needed. According to Armentano and Menges (1986), this fraction varies mostly between 0.33 to 0.67. According to Eggelsman (1976) the fraction is 0.7 and this value was also used by Kasimir-Klemedtsson et al (1997) in their comparison of methods. They found that CO_2 emissions derived from subsidence are in rather good agreement with direct CO_2 measurements (method (c)).

In the Netherlands research on the subsidence of peat soils has a long tradition. In the period 1965 – 1980 surface levels of peat soils were measured every year or with intervals of e.g. 10 years. A series of measurements started by Schothorst (1977) around 1970 is still ongoing. The availability of a lot of data on subsidence of peat soils and the good agreement of method (a) with the direct CO_2 measurements (method (c) (Kasimir-Klemedtsson et al., 1997), was reason to develop a method to calculate CO_2 emissions from subsidence.

Next question is how to reduce CO_2 emissions. High ditch water levels is a way to diminish oxidation and so CO_2 emission of peat soils but will make the traditional dairy farming on peat soils economically impossible. A viable economic dairy farming is needed for the preservation of the highly valued cultural historic landscape in the centre of the Netherlands (the “Green Heart”). Therefore the project ‘What about the peat?’ was initiated to find best water management options to preserve the landscape and to minimize the degradation of peat soils. We present a promising option namely the use of subsurface irrigation by submerged drains with a drain spacing of 4 to 6 meters.

Methods and Materials

Calculation of CO_2 emission from subsidence

The yearly CO_2 emission from the subsidence of peat soils has been calculated according to:

$$CO_{2,em} = F * S_{mv} \cdot \rho_{so} \cdot fr_{OS} \cdot fr_C \cdot \frac{44}{12} \cdot 10^4 \qquad (1)$$

where:

$CO_{2,em}$ = CO_2 emission (kg CO_2 ha yr^{-1})
F = fraction subsidence due to oxidation of organic matter compared to total subsidence
S_{mv} = subsidence (m yr^{-1})
ρ_{so} = bulk density peat (kg m^{-3})
fr_{OS} = organic matter fraction peat (-)
fr_C = carbon fraction organic matter (-)

In equation (1) the parameters F, ρ_{so}, fr_{OS} and fr_C are generally related to the upper layers (upper 20 to 30 cm) of the peat soil. A major source of uncertainty is that the fraction F varies between 0.33 to 0.67 (Armentano and Menges, 1986). Therefore we developed another approach. We used a fraction F = 1 combined with values of ρ_{so}, fr_{OS} and fr_C of the fibric peat layer in the subsoil (at a depth of e.g. 120 cm). This approach is explained in Figures 1 and 2. A major advantage of this approach is also that ρ_{so}, fr_{OS} and fr_C of fibric peat (Von Post classification H1 – H3) depend mainly on the origin of the peat and that the variations in these values are small.

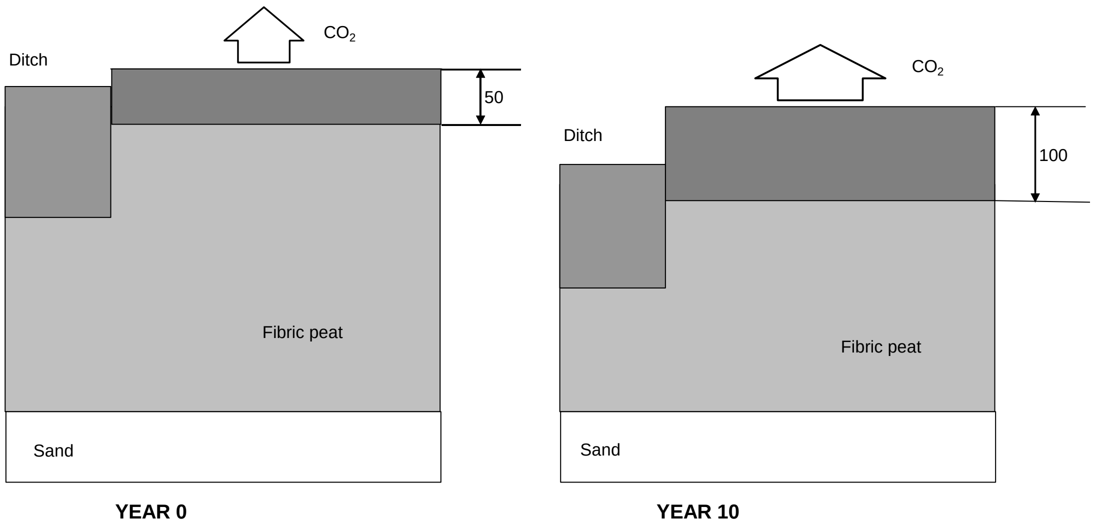

Fig. 1. A schematic presentation of subsidence of peat soils in the first 10 years after drainage of a peat soil. A thick peat layer is situated above a mineral layer. Before the ditchwater levels are lowered the upper humic and mesic peat layer has a thickness of about 50 cm and the subsidence is then mainly caused by oxidation and is low. The deepest groundwater level is about 50 cm. After lowering of the ditchwater level subsidence accelerates and it takes several years before the subsoil is consolidated and the topsoil is (partly) humified by shrinkage and oxidation. From then on subsidence is mainly caused by oxidation. The deepest groundwater level is about 100 cm.

