Response to reviewer comments

We thank the reviewer for the precious and constructive suggestions to improve our manuscript. We have addressed all the comments raised by the reviewer. Please find our point-by-point response below.

Reviewer 2:

It is very valuable to estimate the crop-specific fertilizer in China. However, there are some serious problems in the process of accounting for crop-specific fertilizer, so I question the quality of the final data product.

Response: We thank the reviewer for the suggestions. We fully respect the opinion of the reviewer. We have made a rebuttal by addressing each concern raised in the manuscript below.

1. For the fragmented crop distribution in most parts of southern China, this paper calculated the crop-specific fertilizer application rate from 1952 to 2018 based on the cropland area data with a resolution of 5 km produced by provincial data and just five years' crop rotation data. I have serious doubts about the accuracy of the data.

Response: We thank the reviewer for the suggestion. There are some misunderstandings here and we would like to make these clear. First, the crop-specific fertilizer application rate was originally allocated to a 100-m crop rotation map and resampled to 5-km (not directly allocated to 5 km cropland data). The 100-m crop distribution maps were developed in previous study (an intermediate product before resampled to 5-km cropland maps, please see Yu et al. 2021). Therefore, the fertilizer map was not directly developed at 5-km resolution. Second, the rotation map used for N fertilizer rate allocation were different in each year (not the five fixed maps). The five county-level rotation maps served as potential rotation maps when allocating crop type spatially. For example, in 1981, the nearest-year, county-level rotation maps (e.g.

1980 map) were used as potential rotation map to allocate each crop types spatially. Specifically, a cropland grid-cell was given priority to be allocated the crop type found in the corresponding grid-cell from the potential rotation map in the nearest year. However, the cropland map varies between years, resulting into the dynamics of the planted area annually. Therefore, the rotation map of a different year will also need to be adjusted to ensure the planted area of each crop type to be equal to the data from the officially released reports. The uncertainty has also been clearly discussed in the main text (please see the last paragraph of the discussion section).

Similar approach was adopted in our former study (Cao, Lu, Yu 2018), in which only the rotation data since 2008 was available (please see CDL maps here: https://www.nass.usda.gov/Research_and_Science/Cropland/Release/). However, based on the state-level inventory data (similar to provincial data in China), we extended the rotation maps from 2008 back to 1850 (please see section 2.1.1 in Yu et al. 2018). Despite a limited and shorter coverage of the observed data (e.g. CDL rotation maps from 2008 to 2015), our reconstructed N fertilizer data at 5 arc min × 5 arc min (~8 km resolution) greatly improved the biogeochemical simulations, including N_2O emission accounting (Lu et al. 2022), crop production evaluation (Lu et al. 2018), and carbon budget assessment (Yu et al. 2019). These are strong supports that using a longer coverage data at provincial level in China is decent and reliable (e.g. rotation maps cover the period of 1980 to 2011 at county level).

About the accuracy of the data, please also see our response to the second questions below.

References:

Cao, P., Lu, C., & Yu, Z. (2018). Historical nitrogen fertilizer use in agricultural ecosystems of the contiguous United States during 1850–2015: application rate, timing, and fertilizer types. *Earth System Science Data*, *10*(2), 969-984.

Lu, C., Yu, Z., Zhang, J., Cao, P., Tian, H., & Nevison, C. (2022). Century-long changes and drivers of soil nitrous oxide (N2O) emissions across the contiguous United States. *Global Change Biology*, *28*(7), 2505.

Lu, C., Yu, Z., Tian, H., Hennessy, D. A., Feng, H., Al-Kaisi, M., ... & Arritt, R. (2018). Increasing carbon footprint of grain crop production in the US Western Corn Belt. *Environmental Research Letters*, *13*(12), 124007.

Yu, Z., Jin, X., Miao, L., & Yang, X. (2021). A historical reconstruction of cropland in China from 1900 to 2016. *Earth System Science Data*, *13*(7), 3203-3218.

Yu, Z., Lu, C., Cao, P., & Tian, H. (2018). Long-term terrestrial carbon dynamics in the Midwestern United States during 1850–2015: Roles of land use and cover change and agricultural management. *Global Change Biology*, *24*(6), 2673-2690.

