Response to comments:

We are grateful for the reviewers' insightful comments and constructive suggestions that are highly helpful for us to improve this study, "Global consumption-based deforestation carbon emissions and regional hotspots: 2001–2020" (essd-2026-243).

Following the reviewers' suggestions, we have carefully revised the manuscript and addressed all comments in detail. The major revisions include:

(1) Clarified the methodological framework and spatial allocation procedure. We have revised the description of the SMRIO framework to clearly distinguish between national-level consumption-based deforestation emissions accounting and subsequent spatial disaggregation. Figure 1 has also been revised to better illustrate these procedures. (2) Enhanced the presentation of global patterns and trade-related characteristics of deforestation emissions footprints. We have revised Figure 2 to include global rankings of major net importers and exporters and to better illustrate regional patterns and net trade flows. (3) Expanded the visualization of the gridded dataset. We added cumulative 2001–2020 deforestation emissions footprint maps for additional major net-importing countries, including Japan and Germany, and integrated them into Figure 3. We also added bar charts illustrating the contributions of domestic and major foreign source countries to the footprints of these selected countries. (4) Clarified methodological details and data processing procedures. We have added further details on the spatial harmonization of input datasets and clarified the temporal attribution assumptions and scope of the annual accounting approach. (5) Addressed minor textual and graphical issues. We have corrected typographical errors, improved figure captions, adding geographic coordinates to maps.

We believe that these revisions have improved the clarity of the manuscript and dataset. We sincerely appreciate the reviewers' valuable suggestions, which have helped us strengthen this work.

All comments have been addressed point by point in the following response letter. Changes made in the revised manuscript are highlighted in blue, while unchanged text is shown in black.

Thank you for the opportunity to revise our manuscript.

Response to Anonymous Referee #1

General Comment: Tang et al. solve an important consumption attribution gap by creating the first annual global 1 km gridded dataset attributing intra-country deforestation carbon emissions to countries consuming trade-based products from 2001 to 2020. The dataset was created using a spatial multi-regional input-output framework, which disaggregates national emissions to grid cells based on data for deforestation, road characteristics, and export priority zones. Export priority zones were chosen based on results from a sensitivity analysis of deforestation patch sizes and road densities, with zones subsequently chosen based on spatial plausibility criteria. Overall, this paper is structured well and addresses a critical gap in the literature. With minor revisions, this paper will be ready for publication in Earth System Science Data. The authors must address minor concerns by adding methodological details, correcting minor typographical errors, and adding more figures to the results. Specifically, ranking the global net importers of deforestation and providing additional visual representation (e.g. bar charts) for consumption-based deforestation emissions footprints in specific regions for the United States and China would support the study's data.

Response: We sincerely thank the reviewer for the careful evaluation of our manuscript and for the constructive and encouraging comments. We greatly appreciate the reviewer's positive assessment of our dataset. We have carefully considered all comments and revised the manuscript accordingly. Detailed responses are provided below.

Major Comments

Comment 1: It's unclear what exact data are available in MRIO tables and how they help with estimating deforestation emissions. Considering this is critical for the analysis, it would benefit to further clarify what the MRIO tables contain and how they can be interpreted.

Response: Thank you for this important comment. We have expanded Sections 2.1.1 and 2.2.1 to clarify the main components of the Eora26 MRIO tables and their roles in tracing production–consumption linkages across countries and sectors. We have also clarified that the deforestation emissions used in this study were independently derived from spatial forest-loss and carbon-density information and incorporated into the MRIO framework as environmental extensions.

The revised Section 2.1.1 on Lines 74-89, Page 4 now reads:

"MRIO tables provide a comprehensive representation of monetary flows associated with production, consumption, and trade among economic sectors and countries and are widely used to quantify consumption-based environmental footprints (Kanemoto

et al., 2016; Lenzen et al., 2018; Liu et al., 2022). An MRIO table consists primarily of intermediate transactions, which describe monetary flows of goods and services among producing sectors within and across countries, and final demand, which records purchases by final consumers in each country. Together with sectoral total output, these data trace how production in one country is linked through international supply chains to final consumption in another country. In this study, we utilized Eora26, a simplified version of the Eora global MRIO tables, for 2001–2020. Eora26 provides a consistent time series covering 187 countries and regions with a harmonized classification of 26 economic sectors (Lenzen et al., 2013). Specifically, we used the economic core of Eora26, including intermediate transactions, final demand, and sectoral total output, to characterize production-consumption linkages across countries and sectors. The environmental satellite accounts provided by Eora26 were not used in this study. Instead, the deforestation emissions satellite account was independently constructed using the pixel-level deforestation and deforestation emissions data described in Sect. 2.1.2, to ensure consistency with the spatially explicit deforestation emissions used for subsequent spatial allocation. This independently constructed environmental extension was linked to the Eora26 economic system to attribute deforestation emissions to domestic and foreign final demand through global supply chains. The detailed accounting procedure is described in Sect. 2.2.1."

The revised Section 2.2.1 on Lines 119-121, Page 5 now reads:

"As described in Sect.2.1.1, the MRIO framework links production in each country and sector to intermediate use and final demand both domestically and abroad. Accordingly, total sectoral output (X) is accounted for intermediate transactions (T) and final demand (Y), as expressed in Eq. (1):"

Comment 2: The resulting maps for the United States (Figure 4) and China (Figure 5) are clear and nicely made. Some suggestions for this part of the analysis:

> **Comment 2.1:** An additional figure or bar chart showing the rankings for net importers of deforestation would complement the results. Initially, I thought the United States and China were selected as examples from Figure 3a, but that is not the case as the bar charts show consumption-based deforestation emissions both domestically and internationally.
>
> Response: Thank you for this helpful suggestion. We agree that the rationale for selecting the United States and China required further clarification. To address this concern, we have combined the original production-based and consumption-based comparisons into a mirrored visualization and added the net flow (consumption-based minus production-based). In addition, we have added rankings of the top 10 net exporters and net importers of deforestation emission. These revisions have been incorporated into the revised Figure 2, which now

presents (a) temporal trends of regional consumption-based deforestation emissions, (b) production- and consumption-based emissions with net trade flows, and (c) rankings of major net exporters and importers.

