Section 8

A plot-scale experiment to detect the effect of cultivation on soil organic carbon

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8. A plot-scale experiment to detect the effect of cultivation on soil organic carbon

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8.1. Introduction

The UK LUCF Carbon Emission Inventory requires information on the fluxes arising in the transition between different land uses (Milne 2003). Grassland soils represent a substantial part of the terrestrial carbon stocks in the UK, and there are potentially large losses when these are cultivated, either for conversion to arable land or for improvement of pasture. Globally, it is estimated that around 50 Pg C have been emitted to the atmosphere from soils, following conversion of natural land to cultivated, agricultural land (Paustian *et al.*, 2000). The physical basis for this is that disturbance associated with soil tillage increases the turnover of soil aggregates and accelerates the decomposition of aggregate-associated soil organic matter (SOM). However, the number of experimental data quantifying this effect are rather small, and there are very few experimental data from the UK. Here, we describe a plot-scale experiment to detect the effect of cultivation on soil organic carbon content. Recent work (Smith et al. 2004) suggests that the increase in N_2O emissions in "no-till" agriculture outweighs the effect of carbon sequestration, in terms of Global Warming Potential (GWP). As a secondary aim, we include measurements of N_2O emission in this study, to obtain a more complete picture of the effect of cultivation on the greenhouse gas balance.

8.2. Methods

8.2.1. Field site and treatment

The experimental site chosen was on House O' Muir Farm near CEH Edinburgh (Figure 8-1), which is managed by the Scottish Agricultural College. The site is at an altitude of 290 m in an area which is used for rough grazing at a very low stocking density, but has received no improvement or cultivation. Nearby fields have been improved, and though the experimental site is similar, it is surrounded by steep slopes where improvement or cultivation using farm machinery would be impractical. The soil is relatively shallow (10-15 cm), but relatively high in organic matter (10 % carbon content).

In June 2005, an 11 x 11 m area was fenced to exclude sheep. The vegetation within was cut to a height of 10 cm using a strimmer and the litter removed from the experimental area. Glyphosate herbicide ('Roundup') was applied on 8 July, with a further treatment on 14 July. This killed the remaining vegetation over a number of weeks, and the litter was removed by strimming and raking in August.

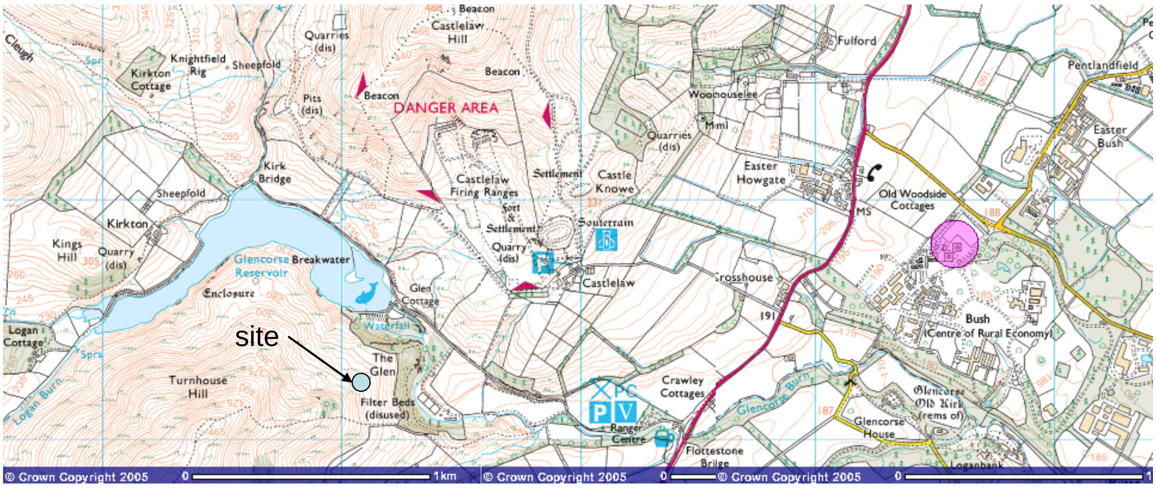

Figure 8-1 Location map of experimental site at House O' Muir Farm.

Within the fenced area, the outermost 1 m was reserved as a buffer zone to reduce edge effects from surrounding vegetation. The inner 9 x 9 m was divided into 1 x 1 m plots. A Latin Square design of 81 experimental plots was laid out, with three treatments: an uncultivated control, a single cultivation, and bi-annual cultivation (Figure 8-2). The first cultivation treatment was applied in November 2005. Treatments 1 & 2 were cultivated to a depth of 10 cm using an edging tool and digging fork to cut out, turn over, and break up turves.

