Earth Syst. Sci. Data Discuss.,
https://doi.org/10.5194/essd-2020-11-AC1, 2020

Open Access Earth System Science Data Discussions

Interactive comment on "A cultivated planet in 2010: 2. the global gridded agricultural production maps" *by* Qiangyi Yu et al.

Qiangyi Yu et al.

qiangyi.yu@gmail.com

Received and published: 20 June 2020

Dear Referee,

Thank you for the comments concerning our Discussion paper entitled "A cultivated planet in 2010: 2. the global gridded agricultural production maps" (Ref. essd-2020-11). These comments were very helpful for revising and improving our paper. To make the reply more readable, we list the comments and corresponding responses one by one in the Authors' Response (AC). The detailed revisions are embedded in the manuscript with the line numbers indicated in the AC.

********** General comments

SPAM products are one of well-known spatially-explicit global agricultural production

datasets. An update of SPAM products can be potentially a great contribution to scientific communities (Earth system modeling and global food security monitoring in particular). However, I think, the current form of the Discussion paper is not sufficiently persuasive for some aspects. An evaluation of the validity of the spatial disaggregation method is lacking. Particularly, although the method estimates harvested area and yield for each of the four farming systems (irrigated, rainfed high input, rainfed low input and subsistence) and this is the most unique characteristics of SPAM products, no evaluation is presented in this Discussion paper (because SPAM products are model estimates, earlier papers (You et al. 2006, 2014) cannot justify skipping evaluation in the paper). A comparison between the latest SPAM product and other independent datasets is partly presented, but there is a space for improvements. For these reasons, I would suggest major revision. My comments are elaborated below.

Authors' Response: Thanks for these general comments and they are very constructive and helpful for improving the paper. We were aware that previous validations should not be taken for granted for the latest updates. As suggested, we underwent a major revision and added several additional analyses, in particular on the evaluation and validation of the results, which mainly include: (1) Cross-checking the national and subnational level statistics. (Comment#1) (2) Cross-checking with the paddy area maps in China and India. (Comment#3) (3) Comparing the changes existing in SPAM products (e.g. between SPAM2005 and SPAM2010) with the changes detected from other products (e.g. between CDL2005 and CDL2010). (Comment#2 and #3) (4) Comparing the yields and farming system yields with other products. (Comment#2 and #4) More details are in the following point-by-point responses.

********** Specific comments

Comment#1. An evaluation of the spatial disaggregation model is required. The most prominent uniqueness of SPAM products, including the latest one (i.e., SPAM2010), is a distinction in harvested area and yield across the farming systems. Currently, global datasets other than SPAM products provide no information on area and yield

specific to farming system. However, area and yield for each farming system in SPAM products are "estimates" derived using a spatial disaggregation model optimized using the entropy method. Although the authors may claim that this is a data-fusion approach but not a model prediction approach, a model evaluation against the validation subset (that is independent of the training subset) is essential even for a data-fusion approach. This is a common practice across studies using models even in global crop yield dataset compilation (Iizumi et al. 2014; grid-cell yield estimates derived using national yield statistics as the model input are compared with reported subnational yield statistics which are not used as the model input). Note that M3 and MIRCA2000 use a simple allocation rule rather than modeling; and GAEZ is a model output but for "potential" geographic distribution of crop suitable area. However, the purpose of this Discussion paper is to present "actual" distributions of area and yield for specific farming systems. Therefore, an evaluation of the model used is a mandate. Probably, for some crop-region combinations, the authors have farming-system-specific area and yield statistics at subnational levels. I strongly encourage the authors testing and reporting the performance of their model in disaggregating national agricultural statistics into subnational ones when national statistics are used as the model inputs.

Authors' Response: Thanks for the constructive comment. Actually, the validation by cross-checking national and subnational level statistics has been applied for SPAM2000 (e.g. Brazil). Following the comment, we have re-applied the approach for the current SPAM2010 for a few selected countries such as Brazil, Bangladesh, Benin, Senegal, Tanzania. We find that the performance has generally improved comparing to the performance of SPAM2000 though this varies from country to country, and from crop to crop. We add Figure 6 and Figure 7 and the relevant description of the validation process in the revised manuscript.