The revised Section 3.1 and Figure 2 on Lines 221-230, Page 9-10 now reads:

"At the national level, differences between consumption-based and production-based deforestation emissions varied substantially among countries (Fig. 2c). The United States, China, Japan, and Germany were among the largest net imports of deforestation emissions, whereas Indonesia, Brazil, Malaysia, and the Democratic Republic of the Congo were among the largest net exporters.

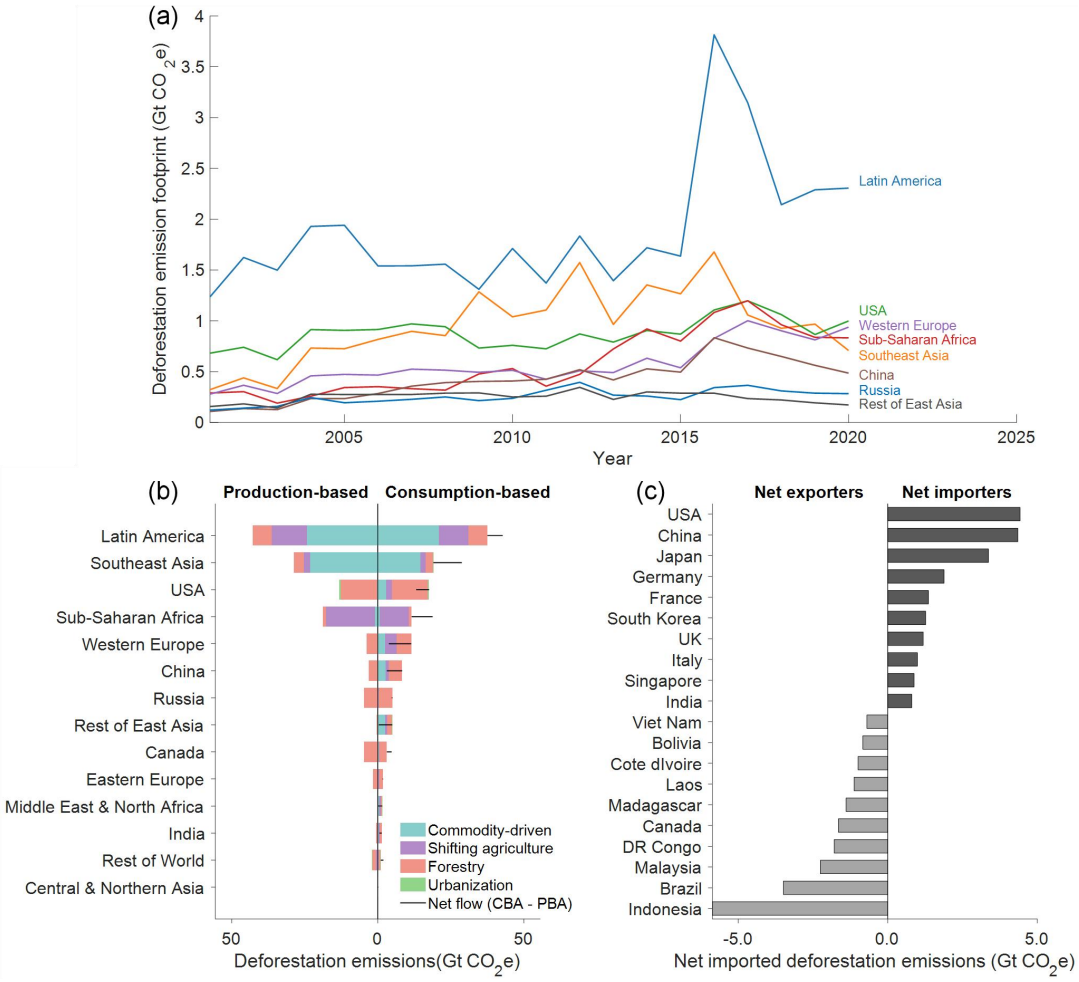


Figure 2. Temporal dynamics, regional patterns, and net trade flows of global consumption-based deforestation emissions, 2001–2020. (a) Temporal changes in consumption-based deforestation emission across world regions. (b) Comparison of cumulative deforestation emissions by drivers across world regions and net trade flows (consumption-based minus production-based emissions). (c) Ranking of the top net exporters and net importers of deforestation emissions based on net trade flows. Positive values indicate net importers, whereas negative values indicate net exporters."

Comment 2.2: Considering the maps for the United States and China are representative of the 1 km gridded dataset, please use the ranking diagram to include 1-2 more maps from the next two largest importers of deforestation emissions. This would further support the usefulness of and need for the dataset.

Response: Thank you for this valuable suggestion. We added cumulative deforestation emissions footprint maps (2001–2020) for Japan and Germany, which are among the largest net importers after the United States and China. These maps, together with those for the United States and China, have been integrated into the revised Figure 3.

The revised Section 3.2 and Figure 3 on Lines 247-259, Page 11-12 now reads:

"The deforestation emissions footprints of Japan and Germany were predominantly distributed across overseas source regions (Fig. 3e–h). For Japan, major foreign emission hotspots are concentrated in Southeast Asia and South America, whereas Germany's footprints are mainly associated with South America, Southeast Asia, and parts of Africa. Japan and Germany showed relatively small domestic contributions, accounting for 5.4% and 8.8% of their respective consumption-based deforestation emissions. The top 11 source countries (including Japan and Germany) accounted for 79.4% and 62.8% of the total footprints, respectively (Fig. 3f, h).

