Interactive comment on "Increased nitrogen enrichment and shifted patterns in the world's grassland: 1860–2014" by Rongting Xu et al.

Rongting Xu et al.

rzx0004@tigermail.auburn.edu

Dear reviewer #1, We thanks for the precious comments and constructive suggestions. These comments were addressed in detail and incorporated into the revised manuscript and supplementary material. All changes have been marked in "blue" to be tractable in the revised manuscript.

1. First, accounting for both the uncertainty and bias of the produced maps. Uncertainty refers to the confidence intervals around the point estimates. Note that none of this study's numbers come with uncertainty estimates. Uncertainty could come from the source data, for example, fertilizer use in the early days (1860) is presumably less precise than the one in the recent days (2014). Uncertainty could also come

from the process (see the next comment). In addition, bias refers to over- or underestimate, for example, L404-405 mentions lack of human-induced sources N input will underestimate N input. Response: We totally agree with the reviewer that uncertainty should be considered in this study. In the main text, we are aware of your concerns and have discussed the uncertainty of this study from several aspects, as shown in section 4.5. We agree with the reviewer that fertilizer/manure use in the early days (1961/1860) is presumably less precise than the one in the recent days. However, this uncertainty is from the source data that beyond the scope of this study. It is hardly to provide uncertainty with numbers since our source data (i.e., FAOSTAT and Zhang et al. (2017)) have not provide uncertainty ranges. It is true that our datasets during 1961-2016 are more accurate as numbers are consistent with FAO national total N manure and fertilizer amounts. For the period 1860-1960, we assumed that the ratio of manure application/deposition to production is the same as for 1961. Combining with the gridded spatial maps of manure production rates in Zhang et al. (2017), we generated the datasets of spatialized manure application/deposition rates to global pastures/grasslands during 1860-1960. This has been described in sections 2.3 & 2.4. In addition, we have changed the section 4.5 "Uncertainties" to "Limitations and uncertainties" and will include uncertainty analysis in our future research.

2. Second, the "spatialization" needs to consider the modifiable areal unit problem (MAUP) and spatial correlation. MAUP is a well-known issue in geography and spatial statistics, referring to the fact that when areal/point-based measures of spatial phenomena are aggregated into other units, they are influenced by both the shape and scale of the aggregation. It appears that the study simply takes the face values to fall into different spatial units without considering possible uncertainty and bias that are propagated through this process (coupled with the first comment). Also, note that the map estimates should somewhat consider spatial correlation. Spatial points are not independent: locations closer together will be more correlated than locations further apart. Response: We thank for the reviewer's comments. The MAUP and spatial correlation mentioned above did not appear in this study. We aggregated the original maps of the

spatial resolution of 5 by 5 arc minute into 0.5 by 0.5 degree. The original spatial maps (HYDE 3.2 and Zhang et al. (2017)) are in raster formats and consist of pixels.

Regardless of these improvements to be made, this study is an essential step in providing the global data and enhancing our understanding of the N issue. Specific comments: L155: the total number of countries is 202? Response: The total number of countries with "manure N application" should be 165. We have updated this number in the main text. L578, Fig 4: Where are the boundaries of grasslands? The 3rd row appears to suggest grasslands cover the entire global landmass. Response: We have updated these figures. The boundaries are showing in Fig. 4g-i.

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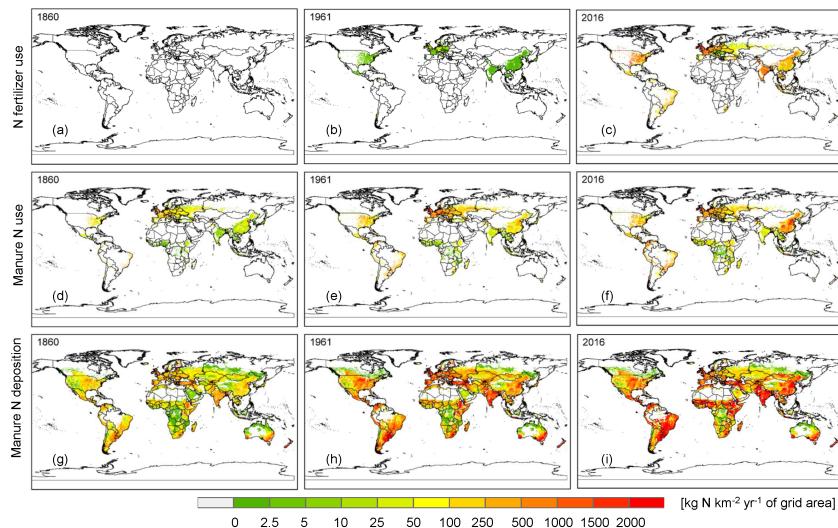
Fig. 1. Spatial patterns of N input rates in global pastures and rangelands in 1860, 1961, and 2016: (a)-(c) N fertilizer application rates; (d)-(f) manure N application rates; (g)-(i) manure N deposition rat