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Geoscientific Model Development Discussions

Interactive comment on "Definitions and methods to estimate regional land carbon fluxes for the second phase of the REgional Carbon Cycle Assessment and Processes Project (RECCAP-2)" *by* Philippe Ciais et al.

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Response to referees comments on "Definitions and methods to estimate regional land carbon fluxes for the second phase of the REgional Carbon Cycle Assessment and Processes Project (RECCAP-2)" by Philippe Ciais et al.

Anonymous Referee #2

This manuscript presents a conceptual and methodological framework for the compu-

tation of land-atmosphere fluxes in the context of the RECCAP-2 project. It describes in detail the main fluxes to be consider for obtaining the net exchange of carbon between land and atmosphere, with special emphasis in the homogenization of top-down versus bottom-up estimates. The manuscript is well written, and it is a meaningful contribution to the literature. Given that the definitions and conceptual framework described here has applications mostly for the RECAPP project, the manuscript could be publish in its current form after minor revisions. However, if this work is intended to transcend RECAPP, and provide a useful conceptual framework for global carbon cycle science, then a major revision is required. I have three main concerns that I will detail below, followed by a list of small minor issues.

Response: We thank the reviewer for this positive comment and have done our best to address the three issues highlighted below.

1 Major concerns From my point of view, the definition of the main component fluxes of the budget presented in this manuscript, and summarized in Figure 2, mixes two different aspects of a carbon budget. On the one hand, many of the fluxes are defined by the specific process that generate a transfer of carbon from one pool to another (lateral transfers), or from a pool to the atmosphere. This definition of fluxes is intuitive and is a good approximation to our scientific understanding of the main processes in the Earth system that produce transfers of carbon among reservoirs. On the other hand, some of the fluxes, and in particular those related to the land use component, are defined based on the proximate cause of anthropogenic emissions. I think this mix on the way the fluxes are defined is confusing and prone to double counting or confusing accounting. For example, a process that generates emissions of carbon to the atmosphere from the land is the respiration of heterotrophic organisms, which includes wild and domesticated animals as well as humans. Heterotrophic respiration is the main biological process that produces the emission, but one could attribute these emissions based on the type of heterotrophic organisms that produce them. In other words, one can define the flux based on the process (heterotrophic respiration) or

based on the proximate cause, e.g. 'carbon emissions from crop biomass consumed by animals and humans' as defined in section 2.5.1. However, it is confusing to define fluxes based on processes and based on proximate causes as part of the same budget. It can also lead to double counting. The same problem appears in the definition of fluxes due to fires and those due to land use change or deforestation. The process that defines the flux is fire, but the proximate cause may be due to crop management, deforestation, or annual natural disturbances. The fluxes considered in this manuscript is a mix of both, fluxes defined by processes and fluxes defined by the proximate cause. I do not think this can help us to get some clarity in constraining the global carbon budget and to understand its change. A better approach would be to define all fluxes based on the processes that lead to the flux, or to define them based on all the different proximate causes. The idea is to be consistent. I personally would be prefer definitions of fluxes based on processes, and in a posteriori analysis, attribute the fluxes to specific proximate causes. I think such an approach would help to get separate two main aims in current C cycle research, to understand processes, and to attribute causes of change.

Response: We agree that fluxes can be defined by process or by cause. In particular, heterotrophic respiration is a process underlying different fluxes (soil microbial decomposition, oxidation of crop products by animal and human metabolism, river and lakes decomposition of DOC, and even part of the "land use change" emissions from slash and legacy soil carbon decomposition. Attribution by cause is beyond the goal of RECCAP-2 because it would require to separate mainly 'direct human induced' and 'indirect effects' rather than considering 'causes' as individual drivers (e.g. fire is a driver but can be of anthropogenic or natural causation, and the state of the science does not allow to properly separate these two causes) which has been a source of confusion between carbon models used for IPCC WG1 and WG3 and national reporting for IPCC Guidelines. See comment by R. Houghton. We offer to mention the issue of 'direct human induced' and 'indirect effects' but clearly adopt an attribution by 'process' in RECCAP2. Thus, we are left with heterotrophic respiration and combustion which are

cross-cutting processes. In our study, the definitions are based on practical methods to estimate each flux. The method used to estimate river outgassing (from river pCO2 data) is for instance different from that used to estimate "terra firme" soil heterotrophic respiration (from site data or models), or animal and human digestion by heterotrophic processes (from agricultural and trade statistics). To address the reviewer concern, we added a table that gives the possibility to regroup all fluxes belonging to 'heterotrophic respiration' into aquatic C decomposition, intact lands and land in transition soil carbon decomposition, and biomass combustion (biofuels and wildfires).

