Spatial variation and correlation between electric conductivity (EM38) and CO_2 emissions from a cultivated peat soil

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Abstract. Approximately 15 percent of Sweden's land area is covered by peat (≥30 cm deep). In drained peatlands, decomposition of the peat produces greenhouse gases such as CO_2 and N_2O. Electric conductivity, measured with the instrument EM38, can be used to assess spatial variation in soil properties. To easier decide the quantity of the CO_2-emissions from a peatland the possible relation between electric conductivity and CO_2-emissions, water content, peat depth and soil temperature is investigated. The test site is located at Bälinge mossar, approximately 20 kilometers north of Uppsala. On the peat field 40 test points are marked where the measurements take place. The results of the investigation show that the only correlation that exists is the one between electric conductivity and water content.

Keywords: EM38, spatial variation, peat, CO_2 emission.

1 Introduction

In their natural state peatlands are accumulating organic matter, which means that they bind large quantities of carbon, about 5 and 50 g C / m ^{2} / year. The drainage and cultivation of peat soils increase the aeration of the soil, which in turn results in faster brake down of the organic material than if the land is left untouched. The degradation of the organic material release greenhouse gases such as CO_2, N_2O and CH_4 (Kasimir-Klemedtsson et al., 1997). CO_2 emissions dominate at high oxygen levels, while CH_4 is mainly released under anaerobic conditions. The organic soils (8% of all cultivated land in Sweden) are the dominant greenhouse gas emitters from arable land in Sweden. Greenhouse gas losses from these soils contribute as much as 10% (Eriksson, 1991) of the total anthropogenic emissions (in which fossil fuels accounts for most) and greatly affect the agricultural sector's contribution of greenhouse gases. Greenhouse gas measurements from cultivated land are often done on few points per field, or by integrating over a larger area with eddy

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covariance methods (Campbell et al., 2004), which gives a large uncertainty in the estimation of gas emissions. A lysimeter study conducted 2002-2005 showed large variations in CO_2 emissions between different places, peat type and drainage depth (Berglund et al., 2010), while field trials during the same period showed a very large spatial variation within the same field. This may be due to the fact that organic soils have very large spatial variations in physical and chemical properties, often larger than on mineral soils. One way to obtain information about this variation is by measuring the electrical conductivity of soil with an EM38 (Geonics Ltd., Mississauga, Ontario, Canada), which is sensitive to differences in the amount of organic matter and water holding capacity (Delin and Berglund, 2005). Another way to estimate the moisture content variation is to measure the natural gamma radiation from ^{40}K, which is released from rock / mineral soil and blocked by water. Peat soils often contains large amounts of water thus providing no or very low reaction at the gamma-ray spectrometer measurements (Ek et al. , 1992). From these variations we identified sub-regions with similar conditions. Within these more homogeneous zones CO_2 emissions are measured and a number of soil properties such as moisture content, bulk density, soil temperature, loss on ignition and pH. In this pilot study, the aim is to find better methods for measuring greenhouse gas emissions from cultivated organic soils.

CO_2 emissions from cultivated peat soils exhibit a large spatial variation, which gives uncertain estimates of greenhouse gas emissions.
Hypotheses:

- CO_2 emission varies with soil properties
- The spatial variability of soil properties in a cultivated peat soil can be identified by measuring the electrical conductivity or gamma radiation
- By correlating the CO_2 emission with different soil characteristics, a better estimate of gas emissions from cultivated peat soils can be made.

2 Materials and methods

The field site was a fen peat soil with a peat depth of about 1 meter. Soil from the field has previously been used in greenhouse gas measurements in lysimeters in EUROPEAT, a European project which ran between 2002 and 2006 (Berglund et al., 2010). EM38 is an instrument that measures soil electrical conductivity (Söderström, 2004). The instrument is drawn after a 4-wheeler while the position is measured with DGPS (position accuracy <2 m) and data from the EM38 and GPS recorded continuously. EM38 creates an electromagnetic field that gives rise to a secondary magnetic field that is recorded and the relationship between the magnetic field and the EM38 value is a function of conductivity. Depending on whether the instrument is angled horizontally or vertically, the conductivity is mainly measured on the soil surface, 0-50 cm in the latter case or 0-100 cm with a maximum response of about 40 cm depth (Sudduth et al., 2001) in the former case. In this experiment, we measured the conductivity with both methods. The conductivity is influenced by organic matter content and soil moisture, so variation in the conductivity shows the variations in these properties, which in turn could affect the CO_2 emission. CO_2 emission was measured by circulating the atmosphere from a 28 cm high dark chamber placed on the ground, through a carbon dioxide analyzer (Vaisala GMP343) for 3 minutes to measure the CO_2 concentration increase (Fig. 1). The water content was measured both gravimetrically (0-10 and 30-40 cm) with defined volume samples and also with a Profile Probe (Delta-T Devices Ltd.), which measures the dielectric constant at depths 10, 20, 30 and 40 cm.

