SECTION 4

Field Measurements of Carbon Loss Due to Ploughing

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Introduction and Measurement Programme

The principal objective of this part of the contract is to establish (in conjunction with CEH Merlewood) an upper limit to the carbon loss from long-term pasture when it is disturbed by ploughing. The approach taken is that of eddy covariance, and further details of the instrumental techniques may be found in Hargreaves *et al* (1998) and Hargreaves *et al* (2001).

The site chosen for the study is at Poldean farm in south west Scotland. It is a livestock enterprise with extensive permanent pasture receiving fertiliser and manure inputs. The flux station is located at grid reference NT 111004 (N55:17:22, W3:24:08) at an altitude of 196 m. Further details can be found in Hargreaves *et al*, 2001. The initial plan was to begin measurements in March 2001, but the foot and mouth epidemic reached the farm on 12 March 2001 and access to the site was no longer permitted. Restocking with sentinel animals took place in September 2001, but "Form A" access restrictions were not lifted until a veterinary visit on 21 December 2001. A biosecurity protocol was subsequently agreed with the local vets in early January and on 8 January 2002 a visit to the site was possible to remove instruments for inspection (they had remained unpowered and therefore prone to the effects of damp for nearly a year by this time) and disinfection. One of the battery boxes, containing four lead-acid batteries was found to be full of water as a result of a blocked drain hole so the four submerged batteries were disconnected from the flux station and removed from the site. The remaining batteries, which had become discharged as a result of the submersion, were left to recharge by the solar panels and wind generator.

Instrumentation

The Licor CO_2 analyser and R.M. Young ultrasonic anemometer appeared undamaged when tested in the laboratory and so were returned to the site in early February in preparation for restarting flux measurements. This stage was delayed for a further 4 weeks as the Licor IRGA requires a source of dry, CO_2-free gas which is supplied by a cylinder of compressed, high-purity nitrogen. The cylinder at the site had become empty during 2001 but it could not be replaced until ground conditions improved enough to allow access by vehicle in early March. Flux measurements therefore restarted on 13 March 2002, but on the next site visit on 20 March it was apparent that the Young ultrasonic anemometer had developed an intermittent fault and was corrupting horizontal and vertical components of wind velocity, rendering flux calculations meaningless. This fault is almost certainly a result of the anemometer being left outdoors for an extended period without power. The anemometer was removed and, after a short delay to source its temporary replacement from another experiment, a Metek ultrasonic anemometer was installed and software modifications made to the logging software to accommodate it. Flux measurements were restarted and in the windy conditions (typically 6 m s^{-1}) during the restart the turbulence and flux data appeared to be normal. The subsequent site visit ten days later, revealed a problem with a spurious positive offset to the measurement of vertical velocity by the replacement anemometer (Figure 1). At high windspeeds the coordinate rotation

