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Earth System Science Data Discussions

Interactive comment on "Global and regional phosphorus budgets in agricultural systems and their implications for phosphorus-use efficiency" *by* Fei Lun et al.

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Dear Editors and Reviewers: Thank you for your letter and for the reviewers' comments concerning our manuscript entitled "Global and regional phosphorus budgets in agricultural systems and their implications for phosphorus-use efficiency". Those comments are all valuable and very helpful for revising and improving our paper, as well as the important guiding significance to our researches. We have studied comments carefully and have already made the revision. The revised portions are marked in red in this reply. The main corrections in the paper and the responds to the reviewer's comments are as flowing:

Reviewer 2: First of all, thank you so much for your great comments, and I have revised all of them as follows: Comment 1: There is also supporting text which provides additional information on sources, references and calculations. I did not find many anomalies (no fertilizer for Belgium? and a cell ref. issue in Detailed worksheet). Reply: Thank you so much for your detailed check and we are sorry for our faults. We have double-checked the data and we have found the related data for Belgium in our revised Data. Besides, we have also revised the related texts, table and figures in the revised manuscript.

Comment 2: The data in the worksheets are easy to follow. However, there are no units specified on any of the columns which significantly detracted from ease of use. Also, the sources of the data is not readily at hand, this would be very helpful. For example in Table SI-4 FAO is cited as a source of a great deal of data, but the exact reference is not given or even the year of the publication. Is it FAO 2002 cited in the reference? In fact the vast majority of the data is from FAO. Another sources, for the 'Phosphate acid' is the IFA- but again publication is not given and there is no citation. The other source is an atmospheric model reported in Liu et al 2007 but here the citation is not given on the table although it is in the text. Reply: Unit: we have added the units for all columns. For the country level, the units for cropland and pasture soil P balance per area are "kg P/ha", the remaining units are all "t P" (ton of P); for the regional level, the units for cropland and pasture soil P balance per area are "kg P/ha", the remaining units are all "Mt P" (million ton of P). Data source: in our last manuscript, all the data source are presented in the texts. For our revised manuscript, we have also added the data source below the tables, like Table SI-3 (Line 396-Line 410, Page 23 in Supporting Information) and Table SI-4 (Line 414- Line 432, Page 32 in Supporting Information).

Comments 3: Some of the parameters, too, are curious. For example, the P:N ratios and P contents in SI-3 have no source and it is curious, for example, that the values for dairy and nondairy cattle is the same. It is not clear why a range is given for P:N and not for P- surely there is uncertainty also for P even if less than P:N. Further, are the same

values used for the entire world. And is the P content based on as is or dry weight? Reply: We have also added the sources for the N and P contents of livestock and their manure, including ASAE (2005), COMIFER (2007), Levington Agriculture (1997), MWPS-18 (1985), OECD Secretariat (1991) and Sheldrick et al (2003). Then we calculated the P:N ratio for livestock manure. Due to the limited data and previous results, we can only use the same result for "dairy cattle and non-dairy cattle". Besides, all the values are the same for the entire world. The P:N ratios is used to calculate the amount of P in livestock manure. In the FAO statistics (http://www.fao.org/faostat/en/#data), they have presented the amount of N in livestock manure and their distribution. Therefore, using the P:N ratios in livestock manure, we estimated the amount of P in livestock manure and their distribution. Besides, P contents of livestock and their products referred to the ration P in livestock and their products. With the amounts of meat, eggs and milk, we calculated how much P stocked in meat, eggs and milk.

Comments 4: Table SI-5 is a summary for cropland P inputs and outputs. There are ranges given but it is not clear how these were determined. Also, I do not know what recycled crop residue means. Is it crop residue left in the field? I find the values for deposition (atmospheric) for P unexpectedly high. I realize these values have been published and were derived form a model. It would help if the source of the deposition was quantified and presented as a part of the budget, otherwise it looks like it came from outside the boundaries of the model which does not seem correct. The human sewage value also seems high. I tracked the values to Liu et al 2008, which supposed that 30% of urban sewage and 70% of rural sewage was applied to agricultural land. But When I looked at some western countries the ratio was less than 10% which seems more plausible but where did these estimates come from. In any case it is not transparent. Reply: The results for Table SI-5 is a summary of the cropland P inputs and outputs from the previous study results, and the ranges present their differences between these results. For example, fertilizer inputs ranged 13.7-15.0 Tg P yr-1 from Liu et al (2008), Smil (2000) and Cordell et al (2009), which means we summarized their results and these results were between 13.7 and 15.0 Tg P yr-1 in the year of 2000.