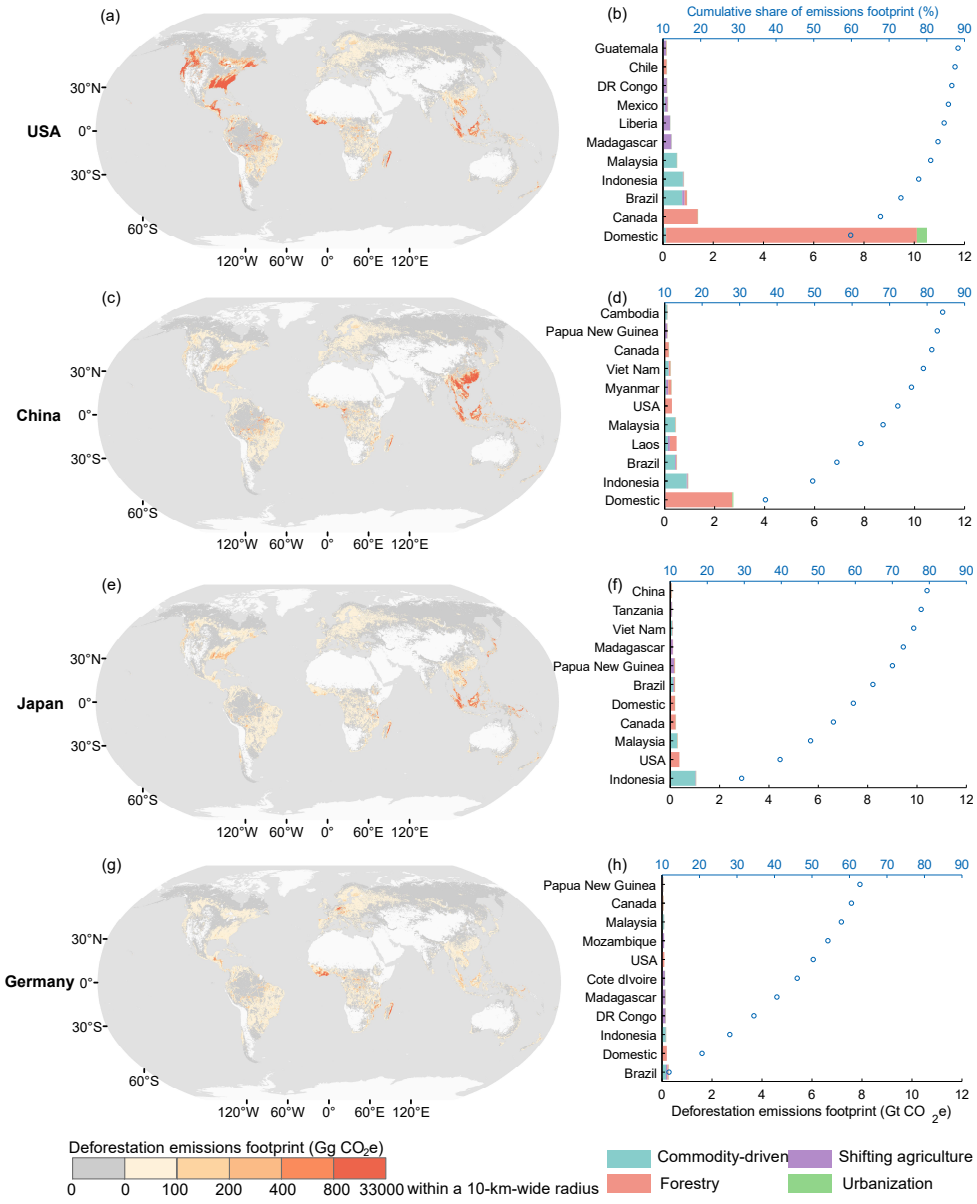


Figure 3. Spatial patterns and source contributions of cumulative consumption-based deforestation emissions footprints for major net-importing countries, 2001–2020. (a), (c), (e), and (g) Global distribution of cumulative deforestation emissions footprints for the United States, China, Japan, and Germany, respectively. (b), (d), (f), and (h) Contributions of domestic and major foreign source countries and deforestation drivers to the cumulative footprints of the four countries. Blue points indicate the cumulative share of total footprint."

Comment 2.3: For each map showing consumption-based deforestation emissions linked to the United States and China, it might also be helpful to include additional bar charts showing the deforestation emissions footprint for each country in other

countries. This would help to further visualize the data generated in this study and enhance interpretability.

Response: Thank you for this valuable suggestion. We have added horizontal bar charts showing the contributions of domestic and major foreign source countries to the deforestation emissions footprints of the four major net-importing countries (the United States, China, Japan, and Germany), together with their cumulative shares. These additions have been incorporated into the revised Figure 3.

The revised Section 3.2 and Figure 3 on Lines 233-246, 254-259, Page 10-12 now reads:

"Fig. 3 presents cumulative maps of deforestation emission footprints associated with consumption in four major net-importing countries, including the United States, China, Japan, and Germany, during 2001–2020, together with the contributions from domestic and foreign source regions. Deforestation emissions induced by consumption in the United States are widely distributed across both domestic and international regions (Fig. 3a). Major hotspots occur within the United States and tropical forest regions, particularly in Southeast Asia (e.g., Indonesia and Malaysia), the Amazon Basin, coastal West Africa (e.g., Côte d'Ivoire and Liberia), eastern Madagascar, and Chile. The source attribution results show that domestic sources contributed 59.8% of the U.S. consumption-based deforestation emissions. The top 11 source countries (including the United States) accounting for 88.3% of the total footprint (Fig. 3b).

China's consumption-based deforestation emissions are more spatially concentrated (Fig. 3c). Domestic emission hotspots are mainly located in north China, while international footprints extend primarily to Southeast Asia, particularly Indonesia and Malaysia, as well as to Central and West Africa, including Gabon and Cameroon. Domestic sources contributed 36.9% of China's consumption-based deforestation emissions, while the top 11 source countries (including China) accounting for 84.1% of the total footprint (Fig. 3d).

