

Dear Topical Editor Nellie Elguindi,

Dear Referees and Editorial Board of ESSD,

As requested, we are submitting responses to the referees' comments.

We will provide as well a track-change version of the manuscript. We will not refer here to grammar or language corrections, but they will appear in the marked-up manuscript. **The lines in the following answers refer to the track-change version of the manuscript.**

Given that both referees for the companion paper "The consolidated European synthesis of CH₄ and N₂O emissions for EU27 and UK: 1990–2017" asked us to merge all data figures in one spreadsheet "data_figures_CO2.xlsx", we did the same for this synthesis and we updated the Zenodo DOI repository with v2 found here: <https://doi.org/10.5281/zenodo.4626578>

Interactive comment on:

"The consolidated European synthesis of CO₂ emissions for EU27 and UK: 1990–2018"

by A.M.R. Petrescu et al.

REPLY TO THE REFEREE #1

The authors thank very much Referee #1 for the very positive and thoughtful comments and for the fact that the Referee acknowledges the manuscript as being a comprehensive source of information regarding a wide range of public products, very useful for modelers and the whole scientific community and for quantifying the progresses towards mitigation target assessed through the global stocktake.

Below we provide answers to the minor comments posted by Referee #1.

Response to minor comments and changes in manuscript:

Line 62: Replace "CO₂ land sources/sinks" with "biogenic CO₂ land sources/sinks".

On L162 we define the two CO₂ components analyzed in this study as CO₂ fossil and CO₂ land. After much discussion in the preparation of this manuscript, we choose to follow the general IPCC GPG, which defines "land" in footnote 4: "The IPCC Good Practice Guidance (GPG) for Land Use, Land Use Change and Forestry (IPCC 2003) describes a uniform structure for reporting emissions and removals of greenhouse gases. This

format for reporting can be seen as “land based”; all land in the country must be identified as having remained in one of six classes since a previous survey, or as having changed to a different (identified) class in that period. According to IPCC SRCCL: Land covers the terrestrial portion of the biosphere that comprises the natural resources (soil, near surface air, vegetation and other biota, and water) the ecological processes, topography, and human settlements and infrastructure that operate within that system”. Some communities prefer “biogenic” to describe these fluxes, while others found this confusing as fluxes from unmanaged forests, for example, are “biogenic” but not included in inventories reported to the UNFCCC. As this comparison is central to our work, we decided that “land” as defined by the IPCC was a good compromise. We added this explanation to footnote 4.

Line 93: “represent the sum of the effects of sources and sinks”.

We made the correction.

Line 98: UK does not use atmospheric observations to complement CO₂ (due to difficulty in representing the biogenic fluxes).

The referee is right, the UK uses inverse observations only for CH₄ emissions and not for CO₂. However, this introduction paragraph (L87-L99) refers in general to GHGs.

Line 166: Include description of acronyms.

We added acronyms for EDGAR, FAOSTAT, BP, CDIAC, EIA and IEA. GCP is explained on L124.

Lines 169-170: Parenthesis do not match.

We made the correction.

Line 177: Replace “show” with “shown”.

We made the correction (now on L179).

Line 215: Isn't the term “CO₂ land fluxes” too generic since the target is LULUCF?

Indeed the target is the LULUCF sector and its component classes: forest, cropland, grassland, wetlands, settlements, other land and harvest. We decided to use “land” fluxes according to the UNFCCC definition (footnote 4): “The IPCC Good Practice Guidance (GPG) for Land Use, Land Use Change and Forestry (IPCC 2003) describes a uniform structure for reporting emissions and removals of greenhouse gases. This format for reporting can be seen as “land based”; all land in the country must be identified as having

remained in one of six classes since a previous survey, or as having changed to a different (identified) class in that period. According to IPCC SRCCL: Land covers the terrestrial portion of the biosphere that comprises the natural resources (soil, near surface air, vegetation and other biota, and water) the ecological processes, topography, and human settlements and infrastructure that operate within that system”.

Line 238: Replace “then” with “than”.

We made the correction on L243.

Line 243: Replace “differing” with “differ”.

We made the correction.

Table 2: Why is there no contact/lab for BU H&N bookkeeping model?

