
Reviewer 1:

This manuscript presents a comprehensive and regionally tailored framework for estimating agricultural ammonia (NH₃) emissions in South Asia, an area critical for understanding reactive nitrogen pollution, yet underrepresented in high-resolution emission inventories. The proposed framework uses a hybrid Tier 1/2 methodology, incorporating national and subnational data (e.g., fertilizer use, livestock systems, crop distribution) at a high spatial resolution of 0.1° x 0.1°. The dataset offers significant value due to its spatial granularity, region-specific emission factors (particularly for urea), and transparent methodology. This makes it a promising tool for atmospheric modeling, policy planning, and future updates. However, several issues need to be addressed to ensure that the dataset meets the standards of accessibility, reproducibility, and robustness required by ESSD.

Key Concerns:

1. **Data Accessibility:** The gridded dataset lacks direct accessibility due to the absence of a persistent identifier (e.g., DOI) or a direct link to a stable, publicly accessible data repository.
2. **Emission Factor (EF) Consistency:** The manuscript applies a uniform emission factor for urea without considering pH variability, which could affect the accuracy of NH₃ emissions estimates.
3. **Uncertainty Analysis:** The manuscript does not provide a quantitative uncertainty analysis for the final gridded product, including error propagation and uncertainty ranges, which is critical for evaluating the reliability of the estimates.
4. **Reproducibility of Input Data:** The manuscript relies on "personal communication" for certain input data, raising concerns regarding the reproducibility and transparency of the study.

Given the manuscript's valuable methodological contribution and the importance of the estimates, major revisions are required to align with ESSD's standards for data accessibility, reproducibility, and rigorous uncertainty quantification.

The authors thank the reviewer for their comments and address them below:

List of Major Revisions Required:

- **Data Accessibility:** The manuscript should provide a persistent identifier (e.g., DOI) or a direct link to a publicly accessible and stable data repository for the 0.1° x 0.1° gridded dataset.
- The authors would like to point to the 'Data Availability' section, where the URL has been amended to the persistent identifier (DOI) address, as opposed to the EIDC catalogue address.
- **Uncertainty Analysis:** A quantitative uncertainty analysis is needed for the final gridded estimates, including error propagation and uncertainty ranges.
- This is an important point that has been considered at length. We have calculated uncertainty ranges for NH₃ emissions from all 5 sectors, using Monte Carlo methods, using data that could be obtained in a timely fashion. Not every single parameter and variable has uncertainty in our estimates, which is noted, but many do. Updates to the text are various - too many to quote here - but aim to sit within the text when appropriate (methods, results, discussion). We applied uncertainty for; total crop area, N-fertiliser application rates, fertiliser NH₃ EFs, total N use per country, crop harvest totals, the burnt fraction of crop residues, the crop above ground dry matter, the NH₃ EF for crop residues burnt, total livestock numbers, typical animal mass and daily N excretion rates. The level of detail and confidence on the uncertainty data is variable but help to provide uncertainty calculations.

- **Reproducibility of Input Data:** Any data cited as "personal communication" must either be made available as supplementary material or detailed justifications should be provided, including a discussion of the implications for reproducibility.
- The authors agree with the principle of the comment and have added the following sentence into the conclusion: "However, it should be noted that some data (e.g. state-wise crop production in India) was obtained via personal communication and cannot be re-published or re-distributed and exemplifies the issues around data flow into emissions estimation models." Two instances of the use of personal comms remain in the manuscript (previously lines 101 and 169) but the third instance (previously line 175) has been removed due to an error.
- **Urea EF Consistency:** The uniform application of the urea emission factor without accounting for pH variability should be clarified and justified, or the potential impacts on accuracy should be discussed.

