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SUBMERGED INFILTRATION TO HALVE SUBSIDENCE AND GHG EMISSIONS OF AGRICULTURAL PEAT SOILS

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SUMMARY

Biological degradation (oxidation) of peat soils used in dairy farming causes subsidence rates up to 13 mm.y^{-1} and emissions of CO_2 and N_2O equal to about 3% of the annual anthropological CO_2 emission in the Netherlands. In 2003 experiments started with subsurface irrigation by submerged drains to raise groundwater levels to reduce oxidation and so subsidence and GHG emissions. Subsidence and so CO_2 emissions were reduced with 50%; amount of inlet water increased on average up to 30%; trafficability improved. Dairy farmers accept and see advantages of the use of submerged drains, which makes them a promising tool to preserve the valued peat soil landscape.

KEY WORDS: peat soils, subsidence, oxidation, submerged drains, GHG emissions

INTRODUCTION

About 9% of the area of the Netherlands is covered by peat soils (about 290,000 ha), mainly drained and in use for dairy farming (about 223,000 ha). Peat soils in the densely inhabited western part of the Netherlands are valued as an open landscape with a rich cultural history, which should be preserved. About 40 years ago a strong modernization and mechanization of dairy farming started. This required improvement of drainage conditions and bearing capacity of peat soils in agricultural use and therefore in large areas ditchwater levels were lowered several decimeters. The lowering of ditchwater levels caused a strong increase of subsidence of the peat soils. The major part of peat soils in the western part of the Netherlands is in use as permanent pasture with ditchwater levels up to 60 cm minus surface. Organic soils above groundwater level are exposed to the air and decompose. This causes a subsidence of 8 – 12 mm per year and emission of greenhouse gasses. Subsidence of one centimeter per year equates to an emission of about 22 tons of CO_2 per hectare per year (Van den Akker et al., 2008). Van den Akker et al. (2008) 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.

In the Netherlands every 10 years ditchwater levels are lowered about 10 cm and so adapted to the subsidence. However, in this way also groundwater levels are lowered about 10 cm. In time the upper part of wooden foundation piles are exposed to oxygen and start to rot. In this way subsidence causes damage to infrastructure and buildings. Because the subsidence is not the same everywhere, water management becomes ever more complex and expensive. Many wetlands become difficult to preserve as "wetland" because subsidence of adjacent drained agricultural land results in 'islands of peat' surrounded by lower elevation agricultural lands. The higher wetlands drain towards the lower agricultural land, become too dry and degrade. In a time with raising sea levels, it is also not wise to allow subsidence rates of one cm per year.

The problems caused by subsidence of peat soils together with the increasing interest in GHG emissions and eutrofication of surface waters by degrading peat soil was reason to start in 2003 the EU funded project EUROPEAT (QLK5-CT-2002-01835) with the aim to identify degradation processes of agricultural peat lands and find ways to diminish peat land degradation (Van den Akker et al., 2008, Van den Akker, 2010). Research on infiltration of ditchwater via submerged drains to raise groundwater levels in summer to conserve peat land started end of 2003 in the EUROPEAT project. The aim was to halve subsidence and CO_2 emission in this way.

In this paper we focus on the measurements of subsidence, and so indirect on CO_2 emission and on the expected extra supply of inlet water due to the improved infiltration by submerged drains.

Subsidence rates of peat soils in agricultural use

In Figure 1 relationships between subsidence rates and ditchwater levels and groundwater levels are presented. Data was available from literature on ditchwater levels and on subsidence of peat soils in the northern part of the Netherlands and a set of data based on own measurements of ditchwater levels, groundwater levels and subsidence of 14 parcels in 5 locations during more than 30 years. The subsidence ranges from 3 to 23 mm and depends strongly on ditchwater and groundwater levels. Note the effect of a thin clay cover. Due to the fact that this clay cover is not prone to oxidation, the subsidence is about 6 mm less than of a peat soil without a thin clay cover.

From Figure 1 we learn that water management is the key to conservation of peat soils. A logical solution to diminish the subsidence of peat soils is to raise ditchwater levels. However, this results in too wet conditions for an economic viable dairy farming, which is needed to maintain the important cultural historical landscape in the heart of the Netherlands (the so called Green Heart). A more effective way to raise groundwater levels in summer without raising ditchwater levels could be subsurface irrigation using drainage tubes below ditchwater levels. Figure 1b 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.