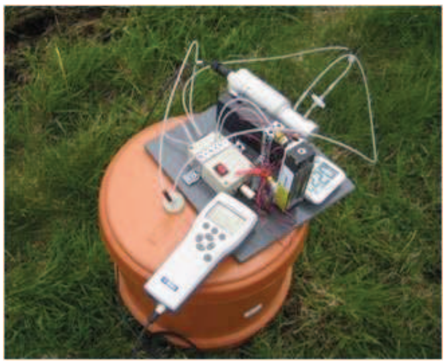

Fig. 1. Chamber and Vaisala GMP 343 for CO_2 measurements

During measurements in the spring of 2009 we also used a "mole" (The Soil Company - www.soilcompany.com), which measures gamma radiation from ^{40}K, ^{238}U, ^{232}Th, and ^{137}Cs (Söderstrom et al., 2008).

3 Results

The measurements were carried out October 21, 2008 and 14 May 2009 in order to compare the variation at different seasons and moisture contents.

Autumn 2008

Conductivity measurements with the EM38 give approximately a value every 2.5 meters in the direction of travel and the distance between the rows was about five meters. In the field a total of 3448 points was measured. Fig. 2 shows all data points from the EM38 run. The reason to run a few zig-zag turns is to be able to ensure that the EM38 value is stable during the entire run.

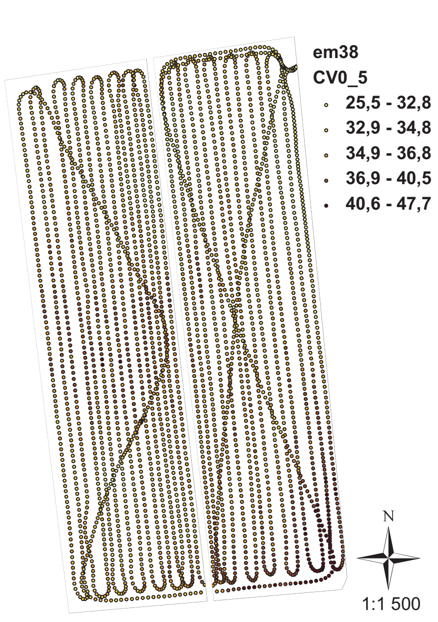

Fig. 2. All data points at EM38 driving at Örke 21 October 2008.

To obtain values for the entire field the values were interpolated with kriging (Oliver et al., 1989). Fig. 3 compares the top soil values (0-50 cm) with the deeper (0-100 cm) layers. The values for the deeper measurement show the same pattern as the top soil, but with higher absolute values.

In the autumn survey the soil dielectric properties were also measured (a form of moisture measurement) with a Profile Probe from Delta-T.

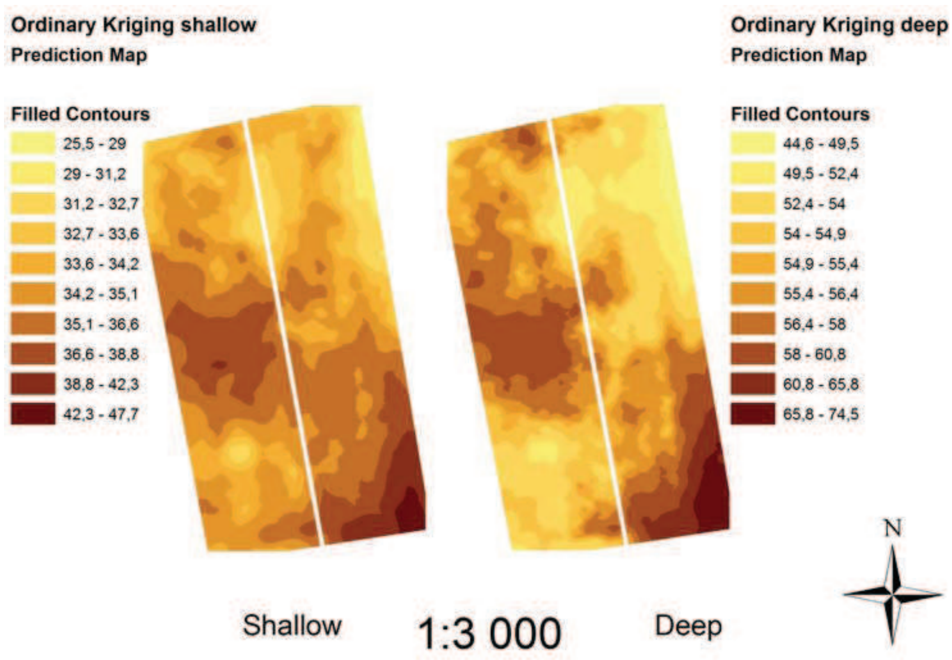

Fig. 3. Interpolated values from the top layer (shallow, 0-50 cm deep) and the deep layer (deep, 0-100 cm depth). EM38 measurements at Örke 21/10/2008.