Comment#2. A comparison of SPAM products and other independent datasets has a space for further improvements. The key shortfalls in the current Discussion paper are: (1) although CDL2010 for the United States and NLCD2010 for China are

compared with SPAM2010, these are for harvested area and no comparison is presented for area and yield for the specific farming systems; and (2) although the relative changes in area between 2005 and 2010 are presented in the paper (Fig. 8), these need be compared with other independent datasets (for instance, CDL2005 and CDL2010 for the United States). The updated M3 dataset which offers the average harvested area and yield for three time points, 1995 (1993–1997), 2000 (1998–2002) and 2005 (2003–2007) is a candidate for the independent dataset and is available online at: http://www.earthstat.org/ (see the dataset labelled "Harvested Area and Yield for 4 Crops (1995-2005)"). For a consistent comparison, if possible, I would encourage the authors updating the earlier SPAM2000 and SPAM2005 products by utilizing the model used for SPAM2010. Such updating is a common practice in global agricultural dataset compilation and important to ensure the continuity of data in products (Iizumi and Sakai 2020, Sloat et al. 2020).

Authors' Response: We have carefully considered this comment by referring to relevant literature and datasets, e.g. Iizumi and Sakai (2020) and "Harvested Area and Yield for 4 Crops (1995-2005)". We would like to elaborate that we have been updating SPAM products over the years by using the same approach (i.e. the cross-entropy model), although not in the same way as Iizumi and Sakai (2020) did with their global crop yield dataset. These suggested comparisons (over time) might improve the reliability of the datasets. Yet further uncertainties might be introduced as well. The main reasons are: (1) "Harvested area" is conceptually different from "yield". For example, the value of harvested area at the country level needs to be equivalent, in theory, to the summed value of all sub-national administrative units. While the value of yield at the country level could be equaling to any value at the sub-national level. This means that the idea of Iizumi and Sakai (2020), i.e. adjusting country-level average yield to spatial grid by considering the spatial variation of NPP, can not be directly applied for disaggregating harvested area from coarser spatial units to finer spatial units. (2) The general framework of cross-entropy model remains the same for SPAM2000, SPAM2005, and SPAM2010. The major difference among them is the input data such as cropland, sub-

national statistics. In fact, we have kept updating all SPAM products over the years with different versions (e.g. after feedbacks from users, and new input data are available). For example, the latest SPAM 2000 is Version 3.07, the latest SPAM 2005 Version 3.20, and the current version of SPAM 2010 is Version 1.1. (3) Even if SPAM2000, SPAM2005 and SPAM2010 were produce by the same approach (i.e. the cross-entropy model), it does not mean the products can be compared directly across years. Because SPAM requires for a large amount of input data, yet the sources of these multiple data inputs can not be guaranteed as the same across different time stages. For example, the cropland layers (one of the most important data inputs) are accessed from different sources to make sure the cropland data and the statistical data are adopted for the same year. We do not evaluate the continuity of these input data, which is almost impossible and is beyond the purpose of SPAM. Therefore, we do not recommend users to cross compare the SPAM products, because such differences may have more input data errors/inaccuracies than detecting the real change on the ground. Nevertheless, we have added the following comparisons as suggested: (1) Comparing yield for four crops by referring to EARTHSTAT2005. (2) Comparing the area changes in maize, wheat and soybean between CDL2005 and CDL2010 (i.e. $\triangle$CDL), and then compare the $\triangle$CDL between $\triangle$SPAM. We find and admit that these comparison results are not so good. You raised a very good question and there is an ongoing consortium called The Land Use Change Knowledge Integration Network (LUCKiNet, www.luckinet.org). SPAM team is part of this consortium which aims to integrate tools and standardize approaches across various ongoing projects that develop gridded information on land-use dynamics for applications in food security, climate change, biodiversity, and other related issue area. Not only LUCKiNet aims to create crop maps comparable over time, we also want to have these maps consistent across land uses such as cropland, grassland, forest. The modelling techniques would consider the spatiotemporal dynamics of different land use forms in an integrative framework. We have acknowledged the latest publication i.e. Iizumi and Sakai (2020) and included these two comparisons in the revised manuscript. Please see the newly added Figure 12 and 14, and the relevant

text in section 7.

Comment#3. Related to the comment#2, Zhang et al. (2017) provides annual paddy area time series from 2000 to 2010 based on satellite remote sensing for China and India. Because recent satellite-based paddy area estimates are quite accurate, this dataset can be a useful source of information to evaluate the relative changes of paddy area in SPAM products.