Yu, Z., Lu, C., Tian, H., & Canadell, J. G. (2019). Largely underestimated carbon emission from land use and land cover change in the conterminous United States. *Global Change Biology*, *25*(11), 3741-3752.

2. When calculating crop-specific fertilizer application, the article mentioned "The N fertilizers use rate for each major crop types (except other crops) was intermittently reported in the Cost-benefit Report of the National Agricultural Products (CBR) covering the period of 2004-2018 (Table 1)". However, there is no corresponding crop fertilizer allocation table in the text or supporting materials, nor is there a link to the data source. I entered to the CBR website to check, but did not get the corresponding data. And this part of data is very critical, which directly affects the accuracy of the final product. Moreover, so-called high-resolution data, based only on provincial rates of crop fertiliser allocation, are crude.

Response: We are sorry that the source for CBR data information was not provided in our original submission. The data can be obtained from the following link: https://data.cnki.net/trade/Yearbook/Single/N2021120200?zcode=Z009

We have added this information in the revised main text. The CBR data was published in Chinese, and a sample data table is pasted below by showing the fertilizer use for corn in 2007 in a few number of provinces:

2007 全国农产品成本收益资料汇编

Fertilizer use for corn

2－6－3　2006 年各地区玉米化肥投入情况

项　　目	单位	平　均	北　京	天　津	河　北	山　西	内蒙古
一、每亩化肥金额	元	85.20	75.96	84.69	71.00	75.48	93.64
(一)氮肥	元	42.13	45.96	43.99	34.78	36.05	47.22
1. 尿素	元	34.21	44.70	42.78	30.91	19.47	42.47
2. 碳铵	元	7.40	1.26	1.21	3.80	15.94	4.75
3. 其他氮肥	元	0.52			0.07	0.64	
(二)磷肥	元	3.27			0.69	14.11	0.58
其中:过磷酸钙	元	2.78			0.27	12.88	
(三)钾肥	元	1.20			0.02	2.86	
其中:氯化钾	元	0.73			0.02	0.08	
(四)复混肥	元	38.19	30.00	40.70	35.44	22.25	45.56
1. 复合肥	元	35.73	30.00	40.70	33.11	17.97	45.56
其中:二铵	元	10.49	13.64	40.70	14.00	1.05	29.46
2. 混配肥	元	2.46			2.33	4.28	
(五)其他肥料	元	0.41			0.07	0.21	0.28
二、每亩化肥折纯用量	公斤	20.05	17.89	20.56	17.08	20.29	21.61
(一)氮肥	公斤	10.80	11.32	11.28	9.05	10.01	12.03
1. 尿素	公斤	8.34	10.91	10.91	7.80	4.74	10.46
2. 碳铵	公斤	2.31	0.41	0.37	1.23	5.14	1.57
3. 其他氮肥	公斤	0.15			0.02	0.13	
(二)磷肥	公斤	1.10			0.26	4.27	0.05
其中:过磷酸钙	公斤	0.93			0.09	3.84	
(三)钾肥	公斤	0.28				0.70	
其中:氯化钾	公斤	0.18				0.03	
(四)复混肥	公斤	7.87	6.57	9.28	7.77	5.31	9.53
1. 复合肥	公斤	7.39	6.57	9.28	7.27	4.28	9.53
其中:二铵	公斤	2.35	3.23	9.28	3.25	0.24	6.53
2. 混配肥	公斤	0.48			0.50	1.03	

