SHORT COMMUNICATION

Reed canary grass on an abandoned agricultural peat soil. Carbon dioxide emissions during two growing seasons after restoration.

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Abstract

Reed canary grass (RCG) can be a suitable energy crop on abandoned agricultural peatland areas. It can be harvested for more than ten years without reestablishment, and nutrient recycling to rhizomes makes the fertilizer demand low. A field near Malå in Sweden was restored by improving drainage and sowing RCG in 2010. The first growing season there were higher CO_2 emission from soil and lower groundwater level and water content on the nearby field that was not restored, than on the reed canary grass field. The reason could to be compaction of peat on the restored field by agricultural machinery and higher transpiration and respiration from vegetation on the abandoned field. The second growing season, the groundwater level was raised on some plots. Neither carbon dioxide emissions nor the growth of the RCG were affected by the higher groundwater level.

Keywords: *Groundwater level, pipe drainage, soil respiration*

Introduction

Reed canary grass, *Phalaris arundinacea* L. (RCG) is a tall wetland grass that grows wild along sea and river shores and also in ditches and abandoned fields where it has been grown for forage in the past. It is considered to be a suitable bioenergy crop for agricultural peatland soil in Sweden and Finland. Reed canary grass has lower ash concentrations when grown on peat soil than on mineral soils, and the high ash content is one of the major restrictions in use of RCG as a fuel.

In the inland of Sweden vast areas of peatlands were ditched for agricultural purposes in the 19th century and the first half of the 20th century. These areas were largely abandoned during the second half of the 20th century, mainly since many soils could not carry heavy machinery. Lately, research has shown that these abandoned ditched areas are still emitting a lot of CO_2, even though they are not used for agriculture today (Maljanen et al. 2007). Some of these peatlands could be restored by deepening ditches and used for RCG cropping. Life cycle analysis of RCG cropping on a former peat extraction site in Finland showed that this RCG fuel had 40% less climate impact than coal (Shurpali et al. 2010). One obstacle for the development of RCG on agricultural peatland is the European Union restrictions for bioenergy crops on peatlands that are supposed to prevent CO_2 emissions from degradation of peat. However, in northern Scandinavia, the effect of restoration of agricultural peatland to RCG cropland on the emission of greenhouse gases is unknown and needs to be assessed.

The first aim of this study was to compare the CO_2-emissions of a newly restored agricultural field cropped with RCG with an adjacent abandoned area. The second aim was to investigate if it was possible to mitigate CO_2-emissions by elevation of the groundwater level during the growing season.

Materials and methods

An abandoned agricultural field of 6 ha close to the lake Fårträsk, in Malå, Sweden, 65°11′N 18°45′E, was cleared from bush vegetation and partly pipe drained with 20 m between pipes, partly drained by deepening the old open ditches. The peat was 0.5 – 1 m deep. The pipe drained area was dominated by Carex peat with remains of deciduous trees while the area with open ditches mainly had Sphagnum peat in the surface. On the pipe drained part, sedge tussocks were removed before the soil preparation. All fields were graded by moving top soil towards the middle of the narrow fields in order to facilitate surface runoff. This was most successful on the part with the open ditches, where the narrow fields between the ditches were 20-25 m wide. On the pipe drained parts where the distance between the open ditches was 40-50 m, surface water was often standing on some parts of the field after heavy rain. Two of the pipe drained fields also had the possibility to regulate the groundwater level by turning up a 90^{o} bend at the ends of the pipes to create a 50 cm deep water lock that prevented the outflow of water from the pipes. On one of these latter fields an old road was following the open ditch and the peat adjacent to the road was mixed with gravel. RCG was sown on the field in the beginning of July 2010.

Carbon dioxide emissions from soil was measured using the EGM 4 portable equipment from PP systems on PVC pipes with 10 cm diameter that were pressed 10 cm into the peat. Carbon dioxide accumulating in the chamber was measured every 4.7 seconds during 80 seconds and only readings with a linear accumulation of CO_2 during the last 10 measurements were used. The pipes were installed once every season; 148 pipes were used 2010 and 128 pipes 2011. Any vegetation within the pipe was removed before each measurement. At every other measuring point, vegetation was cut also 40 cm around the pipe to prevent root ingrowth under the pipe and connected vegetation-derived CO_2.

In the first season, measurements were made in a cross pattern on two places in one field with open ditches and two places on the adjacent abandoned field. In each cross, 19 points were measured with distances of 2-4 m between points. These measurements were used to create semivariograms to determine spatial co-variation and to compare the RCG field with the abandoned field. The difference between the factors 1) RCG or not 2) cut grass or not and 3) low or high (more than 50 cm) surrounding grass, was tested using means for each "treatment" for each cross with the two–level designs analysis of NCSS 8.