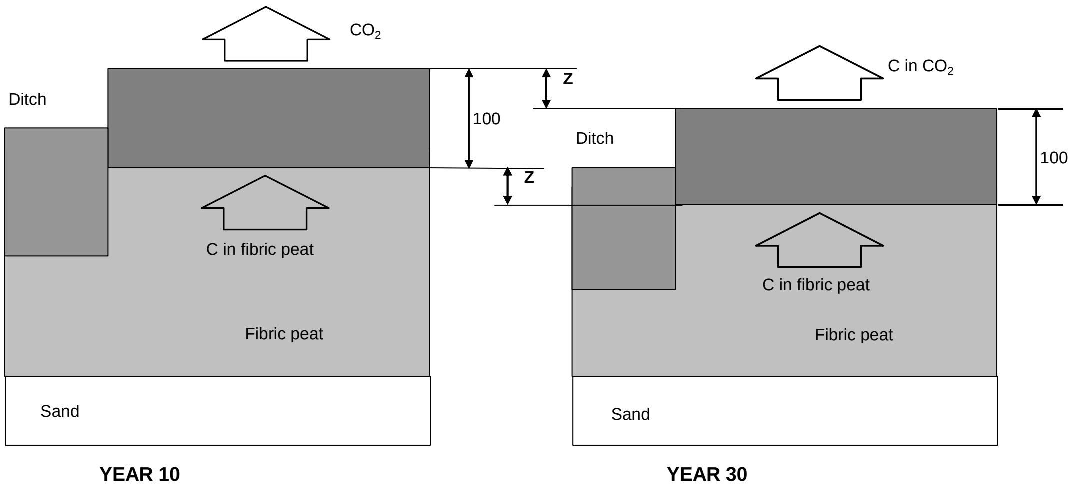

Fig. 2. The next 20 years are considered. From time to time ditchwater levels are adapted to the subsidence. In 20 years the total subsidence is z cm. In this period the layer of fibric peat got z cm thinner, which is added to the top layer of humic and mesic peat above it. In this way there is an inflow of C into the top layer from below and an outflow of C as CO_2 to the atmosphere above the top layer. Considering that in time subsidence is almost completely driven by peat oxidation, this means that inflow of C is equal to outflow of C. Considering long periods this is not completely true due to accumulation of mineral parts and very stable organic components.

Results and discussion

A comparison of our method with the usual method to calculate CO_2 emissions from subsidence
With an example we tested whether the CO_2 emission calculated with our approach is in good agreement with CO_2 emission calculated with a fraction F = 0.33 to 0.67 and values of ρ_{so}, fr_{OS} and fr_C of ripened peat in the upper 20 to 30 cm of the soil profile. We considered a peat soil of the experimental farm “Zegveld” in the Netherlands with ρ_{so} = 358 kg m^{-3}, fr_{OS} = 0.58 and fr_C = 0.55 in the upper 30 cm of the soil profile (Schothorst, 1977) and ρ_{so} = 140 kg m^{-3} , fr_{OS} = 0.80 and fr_C = 0.55 of the fibric peat soil at a depth of 1.2 m. Using our approach with the values of the fibric peat subsoil in equation (1) with a fraction F = 1 results in an emission of 2259 kg CO_2 ha^{-1} yr^{-1} per mm subsidence. Using the values of the upper 30 cm of the peat soil in equation (1) requires a fraction F = 0.53 to result in the same emission of 2259 kg CO_2 ha^{-1} yr^{-1} per mm subsidence. A fraction F = 0.53 fits quite well in the range 0.33 to 0.66 found by Armentano and Menges (1986) in their review, so we conclude that the result of our approach is comparable with results found in literature.

Relationships between subsidence, groundwater level and ditchwater levels.
An unknown factor in Equation (1) is the subsidence. Ditchwater levels are rather well registered in the Netherlands. So, with a relationship between ditchwater level and subsidence we can estimate the subsidence of all Dutch peat soils in agricultural use and calculate the CO_2 emission with equation (1). Available from literature was data on ditchwater levels and on subsidence of peat soils in the northern part of the Netherlands and a set of data based on measurements of ditchwater levels, groundwater levels and subsidence of 14 parcels in 5 locations during more than 30 years. The derived relationships are presented in Figure 3. Note the effect of a thin clay cover.

