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Supplementary information

The global deforestation footprint of agriculture and forestry

In the format provided by the authors and unedited

Supplementary Information for *The global deforestation footprint of agriculture and forestry*

Supplementary Note 1: Global footprint data comparisons

Footprint data from studies applying the land balance approach[1], DeDuCE model[2] and dominant drivers approach[3] (underpinning data provided by study authors) are compared with results displayed in the main text in Figures 1 and 3, and Table 1. Supplementary Table 1 and Supplementary Data 1 provide further description of the precise details of the model variants used in these comparisons. Note that because not all study-variants contain data on the trade and consumption of forestry products, results from the variants used in Figure 1, Figure 3 and Table 1 are those that *exclude* the impacts associated with forestry if these are included in the study's broader results. A comparison of the impacts of forest products is detailed in the '*Comparing footprint estimates*' section of the main text and in the *Supplementary Information: Forestry deforestation footprints* section. Comparisons require alignment of focal countries. The dominant driver study[3] is limited in its country coverage to countries of the G20 and other selected major countries, with some of these countries also only present in aggregated 'rest of world' regions in the land balance and DeDuCE studies. On the consumption-side, full consumption and hybridized full consumption approaches using land balance and DeDuCE data use EXIOBASE MRIO data that has coverage of individual EU countries and selected other major economies[2]. Overall, deforestation footprint results for eighteen common countries are available for comparison purposes.

Supplementary Table 1 | **Model variants and their shorthand names used within this paper's results, derived from studies that provide global deforestation footprint results.**

Variant	**Interpretation**
Land balance - Apparent consumption	Deforestation attribution data derived from the Pendrill et al. 2019 methods[4], later updated in Pendrill et al. 2022[1]. Attached to a physical trade model[5,6], to provide a measure of apparent consumption.
Land balance – Full consumption	Deforestation derived from the Pendrill et al. 2019 methods[4], later updated in Pendrill et al. 2022[1]. Attached to the EXIOBASEv3 monetary MRIO trade model[7], to provide a measure of full consumption.
Land balance – Hybridized full consumption	Deforestation derived from the Pendrill et al. 2019 methods[4], updated to Pendrill et al. 2022. Attached to the hybrid physical-monetary IOTA (MRIO) model[8] within the Global Environmental Impacts of Consumption (GEIC) indicator framework[9], to provide a measure of full consumption.
DeDuCE – Apparent consumption	Deforestation derived from Singh & Persson 2024 methods[10]. Attached to an updated physical trade model[2,5,11], to provide a measure of apparent consumption.
DeDuCE – Hybridized full consumption	Deforestation derived from Singh & Persson 2024 methods[10]. Attached to the hybrid physical-monetary IOTA (MRIO) model within the GEIC indicator framework[8,12], to provide a measure of full consumption.
Dominant drivers – Full consumption	Deforestation attribution derived from Hoang & Kanemoto 2021 methods[3] via application of dominant driver information[13], attached to the Eora monetary MRIO model[14], to provide a measure of full consumption.

In Figure 1, in the center of the diagram and for the inner ring, we provide splits of deforestation attributed to different drivers according to dominant driver data[13] (data used to provide this figure is an average over 2001-2022, sourced from GFW[15]). In the outer ring we provide splits between crop commodities and forest plantations from the DeDuCE dataset[2] – also for the period 2011-2022. The DeDuCE-derived ring is scaled to reflect the absolute amount of deforestation estimated by DeDuCE compared to the forest loss estimates derived from GFW. On the right of Figure 1, the percentage contribution of the five countries with the largest DeDuCE-derived hybridized full consumption footprint is shown, using identical data (agricultural commodities only) to that used in comparisons in Figure 3 and Table 1. Percentages from the EXIOBASE version of the Global Environmental Impacts of Consumption (GEIC) indicator for the year 2022 are shown[2]. Error bars in the bar chart then represent the variation observed from comparator studies in Table 1. Note that – as for Table 1 and for consistency – the percentages are contributions to the footprint across the eighteen comparator countries, rather than country-contributions to the total global footprint.

In Table 2, the total deforestation footprints are aligned for the 2005-2015 timeframe covered by all comparator studies to allow country-rankings for the common countries to be derived for an equivalent time period.

Supplementary Note 2: Vietnamese timber

Data in Figure 1, panel a is derived from FAO's records of timber production, import and export. Statistics cover Vietnamese production of sawnwood, plywood, veneer, particle board and fiberboard, wood pulps, chips and particles, charcoal and papers, with original units from FAOSTAT converted into roundwood equivalents using the conversion factors provided in the Supplementary Information of the original study[16]. Data in panel b is taken directly from Global Forest Watch[17] and DeDuCE[2], both for the year 2022, with DeDuCE's timber deforestation statistics derived from deforestation attributed to 'Forest plantations' (which only includes dedicated, and often intensively managed, tree plantations, but excludes timber harvesting in managed and natural forests). Data in panel c is taken from the Global Environmental Impacts of Consumption dashboard[18]. Here, we provide 'Industrial roundwood' footprint data from the GTAP[19] MRIO version of the deforestation footprint indicator, which remains underpinned by the deforestation attribution methods of DeDuCE) for the 'Industrial roundwood' commodity. The GTAP version of the indicator is used as opposed to the EXIOBASE version as the formers contains Vietnam as a specific country whereas in the EXIOBASE version Vietnam is aggregated alongside other countries in a 'Rest of World Asia and Pacific' region. Use of the GTAP version limits timestamps to 2007, 2011, 2014 and 2017.

