

## ***Interactive comment on “Mechanisms of soil carbon storage in experimental grasslands” by S. Steinbeiss et al.***

**S. Steinbeiss et al.**

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First of all we thank the referee for the comments on our manuscript, especially as the points raised should be helpful for other readers to better assess our manuscript. With our reply we would like to react to the demand for a more elaborate explanation of the equations we used to calculate the proportions of C4 plant derived material in soil organic carbon and dissolved organic carbon. We hope and trust that the extended recalculations presented here will clarify the uncertainties contained in our results and their consequences for data interpretation.

Most of the arguments brought up by the referee were well in our mind, when we started the calculations but we had to make some compromises that in our opinion dealt best with the special features in our experimental setup. At this point, we want to highlight that our C4 labelling experiment was only a small part of a large biodiversity experiment

that included 90 plots with different grassland species communities. The outcome of this main experiment was presented in another manuscript that, unfortunately, is under review at the same time as the manuscript discussed here (see footnote 1 in our manuscript). All general findings in the C4 labelling experiment, such as changes in carbon stocks or measured DOC concentrations fit well in the data derived from the main experiment. The significant changes in carbon storage that were found in the first two years actually became even stronger after four years and made the outcome more robust. Unfortunately, isotopic data of the soil organic carbon after four years are not available, but they will be measured again within the next years. The additional results regarding the pool compositions of soil carbon or DOC derived from the C4 labelling experiment were quite unexpected and of course require further detailed investigations. They should be seen as initiation of future research projects dealing more directly with this topic.

We understand that it might be difficult to find the numbers that were used in the equations 1 and 2 in the text, which is probably due to the fact that the equations were explained in the method's section but the numbers were given in the result's section. This could easily be solved by adding a table with the requested numbers to the manuscript.

The choice of the isotopic values that were used in the equations 1 and 2 seemed to be one of the major concerns of the referee. We conducted all calculations with several logically possible combinations of isotope values but found no real differences in the results that would change the conclusions. Therefore, we presented only one solution per treatment that represented a kind of average result.

Here, we would like to take the chance to list and justify the numbers we used in the manuscript and give some results derived from other possible calculations to clearly demonstrate the uncertainty of the calculations. We only give differences in the results for the top 5 cm of the soil here, because the largest changes in isotope ratios were observed in this horizon and all other deviations derived from other possible calculations would consequently be smaller.

The carbon isotope value of the C4-soil in the numerator of equation 1 was measured from pooled soil samples of each treatment in 2004. Per treatment area (10 x 10 m) 3 independent soil cores were taken, split in 5 cm depth increments and pooled to a treatment specific soil sample already at the field site.

For the carbon isotope value of the C3-soil in the numerator, which should represent the reference value of the respective carbon pool without labelling, we had two possibilities. The first choice would have been to take the soil signal of the C4-plot at the start of the experiment, which represented the C3-signal of the former vegetation and agricultural land use. This would avoid any spatial variability at the field site but would completely leave out changes that must take place due to the land use change. The latter might be more important than differences in isotope values between different species or plant compartments. Therefore, we decided to use the average isotope value for the respective depths of all 90 plots with continued C3 vegetation. In our opinion this best represented the general consequences of land use change on the soil carbon isotope values that coincide with the C3-C4 vegetation change.

To give the uncertainty of this value, we calculated a proportion of plant derived carbon in the no litter treatment in the top 5 cm of the soil of 10.8 percent. If we performed the same calculation with the initial isotope values on the C4 plot measured in 2002, the result would change to 9.9 percent.

In the double litter treatment we calculated a proportion of 15.0 percent C4 plant derived carbon in the upper soil horizon. Using the initial soil isotope value of the C4 plot the proportion changes to 13.9 percent.

Therefore, uncertainties in the reference isotope value in the numerator effected the calculated proportion of new plant derived carbon to a small extend. However, differences between the treatments and interpretation of the results are identical.