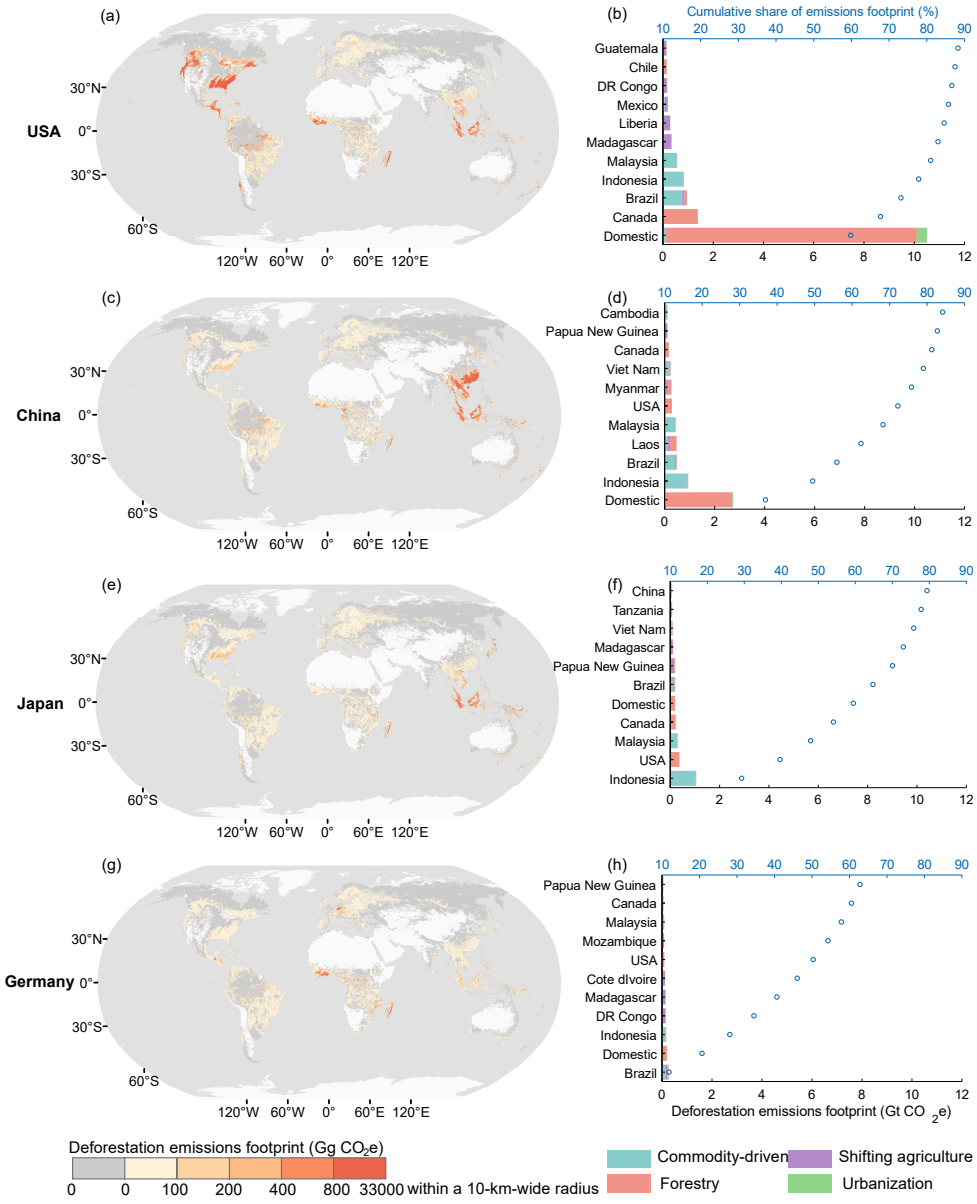


Figure 3. Spatial patterns and source contributions of cumulative consumption-based deforestation emissions footprints for major net-importing countries, 2001–2020. (a), (c), (e), and (g) Global distribution of cumulative deforestation emissions footprints for the United States, China, Japan, and Germany, respectively. (b), (d), (f), and (h) Contributions of domestic and major foreign source countries and deforestation drivers to the cumulative footprints of the four countries. Blue points indicate the cumulative share of total footprint."

Minor Comments

Comment 3: L25: It seems that the introduction section is split into four paragraphs, but paragraph two is not indented (starting with "International trade remains the primary…").

Response: Thank you for noting this issue. We have corrected the indentation of the second paragraph in the Introduction section in the revised manuscript.

The revised Section 1 on Lines 25, Page 1 now reads:

"International trade remains a primary driver of deforestation, particularly through the expansion of commercial agriculture (Pendrill et al., 2019b; Pendrill et al., 2019a)……"

Comment 4: L82-84: Please briefly expand on how deforestation was quantified using Landsat data in one to two sentences. Was NDVI used or another metric?

Response: Thank you for this helpful suggestion. We have expanded the description of the Hansen et al. (2013) dataset to clarify how annual forest loss was quantified from Landsat imagery. Specifically, we have clarified that the dataset uses a decision-tree classification approach based on Landsat-derived spectral metrics, including changes in tree cover and growing-season NDVI, to identify forest loss and determine the year of loss. The corresponding description has been added to Sect. 2.1.2.

The revised Section 2.1.2 on Lines 91-95, Page 4 now reads:

"We obtained annual deforestation data from Hansen et al. (2013), derived from time-series analysis of growing-season Landsat imagery and updated annually on Global Forest Watch. Forest loss was identified using a decision-tree classification based on time-series spectral metrics derived from Landsat observations, while the year of forest loss was determined using the maximum annual decline in tree cover together with the maximum annual decline in growing-season Normalized Difference Vegetation Index (NDVI)."

Comment 5: L90-91: It might be useful to provide a 2-3 word example for each deforestation driver.

Response: Thank you for this helpful suggestion. We have added brief examples for each deforestation driver to improve clarity in Sect. 2.1.2.

The revised Section 2.1.2 on Lines 102-104, Page 4 now reads:

"Deforestation drivers were classified following Curtis et al. (2018) into five major categories: commodity-driven deforestation (e.g., commercial agriculture), shifting agriculture (e.g., shifting cultivation), forestry (e.g., timber harvesting), wildfire (e.g., forest fires), and urbanization (e.g., urban expansion)."

Comment 6: L82-102: Since this study presents a gridded dataset at a 1 km resolution, please expand on how the other datasets outlined in the methods were re-gridded to the 1 km resolution, if applicable (i.e., tables do not need re-gridding, but rasters do). If re-gridding was not performed, please explain why.

Response: Thank you for this helpful suggestion. We have added further details in Sect. 2.1.2 to clarify the spatial harmonization of raster datasets. Specifically, coarser-resolution raster datasets were spatially aligned to the 30 m analysis grid for pixel-level calculations, and the resulting deforestation emissions footprints were subsequently aggregated to the final 1 km gridded dataset.

The revised Section 2.1.2 on Lines 113-116, Page 5 now reads:

"All spatial analyses were conducted on a common 30 m grid. Coarser-resolution raster datasets were aligned to the 30 m analysis grid before spatial allocation and related calculations. The resulting deforestation emissions footprints were subsequently aggregated to 1 km grid cells by summing the constituent 30 m pixels, yielding the final 1 km gridded dataset provided in this study."

Comment 7: Figure 2: It's interesting that Latin America exhibits a pronounced increase in their deforestation emission footprint following 2014. It might be interesting to briefly expand on why this happened.