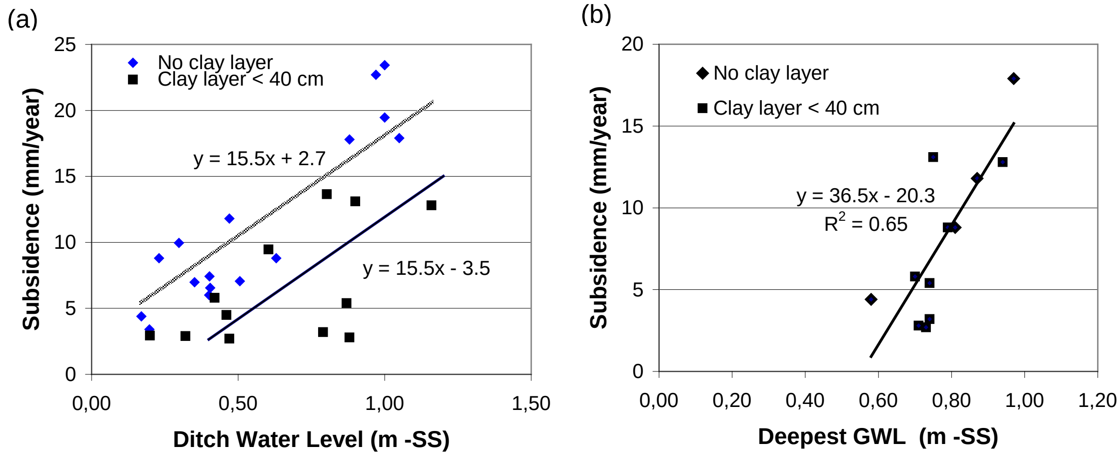

Fig. 1. Derived relationships between (a) subsidence and Ditch Water Levels and between (b) subsidence and Deepest Ground Water Level (GWL) in meters below Soil Surface (m –SS). The Deepest GWL is calculated as the mean of the three deepest groundwater levels measured in 14 days intervals in the period 1992 – 1998 (Van den Akker et al., 2008).

Methods, Measurements and Modeling

To test whether subsurface irrigation with drainage tubes will indeed reduce subsidence and so emission of CO_2 of peat soils, we started in autumn 2003 with installing submerged drains on two parcels (Zegveld 2 and Zegveld 3) on a fen peat soil without a thin clay cover. Distances between the drains were 4, 8 and 12 meter. As a reference in a part of the parcels no drains were installed. On Zegveld 3 we monitor already from 1970 on the surface level of the reference part of the parcel. The long term subsidence of Zegveld 3 is 10.8 mm per year. The ditchwater level is 55 cm below the surface level.

Determination of the reduction in subsidence

Starting in early spring 2004 the surface level was measured in three cross sections. In the reference the distance between the cross sections was 10 m. In the plots with submerged drains the cross sections were situated in the middle between two submerged drains. The measurements were performed in early spring, just before the grass starts to grow and to evaporate soil water. At that moment the swell of the peat is at his maximum. In this way we avoid as much as possible that we measure subsidence due to temporally drying shrinkage of the peat, which can be more than 10 cm at the end of a dry summer.

Modeling the extra water supply

Scenarios with different water level strategies and climate scenarios were modeled with the SIMGRO regional hydrological model for the polder Zegveld. The analysis focused on water level control strategies, in combination with subsurface drains, with the aim of reducing subsidence and minimizing the water supply in dry periods. For more details see Jansen et al., (2009) and Querner et al., (2012).

Scenario 1 is the current water management, the surface water level fluctuates with a margin of plus or minus 2 cm around the ditchwater target level of 60 cm below soil surface. When the water level margins are reached, water is pumped out respectively let in the polder. Scenario 2 is the current water management, however, with submerged drains and a target level of 50 cm. The target level of 50 cm is used to minimize subsidence. This is possible without problems for dairy farming because the drains will lower the groundwater level in wet periods and so reduce trampling and improve trafficability. Scenarios 3 and 4 can be compared with scenarios 1 and 2, however, the margins are plus or minus 10 cm around the ditchwater target level. This is a so-called flexible water regime, with the aim of reducing water movement in and out of a polder.

Further an optimal scenario O was formulated for a situation with drains. This optimal scenario O anticipates on a weather forecasting of 5 days. As much as possible a margin of 2 cm is kept. However, depending on the groundwater level and the weather forecast this margin can become 10 cm above or below the target ditchwater level of 50 cm below soil surface.

RESULTS AND DISCUSSION

The results of Zegveld 3 are presented in Figure 2. The subsidence in the period 2004 – 2012 is strongly influenced by the fact that 2003 was a very dry year and that the summers in the period 2004 – 2012 were all moderately or very wet. This means that the soil was not completely rewetted and swollen in spring 2004 and had a potential of swelling in the following moderately or very wet years. These specific circumstances resulted in a subsidence rate of the reference of just 3.3 mm per year, while the long term subsidence is 10.8 mm. The effect of the large swelling potential after the dry year 2003 becomes also clear in the situation with drains at a distance of 4 meter: the subsidence rate is just 0.5 mm per year and in spring 2008, after the very wet year 2007, the level of the soil surface is even higher than in spring 2004. It is clear that the subsidence rate of the reference is many times higher than the subsidence rate of the parcel area with drains at distances of 4 meter. This in agreement with the results of Zegveld 2, with subsidence rates of 6.1 and 1.3 mm per year of respectively the reference and the parcel area with drains at distances of 4 meter.