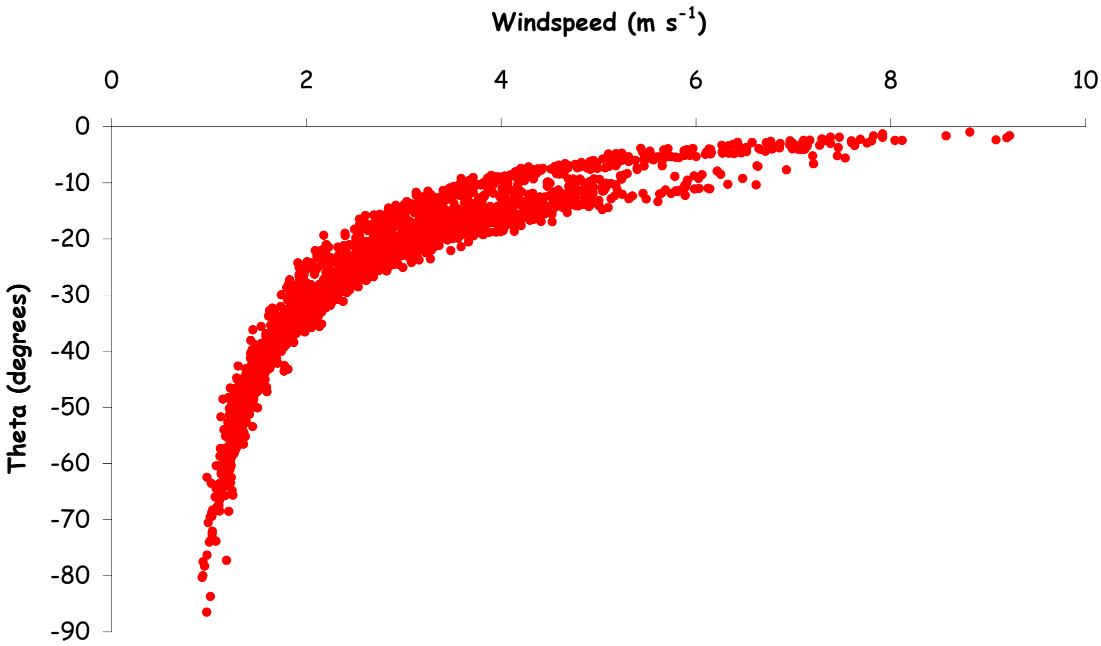

Figure 1: The effect of the offset vertical velocity on the vertical coordinate rotation angle, theta, as a function of mean windspeed.

angle, theta, required to make the mean vertical velocity zero (an essential part of the flux calculations), was small and had little effect on the calculated flux. However, at low windspeeds this fault caused very large rotation angles to be applied by the logging software and consequent corruption of the calculated fluxes. This period of data will be recalculated once the magnitude of the offset has been determined. In the meantime a further replacement Metek anemometer was borrowed and installed and so far has proved trouble-free.

Ploughing

Arrangements were made with a local agricultural contractor in early March 2002 to plough the site. Having inspected the field, the contractor considered that it would be necessary to kill the newly emerging vegetation (standard agricultural practice in south west Scotland when re-sowing pasture) and flail off the small amount of dead material remaining from the previous year's growth. Glyphosate was applied to the field on 12 April 2002 (successful application requires actively growing plants and a frost-free period) and by the end of April the vegetation was dead. On 2 May the field was flailed, but the operation was abandoned after 70% of the field was complete as the ground was very waterlogged and soft resulting in the tractor becoming bogged down. Further attempts to complete the flailing and carry out the ploughing were made on 8 May and 14 May but, again, the tractor was unable to work in the

waterlogged conditions on site. At the time of writing (15 May) the contractor is making regular visits to the site and will plough it as soon as the boggy conditions ease.
On 2 May vegetation samples were taken from ten randomly selected 0.3 m by 0.3 m plots in both the treatment field and the adjacent grazed field in order to estimate the extra biomass present on the treatment field compared to the grazed field.

Results and Discussion

Table 1 summarises the results of the vegetation sampling and shows that the treatment field had an additional 47 g C m^{-2} (assuming 50% of the vegetation biomass is carbon) compared to the grazed field. This, in comparison to the soil C content in the 15 cm surface layer determined by CEH Merlewood (Jones *et al*, 2001) (13.31 kg C m^{-2}) is a relatively small proportion.

Sample Number	Treated Field (g C m^{-2})	Grazed Field (g C m^{-2})
1	151	97
2	151	84
3	102	113
4	158	55
5	128	84
6	137	73
7	131	104
8	132	69
9	125	90
10	141	72
Mean	**123**	**76**

Table 1: Above-ground vegetation carbon from treated and grazed fields at Poldean. Each sample was taken from a 0.3 x 0.3 m plot chosen at random

The micrometeorological results presented here cover the first two weeks of May during which the treatment field was covered in dead vegetation and the remaining fields were being rotationally grazed. Figure 2 illustrates the time course of the sensible and latent heat fluxes and shows a roughly equal partitioning of energy between these pathways of energy transfer on days when the wind blew from over the grazed field (e.g. 11 May). This is typical of grasslands with adequate soil water availability. In contrast, on 12 May when the wind blew over the dead vegetation a smaller proportion of energy was transferred via the latent heat flux since there was no longer an actively transpiring canopy. The gaps in the latent heat flux data are a reflection of the need to minimise the load on the batteries – to achieve this both the eddy covariance sample pump and the Licor IRGA are switched off during periods when the micrometeorological conditions are unsuitable.