Although the aim of this project is on the fluxes of carbon between the atmosphere and land, it is surprising that no effort is placed in quantifying and reporting carbon stocks of the main source pools from the land. Knowledge on the carbon stocks is important for two main reasons: 1) to know the relative proportion of carbon emitted from source pools and how they differ among main regions, and 2) to identify potential mass balance problems when fluxes are much larger than the size of the source pool. For reporting based on Delta methods, reporting the size of the pools is easy and should be recommended.

Response : We agree that carbons stock reporting is important, not only stock changes. Some stocks like permafrost carbon, peat, mineral associated soil organic matter, or carbon sediment have a small exchange flux with the atmosphere. In the revised manuscript we added as a recommendation for RECCAP2 to report the size of pools and how this size was determined.

The recommendation of reporting NPP instead of GPP is troubling, and does not reflect well our current physiological understanding of carbon assimilation in ter- restrial ecosystems. The authors define NPP as 'the flux of carbon transformed into biomass tissues after fixation by GPP', probably assuming that autotrophic respiration is already removed in NPP; i.e. NPP = GPP - autotrophic respiration. The problem with this definition is that we know that autotrophic respiration can only occur from living tissues produced after biomass formation, not before as the definition implies. Only living cells

can respire carbon, and experiments and isotopic analyses have shown that carbon respired from roots and stems can be years to decades old. While GPP quantifies the instantaneous removal of CO2 from the atmosphere, autotrophic respiration is the lagged release of CO2 back to the atmosphere. These fluxes are not necessarily in sync, and therefore NPP is a poor approximation of the instantaneous net flux. This is important for the planned comparison of fluxes from the inversions, because they are computed at much higher temporal resolutions than the NPP estimates from forest inventories. In addition, there are now a range of techniques that aim at quantifying GPP in ecosystems using measurements of fluorescence and COS both from satellites and at flux tower sites. Therefore, there is an opportunity to include independent estimates of carbon assimilation (GPP) as part of the regional carbon balances.

Response : We partly agree that autotrophic respiration occurs not necessarily from very recently fixed carbon into plants (e.g. can come from reserve and labile pools). However, what is important for annual and decadal budgets is the fraction of plant carbon that enters into ecosystems and has a residence time larger than typically one year. Here, NPP, despite definition and measurement issues is a good approximation of this “incoming flux” that can compose a carbon sink or source on annual / decadal scale. In sum, we propose to report GPP and NPP in the revised manuscript.

2 Minor comments

Line 62. Add ’of’ after ’estimates’ Ln 190. Add ’,’ or ’;’ after ’regions’ Ln 224. Add ’be’ in ’needs to paid’ Section 2.2.3. The quantification of carbon fluxes due to trade is interesting. Would it be useful to include also carbon fluxes due to trade of unburned fossil fuels? Line 371. This sentence is similar to line 360 in previous paragraph. Consider removing it.

Response: All minor changes have been made in the revised manuscript

Line 614. NEE at the ecosystem level only considers CO2, at least as it is commonly done in eddy-covariance studies. However, you define regional NEE as the net carbon

balance of carbon, not just CO2. I see a mismatch here between the more traditional definition of NEE at the ecosystem level and your new definition at the regional level. Wouldn’t be better to call your new quantity net regional carbon balance?

Response: We prefer to use NEE-C instead of NEE in the revised manuscript. The difference of NEE “CO2” from eddy covariance data and our definition of NEE-C is clearly explained in the revised manuscript.

âĂćFigure 2. I don’t see the benefit of repeating the same figure twice to only add the names of the fluxes. I would make only one diagram with the abbreviations and define the flux names in a table.

Response : Thank you for this comment. We modified Fig. 2 as suggested with the flux names in a table

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