We made two transects across the fields and in Fig. 4 the Profile Probe value (mv) and EM38 value from the deeper run is shown. Although both EM38 value and Profile Probe value is a measure of water content, the relationship was not entirely clear, with relatively low R^2 values. The deeper EM38 measurements (0-100 cm) gave the best agreement with Profile Probe measurements (Fig. 5).

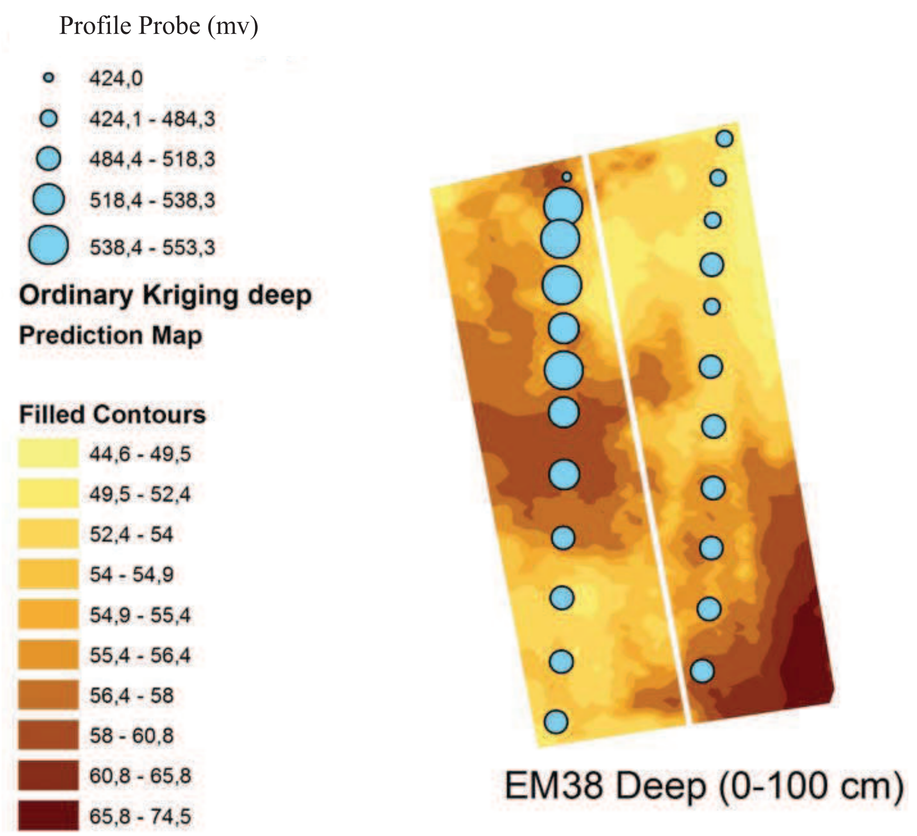

Fig. 4. EM38 measurement 0-100cm (filled contours) and Profile Probe measurement at 30 cm depth (Blue circles).

