

***Interactive comment on* “The impact of lateral carbon fluxes on the European carbon balance” by P. Ciais et al.**

P. Ciais et al.

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Reply to referee #1

Maybe an additional comment of the relevance of this synthesis to C trading concepts would assist (through keyword flags) in promulgation of this re-search into the C policy area. >> In the discussion section 6.1, a new paragraph was added to describe the relevance of lateral transport for carbon trading concepts for policy.

While the ms is well researched and has an appropriate bibliography, there could be merit to refer to any related aggregated database that the authors or the CARBOEUROPE project has developed; on a couple of occasions in reading the ms I felt a need to supplement to data presented herein. >> Unfortunately, there is no aggregated database on lateral fluxes. The research papers upon which this work relies are all

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quoted in the text.

P1537, line 25 The Nile is not in Europe; provide an alternate example >> Sentence changed to “(e.g. 40% for Ebro)”

P1541, line 18 “..over long distances,..” consider inserting the words or idea of {with resultant increased variability in estimates for temporal storage and transformation}. Many of the pieces of the wider jigsaw picture developed in this ms deal with the minutae and specifics of variability in storage and transformation as small scales. This ms is picking up these pieces and putting them together on a large canvas; the suggested text insertion notes that wide small scale variability as an important metric but also one that is but a part of a larger process. >> Suggested sentence has been added to link small-scale variability in the context of continental upscaling

P1541, line 21 “..transport creates” consider inserting “..creates {and accentuates}”. I think this is in keeping with the diverse scales issue the authors are discussing here. >> ‘Accentuates’ has been added

Table 2 Uniformity of metric formats. Either give + sign to all positive metrics or do not use the + sign for positive metrics. I prefer the absence of + sign for positive metrics. >> All + signs were removed for positive flux terms. The choice of atmospheric sign convention is given in the beginning.

Technical Corrections >> All technical corrections were implemented. We are very grateful to the reviewer for his very careful reading of the manuscript and useful corrections.

Reply to Referee #2

1. There is an explanation of how wood is converted to carbon but not an explanation of the conversion methods from grains to carbon. >> A new sentence has been added in section 2.1: ‘Crop biomass (harvest, trade fluxes) data is converted into dry biomass and carbon using crop specific conversion factors (Goudriaan, 2001).’

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2. With respect to wood products I believe there are two types of sinks. The first is essentially a transport and replacement sink. Trees are harvested and then replanted so that the carbon stored in the harvested trees is transported out of a region while new trees will be grown to replace them. The other sink is really storage in the wood usage areas. Unlike grain which will probably be consumed relatively rapidly (human or animal consumption) many wood products are used as building materials that will not be returned to the carbon cycle for decades to centuries or more. There needs to be a discussion of this. What percentage of the annual harvested wood product lateral flux is actually returned to the atmosphere relatively quickly (within a few years) and what percentage remains in storage as building material, furniture, etc. ?

>> A new paragraph was added in the end of section 2.2 on the fate of food product pools to give a rough and ready estimate of the storage in wood products. Given that the net (import minus export) carbon balance for wood trade is only 9 TgC y⁻¹, the associated storage of carbon remains small vs. other lateral flux terms. Rigorously, a distinction between imported and exported wood species would be necessary, given different Mean Residence Times (MRT) associated to products for each tree species. Typical MRT for sawn wood products are of 30 years for picea and 40 years for Quercus in Europe (J. Liski, T. Palosuo, M. Peltoniemi et al., Ecological Modelling 189 (1-2), 168).

>> New paragraph: "At the continental level, wood products imports are currently exceeding exports, inducing a net source of CO₂ of up to 7 TgCyr⁻¹. This value is likely to be a maximum estimate because it assumes that wood products are decomposed into CO₂ instantly, neglecting storage. Using the mean residence times of wood products of Liski et al. (2005), typically 30 years for spruce and 40 years for oak sawn wood, we estimate that on a 10 years horizon, the trade of wood products results in a net source of CO₂ to the atmosphere of 2 TgC yr⁻¹ only, while the remaining 5 TgC yr⁻¹ remain stored in product pools."