We added the Woodwell Climate Research Center.

Lines 256-257: Numbers with and without LULUCF are not consistent with LULUCF contribution.

This is because the numbers for EU27+UK with and without LULUCF are in CO₂eq and include contribution of CH₄ and N₂O as well. The number we report for LULUCF only (0.28 Gt CO₂) is only for CO₂.

Line 541: Replace “variation trend” with “variation”.

We made the suggested correction the new L552.

Line 567: “The sink in ORCHIDEE is due to. . .”

We included “to” on the new L579.

Line 605-606: “for instance the CO₂ fertilization effects. . .”

We deleted “by” on the new L617.

Line 673: “by subtracting from the inversion estimates the emissions. . .”

We deleted “of” on the new L684.

Line 718: It is not clear what are the indirect fluxes on managed land included in NGHGs.

According to IPCC (2010), land fluxes can be differentiated into three processes: (1) direct anthropogenic effects (land use and land use change, e.g., harvest, other management, deforestation), (2) indirect

anthropogenic effects (e.g., changes induced by human-induced climate change, including CO₂ fertilization and nitrogen deposition changes), and (3) natural effects (i.e., that would happen without human-caused climate change, such as natural disturbances). The UNFCCC NGHG inventories use the notion of managed land as a proxy for anthropogenic emissions (IPCC, 2006) and hence in practice include most or all (depending on the specific method) indirect emissions into their anthropogenic estimates (Petrescu et al., 2020b).

We added on L729 the following explanation: *“(indirect fluxes on managed land included in NGHGIs and FAOSTAT e.g., changes due to human-induced climate change, including CO₂ fertilization and nitrogen deposition changes) (Petrescu et al., 2020b)”*.

REPLY TO THE REFEREE #2

The authors thank Referee #2 for acknowledging this study as being a comprehensive overview and summary of the various estimates of CO₂ sources and sinks in Europe, well written and well structured. We thank Referee #2 for the comments to which we answer below.

1) The Reference section contains three different references for “Petrescu et al. 2020” (which are also cited in the text). To avoid confusion, it would be helpful to relabel these as “Petrescu et al. 2020a” etc.

We agree and labeled the three Petrescu references as following: a) Zenodo data sets; b) ESSD AFOLU paper, and the companion synthesis paper on CH₄ and N₂O with 2021, in press.

2) The LUH2 dataset is cited with “Hurtt et al. 2011”, but that paper refers to the LUH1 dataset. LUH2 should be cited with Hurtt et al. 2020 (which is already included in the Reference list), or potentially with both Hurtt et al. 2011 and 2020.

Thank you. We changed everywhere to Hurtt et al., 2020 as we refer to LUH2.

3) Line 432: change “emission” to “emissions”

We made the correction.

4) Line 431: change “taking into account of the” to “taking into account the”

We deleted “of”.

5) Line 457: change “except a daily” to “except for a daily”

We added “for”.

6) Line 461: change “extend” to “extent”

We made the correction.

7) The section around line 490 describes how the ESACCI-LUH2v2 dataset assumes that shrublands are equivalent to forest. A rough estimate of the impact of this assumption for the representation of forest area in Europe is included. However, it seems like this could be explicitly quantified from the data, rather than just estimated – is that possible?

The reviewer would like to see a more precise calculation of the impact of classifying all shrubs as forests in the ESACCI-LUH2v2 product on the NBP fluxes of the EU-27+UK. Note first that ESACCI product effectively distinguishes shrub from forest but that we have further grouped them given that the ORCHIDEE model does not distinguish shrubs. While possible, the scientific benefit is unclear. As mentioned in the paper, the definition of "forest land" varies by Member State in the UNFCCC reporting (table 6.10 in the EU NIR for 2020 gives a nice summary of the forest question <https://unfccc.int/documents/228021>). Changing all shrub land to some other land type in the simulations (either grassland or cropland) would likely get us closer to the "real" answer, but it's not clear how close, or if we would over- or under-estimate it, given that the definition of forest used in the ESA-CCI maps does not match all of the individual definitions for each member state; one definition of "forest" is applied across the whole ESA-CCI product. Due to the lack of a clear mapping between the ESA-CCI land cover classes and the Member State definitions for land cover and land use, we are not convinced that a more work-intensive estimation, while perhaps more precise, would be demonstratively more accurate than the estimation we already give.

