Response to Interactive comment to anonymous referee #1

Thank you for the positive feedback and the suggestions to improve the manuscript. We agree that these are very relevant points that, after inclusion, make the manuscript much clearer to follow. Below are the questions and suggestions followed by answers including the changes that were made in the manuscript.
In addition to addressing the reviewers' comments we extended the analysis to including the newly available LUH2 net dataset in the analysis. Since this dataset will be used e.g. in CMIP6 simulations, we expect this dataset to emerge as one that will frequently be used for modeling studies in the future. As this we included it in the analysis. The inclusion of LUH2 in averages and uncertainties in C stocks and fluxes did not change the outcomes of this study. We also include a section on the inclusion of LUH2 as a model that is indeed not completely independent from LUH1 and HYDE in the discussion.

1. The authors should clarify exactly which version of the HYDE dataset is being used in this study. In Table 1 they cite Klein Goldewijk 2015 but that paper is not listed in the Reference section. They also state that they are using the version of HYDE and the version of LUH used in Le Quere et al. 2015. However those datasets should be identical for global areas of cropland and pasture, although they are apparently not identical in this study (from Figure 1). A statement that the version of HYDE used in this study is not the same as the version of HYDE used as an input to the LUH dataset would be helpful. In addition, if the version of LUH used in this study is indeed the same one used in Le Quere et al. 2015, it would be good to state that this version of the LUH dataset differs from the standard LUH dataset used in most CMIP5 experiments.

We agree with the reviewer that we were not totally clear on the exact versions of the datasets that were used in the study. We followed up with the developers of the datasets and added information to the text and Table 1 that should provide a clear identification of the datasets that were used. This also includes a statement regarding CMIP5 and CMIP6 simulations. We apologise for omitting Klein Goldewijk (2015) from the reference list and have corrected this.

§2.1, lines 155-157: *The HYDE dataset used here was extended until 2005 (Klein Goldewijk et al., 2015), and later until 2013 in the 2014 global carbon budget analysis (Le Quéré et al., 2015a).*

§2.1, lines 169-178: *The LUH1 dataset was extended until 2014 for the 2015 global carbon budget analysis (Le Quéré et al., 2015b), using an early version of HYDE 3.2 as the basis (now published in final version as Klein Goldewijk, 2016) and following the same methodology as described in Hurtt et al. (2011). The version of LUH1 used in this study is therefore a more recent development than that used for CMIP5 experiments (Taylor et al., 2012), but an earlier version than the very recent LUH2 release (Hurtt et al., 2016). As LUH1 is a modeled product that is based on the underlying HYDE database, these products are very similar when the corresponding versions of each dataset are considered (Hurtt et al., 2011). Note that the version of HYDE used for our study (version 3.1.1, see above) is not the same as the version of HYDE that underlies the LUH1 data used here (early version of HYDE 3.2); the HYDE and LUH1 data used in this study differ in several aspects.*

revised Table 1:

Table 1. Overview of LPJ-GUESS simulations carried out as part of this study.

Land-use model		First year	Last year	Representation of LUC transitions	Spatial coverage
Abbreviation	**Reference**				
LUH1	1500-2005: LUH1 (Hurtt et al., 2011), extension until 2014: Le Quéré et al. (2015b)[a]	1700[b]	2014	gross	global
		1700[b]	2014	net	global
		1700[b]	2014	LUC fixed to 1700	global
RAMA	1700-1992: Ramankutty and Foley (1999), extension until 2007: Ramankutty (2012)	1700	2007	net	global
		1700	2007	LUC fixed to 1700	global
HYDE	10 000 BC to AD 2000: HYDE3.1.1 (Klein Goldewijk et al., 2010, 2011), extension until 2005: see Klein Goldewijk et al.(2015), extension until 2013: see Le Quéré et al. (2015a)	1700[b]	2013	net	global
		1700[b]	2013	LUC fixed to 1700	global
LUH2	850-2015: LUH2 v2 (release 14 Oct 16), (Hurtt et al., 2016)	1700[b]	2015	net	global
		1700[b]	2015	LUC fixed to 1700	global
HILDA	HILDA v2.0 Fuchs et al. (2015b)	1900	2010	gross	EU27[bc]+CH
		1900	2010	net	EU27[c]+CH
		1900	2010	LUC fixed to 1900	EU27[c]+CH
LUH1	1500-2005: LUH1 (Hurtt et al., 2011), extension until 2014: (Le Quéré et al., 2015b)	1900[d]	2014	net	EU27[c]+CH
		1900[d]	2014	LUC fixed to 1900	EU27[c]+CH

[a]Note that this version of LUH1 is based on an early version of HYDE 3.2, which is different from HYDE version 3.1.1 as used below, see methods. [b]1700 was selected as earliest start year, [c]EU 2007-2013, [d]1900 was selected as start year for European simulations.