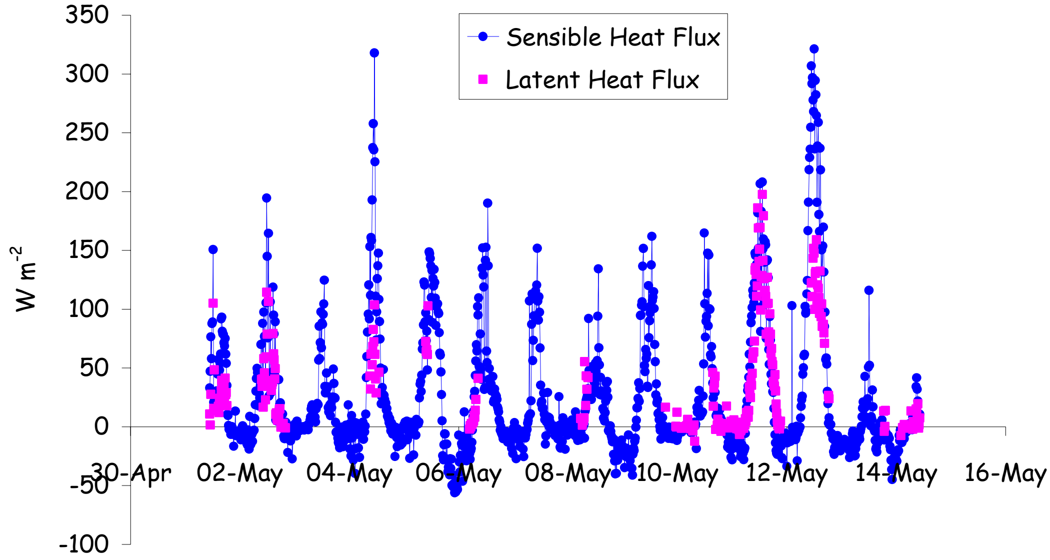

Figure 2: Sensible and latent heat fluxes at Poldean

Figure 3 shows the time course of CO_2 exchange over the two-week period, the large gaps in the data reflecting the small proportion of the time during this period when micrometeorological conditions were suitable. Nevertheless, as Figures 4 and 5 illustrate,

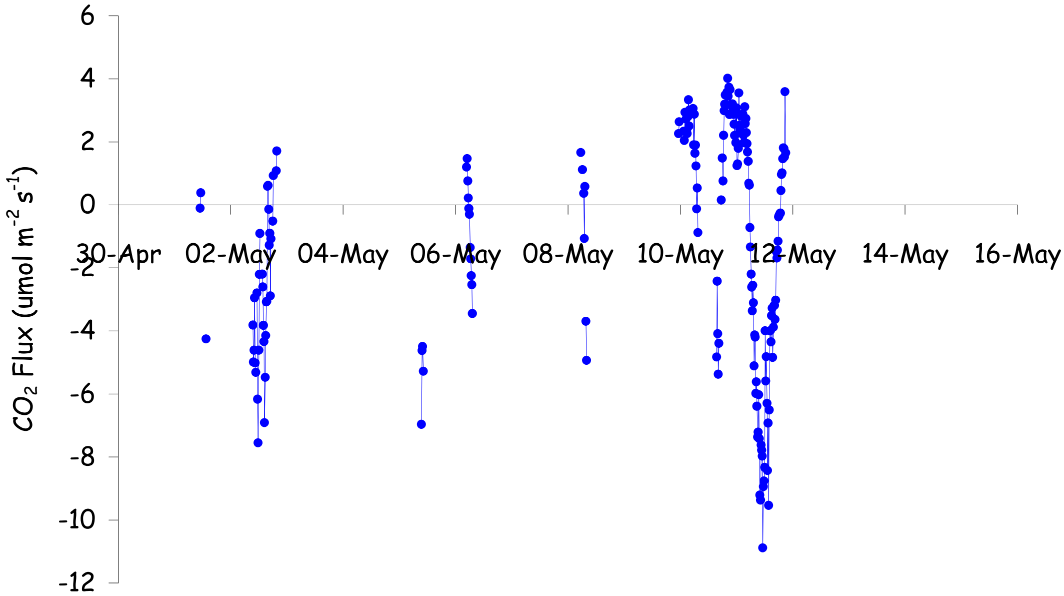

Figure 3: CO_2 Fluxes over the grazed fields at Poldean. Gaps in the data correspond to periods of bad wind direction or poor micrometeorological conditions

even this small amount of data enables a simple empirical model to be constructed (for details see Hargreaves *et al*, 1998) that allows the continuous CO_2 exchange over the grazed area to be simulated (Figure 6). Over the two weeks the grazed area fixed an average of 3.0 kg C ha^{-1} day^{-1}.