3. The use of the terms project and projected bother me a little. Phrases like “ Statistical

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data (FAO, 2004) on feedstuff and food producers is projected on a 1_ by 1_ map” I do not believe that is geographically correct terminology. Essentially the statistical data were converted to a geospatial data layer that can be used along with other geospatial data layers to perform some basic GIS analysis on where the major source and sink areas are in Europe. >> We changed ‘projected’ into ‘converted into a geospatial dataset’.

4. The text has quite a few grammatical and spelling errors. For example in the quote above the word data is plural therefore it should read ‘data are projected’. >> Grammar was checked again

5. Need to go through the references more thoroughly. Formats of cited literature are not consistent. Sometimes spelled out completely other times abbreviations are used. Needs to be consistent and correct according to journal specifications. >> References were checked and made consistent

6. I looked at figure 1 for quite awhile and I am still not exactly sure what the authors are trying to show. It seems a little muddled and not easily understood without a very careful reading of the figure caption. Even then it was not clear to me. >> Figure 1 was entirely redone and clarified, and linked to the flux estimates in Table 2

7. Not sure that the assumptions listed for Table 2 are valid/realistic. >> The assumptions are discussed in the text, and a qualitative uncertainty index given in Table 2

8. Conclusions seem a little weak. To borrow from a colleague what is the cosmic significance of the findings of this paper? How might these findings affect our greater understanding of lateral carbon fluxes and carbon cycling? Also, they should reflect the three main goals of the paper described in the introduction.

>> Conclusion were rewritten to be streamlined with the initial objectives

>> New conclusion : "The lateral carbon fluxes induced by crop and forest product

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trade, photo-oxidation and atmospheric transport of reduced carbon compounds, and river transport are shown to be important contributors to the carbon budget of the Europe at the regional and continental level. Altogether, we estimated that the horizontal fluxes require a terrestrial CO₂ sink of 165 TgC yr⁻¹. This CO₂ sink is larger than the carbon accumulation in forests deduced from biomass inventories at the European level. Including this CO₂ sink thus doubles the imbalance between photosynthesis and ecosystem respiration over Europe's forests. In this work, we only attempted to estimate lateral transport processes at the continental level, but these fluxes should also be taken into account at the site level and at the regional level, for instance to reconcile eddy covariance estimates of the CO₂ fluxes and biometric measurements of changes in biomass and soil carbon stocks. This work also demonstrates that a substantial amount of carbon is displaced in proportion to the NPP, roughly about 10% of the NPP of the European continent. Lateral carbon transport may also explain why inverse modeling estimates of the CO₂ sink are nearly always systematically higher than forest inventory numbers of carbon stock changes. Maps of CO₂ sinks required to match lateral transport fluxes should be accounted for in inversion studies, for instance by prescribing an adapted a priori flux structure. In future work, investigations of lateral carbon fluxes should also reflect changes in economic and land use drivers in the context of implications for future climate change."

Page 3, line17, indicates that no strong correlation was found but no statistical results are shown. Just a visual comparison or was a form of formal correlation used?? >>
Just visual comparison (i.e. harvest and export are not related)

Page 3 lines 28 and 29, Sentence needs some rewording. "Such a large net. . ."
Sentence was reworded

Page 4, lines 5-8, several grammatical/spelling errors e.g. farmed should be farm, area should be areal, should be according to the animal density, etc. Page 5, line19, should read sequence of an RCC Page 8 lines 13 and 16 should be subscript on CO₂ Page 8 line 27, I don't know why but stream gaging is not spelled stream gauging. >> All

these corrections were made

Page 11, line 2, fjords and fjards are two spellings of the same feature I think. >> No! Fjords have steeper walls and are much deeper than fjärds. These two estuarine types probably have very different C cycling patterns.

Page 12, line 12 need to drop the of before (Janssens et al., 2005) Page 13, line 23, should read sink is large compared to (there is an extra the in the text now) Page 14, line 18, estimated should be estimates Page 15, line 8 freshwater should be freshwater. >> All these corrections were made

Page 15, line 9 should be a space after CO₂ and last sentence needs to be re-written. I would suggest, 'In future work, investigations of lateral carbon fluxes should reflect changes in economic and land use drivers in the context of implications for future climate change.' >> The suggested sentence was used. We thank the referee for his thoughtful comments.

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