Authors' Response: Thanks for the comment. As suggested, we have obtained the paddy rice maps from Zhang et al. (2017) and added the comparison between these maps with the rice area estimated by SPAM2010. In addition, we compared the $\triangle$Rice (difference between the rice map in 2005 and 2010) between $\triangle$SPAMrice (difference between SPAM2005 and 2010). Please see the newly added Figure 10 and 15, and the relevant text in section 7.1 and 7.2.

Comment#4. Related to the comment #2, a distinction between average irrigated and rainfed yields for the 1998–2002 period at the global scale is made in Siebert and Doll (2010). These estimates are also used in recent study (Sloat et al. 2020). I think, these estimates can be a useful source of information when evaluating the reliability of farming-system-specific estimates in the SPAM products once updating of SPAM2000 and SPAM 2005 using the latest model is done.

Authors' Response: As we have responded in comment#2, we are not able to update SPAM following the same way as Iizumi ad Sakai (2020) did with their global crop yield dataset. In fact, SPAM has been compared with MIRCA in terms of irrigated and rainfed area in one of our previous paper (Anderson et al., 2015). As suggested, we underwent a new comparison between SPAM and Siebert and Doll (2010), in terms of irrigated and rainfed yields. Please see the newly added Figure 11, and the relevant text in section 7.2.

Comment#5. A more in-depth discussion on advantages, disadvantages and limitations of the spatial disaggregation model is required. Although the authors hypotheti-

cally assume that the use of economic factors, including prices and access to markets, in the disaggregation model is superior to other methods, such as the proportional allocation. However, this working hypothesis has never been tested (at least, I could not find any result neither in this Discussion paper nor in earlier work (You et al. 2009, 2014)). "garbage in garbage out" is a well-known behavior of models. In general, price statistics are less reliable than other variables (e.g., production). I have the same concerns for the quality of data on production share by farming system and the indicator of market access. If some of model inputs are not reliable, model outputs are expected to be unreliable, depending on the sensitivity of model output to specific inputs. I like the idea that economic factors are considered in disaggregation, but the idea does not automatically guarantee that model outputs (disaggregated area and yield by farming system) is correct. I think, the advantages of the model relative to simpler methods are stated too bold throughout the Discussion paper. The authors' claims might be true, but need be tested in a standard way of model evaluation (e.g., by using the cross-validation technique).

Authors' Response: Thanks for the comment. We have examined the manuscript thoroughly and carefully avoided such self-judgment statements. In the revised manuscript, we only keep the explanations by citing literature on the inclusion of economic factors. For example, Market is important for both subsistence farmers and commercial ones. So many researchers have assumed that farmers are risk averse and profit maximizers (e.g. Hazell and Norton, 1986; Roundevell et al., 2003). See the discussion in Section 7.1 (Line 580). In addition, we elaborated more on the indicator of market access and admitted that the idea of including economic factors does not automatically guarantee that model outputs. We have revised the text along with other discussion on the limitations of SPAM in Sections 7.2 and 7.3.

********** Technical corrections

Comment#6. L71-73. I strongly suggest removing this description. Researchers would use the latest version once global agricultural dataset is updated, but no such update is

available to date. This is the reason why the studies cited here use an earlier version. The authors' criticism made here is inappropriate.

Authors' Response: We have rephrased the sentence to avoid any inappropriate criticism. Now the rational is more focused: an update of existing global agricultural production maps is very desirable. Please see Line 74. Thank you very much.

Comment#7. L107. The current text is a bit misleading. This text should read "M3 has no distinction across farming systems ..." or similar.

Authors' Response: Revised accordingly. See Line 107.

Comment#8. L156. Country crop-specific production costs for a specific year (e.g., 2011) are available via GTAP9 database (Aguiar et al. 2016). Just for your information.

Authors' Response: Thanks for the comment. After a careful consideration we choose to retain the use of FAO gross production value, because: 1) the GTAP provides data on 2004, 2007, 2011 and 2014, yet data on 2010 is not available; 2) the two data source is very close to each other, as GTAP database is constructed by referring to the FAO data; 3) the values between GTAP and FAO has no significant variance, for example, the rice production value in the US in 2014 is recorded as 2938 million from GTAP and 2973 million from FAO, respectively.