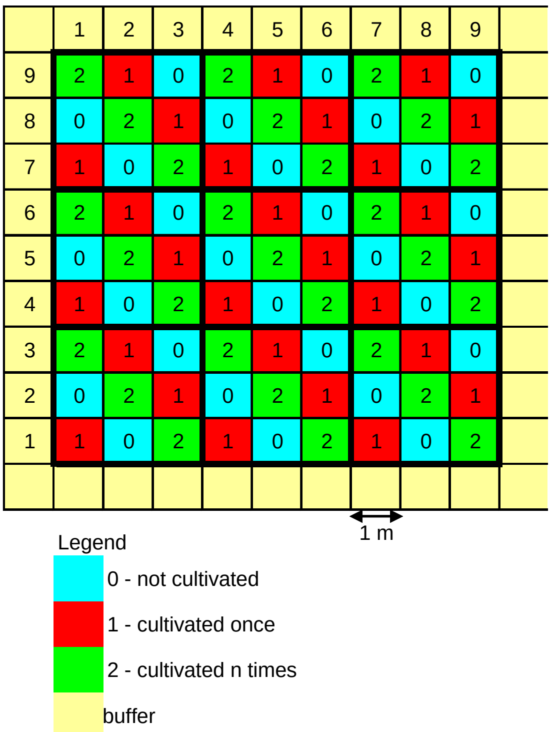

Figure 8-2 Replicated Latin Square experimental design, showing 11 x 11 m area with three treatments applied to 1 x 1 m plots in a 3 x 3 Latin Square, repeated 3 x 3 times.

8.2.2. Soil carbon measurements

Immediately following cultivation in November 2005, soil samples were taken from all plots for analysis of carbon content. Cores were removed by inserting sections of plastic tubing into the soil, and then cutting these out with a knife. Cores were 8 cm deep x 3.8 cm diameter. Taking deeper cores proved impractical because of the limited soil depth. Samples were analysed at CEH Lancaster for total carbon by loss on ignition (LOI) and bulk density. A sub-sample of 18 cores were analysed using an Elemental Analyser for carbon and nitrogen content. These data were used to establish the following relationship between LOI and carbon content (C):

$$C\ (\%) = 0.497 \cdot \text{LOI}\ (\%)$$

which was applied to the other samples to calculate carbon content.

8.2.3. Soil respiration measurements

A dynamic closed-chamber system (EGM-4, PP Systems, Hitchin, UK) was used to measure soil respiration on each of the 81 plots in October 2005, prior to the treatment being applied. An opaque chamber 10 cm in diameter and 15 cm in height was pressed into the soil. An internal fan provided mixing whilst air was pumped through the chamber and an infra-red gas analyser in a closed circuit. The chamber was left in position until a rise of 50 ppm CO_2 was measured, usually ~70 s. The soil respiration rate, *R*, from the soil was calculated as

$$R = dCO_2/dt \cdot w$$

where dCO_2/dt is the rate of increase in CO_2 with time (μmol mol^{-1} s^{-1}), and *w* is the system volume: area ratio in units of mol air m^{-2}. Corrections to this equation, using polynomial functions of time to correct for effects of leaks were investigated but made little difference.

8.3. Results and Discussion

Figure 8-3 shows the spatial pattern in soil respiration and soil carbon before cultivation. Some pattern may be discernible in the soil respiration data, increasing from left to right, but this is not very clear. Although there is variability in the soil carbon data, no spatial pattern is present. Figure 8-4 and Table 8-1 show the results of a one-way analysis of variance. There are no significant differences in the means for the plots allocated to the different treatments, prior to cultivation.

Table 8-1 Analysis of Variance table for pre-treatment differences between plots allocated to the three treatments. There are no significant differences prior to treatments.