Response: Thank you for this helpful suggestion. We have added a brief explanation in the Results section to clarify the pronounced peak in Latin America in 2016, highlighting the dominant contribution of Brazil and the increase in its production-based deforestation emissions.

The revised Section 3.1 on Lines 209-212, Page 8 now reads:

"The pronounced peak in Latin America in 2016 was predominantly driven by Brazil, where forest loss and production-based deforestation emissions increased substantially. As most of Brazil's consumption-based deforestation emissions were associated with domestic final demand, the increase in its production-based emissions was also reflected in the regional consumption-based footprint."

Comment 8: Make sure all maps have latitude and longitude coordinates.

Response: Thank you for this suggestion. We have added latitude and longitude coordinates to the global maps in the revised Figures 3 and 7. In addition, the coordinates of the sample-window centers have been included in the captions of the regional example maps (Figures 4 and 7).

The revised Figure 3 on Lines 254-259, Page 12 now reads:

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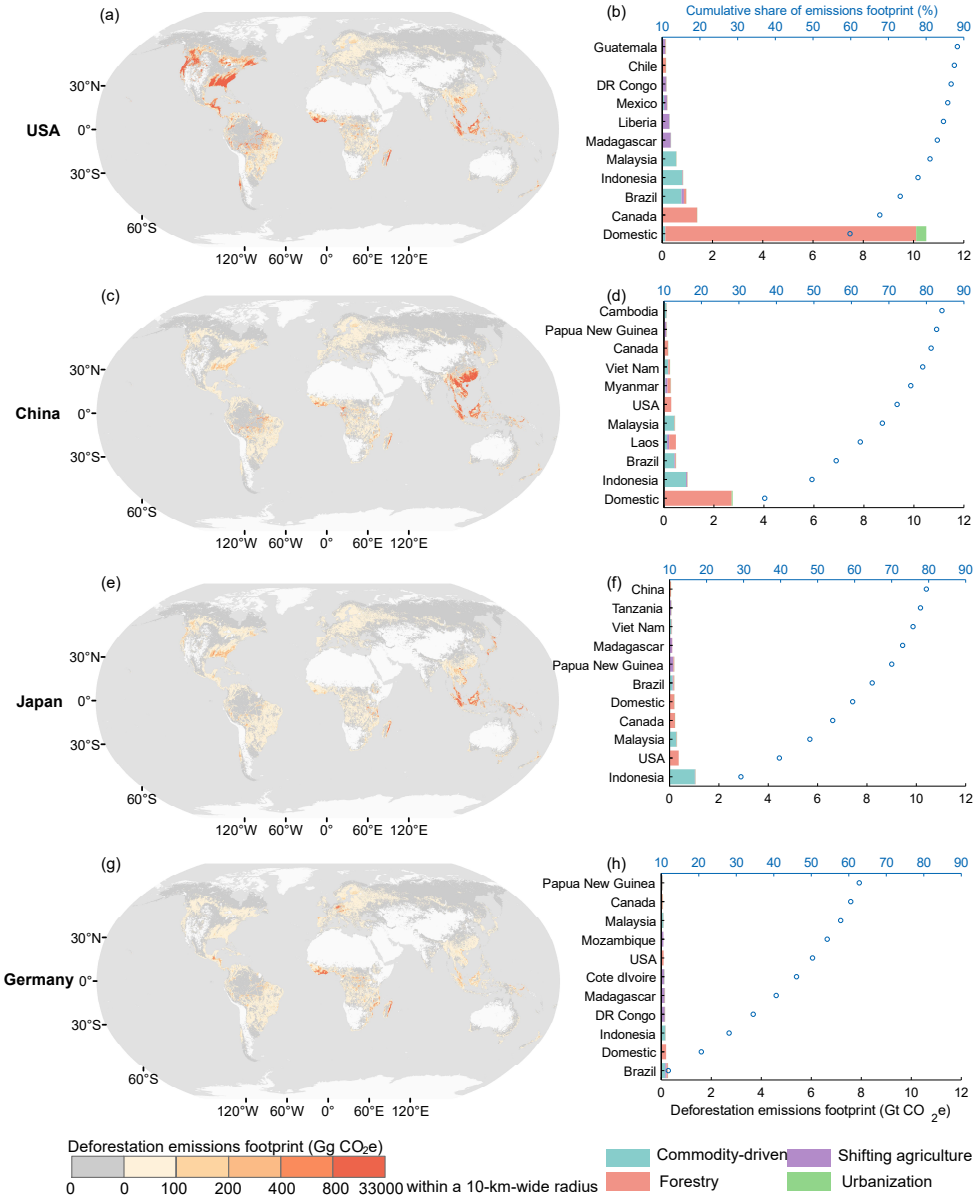


Figure 3. Spatial patterns and source contributions of cumulative consumption-based deforestation emissions footprints for major net-importing countries, 2001–2020. (a), (c), (e), and (g) Global distribution of cumulative deforestation emissions footprints for the United States, China, Japan, and Germany, respectively. (b), (d), (f), and (h) Contributions of domestic and major foreign source countries and deforestation drivers to the cumulative footprints of the four countries. Blue points indicate the cumulative share of total footprint.”

The revised Figure 4 on Lines 273-279, Page 13 now reads:

“Figure 4. Regional examples of consumption-based deforestation emissions (Gg CO_2e) at 1 km resolution. Panels (a–c) show cumulative emissions attributable to U.S. final consumption within a 25 km × 25 km sample window in the Amazon Basin (centered at 9.58° S, 63.26° W) from 2001 to 2020, along with high-resolution Google Earth imagery in 2001 and 2020. Panels (d–f) and (g-i) present the corresponding results for the 25 km × 25 km sample windows in Southeast Asia (centered at 12.18° N, 106.77° E) and West Africa (centered at 7.30° N, 3.15° W). Second column: 2001 imagery; third column: 2020 imagery. Satellite imagery © 2001, 2020 Landsat / Copernicus, Map data © 2001, 2020 Google.”

