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Interactive comment on "Comparing the influence of net and gross anthropogenic land use and land cover changes on the carbon cycle in the MPI-ESM" *by* S. Wilkenskjeld et al.

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Answer to anonymous review #1

We thank the reviewer for his or her thoughtful comments, which helped us clarify our manuscript in many respects. We are pleased that the reviewer found our paper to contain useful information for both the modeling and data communities.

General comments

The paper shows how terrestrial carbon cycle model of MPI-ESM treats the land use change transitions and its effect on resultant carbon flux, however, some conclusions are discussed without explicit results. Thus, the authors should show more quantitative result to conclude, particularly for the effect and process of wildfire emissions which may be affected by the sub-grid scale land-use change implementations.

The reviewer is right that we do not show all results discussed results in the manuscript quantitatively using figures or tables. This is a very conscious choice of ours, since we aim at highlighting the important conclusions on the difference in the carbon cycle between using gross and net LULCC, without confusing the reader with a lot of details of only marginal importance for the main topic of the paper. Since we find that the number and size of the figures included in the submitted paper are already at the upper limit for a paper of this length, we are hesitating to add more figures to the paper itself, but we have added more figures as supplemental material to the revised manuscript for the interested reader.

Specific comments

1. Page 5449, line 13: ***Could you describe the reason to use "a fixed rate of wood harvest" in the without LULCC experiment? I felt it is natural to conduct experiments a) without wood harvest in the "without LULCC experiment" or b) with the same wood harvest of the experiment with LULCC in the "without LULCC experiment" as a baseline.***

   The general idea of the experiments "without LULCC" have been to keep the human influence fixed to the conditions of our reference year (1850) to be able to explore the difference between the total human influence in this year and the transient behaviour as described in the “Land-use Harmonization Dataset”.

(a) Since the spin-up of our carbon pools (i.e. the coupled CMIP5 runs) have been conducted using a fixed (1850) rate of wood harvest, this kind of experiment “without wood harvest” would cause an initial imbalance in our carbon pools. This would have unpredictable influence on our results, and therefore this experimental design has not been considered.

(b) We agree that using transient wood harvest for the experiments “without LULCC” is a consistent experimental design. However this setup would answer a different scientific question, namely the separation of the influence of wood harvest and land-cover-changes in contrast to the total influence of LULCC (wood harvest and land-cover-changes) which is the focus of our study. Our main question is the LCE-difference between including or excluding sub-grid LULCC processes (i.e. gross and net implementations of LULCC) and the “without LULCC” experiment does not influence this difference. The absolute values of LCE (and thus the relative difference between net and gross) are of course changed by changes in the ‘without LULCC” experiment setup. For comparison, we conducted additional “without LULCC” experiments using transient wood harvest as suggested by the reviewer. These reveal that 13 PgC of the LCE during the historical period and 20–31 PgC of the LCE of the different RCPs (Figure 1-1 and S7 in the supplemental material of the revised manuscript) can be attributed to the wood harvest. Except for RCP4.5, this corresponds to lowering the relative LCE difference by 2–4 percent points. In RCP 4.5 the LCE changes sign when the contribution from wood harvest is not considered, and thus the relative difference between LCE from net and gross becomes somewhat confusing. The changes from excluding the LCE from wood harvest are of secondary importance compared to the absolute difference between gross and net implementations of LULCC and we prefer to stay with our original research question. However, we have added a presentation of the results from this alternative approach in the manuscript to the last paragraph of section 4.2.1 and a short discussion in the 5th paragraph of section 5 as well as the additional experiments are now mentioned in the description of the experiments (section 3).

2. Fig 1: ***The figure seems to be too complex after 2006. It may be better to draw historical, RCP2.6, RCP4.5 and RCP8.5 separately.***

   It is true that this figure turned out somewhat busy. However, drawing it in this way is the only way to allow direct comparisons between both the development during the different RCPs and the different vegetation types. This figure rather shows some of the pre-requisites for our study than one of our central results and does in our opinion not deserve to occupy more space than it does. We have attempted to optically clarify the figure without changing the presented data.