In the pipe drained fields an attempt to regulate the groundwater level by turning the pipes up was made. On two fields eight plots were marked, each having two drainage pipes. On each field, the two plots closest to the lake were considered to be one block and the two plots further away from the lake one block. Using a randomized block design, the pipes of a plot were either free draining or blocked by a water lock. CO_2 emission measurements were made in the area between the two drainage pipes in 3 points close to the ditch and 6 points in the middle of the field the first year and in 16 points at least 2 m apart in a zigzag-pattern covering the plot area the second year. The first year, vegetation was cut 40 cm around 4 (every other) of the pipes. The second year, 3 of these cut areas on each plot were reused, but without installing the pipe at exactly the same point. New non-vegetated areas were created by glyphosate treatment in June and cutting of the killed vegetation one week later. Also the old non-vegetated plots were glyphosate treated.

Ground water level was determined in 48 ground water pipes installed down to the bottom of the peat layer. In each plot, Groundwater pipes were installed both close to and between the drainage pipes and also close to the open ditch and in the middle of the field. Surface water content was determined in 28 points using a profile probe PR2 calibrated with different calibration functions determined from fixed volume sampling for a) the abandoned field, b) gravel mixed peat and c) the remaining RCG field. Significant effects of groundwater regulation and the cutting treatments were tested by General Linear Model in NCSS 8. The significance level used was $p<0.05$ for all statistical testing.

Vegetation biomass was sampled (three 0.25 m^2 samples, cut with a 2 cm stubble, evenly distributed over the plots) from each plot in the pipe drained fields. The samples were dried at 60^oC to determine the dry weight (DW).

Results and discussion

The semivariograms made from the measurements in the field with open ditches and the abandoned field in the first year showed no spatial co-variation on the scale 4-24 m. The CO_2 emissions were higher in the abandoned field than in the RCG field both on Sep 03 and Sep 22 (Figure 1). The distribution pattern was normal but there were some hot spots that were outliers in both fields. Logarithmic transformation gave different results in the different fields so it was not used. In Sep 22, the measuring points where vegetation had been cut, had a lower CO_2 emissions. This shows that at least 28% of the CO_2 emission on the abandoned field, and 14 % on the RCG field, derived from root or root associated respiration. Measuring points close to the ditches on the RCG field also had lower CO_2 emissions. There the top soil was thinner and vegetation was lower than on the middle of the field. The groundwater level was lower in the abandoned field (57-78 cm from soil surface) than the RCG field (49-63 cm from soil surface) and soil water content also was lower: 0.54-0.55 g H2O/ml soil on the abandoned field and 0.73-0.74 g H2O/ml soil on the RCG field. The reason for the impeded drainage on the RCG field could be differences in peat hydraulic conductance and also compaction by the heavy machinery used for drainage and soil preparation of the RCG field. When equipment was installed we noticed that the soil was softer in the abandoned field. Since no reference measurements were done before the restoration, the lower CO_2 emission on the RCG field could be an inherent difference in soil properties, an effect of soil compaction, or an effect of lower primary production allocated below ground during the establishment year. Soil compaction in wheel ruts led has been shown to give lower CO_2 emissions on stump harvested podzolic soils (Strömgren et al. 2012).

In the experiment with regulation of the groundwater level, the groundwater level was significantly higher in regulated plots in June 2011 only. In 2010 and later in the season 2011 many groundwater pipes were empty most of the time. Groundwater means for freely draining plots were 80-93 cm and regulated plots 66-86 cm from ground level. CO_2 emission rate was never significantly affected by groundwater regulation. Amount of RCG biomass at the end of the season (mean value was 790 g DW*m^{-2}) was also not affected by the regulation. The precipitation in the summer of 2011 was higher than normal both in June, July and August. The measured soil moisture in the surface soil was high at all (measurements means of 0.71-0.72 g H2O/ml soil). Plant production and soil microbial activity probably never was water limited. Generally a lowering of the water table of peatlands should increase CO_2 emissions, but the effects are in reality very complex. In a review, Laiho (2006) suggests that peats that are already well decomposed due to a long term exposure to air, are more resistant to further decomposition, and thus less affected by drainage. This would be true for our site in Malå, which has long been used for agriculture.

The presence of vegetation around the measurement pipes enhanced CO_2 emissions significantly in 2011 but not in 2010. Also, in 2011 the difference between vegetated and non-vegetated measurement points increased during the season to a maximum of 33% in August (Figure 2). The difference between points cut already in 2010 and points cut only in 2011 prevailed two and a half months after the killing of the vegetation. This shows that in a boreal climate microbial respiration from dead roots can still constitute a substantial part of the CO_2 emission after one growing season. Similarly, Norberg et al. (2012) found a reduction of CO_2 emissions by 30- 40% on non-vegetated plots compared to the surrounding grassland on agricultural peat soil in southern Sweden.

In conclusion, there was no indication that restoration of abandoned agricultural field to reed canary grass production gave higher carbon dioxide emissions from decomposition of the peat substrate than the abandoned field. More research is needed to be able to quantify carbon dioxide emissions on a yearly basis from the field.