Source	DF	SS	MS	F	P
Treatment	2	10945	5472	0.77	0.469
Error	78	557707	7150		
Total	80	568651			

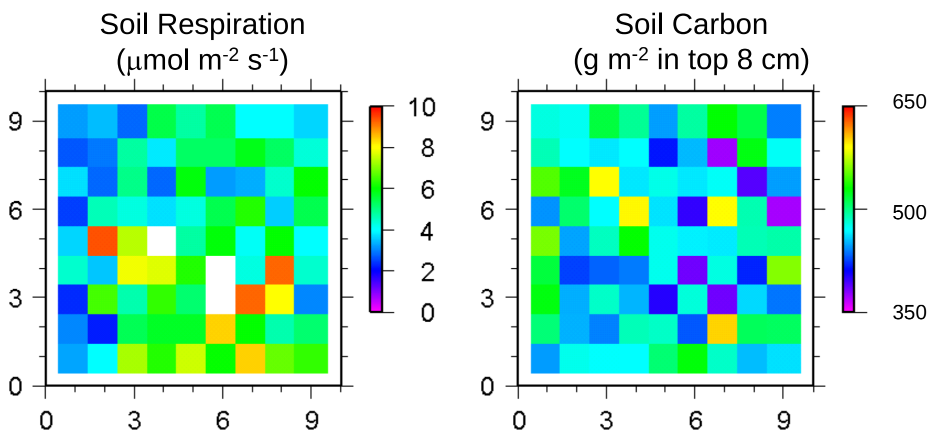

Figure 8-3 Plots of soil respiration and soil carbon measured before cultivation in October/ November 2005. X- and y- axes give the spatial position within the experimental area, in metres. The origin is the NE corner of the area.

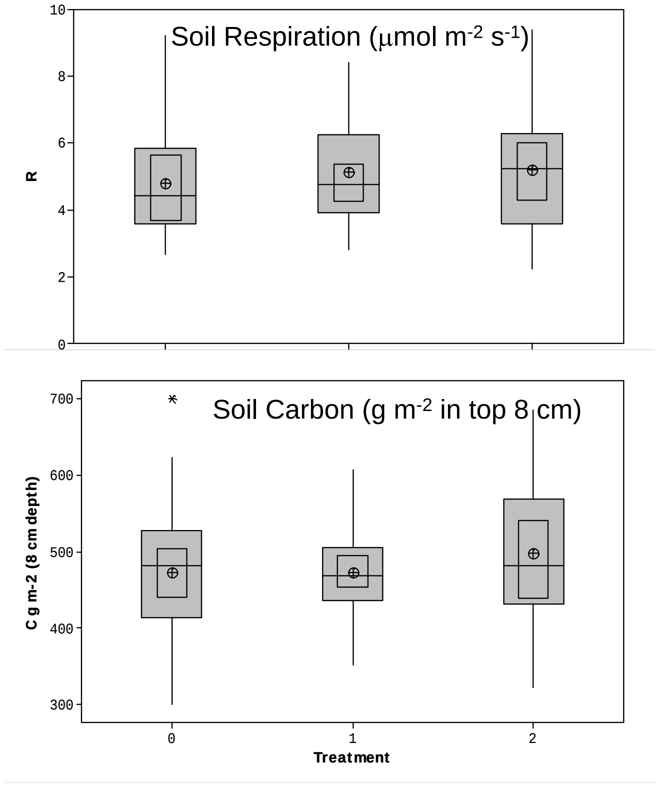

Figure 8-4 Box-plots for pre-treatment soil respiration and soil carbon measurements shown in Fig 8.3. Treatments are: 0 – uncultivated control; 1 – cultivated once; 2- cultivated bi-annually. Statistics shown are: means (circle), median (horizontal line), 95 % confidence interval (inner box), inter-quartile range (outer box), and range (vertical line) excluding outliers (asterisk). There are no significant differences prior to treatments.

The results show that there are no clear differences between the treatments at the start of the experiment. The advantages of this experimental design are that the major source of variation, the initial soil carbon content, can be accounted for as a co-variate when analysing future samples, and any remaining spatial variation can be largely removed due to the blocking of the plots. Because the Latin Square design ensures that all treatments are distributed across the experimental area in a balanced way, this can be analysed as a simple ANOVA with no block effect, as a full Latin Square, or with intermediate degrees of blocking, depending on the spatial variation observed in the data. If the variation between blocks is negligible, the number of degrees of freedom (and the statistical power of the experiment) is maximised by analysing as a completely randomised design with no block effect.

Measurements of nitrous oxide (N_2O) and methane (CH_4) flux are in progress at the time of writing (April 2006) and will be reported on if the experiment is continued under a future contract. These will allow us to calculate the effect of cultivation on the total greenhouse warming potential (GWP). GWP is calculated by adding changes to the N_2O and CH_4 fluxes to the change in soil carbon stock, weighted by their relative effects on radiative forcing (297 and 23, respectively). CO_2 and N_2O fluxes will be analysed in the same way as for stocks, with the exception that a time series of data should be available at ~bi-monthly intervals. A repeated measures technique may be applied to account for changes with time.

8.4. References

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8.5. Acknowledgements

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