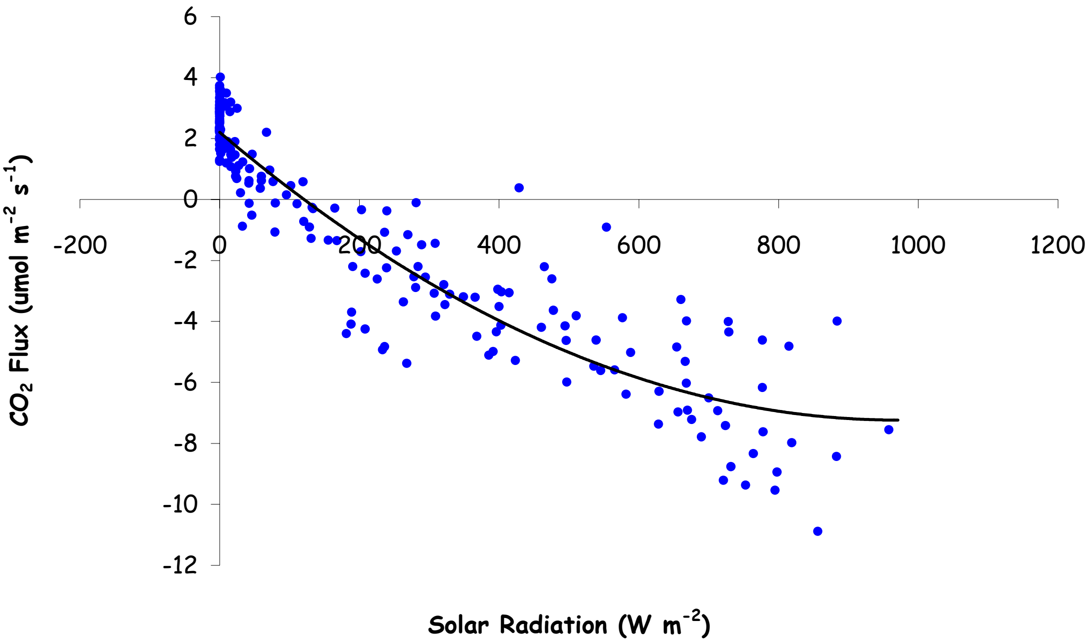

Figure 4: Photosynthetic light response curve for the grazed area at Poldean

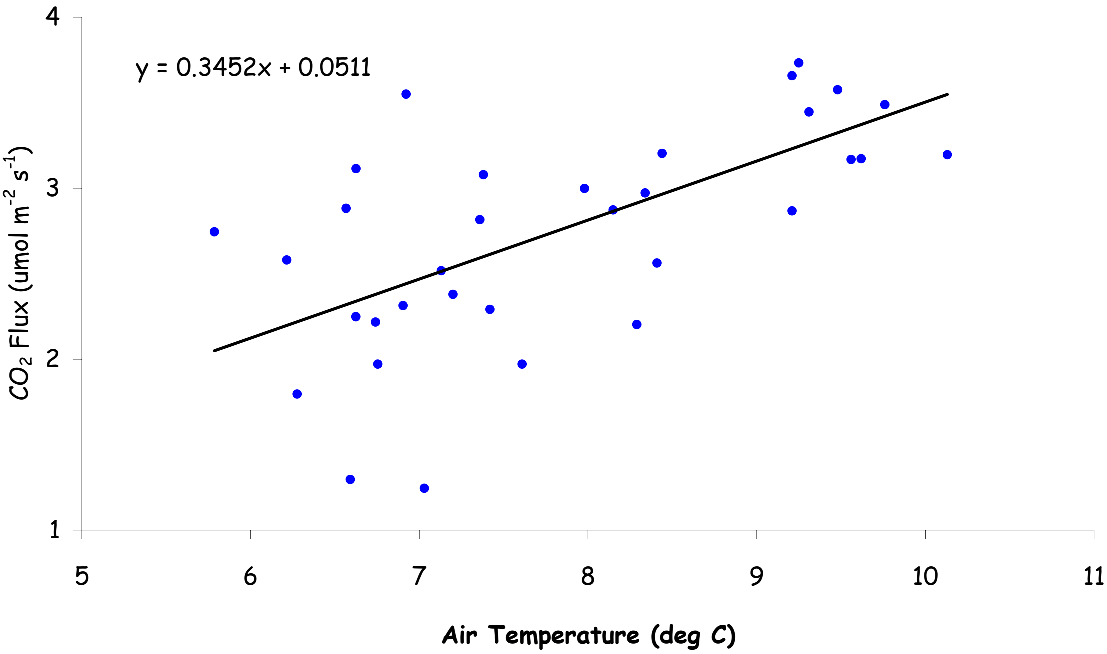

Figure 5: The relationship between air temperature and nocturnal respiration rate over the grazed area at Poldean

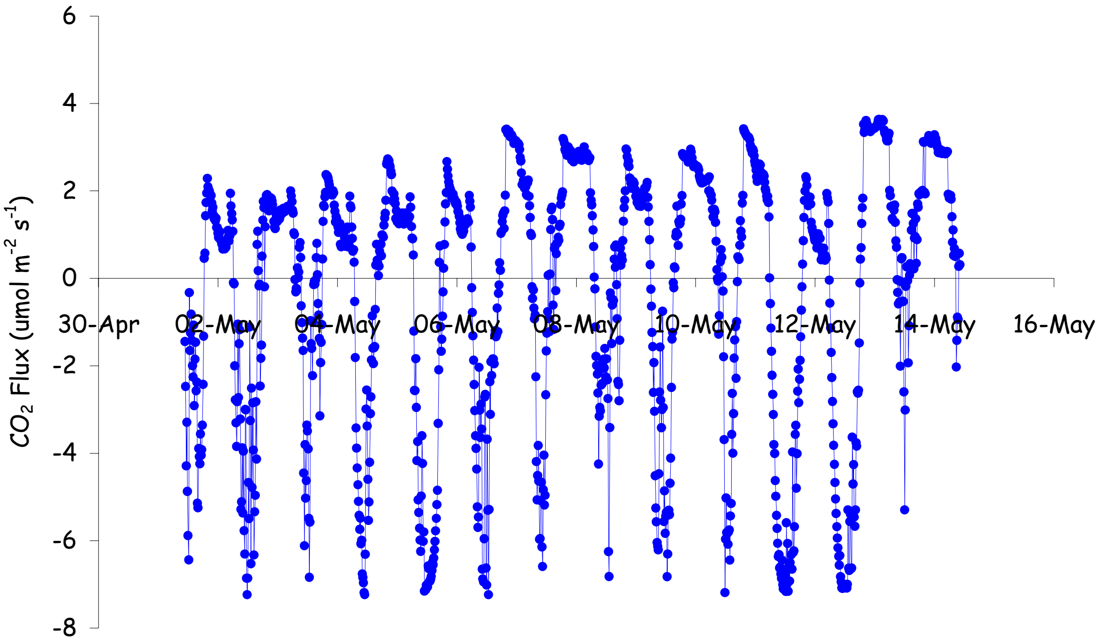

Figure 6: Simulated CO_2 Flux over the grazed area at Poldean. The mean carbon fixation over this period was 3.0 kg C ha^{-1} day^{-1}

The time course of CO_2 exchange over the treatment area (Figure 7) is in marked contrast to that of the grazed area. The site was steadily losing carbon to the atmosphere at rates of between 1 and 3 μmol m^{-2} s^{-1}, but so far it has not proved possible to determine a relationship between the magnitude of the flux and the variables which may be expected to control it such