Comment#9. L158. GAEZ only provides "potential" crop suitability area. Please consider keeping precise terminology in the Discussion paper.

Authors' Response: Revised accordingly throughout the paper (8 places in total). Thanks for the kind reminder.

Comment#10. Eq. 7. What is "CE"? The abbreviation suddenly appears without definition. And I would appreciate it if the authors could provide a brief explanation what is the difference between {s ln s} versus {s ln π}.

Authors' Response: CE is the abbreviation for cross entropy. As entropy is defined as

the log function of probability, the difference between {s ln s} versus {s ln π} means the estimated probability s and its prior probability π are minimized subject to certain constrains. The more detailed explanation is provided in Line 190.

Comment#11. Eq. 16. AdjCropY suddenly appears in main text although it is explained in Supplement. A brief explanation need be added in main text for readability.

Authors' Response: revised accordingly. See Line 253.

Comment#12. L304-305. Are the yield conversion factors in the text same with those shown in Table S6? Table S6 shows only for irrigated versus rainfed. Where is rainfed high input versus rainfed low input?

Authors' Response: Yes, indeed Table S6 shows part of the yield factors. In fact, Table S6 showed both the factor of crop yield under irrigated versus crop yield under rainfed (with a "I") and that of yield under rainfed high input versus yield under rainfed low input (with a "R"). See the Note under the table: "Production systems – irrigated (I) lists factor for irrigated vs. rainfed; rainfed (R) lists factor for rainfed high vs. rainfed low".

Comment#13. 372-373. This assumption is too crude. Dong et al. (2017) presents a nice global dataset in specifying urban areas. It can be useful to distinguish rural and urban areas more accurately.

Authors' Response: We have carefully considered the comment, then we find that the original text in the manuscript is misleading. We do not aim to distinguish rural area from urban area. The aim of introducing the variable AggRurPopi is to estimate the market accessibility and to account for subsistence production. We have further revised the text. Please see line 413.

Comment#14. L532. I do not understand "methodological-cum-data". Please consider rephrasing.

Authors' Response: It literally means the combination of method and data. We have revised the expression as "methodological-data" to avoid confusion. Please see line

584.

Comment#15. L626-627. This is true but has not been demonstrated yet. I would suggest removing this statement unless a comparison in area and yield for each farming system against subnational statistics is presented.

Authors' Response: The sentence has been removed accordingly. Please see Line 705.

16. L636. Zhang et al. (2017) reports the northward shift of paddy area in China and the westward shift of paddy area in India for the 2000-2010 period. These tendencies seem be inconsistent with the upper panel of Fig. 8.

Authors' Response: This is a misreading. The SPAM results are consistent to Zhang et al. (2017). According to the color schemes in Figure 13 (Figure 8 in the original submission), red means "increase" and blue means "decrease". The northeast part of China and northwest part of India are colored as red, suggesting a notable expansion of rice planting in these regions.

17. L679-680. Global roads and railways database used in Koks, E.E. et al. (2019) is maybe of your interest to more accurately define accessibility to markets. Just for your information.

Authors' Response: Thanks for the great suggestion. In the current SPAM, market accessibility is used to calculate the gross revenue of crop production which is then used to estimate a prior for the crop area (Equation (10) in the revised manuscript). As this crop-specific revenue is divided by the total revenue within a pixel (Eequation (11) and (12) in the revised manuscript), the prior is not affected by market accessibility if it is not crop-specific. In other words, crop-specific market accessibility is preferable for the current SPAM model. Such accessibility data doesn't exist now. We would consider modifying the role of market accessibility in the next version of SPAM model and then will probably use the global roads and railways database.