The authors have reviewed the paragraph referred to and replaced it with the following, which addresses the comment and also amends an error (the EF is 11.4% N as NH₃-N, not 13%): "In the EEA (2023), Urea fertiliser has an EF of 16-17% of total N lost as NH₃-N (pH dependent); this study used work by Bhatia et al. (2023), drawing upon 20 experimental plots measuring NH₃ emissions from the application of prilled-Urea within South Asia in 2018, to adjust the NH₃ EF of Urea fertiliser to 11.4% of total N lost as NH₃-N (or 13.8% as NH₃), which was applied to all SAARC member states. This Urea EF was not measured with pH variability and so was used uniformly in the domain. Whilst this introduces a lack of distinction between higher and lower pH soils, in comparison to non-Urea fertilisers, the initial EF (EEA, 2023) for Urea in high pH soils is only ~5.5% larger than that in low pH soils, and it was deemed more suitable to use this localised study, even for the loss of pH related sensitivity."

Specific Comments:

- **Table 1 Correction:** The "Maldives 1.2" formatting error in Table 1 should be corrected.
- The superscripts '1,2' are intended to both be present.
- **Abbreviations List:** It is suggested to include a list of abbreviations to improve readability.
- The authors are of the opinion the abbreviations are all well defined and it is rare to see such a list in this journal.
- **Metadata Enhancement:** The dataset in EIDC should be accompanied by a README file, including:
 - Explanation of the file structure
 - Units of measurement
 - Reference to this manuscript
- The authors would like to mention that the downloadable document under 'Supporting docs' in the EIDC deposition does contain an explanation of file structure and units. With regards the 3rd point, the Earth Systems Science Data journal requires a published dataset with a DOI to be placed into the manuscript, which means there is no paper to reference in the dataset (at the time of the data publication). Unfortunately, the dataset documentation cannot be altered due to the DOI.

Reviewer 2:

This is a strong and valuable paper that successfully produces a improved, high-resolution ammonia inventory for South Asia by incorporating crucial regional data. Its major strengths are the application of a lower, region-specific urea EF and the use of a more appropriate N-flow approach for livestock. The main weaknesses are the under-specification of the proposed "framework," the lack of a formal uncertainty analysis, and the relatively high uncertainty in the crop residue sectors. Addressing the major comments, particularly regarding the livestock discrepancy and uncertainty, would significantly enhance the paper's impact. The minor comments are primarily suggestions for improving clarity and rigor.

The authors thank the reviewer for their comments and address them below:

Major Comments

The paper's title and abstract position it as presenting a "framework" for integrating indigenous data. However, the manuscript reads more like a single implementation of that framework for the year 2015. The "framework" itself is not explicitly detailed as a standalone, reusable methodology. It is embedded within the specific calculations for SAARC.

Strengthen the "framework" aspect. Consider adding a flow diagram or a more explicit, generalized description of the data ingestion and adjustment process in the Methods section (Section 2). This would make it clearer how other researchers or inventory compilers could apply the same steps with their own local data.

The authors appreciate this comment, but we agree that the paper itself is the flow diagram. To make it clearer that the framework is being applied as an example, we have added "single implementation of a framework..." to the abstract and added text to the main aim (last paragraph, Section 1) making it clearer this is a re-useable method for countries looking to use their own data and move away from Tier 1 EFs.

The adjustment of the urea EF from ~16-17% (EEA, 2023) down to 13% is a major driver of the study's results (a ~20% reduction in total emissions). While this is justified by referencing Bhatia et al. (2023) and IARI (2016), the treatment is somewhat brief.

Provide more context. How many of the 29 South Asian studies from Bhatia et al. were specifically on urea? What was the range of EFs found? A brief discussion on why EFs might be lower in South Asian conditions (e.g., different application practices, soil types, climate) would bolster this critical decision. Furthermore, stating that this adjusted EF was applied uniformly across the domain, despite having pH data, is a significant simplification that deserves a more explicit justification.