3. Page 5450, line 16,24: ***You describe the decrease of desert area is both caused from natural change and increase of cropland and pasture. But I couldn't understand why some area of desert are converted to cropland and pasture. Could you show which part of the desert is converted to the agricultural land?***

   Our text might be have been misleading and is clarified in the revised manuscript. We here describe only the development of the globally integrated areas. When looking in detail, the major changes are that forests expand into the cold desert areas of the high northern latitudes (mainly central and eastern Asia), while elsewhere forests are cut and converted to agricultural areas (cropland and pastures). In the net global effect, this leads to expansion of agricultural land on the cost of desert area, but it is not a direct conversion from desert to agriculture but rather a combination of different processes occurring in different regions.

"During this period in total..." has been replaced by *"The global net effect is that in total..."*

4. Page 5451, line 5–14: ***It maybe better to add supplemental figures (like Fig. 2) for the RCPs period to support the description.***

   We have added such figures as figures S1 to S3 in the supplemental material (here included as figures 1-2 (RCP2.6), 1-3 (RCP4.5) and 1-4 (RCP8.5)).

5. Page 5452, line 6–9: ***Is it really the conversions from grassland to pasture? It seems the area from grassland to cropland match the uptake of carbon (e.g. in South-West U.S., Southern Argentina). Could you please add quantitative analysis here? Also, you didn't show any result of changes in fire activity in these regions.***

   We thank the reviewer for pointing out that we had accidentally swapped the data for the plots of crop and pasture in Fig. 2. We have now corrected this.

   We have added figure 1–5 (S6) showing the burned area for the historical period from the gross LULCC and the difference in burned area between the "without LULCC" and "gross LULCC". Only wildfires are included, since in JSBACH/CBALANCE deforestation fires and field burning are included as part of the LULCC-treatment.

6. Page 5452, line 13–14: ***You should show quantitative result of the fraction of converted cropland originally occupied by the forest.***

   Due to the many back and forth conversions as well as the variations in time and space, it is impossible to state a number for exactly which fraction of a specific PFT is in the end converted to another specified PFT. We have attempted to quantify our statements statistically by plotting (figure 1-6, not in the supplemental material) – for each grid point – the change in cover fractions during the historical period, sorted by the change in crop (top) and pasture (bottom) fraction respectively and for the other vegetation classes (forest and grass and pasture or crop respectively) in the same sorting order and build the trends of these "point-clouds". The slope of the trend-line is then a measure for the fraction of the gain of the main vegetation class stemming from each of the other classes. For crop, the forest has by far the strongest trend, while grass and pasture only have a small positive trend. This reflects the general global trend that forest and grass is converted to crop and pasture. For pasture, we see a similar trend in forest and crop, but here, grass has an even stronger trend. This is a direct consequence of the pasture rule. Crop hardly has any trend. Because an exact quantification is not possible and because our general statement is true qualitatively simply by definition of the applied rule of preferential allocation of pasture on grasslands ("the pasture rule") we prefer to not add the above analysis to the manuscript.

7. Table 2: ***From Brovkin et al. 2013, LCE is 1.84 Pg C yr^{-1} for RCP2.6 and 2.16 Pg C yr^{-1} for RCP8.5 with MPI-ESM-LR. In Table 2, however, it shows 1.69 Pg C yr^{-1} for RCP2.6 and 2.38 Pg C yr^{-1} for RCP8.5. What causes the differences between offline CBALANCE and coupled MPI-ESM-LR?***

   The LUCID experiment setup presented in Brovkin et al. 2013 defined 2006 as their reference year from which the experiments for "without LULCC" and "with (for MPI-ESM: gross) LULCC" both originate. Our experiments use 1850 as reference year, and we thus have different 2006 states for our "without LULCC" runs. Furthermore, Brovkin et al. present their results as an ensemble mean of three ensemble members, whereas we only use one of the members. With their coupled runs, their "without LULCC" experiments furthermore produced slightly different atmospheric states, whereas we – as mentioned in our discussion (because such "without LULCC" atmospheric forcing only was available for RCP 2.6 and RCP 8.5 using 2006 as reference year) – have used the same atmosphere for our "with" and "without" LULCC runs. Thus there are several reasons that our results are not identical to those of Brovkin et al., of which only the latter can be somehow related to the difference between CBALANCE and a fully coupled run. From the LUCID experiments of Brovkin et al. (2013) MPI-ESM forcing data consistent with the "without LULCC" experiments with 2006 as reference year have been available to us for RCP2.6 and RCP8.5, and for these scenarios, we have tested the influence of the different forcing, allowing us to conclude that this is only causing minor changes compared to the difference in reference year. Basically the use of the "without LULCC" forcing data adds noise to the LCE data which is integrated out over a period of 5–20 years. This finding is also consistent with Pongratz et al. (Ph.D. Thesis, 2009) (http://www.mpimet.mpg.de/fileadmin/publikationen/Reports/WEB_BzE_68.pdf), who showed that global land use emissions are hardly altered by biogeophysical feedbacks.