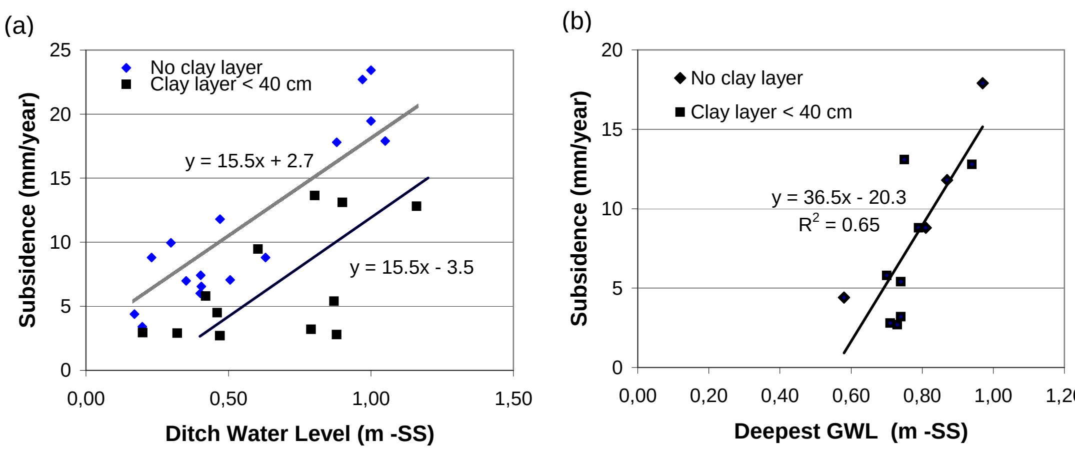

Fig. 3. Derived relationships between (a) subsidence and Ditch Water Levels and between (b) subsidence and Deepest Ground Water Level (GWL) in meters below Soil Surface (m –SS). The Deepest GWL is calculated as the mean of the three deepest groundwater levels measured in 14 days intervals in the period 1992 – 1998.

Calculation of the CO_2 emission of peat soils in agricultural use in the Netherlands

The data of the Soil Map 1 : 50 000 of The Netherlands was combined with Dutch land use databases to determine the area of peat soils in agricultural use. The Netherlands have nowadays about 290,000 ha peat soils of which 223,000 ha in agricultural use, almost completely as grassland. About 92,000 ha of the 223,000 ha have a clay layer of 15 – 40 cm, and about 9,000 ha a sandy layer. The data of the Soil Map 1 : 50 000 of The Netherlands includes information about the drainage situation. We used this information to make a estimation of the ditch water levels of the peat soils in agricultural use. About 84,000 ha has a shallow (around 30 cm); 117,000 ha an intermediate (around 60 cm) and about 22,000 ha a deep (> 90 cm) ditchwater level.

After the collection of all this data it was in fact a simple GIS exercise to combine the data with the relationships in Figure 3a to derive the subsidence and to calculate the CO_2 emissions from the subsidence by using equation 1. We calculated an emission of 4.25 Mtonne CO_2 per year for the agricultural peat soils in the Netherlands. Per ha this is about 19 tonne CO_2 per year. The total CO_2 emission per year by oxidation of peat soils is equivalent with the CO_2 emission of 1.7 million cars and is about 2.5 % of the national anthropological CO_2 emission of the Netherlands.

Climate change can increase the subsidence rate substantially. According to Querner et al (2008) a climate scenario with an increase of temperature with 2^0 C in 2050 and a change in air circulation will increase the subsidence rate and so the CO_2 emission by almost 70 %. According to Hendriks et al (2008) the subsidence rate and CO_2 emission will almost be doubled at the end of this century in the worst case climate scenario.

The increasing problems caused by the subsidence of peat soils and the associated CO_2 emissions was reason to start the project “What about the peat soils?” to find ways to diminish peat oxidation. Since 2003 a promising solution has been investigated: raising groundwater levels in summer by infiltration of ditchwater via submerged drains. Figure 3b shows that raising of the deepest groundwater level towards a ditchwater level of e.g. 60 cm below the soil surface can reduce subsidence substantially. Results of this field experiment show that groundwater levels can be raised enough to reduce subsidence now and in future by 50%. This is confirmed with modeling simulations (Hendriks et al., 2008).

Conclusions

The problems with oxidation and subsidence of peat soils are ever more increasing. Climate change will make the problems even worse. The calculation of CO_2 emission from subsidence is a robust and reliable method. Sub-irrigation via submerged drains might be a good solution to diminish subsidence and CO_2 emissions of peat soils considerably.

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