The isotopic values for the C4 plant material (in the denominator) in the different treatments were taken from the collected root material of the respective treatment areas. In the no litter treatment this root material represented the only plant material input source. Therefore, we used the measured value of -14.1 permil. Also in the double

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litter treatment production and decomposition of root material was the major plant carbon source, because the litter is not mixed into the soil and can not reach deeper soil horizons. Therefore, we used the measured value of -15.1 permil in this treatment for all depth segments. If we would use, as a worst case scenario, the measured isotope value of the above ground C4 plant biomass (the bulk value for the litter) of -13.2 permil for the calculation in the top 5 cm, the proportion of C4 plant derived carbon in the SOC (then 13.1 percent instead of 15.0 percent or 13.9 percent (see above)) would still by far exceed the stored amount of carbon in the soil, which was only 7.7 percent. This would lower the total contribution; however, general result and interpretation are not affected.

The isotope content of the C3 plant material required as unlabelled reference value in the denominator of equation 1 should be the value of the root material of the current C3 vegetation that caused any shifts in the soil carbon pool of the C3 plots between 2002 and 2004, not the value of the previous crop input. The best choice here would of course have been the carbon isotope values of the root material averaged for all C3 plots according to the procedure for the soil carbon. We are very sorry that those data were not available for the whole field site and we are fully aware that above and below ground plant compartments differ in the carbon isotope content as could be seen on the C4 plot. Still, the difference in the calculated proportion of C4 plant derived carbon in both litter treatments would not change drastically, because the reference value for both treatments had to be changed.

To give an example for the uncertainty: even if we calculated the proportions with a deviation of 2 permil (like the difference between above and below ground plant material measured in the double litter treatment of the C4 plot) we would end up with a proportion of 9.5 percent instead of 10.8 percent in the no litter treatment and 13.1 percent instead of 15.0 percent in the double litter treatment.

To shortly summarize and refer to figure 4, with all minor uncertainties mentioned here, we still do not fit the carbon storage observed in the double litter treatment in 0 - 5

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cm depth with the proportion of plant derived carbon, which is the only plant derived carbon source for SOC on the C4 plot. Neither can we explain the observed carbon storage below 5 cm depth in the no litter treatment by newly plant derived carbon as we never found a sufficient C4 signal in the SOC in these depths (fig. 3 and 4).

We finally want to briefly explain the motivation of the isotope values used in equation 2, which aimed to calculate the proportion of C4 plant carbon in the DOC that derived from the current plant production in the year of investigation, i.e. root exudates and decomposing plant material (roots or litter). Consequently, the contribution of C4 plant derived material from previous years already transformed into soil organic carbon has to be considered.

The most pronounced difference between equations 1 and 2 is the fact that equation 2 only used measured data of the C4 plot or rather the C4 treatments itself but did not include any values of C3 plots for comparison or reference.

In general, we discuss only two possible sources for DOC in the soil solution, which are plant derived carbon and soil derived carbon holding a constant C4 signal and a temporally drifting C3 isotope signal, respectively. The isotope ratio of soil organic carbon is systematically drifting from initial values in 2002 to heavier values in 2004 as new C4 derived soil carbon is formed over the time of the experiment (fig. 3). To account for this drift we used both end members for the soil derived carbon source in equation 2. In the denominator we used the initial C3 soil carbon signal measured on the C4 plot in 2002. This gives the conditions at the beginning of the experiment and represents the maximum possible difference of both DOC sources. In the numerator we consider that all DOC that derived from the current SOC would hold the isotope signal of the soil organic carbon in 2004. Evidently, the isotopic signal of DOC was never lower than the respective transient isotopic signal of the soil organic carbon (fig. 7).

Alternatively, we could calculate the total proportion of C4 derived carbon in DOC. This would combine contributions of current plant production and newly formed soil organic

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carbon. In this case we would use only the soil organic carbon values of 2002. In 10 cm depth the maximum proportion of C4 plant derived carbon in DOC would increase from 29 percent to 37.5 percent in the double litter treatment and from 13.7 percent to 20.3 percent in the no litter treatment. However, these changes are not affecting our conclusion that the increased proportion of plant derived carbon in the DOC in the double litter treatment compared to the no litter treatment causes priming of existing soil organic carbon.

We hope we could clarify some of the referee's concerns and apologize that we have not been detailed enough in the manuscript. Perhaps an appendix explaining what assumptions the equations are based on, would help clarify the situation for further readers?

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