We have as part of our response to comment 4 from reviewer #3 added a comment that our experimental setup is different from that of Brovkin et al. (2013) to the third paragraph of section 5.

"Brovkin et al. (2013) compares for a slightly different experimental setup than ours the (cumulated) LCE for a sub-set of five CMIP5 models. Indeed, the two models with highest LCE (MPI-ESM and MIROC) are using gross transitions, while the others used net transitions. MPI-ESM is the only of the five models implementing wood harvest."

8. Page 5453, line 10–13: ***Could you elaborate more about "The convergence of gross and net LCE towards the end of the 21st century is most likely to be due to the projections prescribing essentially constant rates of conversion..."?***

   Motivated by this question (and a similar question from reviewer #3 to whom this answer is co-listed) we investigated in more detail the reason for the convergence towards 2100 in RCP 4.5 and RCP 8.5 – a feature not found in a study by Stocker et al. (2014) also dealing with net vs. gross transitions (and which was published

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June 2014 in Tellus B). Towards the end of the 21st century some regions have – as expected – higher LCE for gross than for net LULCC, whereas others (mainly in the regions at the edges of the African and South American rain forests) have higher net than gross LCE. The convergence is thus in reality due to different regional phenomena which are canceling each other when integrated over the globe. The phenomenon arises as a complicated interplay between the forcing climate, the pasture rule, the dynamic vegetation, wildfire activity and the way JS-BACH/CBALANCE prevents its living carbon pools from becoming unrealistically high. There are several part-explanations of which two examples are:

(a) JSBACH/CBALANCE has a structural (PFT-dependent) limit for the size of its living carbon pools and NPP which would lead to exceeding this limit is ignored. This is more often the case when using net than gross transitions since less carbon is removed by LULCC. Gross transitions rather use the NPP that net ignores to produce additional litter.

(b) As described in the paper, fire is (due to different litter availability) differently affected by net and gross transitions. Specially in the Sahel region, this leads to runs with gross transitions having more desert than those with net. With net transitions we thus have a larger vegetated area which can produce LCE.

We have adapted the relevant paragraphs (mainly the last in section 4.1.2 and the first in section 5) in the revised manuscript according to this new knowledge.

9. Page 5454, line 10–13: ***Related to the above point, you might need to explain the difference about the conversion pattern between RCP2.6 and RCP8.5.***

   There are hardly any differences between the conversion patterns between RCP2.5 and RCP8.5 (figures 1-2 and 1-4, S1 and S3). The reason for RCP8.5 net and gross LCE converging towards 2100, while RCP2.6 hardly does, is found

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in the climate leading to different NPP which though the explanations in response to the previous comment leads to differences in the carbon cycle.

Figures for answer to anonymous review #1

Full caption for:

fires (upper panel) during hist_gross and differences between average annual area fraction burned in wildfires between hist_none and hist_gross (lower panel).