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Figure 1

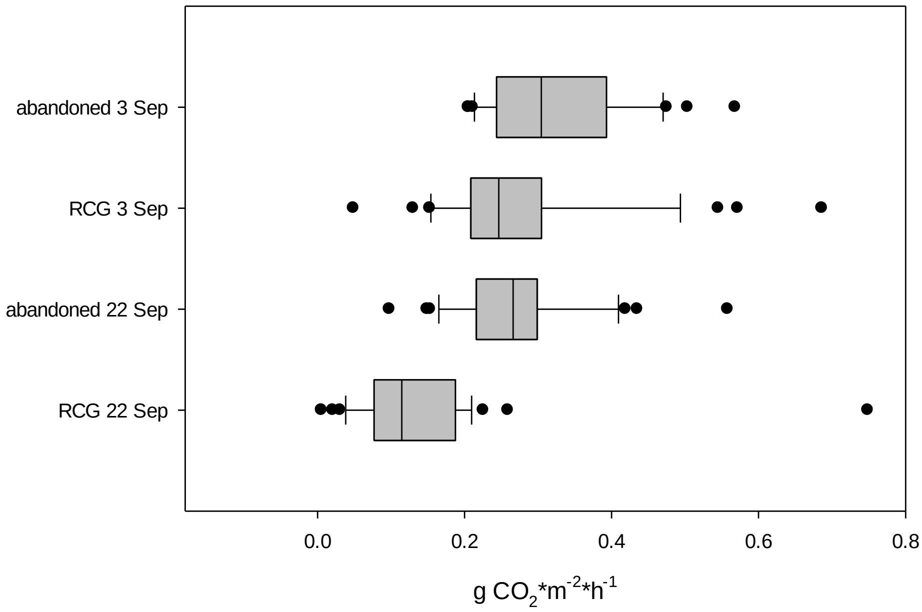

Figure 1: Soil respiration measured in September 2010 in a newly established reed canary grass (RCG) field and an adjacent field where agriculture ceased in the 1960’s (abandoned). The middle line shows the median, the box the 25% and 75% percentiles, the whiskers the 10% and the 90% percentiles and the dots the outliers. n=33-38 measurement points.

Figure 2

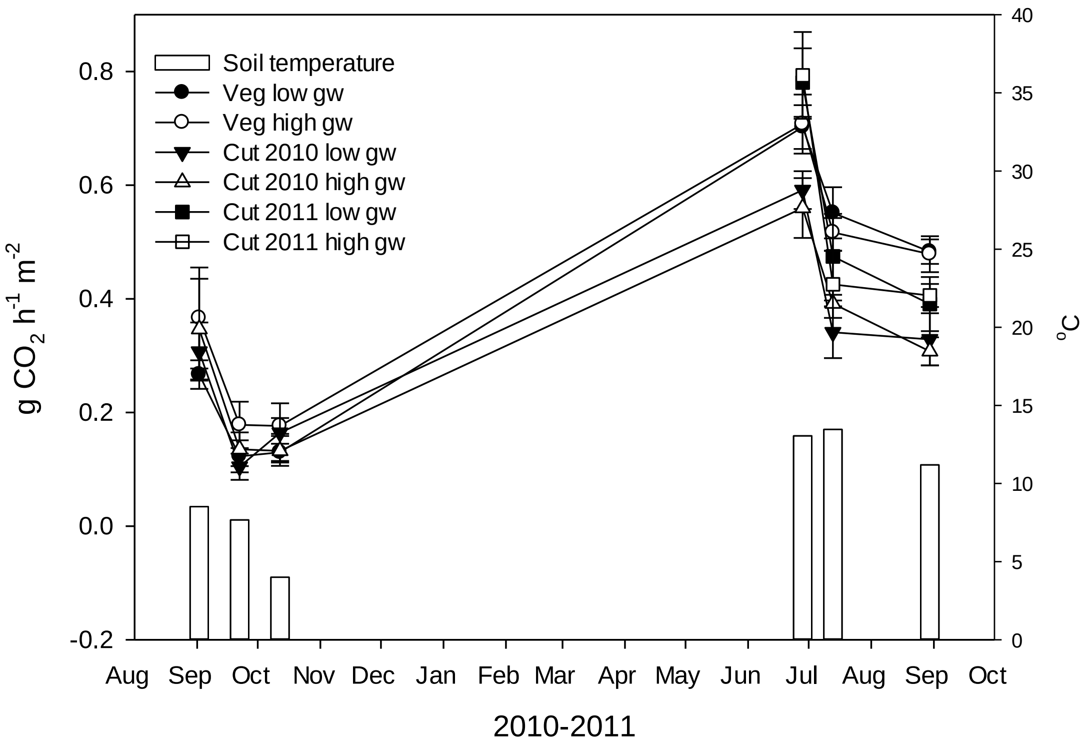

Figure 2. Soil respiration from plots with free draining pipes (low groundwater, gw) or water lock regulated drainage pipes (high gw). Points cut 2010 were also kept free of vegetation 2011. Means and SE of four plots per treatment. Soil temperature is means from 7 cm depth from all measurement points.