Indeed, the CBR data is one of the most critical data available for research which may determine the accuracy of the final product. However, the CBR is the legitimate data source (please see introduction of the 2019 report in this link: http://www.stats.gov.cn/tjsj/tjcbw/202008/t20200824_1785455.html), which provides officially released fertilizers use information summarized from thousands of samples collected in each province in China. The first CBR was published in 1981, while the crop-specific fertilizer use was not available until 2004. We purchased the reports and entered the data manually for our study. As the CBR data source has become the most reliable and available data in China, we do not agree that provincial data are crude. First, the provincial, crop-specific N fertilizer use rate obtained from CBR are reliable (supported by large sample collected during summarization as aforementioned). This guarantees the accuracy of provincial results. Second, at a finer scale (i.e., sub-provincial), the N fertilizer use is more closely related to crop type planted spatially (e.g., corn vs soybean). Therefore, sub-provincial N fertilizer use pattern were determined by crop rotation maps. The crop rotation maps, developed from county-level survey data (2341 counties, please check Liu et al. (2018) for more details), are also the most reliable maps available in China to date. Third, the rotation maps were also dynamic as adjusted by the planted area of each crop type officially reported (please also see our response before). Moreover, comparing with former N fertilizer product developing from crop specific fertilizer use from country level (e.g., Lu and Tian 2017), our provincial data is a step forward in providing a finer N fertilizer use data in China.

Despite there are uncertainties (and we admit it), we have explained this in the last paragraph of the discussion of the manuscript (Lines354-355 in the original version). Another advantage of our data is that we developed the N fertilizer use maps based on improved cropland data. As elaborated in our previous studies (Yu et al. 2021, Yu et al. 2022), FAO-based data greatly biased in depicting cropland distribution in China (see Figures 1&2 below). The two most serious biases are: 1) FAO-based cropland data underestimated cropland coverage in traditional cultivated areas, but it overestimated cropland coverage in low cultivated areas (see Figure 1a-e and 1i-m below); and 2) the temporal change of cropland coverage is greatly biased in FAO-based cropland data due to false cropland expansion signals. The major reason is because of the distinct surveying methods used in China historically, as well as the political issues involved. For example, the amount of FAO-based (e.g. HYDE, LUH2) cropland abnormally increased by 28–32 Mha from 1980 to 1990, which contradicted the 4 Mha decline in cropland acreage revealed in our reconstructed cropland data in China (Yu et al. 2021). This is because the FAO data were reported from the Chinese Agricultural Yearbook, in which cropland underestimations have now been officially acknowledged (Figure 2). More details about the biased sources can be found in Yu et al. (2021, 2022).

It should be point out that the cropland data is the basis for allocating N fertilizer use spatially. Due to such large biases, the existing, global N fertilizer products, which heavily relies on FAO-based cropland products (e.g. HYDE, LUH2), would inevitably inherit these biases in depicting historical N fertilizer use in China. Therefore, the existing products of N fertilizer use is expected to be 1) diluted spatially (due to lower but more extensive cropland distribution maps, which was also discussed in Tian et al. (2022). Please check the discussion in Lines480-488 in Tian et al. (2022)); and 2) distorted temporally (by the biased cropland area dynamics at grid-cell level, see differences between Figure 1e-h and Figure 1n-q).

All in all, we admit that our data is not perfect (and there is no perfect data), but this is one of the most updated and advanced datasets at present in China. It has corrected some of the most serious and commonly seen biases in existing products in China. We believe it could greatly improve the biogeochemical cycle-related simulations (e.g. N_2O accounting in China), and we argue that the reconstructed data has the great value for future research.

References:

Tian, H., Bian, Z., Shi, H., Qin, X., Pan, N., Lu, C., ... & Zhang, B. (2022). History of anthropogenic Nitrogen inputs (HaNi) to the terrestrial biosphere: A 5-arcmin resolution annual dataset from 1860 to 2019. *Earth System Science Data Discussions*, 1-32.

Yu, Z., Jin, X., Miao, L., & Yang, X. (2021). A historical reconstruction of cropland in China from 1900 to 2016. *Earth System Science Data*, *13*(7), 3203-3218.

Yu, Z., Ciais, P., Piao, S., Houghton, R. A., Lu, C., Tian, H., ... & Zhou, G. (2022). Forest expansion dominates China's land carbon sink since 1980. *Nature communications*, *13*(1), 1-12.