The authors have reviewed the paragraph referred to and replaced it with the following, which addresses some comments and also amends an error (the EF is 11.4% N as NH₃-N, not 13%): "In the EEA (2023), Urea fertiliser has an EF of 16-17% of total N lost as NH₃-N (pH dependent); this study used work by Bhatia et al. (2023), drawing upon 20 experimental plots measuring NH₃ emissions from the application of prilled-Urea within South Asia in 2018, to adjust the NH₃ EF of Urea fertiliser to 11.4% of total N lost as NH₃-N (or 13.8% as NH₃), which was applied to all SAARC member states. This Urea EF was not measured with pH variability and so was used uniformly in the domain. Whilst this introduces a lack of distinction between higher and lower pH soils, in comparison to non-Urea fertilisers, the initial EF (EEA, 2023) for Urea in high pH soils is only ~5.5% larger than that in low pH soils, and it was deemed more suitable to use this localised study, even for the loss of pH related sensitivity."

The paper identifies a massive discrepancy between its livestock emissions and those in REAS/HTAP, primarily attributed to differences in Typical Animal Mass (TAM). This is a crucial finding.

This point is so critical that it warrants a more in-depth discussion. A simple comparative table showing the TAM, N excretion, and resulting implicit EFs from this study versus the assumptions in EEA (2019)/REAS would be highly effective. This would visually underscore the source of the disparity and strongly support the paper's argument for region-specific parameters.

Thank you for highlighting this discussion point. We are unable to make a comparative table due to the lack of information in the referred to study (REAS). We do highlight the very large difference in TAM values used in REAS and this paper and also the large proportion of excreta-N that is used for fuel in South Asia, compared to what is *probably* accounted for in the T1 EF, which very likely constitutes a large amount of the difference in emissions from livestock management. We have added the following sentence: "This issue highlights the difficulty in using T1 EFs and how hard they can be to adapt to different regions of the world."

The paper correctly states that "Estimated uncertainty... was not estimated." For a study aiming to improve upon existing inventories, this is a significant omission. The discussion of uncertainties is qualitative (e.g., "highly uncertain," "large uncertainty").

A more formal, even if semi-quantitative, discussion of uncertainty is needed. The authors could adopt a tiered approach, discussing the likely direction and relative magnitude of uncertainty for key parameters (e.g., $\pm X\%$ for Activity Data, $\pm Y\%$ for EFs, especially for crop residues and burning). This would provide readers with a much better understanding of the confidence bounds around the final estimate of ~ 6 Tg.

This is an important point that has been considered at length. We have calculated uncertainty ranges for NH_3 emissions from all 5 sectors, using Monte Carlo methods, using data that could be obtained in a timely fashion. Not every single parameter and variable has uncertainty in our estimates, which is noted, but many do. Updates to the text are various - too many to quote here - but aim to sit within the text when appropriate (methods, results, discussion). We applied uncertainty for; total crop area, N-fertiliser application rates, fertiliser NH_3 EFs, total N use per country, crop harvest totals, the burnt fraction of crop residues, the crop above ground dry matter, the NH_3 EF for crop residues burnt, total livestock numbers, typical animal mass and daily N excretion rates. The level of detail and confidence on the uncertainty data is variable but help to provide uncertainty calculations.

Crop Residue Burning (CRB) and Left in Fields (CRR): These sectors are acknowledged to be highly uncertain, and the methods seem less refined than those for synthetic fertilizer and livestock. The use of a single, mean EF for all crop burning and the reliance on the generic Yevich and Logan (2003) FB value for many cases are notable weaknesses.

The authors would like to point to footnote 1 in Table A6 which attempts to outline some of the alternative values used for the fraction burnt (FB), instead of simply using Yevich and Logan (2003), across the countries of South Asia. These adjustments inform the final emissions estimate (not the EF) and have a general regional uncertainty associated with them (see response re uncertainty). We also recognise the simplicity of a single EF for NH_3 from burnt residues. Whilst the underlying methods consider crop type, burnt fraction etc., studies that give values on NH_3 emitted from burnt residue are not common and many cross-reference each other, occasionally leading back to the same few studies in the past. It is, therefore, hard to fully trust the range of EFs quoted in the literature as being sound for individual crops. The uncertainty on many EFs, per crop type, overlap and so it was considered safer to use a mean (range = s.d.). This EF is applied at the crop level to allow for better data to be ingested and a sentence reflecting this has been added.