2. In the abstract the authors state that the main reason that gross land-use transitions have previously not been included in carbon modeling studies is the lack of detailed information on historical gross land-use changes. However, I would also argue that until recently many carbon models were not able to use even the simple gross land-use changes provided by land-use datasets.

This is indeed an additional factor which was so far only picked up in the conclusions. We changed the abstract accordingly, which reads now:
abstract, line 23-26: *These complex changes between classes within a gridcell have often been neglected in previous studies, and only net changes of land between natural vegetation cover, cropland and pastures accounted for, mainly because of a lack of reliable high-resolution historical information on gross land transitions, in combination with technical limitations within the models themselves.*

3. Another clarification: the LUH dataset includes shifting cultivation only in some locations within the tropics (based on the map of Butler 1980). There are currently several places in the paper where it is implied that shifting cultivation occurs throughout the tropics.

It is true that shifting cultivation occurs not throughout the entire tropical area but is restricted to specific locations within the tropics according to implementation in the LUH dataset which is based on the map of Butler 1980. We changed the wording at several occasions in the text to "*certain tropical regions*" to be clear that the extent is not the entire tropical region (lines 31, 106, 123, 160, 169, 407, 412, 534,649) and inserted a link to the Butler map at the first occurrence of the expression.

4. Although the authors use both net and gross land-use transitions in this study, they do not describe how they determine the net transitions for the LUH dataset (which by default provides gross transitions) or the HYDE dataset (which does not provide transitions at all – just land-use states). The calculation of net transitions should not be difficult in either case, but a brief description should be included for completeness in the methods section.

The missing information was added to the methods section:

§2, lines 255-261: *LPJ-GUESS uses annual land use states of the classes cropland, pasture, natural vegetation and barren land (no vegetation, e.g. water or ice covered) as input for net LUC runs, that are complemented for gross LUC runs by annual gross transitions for each combination of two land-use classes. Land-use states of RAMA, HYDE and LUH2 were used directly. To generate net transitions from LUH1, annual land-use states were derived from land use states in 1700 and gross transitions from 1700 to 2014. HILDA land-use matrices providing land-use states and transitions together in form of an integer land-use category were translated to annual land-use states and gross transitions for each combination of two land-use classes.*

5. The lack of wood harvest is a limitation of the modeling approach used by the authors and it would be good to include some more discussion of this. Wood harvest is one of the largest land-use transitions in terms of both area and carbon emissions. Although the spatial pattern of wood harvest is uncertain, national data on wood harvest amounts and areas are available. When comparing the effects of including only net vs. gross transitions it is important to consider that wood harvest is a gross transition that is currently not included in this study.

We agree with the reviewer that wood harvest is an important form of managing natural resources, accounting for intense land-use transitions and carbon emissions. The uncertainty in the actual spatial pattern of wood harvest and the many existing ways wood harvest is done in practice over the globe (clear cut, selective harvesting of specific age classes or a mixture of both) introduces many possibilities as to how this process can be implemented in DGVMs. In an LPJ-GUESS-type of model where forest ecosystem and wood parameters vary significantly over tree age classes, this would result in a wide span of possible solutions depending on the parameters used for implementation of wood harvest. For this reason, we decided not to include one or more representation of wood harvest in our analysis as is stated in the introduction (lines 121-123), but in fact cite previous studies that assessed carbon emissions from wood harvest, sometimes in combination with the effects of shifting cultivation in the discussion (Houghton et al., 2012; Shevliakova et al., 2009, 2013; Wilkenskjeld et al., 2014). We feel that for a good estimate of carbon emissions from wood harvest an individual study would be necessary, allowing consideration of a variety of reasonable and technically possible implementations with a DGVM that represents age classes such as LPJ-GUESS.

