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Interactive comment on "Global nitrogen and phosphorus fertilizer use for agriculture production in the past half century: Shifted hot spots and nutrient imbalance" *by* Chaoqun Lu and Hanqin Tian

Chaoqun Lu and Hanqin Tian

clu@iastate.edu

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Notes on ESSD 2016-24 and ESSD-2016-35.

1. Both products achieve the same global resolution (0.5 x 0.5 degrees over global land areas) for approximately similar time periods (1961 to 2010 in one case, 1961 to 2013 in the other case). Both report total synthetic N applied as chemical fertiliser. One elaborates NO3 and NH4 components of the total N, the other adds total P. One starts from country self-reported fertilizer use statistics (from FAO) while the other starts from industry reported fertiliser consumption records (IFA). Both use identical third party crop

area data (e.g. Monfreda) but different historical land use data. Both adopt the year 2000 for intercomparison and validation purposes. Both report very similar increases in total global use of N fertilisers over the time period but they differ slightly in their discussion of geographic and country-specific use patterns over time. If, as I suspect, both data sets achieve positive reviews, e.g. seem likely to prove useful to readers and subsequent users, and presuming that from the separate review processes ESSD would not designate one or the other data set as preferred, then subsequent users will necessarily need to make a choice between somewhat similar data sets. In that case it seems fair and useful, and a proper use of the open discussion process, to pose a short series of questions to both sets of authors, and to expect that the separate responses should provide a guide to unique aspects and strengths of each data set.

Response: Thanks for your careful reading and positive comments. There are some differences between these two data products that may influence the choice of future users. Although we both used crop area data from Monfreda et al (2008, M3-crops data), it's for different purpose. In our study, combined with IFA crop-specific fertilizer use data, the harvested area and crop type distribution revealed from M3-crops data have been used to calculate the area-weighted crop fertilizer use rate in each grid cell, and to allocate national fertilizer use amount based on crop distribution. Therefore, cross-crop divergence in using fertilizer has been considered and displayed in our data. However, ESSD 2016-24 used M3-crops data to identify dominant crop type, and combining crop calendar data (Sacks et al., 2010) to decide the timing of fertilizer use in each grid cell. We have addressed your questions and more difference aspects between this study and the other data product (ESSD 2016-24 hereafter) as below.

2. How does the choice of different starting sources, FAOSTAT vs IFA, influence the subsequent processing and overall quality of the derived product?

Response: In this study, we adopted the data of fertilizer use by crop from IFA (Heffer, 2013) to spatialize country-level fertilizer use amount derived from IFA into time-series gridded maps. Therefore, this data product demonstrates both cross-country and within-country heterogeneity in fertilizer uses by considering different fertilizer use level among crop types (e.g., N fertilizer use rates are quite different in corn and soybean). We use crop-specific data and country-level fertilizer survey both from IFA to make the estimate consistent.

3. Does the difference in tactics adopted to deal with variable completeness of country data (imputation to fill gaps in one case and focus on primarily the largest fertilizer users in the other case) induce a substantial or insubstantial difference in the outcomes of the two data production efforts.

Response: Thanks for pointing out this. We would like to clarify that our study doesn't only focus on the largest fertilizer use, but overlooked the rest. We used IFA data of fertilizer use by crop that covers over 94% of global fertilizer consumption, to spatialize country-level fertilizer use amount onto grid cells. But for the rest less intensive fertilizer use countries (consuming $\sim$6% of global fertilizer), we adopted IFA time-series country and continental record (removing the reported countries) of fertilizer use rate, by assuming uniform fertilizer use among crop types in each country. We clarified this in our revised manuscript and redrew figure 2 to demonstrate countries with and without crop-specific fertilizer use in IFA data and those countries excluded by IFA.

Overall, this approach captured spatial cross-crop variation in fertilizer use rate across those intensive fertilizer using countries, while keeping the global total consistent with IFA data record. We think the substantial difference between these two data sets is not from the resulted global total fertilizer use amount we reported or the way we fill gaps (i.e. use continental average rate with reported countries removed in this study, or use covariate information in ESSD 2016-24), but from the spatial heterogeneity we presented in these two data sets (i.e., cross-crop within-country heterogeneity in fertilizer use in this study, and country-level uniform fertilizer use rate in ESSD 2016-24).

4. Both sets of authors compare their products to Potter et al. 2010 and specifically for the year 2000. If each set of authors now includes the other data set in that comparison,

do their overall conclusions change?

Response: In addition to Potter et al. 2010, we compared our data with Mueller et al. (2012) that also demonstrate N and P fertilizer use rate at gridded level (Figure 8). Our approach is more like the way that Potter et al. (2010) used in their study by considering weighted crop-specific fertilizer use to spatialize fertilizer pattern within a country. If compared in global fertilizer consumption amount, our study is very close to IFA and FAO record (e.g., N fertilizer use in 2000 is estimated as 82.1 Tg N/yr by IFA, 80.8 Tg N/yr by FAOSTAT, and ours is 80.1 Tg N/yr, Table 1), while ESSD 2016-24 has a higher estimate of 85 Tg N/yr in the same year. Compared to ESSD 2016-24, our data provides more spatial details based on distribution of crop types (through M3-crop), IFA data of fertilizer use by crop in the most intensive fertilizer use countries, and IFA country- and continental fertilizer use data in the rest countries, while they used national consumption data from FAOSTAT and statistical gap filling to depict spatial pattern of fertilizer use.

5. What specific information about time histories or geographic patterns of fertiliser use do readers and users gain from the inclusion of NH_4 and NO_3 data in the one case and from the inclusion of P data in the other case?

Response: In our case, we didn't split N fertilizer into NH_4 and NO_3, but include P fertilizer data since it provides more information on anthropogenic nutrient input and has important implications on historical stoichiometric changes. We anticipate this data could better serve the Earth System Modeling communities by demonstrating cross-country, cross-crop variations in fertilizer uses (both N and P), and revealing the shift of hot spots of nutrient input across the globe during 1961 to 2013. It can inform both field and modeling studies of the spatial and temporal changes in agricultural fertilizer uses, and assist complex assessment and decision support in effective balanced nutrient (both N and P) management in the future.

6. Finally, how does each set of authors see their efforts and products as complimen-

tary to the other effort?

Response: Thanks for this great question. We summarized a few things in our study that could compliment ESSD 2016-24 as below: 1) As described above, our study demonstrates both cross-country and cross-crop heterogeneity in fertilizer uses by compiling a number of data sources (e.g., annual record of national fertilizer use amount, crop-specific fertilizer use, crop type and its gridded distribution across the globe, time-series land use data). It covers global cropland areas with consideration of their annual change during the period 1961-2013. 2) Our study includes both agricultural N and P fertilizer use rate, which is important anthropogenic nutrient source that could substantially contribute to global food production, biogeochemical cycles, greenhouse gas balance, climate change, and riverine nutrient export from land to coastal oceans. Ratio of agricultural N and P fertilizer input and its change could give us potential explanation to global nutrient imbalance and ecosystem stoichiometric trend. 3) With finer-scale spatial variation in this study, we reveal the hot spots of agricultural fertilizer use shifted from the U.S. and western Europe to East Asia for N, and from Europe to Central China and small area of Brazil for P over the past half century. It is helpful in understanding the spatial shift of environmental consequences of agricultural nutrient enrichment and forecasting the future trend of earth system responses.

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