However, we have indeed carried out more precise estimate, looking at the amount of land area classified as "shrubs" and "tree" in the original ESA-CCI land cover classification from 2015 for the EU-27+UK. We find a total of 1.01 Mkm² for trees and 0.498 Mkm² for shrubs, which means the proportion of shrubs is significantly higher (50 %) than our previous estimate (10 %). A similar analysis for the FAOSTAT domain Land Cover, which maps and disseminates the areas of MODIS and ESA-CCI land cover classes to the SEEA land cover categories <http://www.fao.org/faostat/en/#data/LC>, shows that shrub-covered areas are around 20 % of that of forested areas. Given the uncertainty in land cover definitions mentioned above, we have modified the text in the manuscript as following, L490-499:

“For this study, the ORCHIDEE model used a so-called ESA-CCI LUH2v2 PFT distribution (a combination of the ESA-CCI land cover map for 2015 with the historical land cover reconstruction from LUH2 (Lurton et al., 2020)), and assumes that the shrub land cover classes are equivalent to forest. In terms of area, the original ESA-CCI product corresponding to our domain of the EU-27+UK shows shrub land equal to about 50 % of the tree area in 2015. A similar analysis using the FAOSTAT domain Land Cover, which maps and disseminates the areas of MODIS and ESA-CCI land cover classes to the SEEA land cover categories (<http://www.fao.org/faostat/en/#data/LC>), shows that shrub-covered areas are around 20 % of that of forested areas for the EU-27+UK. The impact of classifying shrubs as “forests” on the total carbon fluxes could therefore account for a significant percentage of the differences between ORCHIDEE and other results in Figure 6.”

8) The description around line 496 about the forest area data from FAOSTAT could use some additional clarification. If FAOSTAT provides the current forest area, not just the FL-FL category, then would it not consider both afforestation and deforestation? Also, line 497 states “This area is based on the same land use/land cover maps”, but it is not clear to me what these maps are the same as.

We agree that this is an unclear explanation of the area used by FAOSTAT and we corrected as following L507-509:

“FAOSTAT forest land area is based on country statistics from the FAO/FRA process and includes not only forest remaining forest area but all forested land, including afforestation.”

9) Line 657: change “emission” to “emissions”

We corrected, now on L668.

References:

IPCC: Good Practice Guidance for Land use, Land use Change and Forestry, available at: https://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_files/GPG_LULUCF_FULL.pdf (last access: January 2020), 2003.

IPCC: Uncertainties, chap. 3, in: 2006 IPCC Guidelines for National Greenhouse Gas Inventories, available at: https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/1_Volume1/V1_3_Ch3_Uncertainties.pdf (last access: December 2019), 2006.

IPCC: Revisiting the Use of Managed Land as a Proxy for Estimating National Anthropogenic Emissions and Removals, edited by: Eggleston, H. S., Srivastava, N., Tanabe, K., and Baasansuren, J., Meeting Report,

INPE, Sao José dos Campos, Brazil, 5–7 May 2009, Pub. IGES, Japan, 2010.

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Hurtt, G. C., Chini, L., Sahajpal, R., Frohking, S., Bodirsky, B. L., Calvin, K., Doelman, J. C., Fisk, J., Fujimori, S., Klein Goldewijk, K., Hasegawa, T., Havlik, P., Heinemann, A., Humpenöder, F., Jungclaus, J., Kaplan, J. O., Kennedy, J., Krisztin, T., Lawrence, D., Lawrence, P., Ma, L., Mertz, O., Pongratz, J., Popp, A., Poulter, B., Riahi, K., Shevliakova, E., Stehfest, E., Thornton, P., Tubiello, F. N., van Vuuren, D. P., and Zhang, X.: Harmonization of global land use change and management for the period 850–2100 (LUH2) for CMIP6, *Geosci. Model Dev.*, 13, 5425–5464, <https://doi.org/10.5194/gmd-13-5425-2020>, 2020.

Additional changes :

We added A. to co-author Richard Houghton

L480: Caption Figure 6: we corrected the mean common period to 2006-2015.