********** Reference Aguiar,A. et al. (2016) An Overview of the GTAP9 Data Base. Journal of Global Economic Analysis, 1,181–208, http://dx.doi.org/10.21642/JGEA.010103AF Dong, Y. et al. (2017) Global anthropogenic heat flux database with high spatial resolution. Atmospheric Environment, 150, 276-294, https://doi.org/10.1016/j.atmosenv.2016.11.040. Koks, E.E. et al. (2019) A global multi-hazard risk analysis of road and railway infrastructure assets. Nature Communications, 10, 2677, https://doi.org/10.1038/s41467-019-10442-3 Iizumi, T. et al. (2014), Historical changes in global yields. Global Ecology and Biogeography, 23, 346-357, doi:10.1111/geb.12120 Iizumi, T., Sakai, T. (2020) The global dataset of historical yields for major crops 1981–2016. Sci Data 7, 97, https://doi.org/10.1038/s41597-020-0433-7 Siebert, S. & Doll, P. (2010) Quantifying blue and green virtual water contents in global crop production as well as potential production losses without irrigation. Journal of Hydrology, 384, 198–217, https://doi.org/10.1016/j.jhydrol.2009.07.031 Sloat, L. L., et al. (2020) Climate adaptation by crop migration. Nature Communications, 11, 1243, https://doi.org/10.1038/s41467-020-15076-4 Zhang, G, et al. (2017) Spatiotemporal patterns of paddy rice croplands in China and India from 2000 to 2015, Science of The Total Environment, 579, 82-92, https://doi.org/10.1016/j.scitotenv.2016.10.223.

Interactive comment on Earth Syst. Sci. Data Discuss., https://doi.org/10.5194/essd-2020-11, 2020.

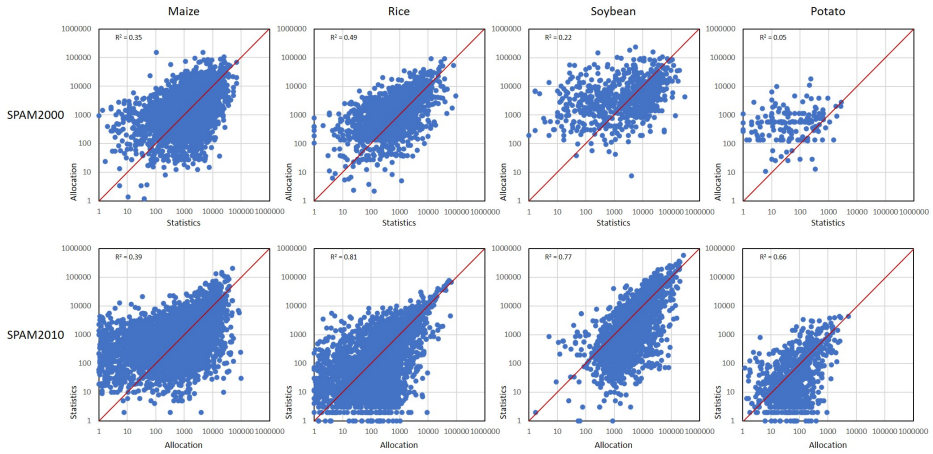

Fig. 1. Figure 6: Comparison between the allocated crop area and statistics crop area at the ADM2 level in Brazil (log-log scale plot, unit: ha.). The upper part is for SPAM2000 and the bottom part is for SPA