Extra water supply

In Table 1 the results are presented of the water management scenario study. The use of drains combined with raising the target ditchwater level with 10 cm results in an extra water supply of 39 mm. This is an increase of about 30%. In an average year this will not be a problem, however, in a real dry year every extra mm inlet counts. Increasing the margins up to 10 cm results in a significant reduction of inlet water. This effect of the flexible water management regime can compensate completely the extra inlet required by submerged drains, however, on costs of the subsidence. The optimal scenario O indeed combines a very modest increase of inlet water with a strong reduction of subsidence.

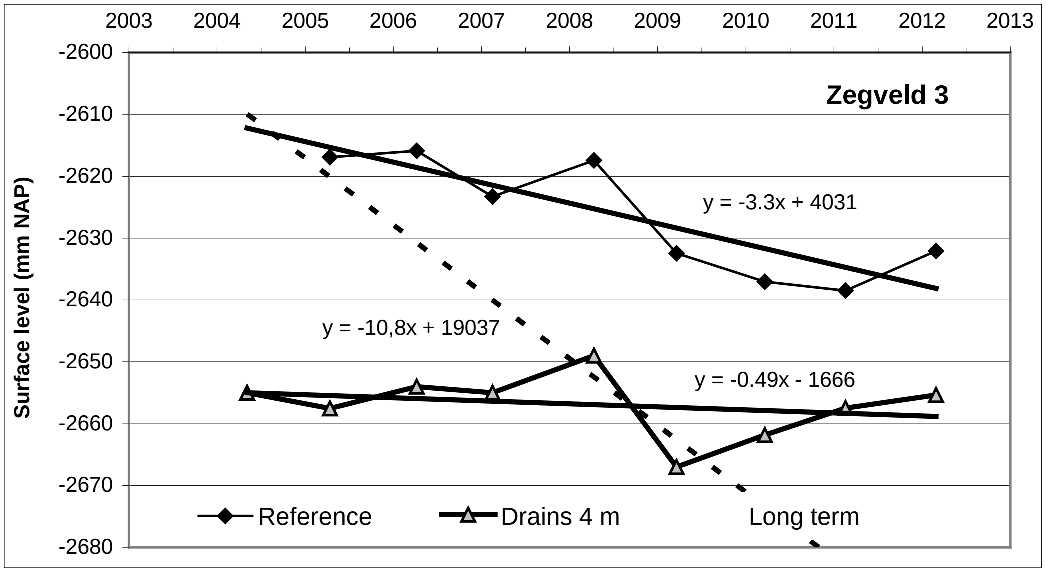

Fig. 2. Subsidence 2004 – 2012 of peat soil without submerged drains (Reference) and with submerged drains at a distance of 4 meters (Drains 4 m). The long term subsidence is 10.8 mm per year. NAP = the Dutch national reference level, which is about the average sea water level.

Table 1. Results of scenario calculations of peat soils without a thin clay cover. Scenario 1 is the reference scenario and the basis of the calculation of increase of inlet and subsidence.

Scen.	Water management	Drains	Target water level (cm)	Margin (cm)	Inlet summer (mm/y)		Calculated subsidence (mm/y)	
					Inlet	Increase	Subsidence	Decrease
1	Current	No	60	+/- 2	116		10.7	
2	Current	Yes	50	+/- 2	155	39	6.2	4.5
3	Flexible	No	60	+/- 10	85	-30	11.7	-1.0
4	Flexible	Yes	50	+/- 10	113	-3	7.5	3.2
O	Optimal(1)	Yes	50	+/-10	122	7	6.4	4.3

(1) optimal = optimal reduction of subsidence and the amount of inlet water in summer.

Note that the effect of submerged drains on subsidence as calculated in Table 1 is much less than was measured in Figure 2. Probably the calculated values are too conservative.

CONCLUSIONS

The effect of the very dry year 2003 and the wet summers of 2004 – 2012 on the subsidence rate was very pronounced and requires a longer period of monitoring. Nevertheless the results are convincing and the use of submerged drains to minimize subsidence is very promising. Probably the aim to halve the subsidence and CO_2 emission can be fulfilled easily.

The extra inlet of water in summer can be a serious problem in very dry summers. Optimum water management regimes can reduce the problem, however, this problem requires more attention and research.

Farmers are firmly opposing the raising of ditchwater levels, however, are positive about the use of submerged drains for subsurface irrigation. Raising ditchwater level reduces trafficability and increases the risk of trampling by cows, while the use of submerged drains has the opposite effect. Farmers also appreciate the fact that the use of submerged drains makes farm management easier and reduces the problems in case of long wet periods. Therefore we have good hope that submerged drains will be widely adopted in practice.

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