The revised Figure 7 on Lines 322-325, Page 16 now reads:

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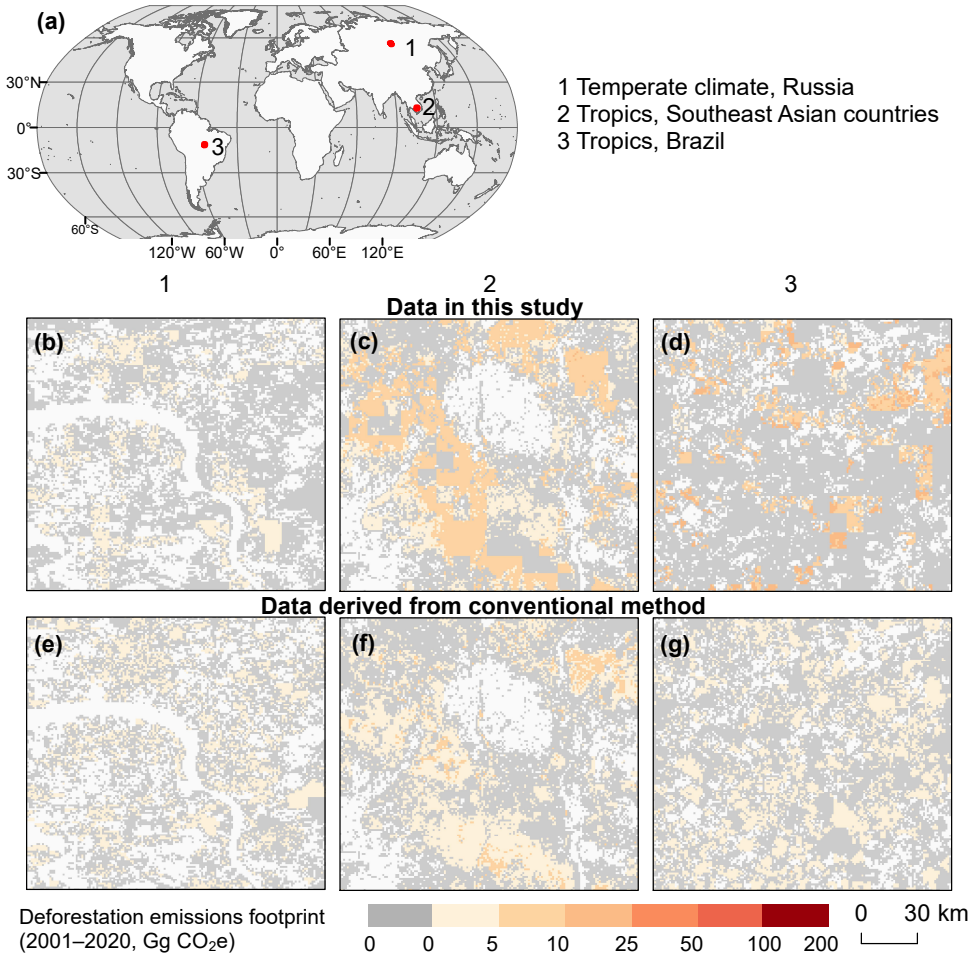


Figure 7. Spatial distribution of deforestation emission footprint hotspots from 2001–2020 derived from this study and from the conventional method. The three sample windows are centered at (1) 55.99°N, 102.90°E, (2) 12.98°N, 105.59°E, and (3) 11.30°S, 54.71°W.”

Comment 9: Grammatical suggestions:

Comment 9.1: L179-180: There is a typographical error. “Resulting” should be “resulted.”

Response: Thank you for pointing out this typo. We have corrected this error in the revised manuscript.

The revised Section 3.1 on Lines 201-202, Page 8 now reads:

"During this period, global deforestation resulted in total emissions of 124.5 Gt CO2e. Notably, 39.6 Gt CO2e of these emissions were embodied in trade……"

Comment 9.2: L186: The "R" in "Rest" should not be capitalized.

Response: Thank you for noting this issue. We have corrected the capitalization in the revised manuscript.

The revised Section 3.1 on Lines 208, Page 8 now reads:

"In contrast, Russia and the rest of East Asia exhibited relatively small interannual variability throughout the entire study period."

Comment 9.3: Figure 8: I recommend changing the title "My study" for Figures 8a and 8c to "This study," for consistency with the caption that says "this study." Additionally, in Figures 8c and 8d, make sure to put units in the legend.

Response: Thank you for this suggestion. We have changed "My study" to "This study" and added the corresponding units to the legends. The original Figure 8 has been renumbered as Figure 6 in the revised manuscript.

The revised Figure 6 on Lines 309-312, Page 15 now reads:

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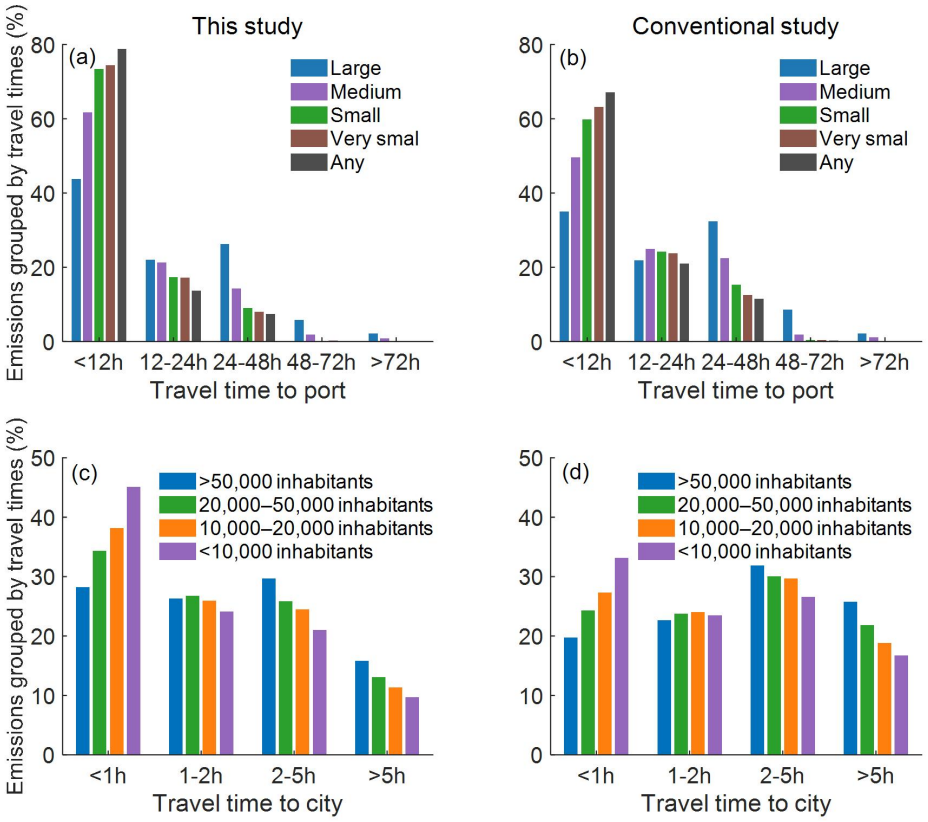
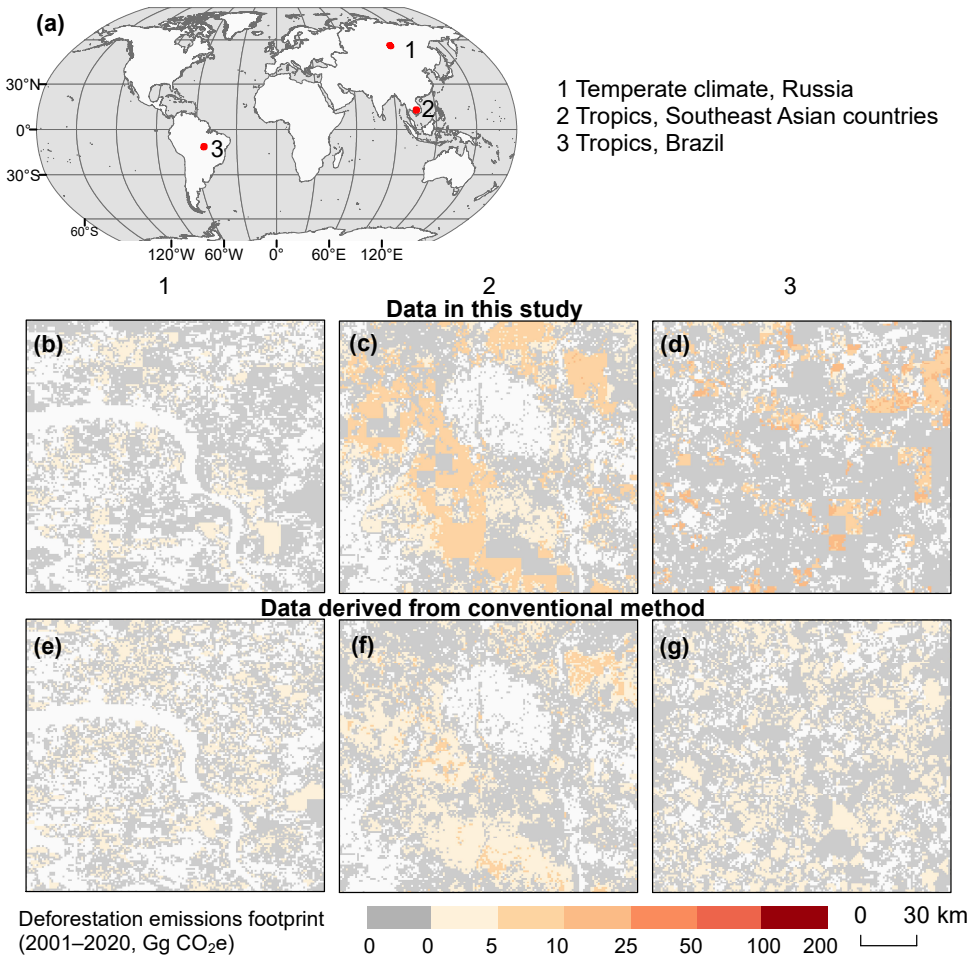


Figure 6. Proportion of export-driven deforestation emissions across accessibility zones. Accessibility is measured as travel time to ports (panel a–b) and cities of different population sizes (panel c–d). Panels (a) and (c): this study; panels (b) and (d): conventional methods.”

Comment 9.4: Figure 9: Same suggestion as for Figure 8, change the title for Figures 9b, 9c, and 9d to “This study” instead of “My study.”

Response: Thank you for this helpful suggestion. We have changed “My study” to “This study” in the corresponding figure titles. Following the reorganization of the figures, the original Figure 9 has been renumbered as Figure 7 in the revised manuscript.:

The revised Figure7 on Lines 322-325, Page 16 now reads:



“ Figure 7. Spatial distribution of deforestation emission footprint hotspots from 2001–2020 derived from this study and from the conventional method. The three sample windows are centered at (1) 55.99°N, 102.90°E, (2) 12.98°N, 105.59°E, and (3) 11.30°S, 54.71°W.”

Response to Anonymous Referee #2

General Comment: This is an important topic, and the dataset could be useful both for scientific research and for initiatives to reduce commodity-driven deforestation.

Response: We thank the reviewer for the positive and constructive comments on our work. We have carefully revised the manuscript in response to these comments and suggestions. Detailed responses are provided below.

Comment 1: Either more detail or examples are needed to effectively explain how deforestation emissions are allocated to exports vs. domestic production. It is clear that exports are assumed to be the more likely driver where deforestation patch sizes are larger and road density is higher. But it is not clear what fraction of deforestation emissions are assumed to be due to exports rather than production for domestic

markets. Alternatively, what fraction of exports are assumed to be immediately associated with deforestation? For example, in Brazil, beef, palm oil, and sugar can be produced in areas that were deforested in colonial times, that were just deforested last year, or any intermediate timing. So what fraction of these exports are assumed to be associated with deforestation emissions?

Response: Thank you for this important comment. We agree that the respective roles of the export-priority criteria and the MRIO framework required further clarification. We have revised the Methods section and Figure 1 to better illustrate the structure of the SMRIO framework. Specifically, we have clarified that the export-priority criteria are used only for spatial disaggregation within producing countries, whereas the allocation between domestic and foreign final demand is determined by the MRIO framework. We have also clarified that annual deforestation carbon emissions are treated as an environmental pressure associated with the production and trade system represented in the corresponding MRIO year. The framework therefore does not explicitly link individual commodities produced or exported in a given year to specific historical forest-clearing events. We have also clarified the temporal scope of this annual accounting approach in the Discussion section.