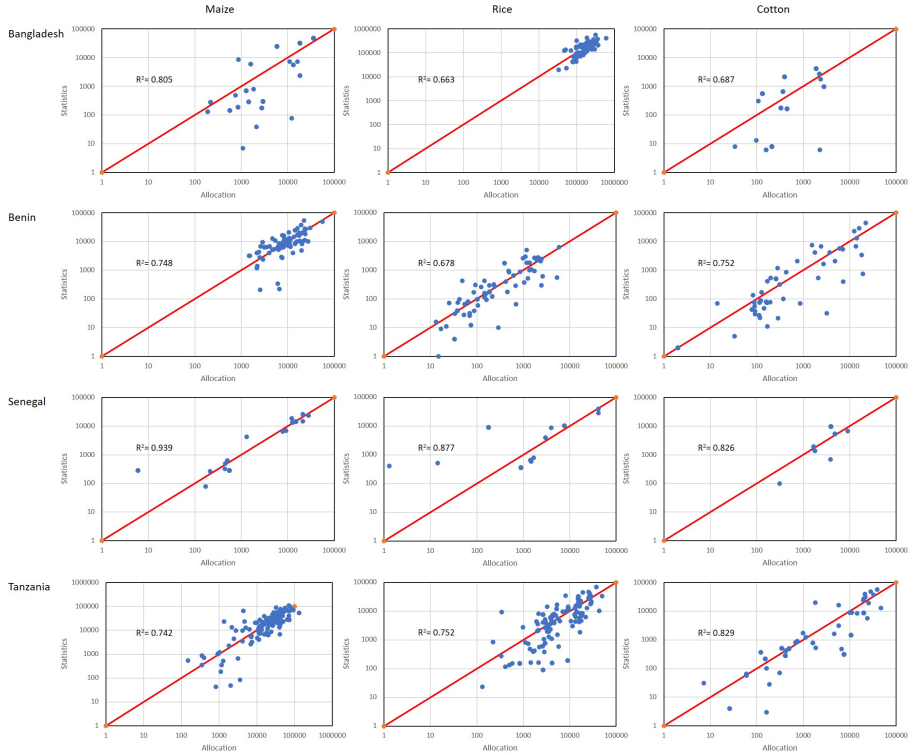

Fig. 2. Figure 7: Comparison between the allocated crop area and statistics crop area at the ADM2 level in Bangladesh, Benin, Senegal and Tanzania for maize, rice and cotton (log-log scale plot, unit: ha.).

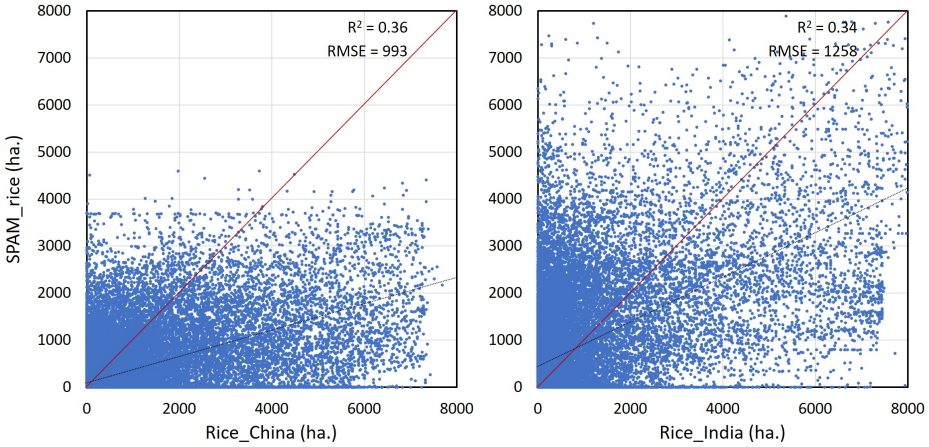

Fig. 3. Figure 10: Grid-by-grid comparison between SPAM2010 and Zhang et al. (2017) rice area in China and India.

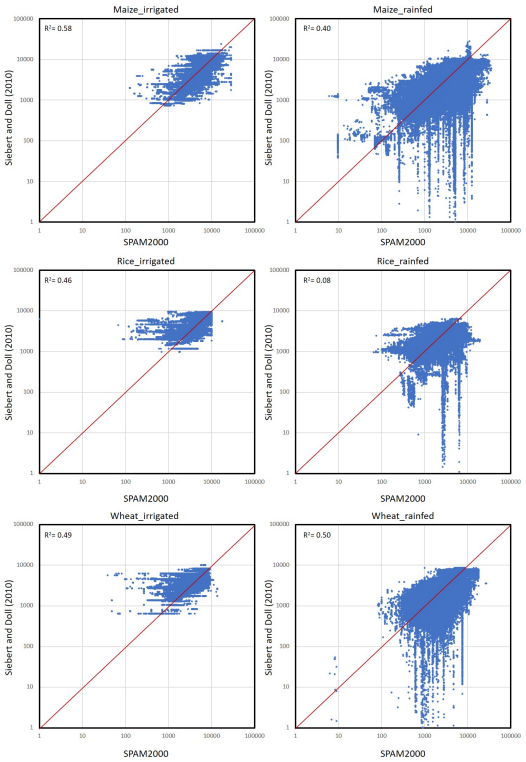

Fig. 4. Figure 11: Grid-by-grid comparison between SPAM2000 and Siebert and Doll (2010) in average irrigated and rainfed yields (log-log scale plot, unit: kg/ha.).