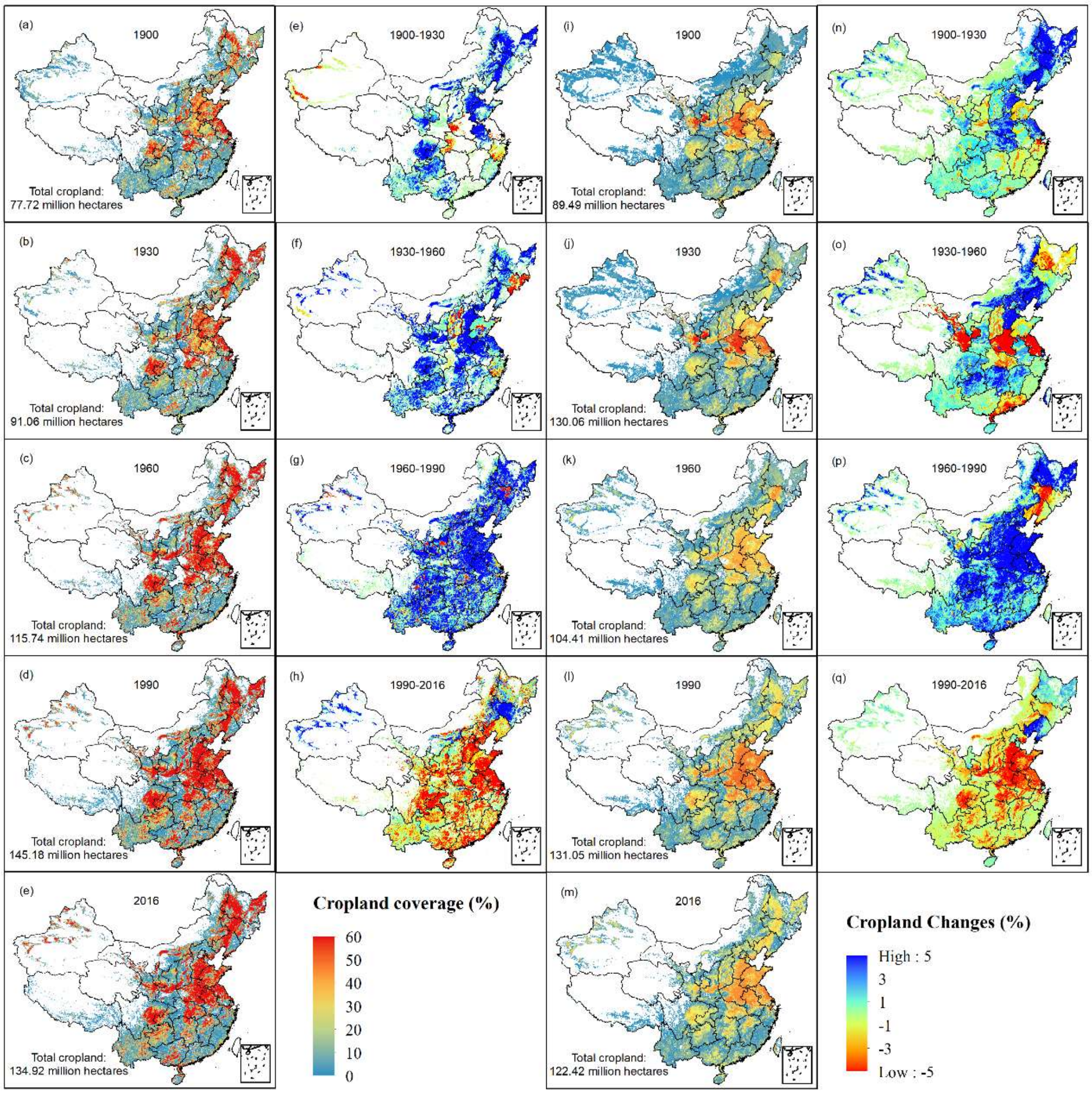

Figure 1. Comparisons of cropland coverage and changes during different periods in China. The left two columns are our reconstructed cropland maps, while the right two columns were derived from HYDE (FAO-based cropland maps).