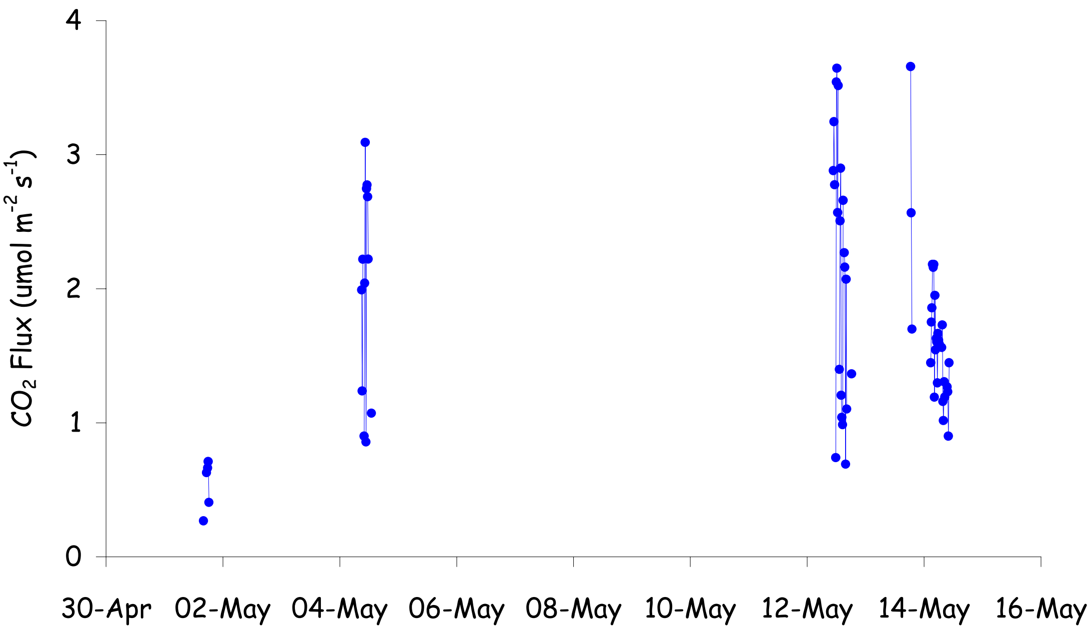

Figure 7: CO_2 fluxes over the treated field at Poldean. Gaps in the data correspond to periods of bad wind direction or poor micrometeorological conditions

as soil or air temperature. This is not entirely surprising since the boggy area which caused problems for the tractor is very close to the sampling mast and it can be expected that respiration rates in this area would be smaller than those from other parts of the field. Thus, small changes in wind direction could result in large changes in respiration rate and at present we do not have sufficient data to quantify this. However, compared to the grazed area, the nocturnal fluxes from the treated area are somewhat smaller with, for example, a grazed area respiration rate of 3.0 µmol m^{-2} s^{-1} on the night of 13/14 May and a treated area respiration rate of 1.7 µmol m^{-2} s^{-1}. This latter figure represents a loss of 1.8 g C m^{-2} day^{-1} from the treated area and is unlikely to be sustained for a long period as the bulk of this flux is probably coming from the decomposition of the recently killed grass and the total mass of dead vegetation on the treated field was 123 g C m^{-2} as measured on 2 May (Table 1). The smallest fluxes so far reliably detected by the eddy covariance system are around 0.01 µmol m^{-2} s^{-1}, equivalent to 0.01 g C m^{-2} day^{-1}, which should be adequate for detecting the reduced rates of carbon loss from the ploughed site once the decaying vegetation flux has declined.

Conclusions

- The eddy covariance system is, after some initial problems, functioning correctly and with adequate sensitivity to measure the small respiration fluxes anticipated after ploughing.
- Carbon fixation has ceased over the treated area following application of Glyphosate.
- During early May the grazed area was fixing an average of 3.0 kg C ha^{-1} day^{-1}.
- Standing (dead) biomass on the treated site was estimated at 123 g C m^{-2} on 2 May, compared with 76 g C m^{-2} on the grazed site.
- Nocturnal respiration rates over the dead vegetation are already significantly smaller than those over the grazed area.
- Ploughing is delayed until the extremely boggy conditions on site have eased.

References

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Acknowledgements

We acknowledge the cooperation and extensive practical assistance provided by Willy Davidson, Poldean Farm, Moffat.