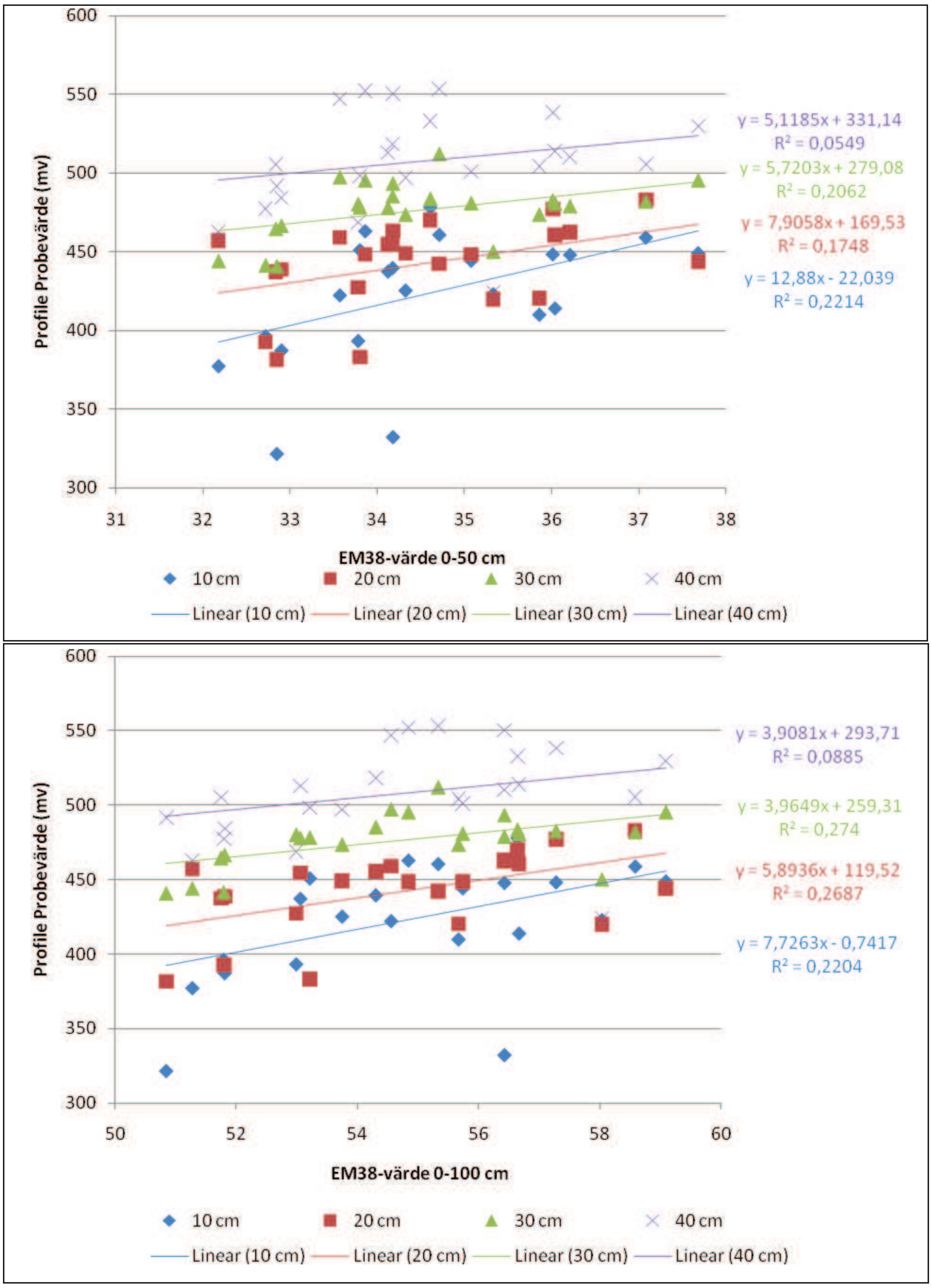

Fig. 5. Surface (0-50 cm) and deep (0-100 cm) EM38 measurements compared to the Profile Probe value at depths 10, 20, 30 and 40 cm.

Spring 2009

In the spring (14/05/2009) we conducted a more detailed study in which an EM38 survey was supplemented with gamma-ray measurements with a mole (Fig. 6). The correlation table (Table 1) shows that the EM38 values show a similar variation both between depth and between autumn and spring but there is no correlation between the different gamma ray measurements. At the same time as the EM38 measurements was done we also carried out a field survey of 40 points in which CO_2 emissions, water content (gravimetrically), moisture (ProfileProbe), C, N, pH, peat depth (19 points) was measured.