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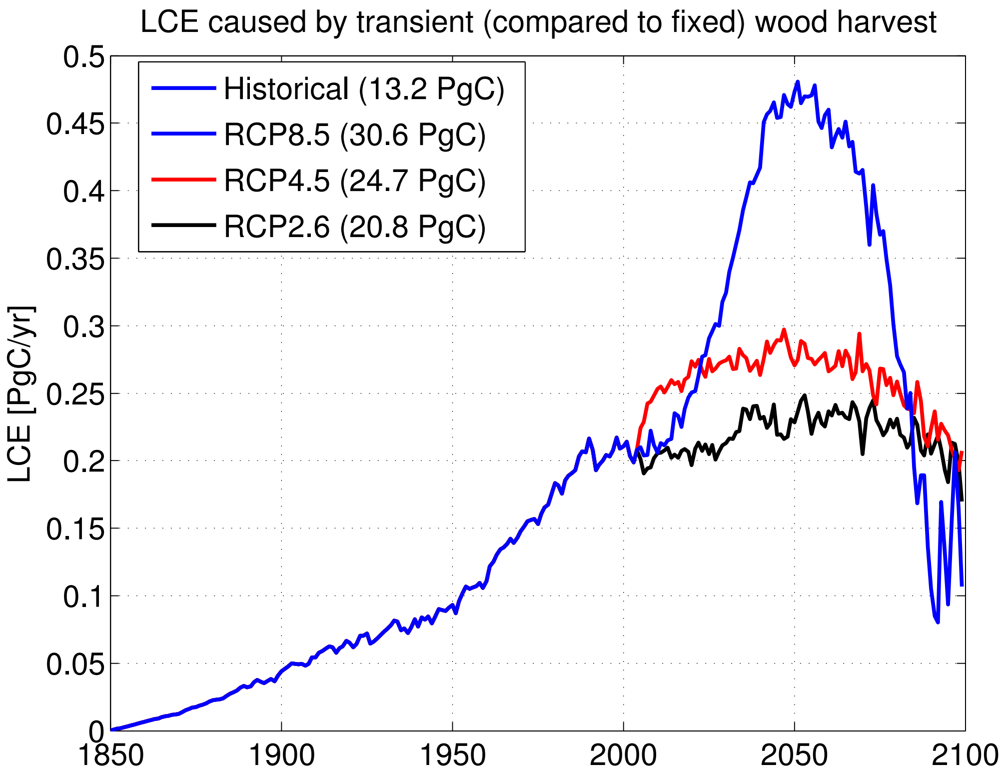

Fig. 1. Figure 1-1: LCE contribution from wood harvest.

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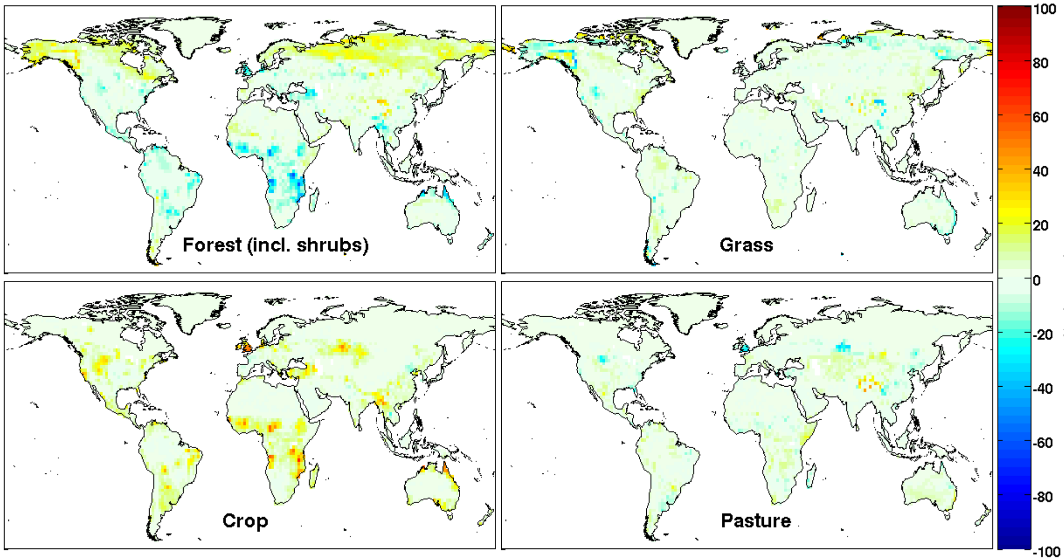

Fig. 2. Figure 1-2: Vegetation changes between 2006 and 2100 for RCP 2.6.