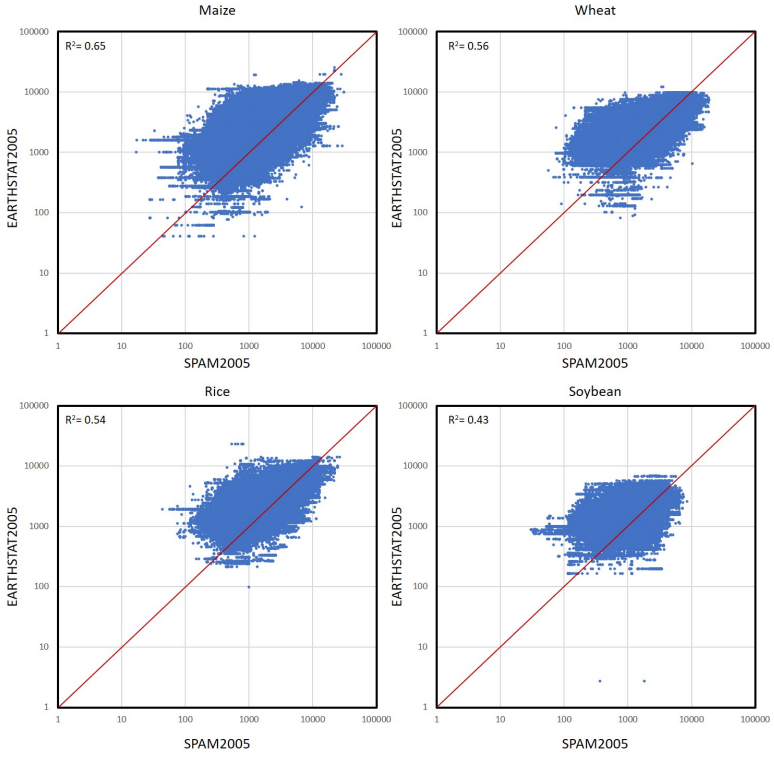

Fig. 5. Figure 12: Grid-by-grid comparison between SPAM2005 and EARTHSTAT2005 in crop yields. (log-log scale plot, unit: kg/ha.).

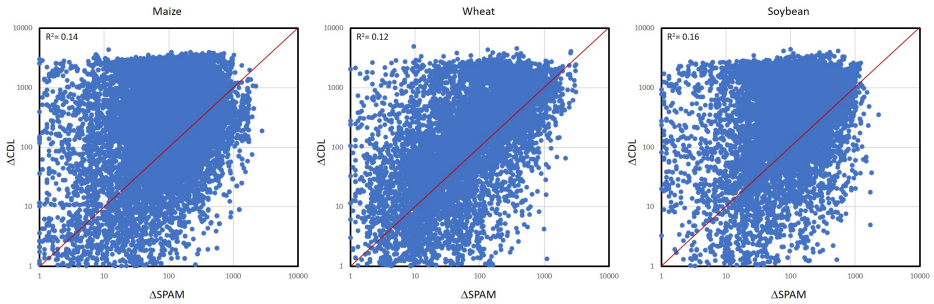

Fig. 6. Figure 14: Comparison between SPAM crop area change and CDL crop area change (log-log scale plot, unit: ha.).

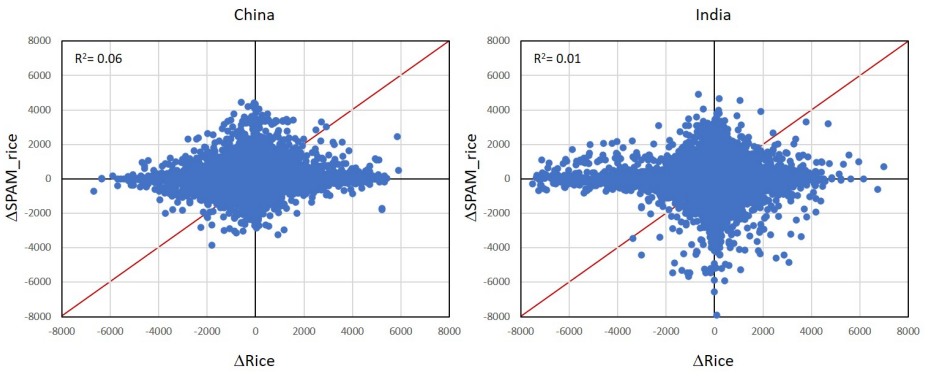

Fig. 7. Figure 15: Comparison between SPAM rice area change and Zhang et al. (2017) paddy rice change (unit: ha.).