For the recycled crop residue, it referred to the crop residue left in the field. For the atmospheric decomposition and human sewage, our estimates were presented in Figure 2. The ranges of these two sections in the Table SI-5 were summarized from other previous studies, including Liu et al (2008), Smil (2000), Cordell et al (2009), MacDonald et al (2011), Bouwman et al(2009, 2011). Due to the limited data, we also used Liu's results (2008) in our estimate, which supposed that 30% of urban sewage and 70% of rural sewage was applied to agricultural land for all countries in the world. The human manure to cropland amounted to 1.37 Tg P yr-1 for the period of 2002$\sim$2010, which was in the range of 1.3-1.5 of other previous studies (Liu et al., 2008; Cordell et al., 2009). However, we used the same level for all countries in the world and there were no differences among countries, and therefore to do further detailed research on human sewage to croplands and pastures in our future next research. Comment 5: In Table SI-7 cropland PUE> total PUE; this seems wrong and is in contrast to lines 271-272. Reply: We have corrected the Table SI-7 in the revised Supporting Information (see Line 452-453, Table SI-7, Page 29 in Supporting Information).

Comments 6: Globally, half of the total P input (21.3 TgP yr-1) into agricultural systems accumulated in agricultural soils during this period, with the rest lost to bodies of water through complex flows. Comment I could not find this in the document Reply: In our manuscript, this results presented in our manuscript "Line 268-270" as follows: "Outputs from the agriculture system amounted to 12.5 Tg P yr-1, which combines outputs from leaching and runoff into bodies of water (5.4), non-recycled manure waste (4.3) and sewage (2.2), bio-energy (0.4), and burned crop residues (0.2)" .

Comments 6: Global P accumulation in agricultural soil increased from 2002 to 2010, despite decreases in 2008 and 2009, and the P accumulation occurred primarily in cropland. Despite the global increase of soil P, 32% of the world's cropland and 43% of the pasture had soil P deficits. Comment: I could not find this in the document Reply: In our manuscript, this results presented in our manuscript "Line 289-291", "Figure 3", "Line 360-367", and "Line 367-369" as follows: Overall, P in agricultural

soils increased by 1.3% annually for the period of 2002∼2010, whereas P losses to the environment increased faster (6.4% yr-1) than fertilizer inputs. About 32% of the global cropland area (in 75 countries) had annual soil P deficits from 2002 to 2007, with the net cropland soil P accumulation of 6.20∼7.66 Tg P yr-1. This fraction increased to 50% in 2008 and 2009 but the net cropland soil P accumulation decreased to 4.38Tg P yr-1 in 2008 and 5.39 Tg P yr-1, at the time of the global financial crisis, as a result of high P prices and the resulting reduction in fertilizer application (Cordell et al. 2009, 2012). However the fraction of cropland soil P deficits returned close to the decadal mean value in 2010, with the net soil P accumulation of 7.30 Tg P yr-1. Compared with croplands, a slightly larger proportion of the total global pasture area had a net annual soil P deficit from 2002 to 2010, mostly in Europe and North America. The deficit proportion of grassland was only about 38% in 2002 and 2003, with the annual net soil P accumulation of 2.26 Tg P yr-1; however, it increased to 43% during the period of 2004∼2010 and the annual pasture soil P accumulation was about 2.10 Tg P yr-1, with the smallest of 2.00 Tg P yr-1 in 2009.

Comments 7: The trend of increasing consumption of livestock products will require more P inputs to the agricultural system, implying a low P-use efficiency aggravating the P stocks scarcity in the future. Comment: While technically this is correct, I don't really see a strong connection with the data set. There is more prospects for recycling animal P than N. Reply: Global pasture soil P balance mask large regional differences and global pasture soil P deficit mostly occurred in Europe and North America. These countries export livestock products, and only a small fraction of livestock manure is recycled to pasture, so there is currently a soil P deficit; in the long term, this may result in a loss of soil fertility. Consequently, improving the manure utilization efficiency and applying more livestock manure to pasture will be important strategies (Wu et al., 2014). Dietary changes to more livestock products are requiring higher P inputs in cultivated land and increased mining of P ores (Grote et al., 2005; Foley et al., 2011), and human dietary shifts may have been responsible for half of the increase of P ore mining. Besides, livestock PUE were much lower than other PUEs, and it is very

important to improve livestock PUE. Different from N, P ores are the limited sources, and it should be paid more attentions on livestock P.

Again, special thanks to you for your good comment and correction in our manuscript, which are all valuable and very helpful for revising and improving our paper. We have studied comments carefully and have made correction and improvement according to the reviewer's suggestion. These changes will not influence the content and framework of the paper. We appreciate for Editors/Reviewers' warm work earnestly. We hope that the correction will meet with approval for publication, and look forward to hearing from you at your recent convenience.

Yours sincerely, Fei Lun on behalf of all co-authors

Please also note the supplement to this comment:
https://www.earth-syst-sci-data-discuss.net/essd-2017-41/essd-2017-41-AC2-supplement.zip

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