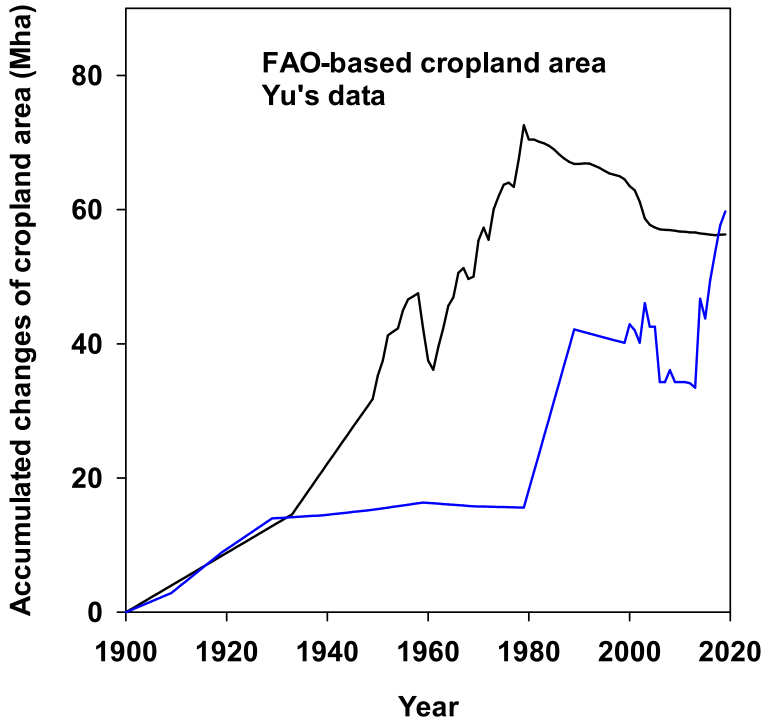

Figure 2. The accumulated changes of cropland areas in China (FAO-based cropland area is from LUH2-GCB, and it can be downloaded from https://luh.umd.edu/data.shtml; Yu's data is from Yu et al. 2021)

All in all, I don't think this article has enough innovation or contribution in terms of data source and data production method for publishing in the ESSD. The final data product was only qualified in terms of the average cropland fertilization, but the crop-specific fertilizer data was very crude, which greatly weakened the use value of the data. To sum up, I suggest rejecting the manuscript.

Response: Here we would like to re-iterate the innovation and contribution of our data. Our N fertilizer maps corrected the presence of serious biases in existing data products in both spatial and temporal at gridcell level. These corrections will greatly benefit the modeling community for greenhouse gas emission accounting, crop production evaluation, water pollution assessment, and vegetation growth simulations. In our former study, we made similar improvements with specific focus on contiguous

US (Cao, Lu, Yu 2018). In that study, we corrected biases in FAO-based cropland maps in the US, and reconstructed N fertilizer use using state-level inventory data (similar to provincial-level data in China), such as crop rotation and cropland area data. The N fertilizer product has been widely used in different studies (citation number for Cao, Lu, Yu (2018) is 156 as indicated in Google Scholar, which is ~39 citations annually). A simple example of our data's application is to benefit the global model intercomparison projects in carbon and nitrogen cycle simulations (e.g., NMIP: the global N_2O Model Intercomparison Project, MsTMIP, and TRENDY project). These projects were often driven by 0.5 degree N fertilizer use data, which was derived from FAO-based cropland data (e.g. HYDE, LUH2, FAO stats: https://www.fao.org/faostat/en/). As we elaborated before, FAO-based products underestimated cropland coverage in traditionally cultivated areas, but it overestimated cropland coverage in low cultivated areas in China. Therefore, the N fertilizer input might be underrated in intensively cultivated areas in China (which is also found in this study - please see Figure 7). We believe the simulations (e.g., N_2O accountings) will be improved in China if the N use data is updated.

Therefore, we would kindly advise the reviewer to revisit our revised manuscript and to reconsider for the final recommendation.

References:

Liu, Z., Yang, P., Wu, W., & You, L. (2018). Spatiotemporal changes of cropping structure in China during 1980–2011. *Journal of Geographical Sciences*, *28*(11), 1659-1671.

Lu, C., & Tian, H. (2017). Global nitrogen and phosphorus fertilizer use for agriculture production in the past half century: shifted hot spots and nutrient imbalance. *Earth System Science Data*, *9*(1), 181-192.