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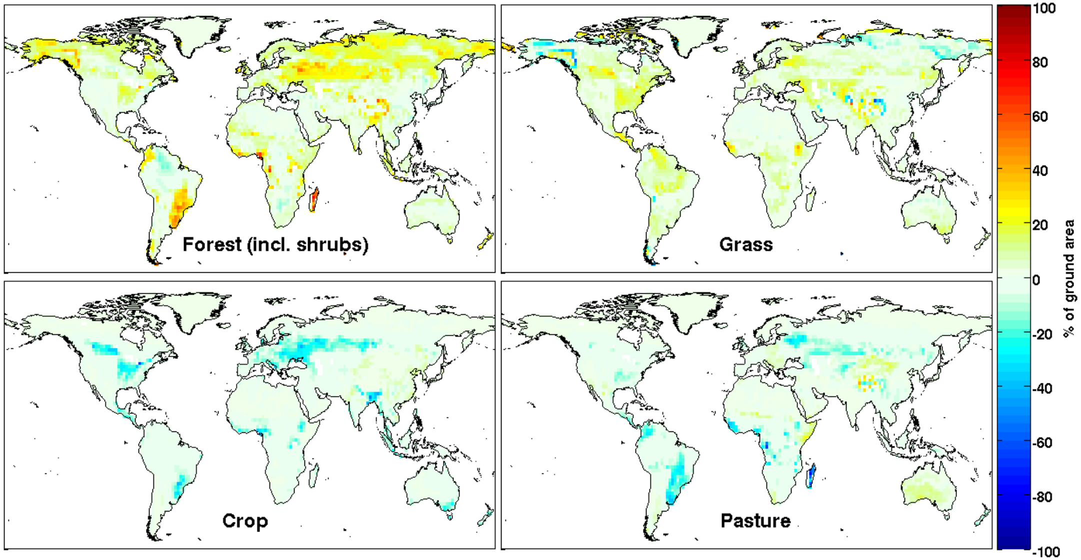

Fig. 3. Figure 1-3: Vegetation changes between 2006 and 2100 for RCP 4.5.

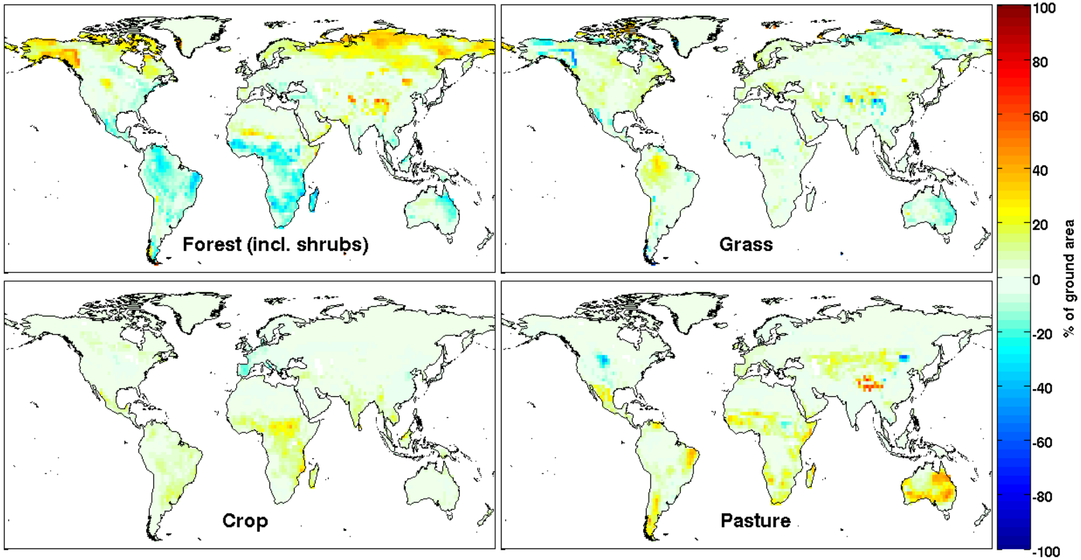

Fig. 4. Figure 1-4: Vegetation changes between 2006 and 2100 for RCP 8.5.