To address the comment of the reviewer we added in the introduction that wood harvest is a form of forest management that can be represented as gross land transitions (lines 122-126) and added an explanation on the uncertainty that would come with an assessment of wood harvest with an LPJ-GUESS-type of model to the discussion section (lines 549-555).

introduction, lines 125-129: *We exclude wood harvest as a form of forest management that can be represented as gross land transitions from our analysis as, although national data on wood harvest are available, its parameterization in models is poorly constrained on a global scale, e.g. the effects strongly depend on assumptions on the harvest type (clear cut, selective logging, or a mixture of both), or assumptions regarding turnover times of harvested C (Wilkenskjeld et al., 2014).*

discussion, lines 600-607: *We did not account for wood harvest in this study as the uncertainty in the actual spatial pattern of wood harvest in combination with the ways wood harvest is done in practice over the globe (clear cut, selective harvesting of specific age classes or a mixture of both) introduces many possibilities as to how this process can be implemented in DGVMs. In a model such as LPJ-GUESS, where forest ecosystem and wood parameters vary significantly over tree age classes, this would result in a wide span of possible solutions depending on the parameters used for* *implementation of wood harvest that would be better addressed in a thorough sensitivity study investigating a variety of possible implementations, rather than with a single representation.*

*6. The Discussion section begins by stating that a key uncertainty in estimating C stocks and fluxes from land-use stems from the choice of LUC dataset used. I think it would be good to rephrase this opening statement slightly to remind readers that historical reconstructions of land-use are inherently uncertain, and it is not just the choice of LUC dataset that introduces uncertainty. For example, *all* LUC datasets used in this study show a peak in LU transitions around 1950-1960, although there is some evidence that this is likely due to the reconstruction process itself (i.e. the merging of two or more data sources during that time period).*

Also here, the reviewer raises a valid point. It is true that LU datasets are inherently uncertain as a consequence of the limited data base on historical land use and land use transitions that need underlying model assumptions. We changed the statement accordingly. It reads now:

discussion, lines 433-436: *Resulting from the fact that historical reconstructions of land use and its changes are inherently uncertain because of the limited existing data base that needs complementary assumptions (e.g. on land rotation times), it is widely acknowledged that a key uncertainty in estimating changes in C stocks and fluxes as a response to LUC change stems from the choice of the LUC dataset (e.g. Houghton et al., 2012; Jain et al., 2013).*

7. In the Conclusion section the authors state that the consideration of multiple LUC reconstructions exploring the full range of reasonable assumptions is needed. This was actually a central component of the paper of Hurtt et al. 2011 in which those authors performed a large sensitivity study by varying all model inputs and decision parameters to explore a range of possible land-use reconstructions.

We added a link to this publication in the sentence.

conclusions, lines 630-635: *To account for the uncertainty arising from different reconstructions of historical LUC in the dynamic modeling of C stocks and fluxes and to provide realistic estimates of this uncertainty for the land-use C flux, the consideration of multiple LUC reconstructions exploring the full range of reasonable assumptions is needed, as well as efforts to narrow the uncertainty in constructions of historical land use. Multiple LUC reconstructions were calculated by Hurtt et al. (2011), but the consequences of uncertainty in land-use transitions are not routinely explored by the carbon cycle community.*

8. Also in the Conclusion section the authors state that the differences in C stocks and fluxes predicted by the HYDE and LUH datasets is surprising given that they are based on the same data inputs etc. However, it appears that two different (inconsistent) versions of these datasets were used – see comment 1 above.

See reply to comment 1 above for clarification on datasets used in the study. We excluded the statement from the discussion as indeed different versions were used for LUH and HYDE, so that differences are not surprising. We added a statement on the difference between the, now 4, datasets related to the date of their preparation.

discussion, line 621-625: *In our global simulations, HYDE/ RAMA and LUH1/LUH2 data often lead to similar results in ecosystem C stocks and fluxes. Therefore LUH1 and LUH2 as the more recent developments under the four considered reconstructions (both based on HYDE version 3.2, however*

LUH1 on an intermediate version and LUH2 on the final version) differ more from older developments than these from each other (see methods for model versions used in this study).