The revised Section 2 on Lines 58-71, Page 2-3 now reads:

"The SMRIO framework consists of three major steps: (1) national-level consumption-based deforestation emissions accounting based on MRIO analysis; (2) spatial disaggregation of these footprints to grid cells using export-priority criteria; and (3) spatial plausibility assessment of the resulting gridded dataset using accessibility-based criteria and comparisons with conventional allocation approaches. The key innovation lies in incorporating export-priority zones into the spatial disaggregation procedure, using deforestation patch size and road density to identify locations where deforestation is more likely to be associated with export-oriented production.

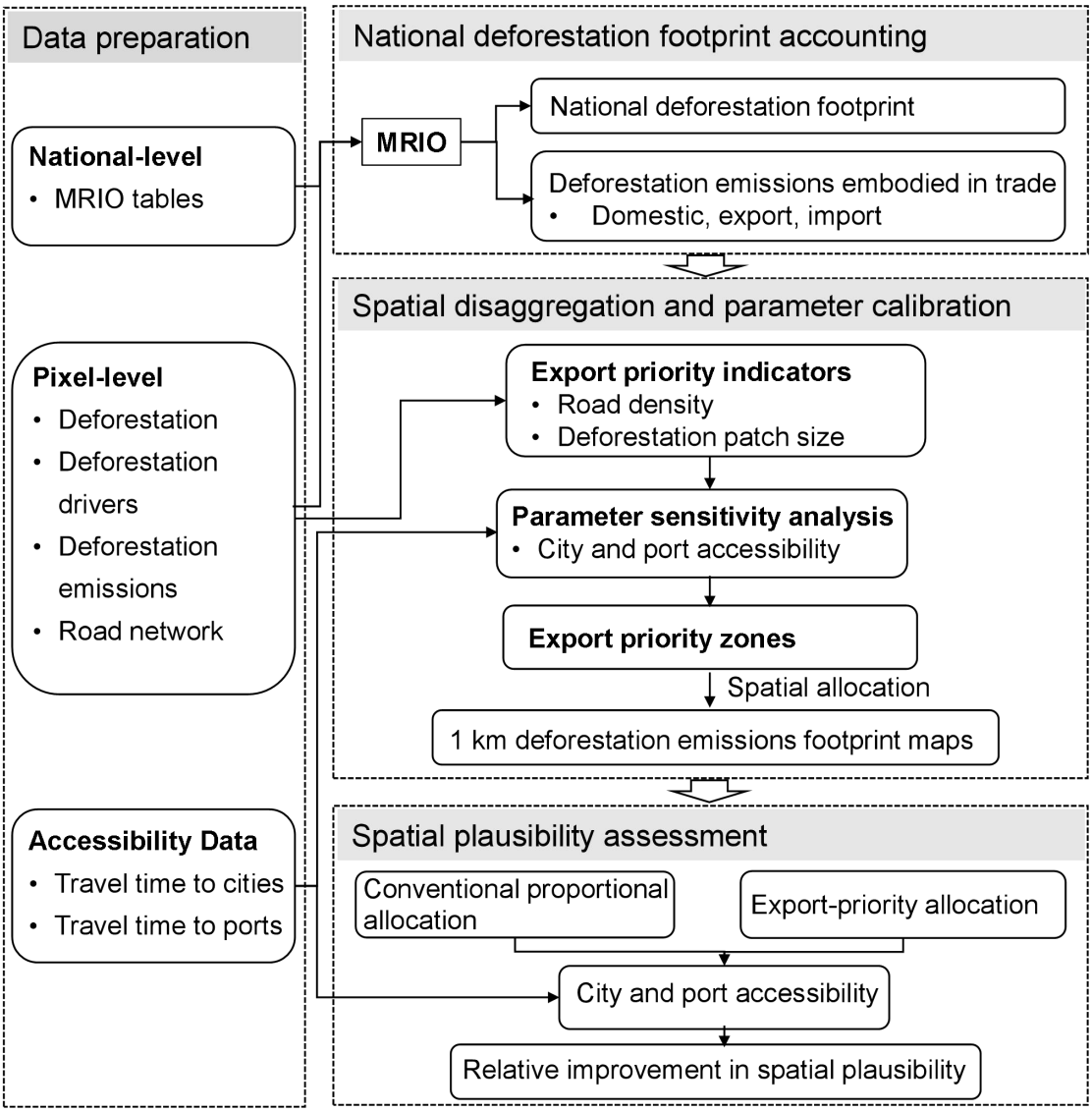


Figure 1. Overview of the SMRIO framework and data processing workflow for generating the global 1 km gridded consumption-based deforestation emissions footprint dataset. The workflow includes data preparation, national-level deforestation emissions accounting, spatial disaggregation, and spatial plausibility assessment, together with the corresponding data sources. Parameter calibration and sensitivity analysis were conducted during the spatial disaggregation stage based on spatial plausibility criteria."

The revised Section 2.2.1 on Lines 138-141, Page 6 now reads:

"The framework does not assume a direct temporal correspondence between deforestation occurring in a given year and commodities produced or exported in that same year. Instead, annual deforestation emissions are treated as an environmental pressure associated with the production and trade system represented in the corresponding MRIO year and attributed to final demand based on annual production–consumption linkages."

The revised Section 2.2.2 on Lines 145-148, Page 6 now reads:

"The allocation of deforestation emissions to domestic and foreign final demand is determined by the MRIO framework. Export-priority zones are used only to identify grid cells more likely to be associated with export-oriented production during spatial disaggregation within producing countries. The spatial allocation procedure is formulated as follows:"

The revised Section 4 on Lines 371-374, Page 18 now reads:

"The annual accounting approach used in this study does not explicitly capture temporal relationships between forest clearing and subsequent commodity production. Instead, annual deforestation emissions are attributed to final demand through the production–consumption linkages represented in the corresponding MRIO year."

Comment 2: As a minor technical point, Paragraph 25 reads "International trade remains the primary driver of deforestation, particularly through the expansion of commercial agriculture (Pendrill et al., 2019b; Pendrill et al., 2019a)." The following sentences suggest that international trade is better described as "a primary driver" rather than "the primary driver."

Response: Thank you for this helpful suggestion. We have revised "the primary driver" to "a primary driver" in the revised manuscript.

The revised Section 1 on Lines 25, Page 1 now reads:

"International trade remains a primary driver of deforestation, particularly through the expansion of commercial agriculture (Pendrill et al., 2019b; Pendrill et al., 2019a)."