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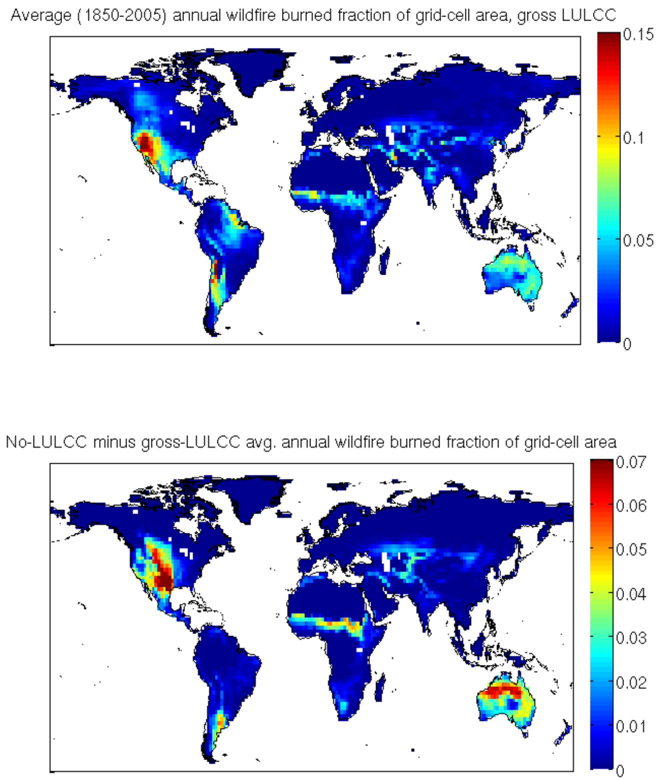

Fig. 5. Figure 1-5: Burned area fractions. Se full caption above.

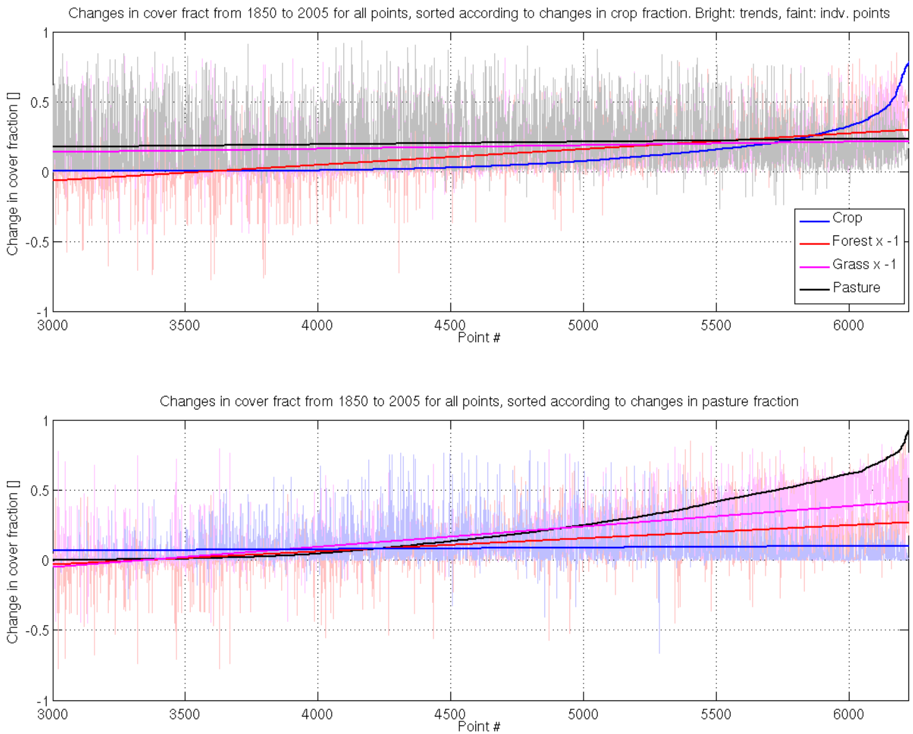

Fig. 6. Figure 1-6: Correlation analysis between changes in crop (upper panel) and pasture (lower panel) and other vegetation types (see the response to comment #6 for detailed description).

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