The discussion here is good, but the methods could be more transparent about the limitations. A clearer summary table in the main text (not just the appendix) showing which country-specific FB values were used and which fell back to the default would be helpful. The conclusion that these sectors are a small part of the

total NH_3 budget should be tempered with the statement that they might be a more significant source of other pollutants (PM_{2.5}).

A new table, Table 1, has been added to add clarity to the new values of FB that have been incorporated into the study. Furthermore, the authors believe that the important point about PM_{2.5} pollutants is addressed by the sentence “Due to the importance of crop residue burning to ambient fine particulate matter (PM_{2.5}) formation, particularly in proximity to urban areas (e.g. Lan et al., 2022), more information is needed within the SAARC domain on the crops that undergo burning, the proportion of the crop burnt and the spatial variability of burning practice.”

Minor Comments

- The text references "equation 1 (Eq. 1)" but the equation itself is not numbered in the provided text. All equations should be clearly numbered.
- Respectfully, equation 1 does appear to be numbered in the text, in the same manner as other equations. However, there is some inconsistency in equation naming in the text, which has been resolved.
- In Section 2.4, Equation 9 is used twice (for E.grz and E.h). This is confusing and should be corrected (e.g., Eq. 9 and Eq. 10).
- The suggested correction has been implemented
- The description of Eq. 2 is unclear. The term H(E,N) is not well-defined in the text.
- Terms E_a & N_o in equation 2 have been altered to E & N, to be consistent with the rest of equation 2, and represent specific coordinate pairs, and therefore a grid cell. H is a fraction of the grid cell, for example crop coverage fraction, and is used in the application of spatial proxies. In the text, “to the total of p ” has been updated to “to the total of P ”
- Define SAARC at its first occurrence in the abstract.
- SAARC is defined in the first use, the 3rd line of the abstract.
- The acronym "GRM" (Livestock grazing & manure spreading) is introduced in Table 1 but is not defined in the methods section, where the components are treated separately. It should be defined where it first appears in the results.
- Thankyou, we have added the following sentence to the end of Section 2.4: “From Section 3 onwards, emissions from the above N-flow that are from grazing and manure spreading activities will be referred to as GRM and those from livestock management activities as MNM.”
- "Tier 1" methods are mentioned but not briefly explained for a broader audience. The authors feel the citation to Tier 1 methods in the Discussion is sufficient (and perhaps not appropriate to be cited in the abstract).
- The use of gridded crop data from the year 2000 (EarthStat) for a 2015 inventory is a potential source of error. This should be explicitly acknowledged as a limitation in the discussion, though the scaling to 2015 national totals mitigates this.
- The authors have addressed this point in the expanded uncertainty discussion
- The statement that ~103% of total N use was estimated before rescaling suggests the bottom-up method was reasonably accurate; this is a good result and could be emphasized.
- This has been noted and emphasized.
- Figure 3 and 4 are crucial but are described in the text before they are presented. Ensure the figures are correctly positioned in the final manuscript.
- We have made some re-arrangement to the text (Figures 3 & 4 are now known as Figures 4 & 5).

- The caption for Figure 2 should more clearly state that the five maps are the spatial distribution for each of the five sectors, and the single legend applies to all.
- The words “(common scale/legend)” has been added to Figure 2 and also to the new Figure 3.
- Page 1, Abstract: "oil acidification" should be "soil acidification."
- Correction made.
- Page 5: "Azhar et al., 2019" is likely a typo for "Azhar et al., 2019".
- Correction made.
- Page 14: "THIS_STUDY_NRU in Figure 2" should probably be "Figure 3".
- It was supposed to be Figure 3, agreed, but it now Figure 4 due to the addition of a figure. Correction made.