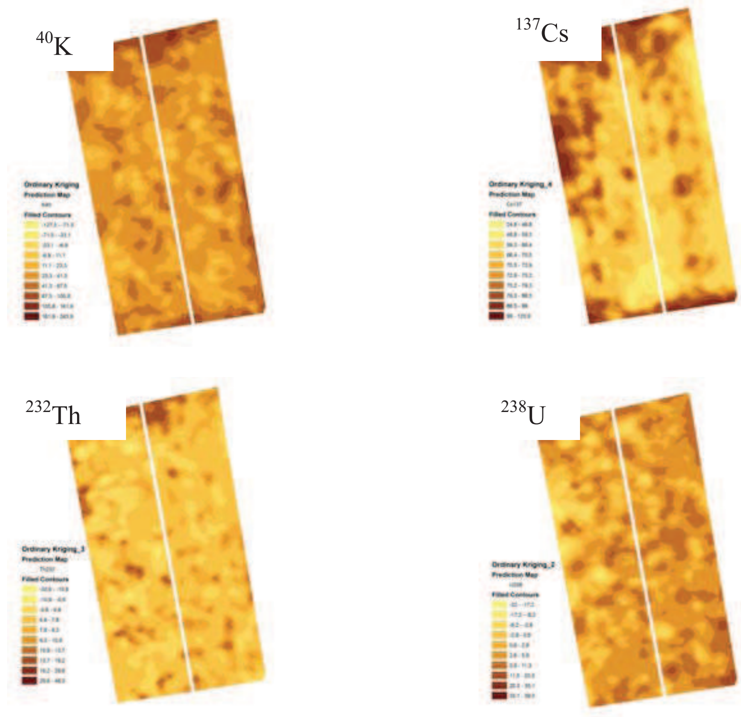

Fig. 6. Gamma radiation maps from ^{40}K, ^{137}Cs, ^{232}Th and ^{238}U.

We only found a correlation between C and N and between water levels. Fig. 7 shows the CO_2 emission from the 40 sampling points. There is considerable variation in gas emission between the points, from 521 mg CO_2 m^{-2} h^{-1} to 6638 mg CO_2 m^{-2} h^{-1}. We found no correlation between gas emission and any of the other parameters we measured. The field was divided into eight conductivity zones (EM38) to obtain a better correlation between conductivity and water content measured with the Profile Probe. When excluding two outliers the relationship between EM38-value and

Profile Probe-value of 20 cm depth was much better (R^2 = 0.89), but there was still no relationship between the EM38-value and the CO_2 emission or peat depth.

Table 1. Correlation between the deep EM38 measurement 2008 (08EM38 100), the Toplayer 2008 (08EM3850), Toplayer 2009 (09EM3850) and gamma radiation from potassium (K40), thorium (Th232), uranium (U238) and cesium (Cs137)

Layer	08EM38 100	08EM38 50	09EM38 50	K40	Th232	U238	Cs137
08EM38 100	1	0.95	0.87	0.04	-0.01	0.10	0.10
08EM38 50		1	0.91	-0.05	-0.05	0.12	0.05
09EM38 50			1	-0.05	-0.08	0.21	-0.09
K40				1	0.26	-0.16	0.41
Th232					1	-0.37	0.09
U238						1	-0.28
Cs137							1

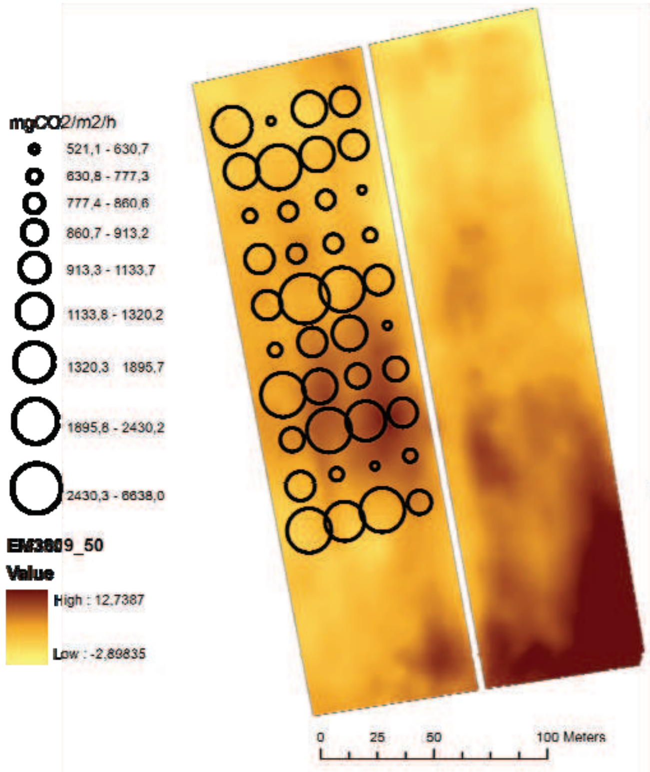

Fig. 7. Map of the field at Örke showing EM38 values as background colors and CO_2 emission from the 40 points as circles.

4 Conclusions

The maps from the EM38 runs show that there is a consistent variation of the conductivity between depths and between seasons. There is some correlation between EM38 values and water content measured with Profile Probe, but otherwise there was no correlation between the different parameters (EM38, CO_2 emissions, pH, peat depth, γ-rays, C, N, and bulk density). It must therefore be one factor that we have not measured that affect the variation shown by the EM38 map. As in previous studies, we can see that the CO_2 emissions show a large spatial variation, but we could in this pilot not find a correlation with the parameters we measured.

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