Previous analysis[16] highlighted that successes in promoting regrowth of Vietnam's forests between 1987 and 2006 had been offset by the displacement of forest extraction to other countries. Deforestation data indicates that, despite official statistics[20] indicating that Vietnam's forest area has continued increasing since the 2000s, primary forest area (from Global Forest Watch[21]) is declining as tree cover loss increases, with estimates of permanent deforestation (data from DeDuCE[2]) sitting below total tree cover loss but also increasing due to forestry and other activities. According to data from the hybridized full-consumption deforestation footprint model, Vietnam's production-linked timber deforestation has increased markedly with an increasing share of this production driven by overseas demand. Vietnam's timber-linked deforestation footprint is comparatively lower (but increasing) from a consumption perspective (this perspective accounts for domestic production and overseas production that is linked to Vietnam's consumption) and is dominated by its domestic production activities. Overall, these trends conclude that despite reforestation efforts, Vietnam has a significant and growing deforestation footprint linked to its domestic and overseas timber demand

Supplementary Note 3: Comparisons to regional studies

A regional study by Bausano et al. 2023[22] links palm oil production in Indonesia, Malaysia and Papua New Guinea to selected EU destinations (using an apparent consumption approach which differs to that, for example, of methods linked to the land balance[1] and DeDuCE[2] approaches) and provides three sets of results using different deforestation footprint methods. Their 'concession' approach is based on estimates of annual deforestation intensity, derived from localized studies, that were multiplied by land requirements within active palm oil concessions. A 'historical' approach uses a long-time series (from 1989) estimate of total historical deforestation in the regions linked to palm oil, whereas the 'rapid' approach uses a shorter timeframe capturing deforestation in a period five-years prior to the start of palm oil production. Results for focal countries of consumption are summarised in Supplementary Table 2. The authors state that the concession-based approach is not comparable to other methods. We provide comparisons to the data provided by the apparent consumption version of

DeDuCE[2], averaged over the period 2005-2020 and 2020 estimates only. Except for Germany, the 2005-2020 average estimates of DeDuCE are lower than the ‘historical’ estimates of Bausano et al. 2023[22] which reflects the fact that a shorter allocation period is utilised. However, both these estimates are much higher than the estimates focusing on the more recent past - the ‘rapid approach’ of Bausano et al. 2023 and the 2020 results of DeDuCE – reflecting the fact that deforestation for palm oil plantations has decreased rapidly in recent years. However, despite both attempting to capture deforestation over similar time-horizons (a five-year amortization period is also used within DeDuCE), there are still substantial differences in the estimated deforestation footprints for France and Germany.

Supplementary Table 2 | **Comparison of deforestation footprint results from Bausano et al. 2023[22] with those of the DeDuCE ‘apparent consumption’ results[2].**

	Italy	**France**	**Germany**	**Spain**
Concession deforestation (annual)	515	318	721	382
Historical embodied deforestation (annual)	15214	7450	13396	17076
Rapid' embodied deforestation (annual)	3200	1527	2746	3500
DeDuCE apparent consumption (2005-2020 average)	12925	4723	14928	12446
DeDuCE apparent consumption (2020 only)	3,467	949	1,308	4,152
DeDuCE average (2005-2020) compared to historical approach	85%	63%	111%	73%
DeDuCE 2020 compared to rapid approach	108%	62%	48%	119%

In Figure 4 of the main text, estimates of deforestation-linked emissions are compared between the DeDuCE ‘hybridized full consumption’ data[2] and Figure 2 of Karstenson et al 2013[23] (with plot digitisation used to extract the appropriate values from this figure). To align datasets, certain countries and regions of consumption captured within the DeDuCE dataset had to be assigned to regions provided in the Karstenson et al 2013 paper. EU countries plus Switzerland, Norway, UK and ‘RoW Europe’ are assigned to the ‘Europe’ region. United States, Mexico and Canada are assigned to the ‘North and Central America’ region. Japan, Russia, Turkey, Taiwan, China, South Korea, Indonesia, and the ‘RoW Asia and Pacific’ and ‘RoW Middle East’ regions have been assigned to 'Asia'. South Africa and the ‘RoW Africa’ region have been assigned to ‘Africa’. Australia has been assigned to ‘Oceania’. The ‘RoW America’ region has been assigned to ‘South America’.

Lower panels in Figure 4 of the main text show that the distribution of the total deforestation footprint across consumer regions is quite similar, with beef predominately being consumed domestically and the three major soybean consumption regions being Brazil, Asia, and Europe. However, as per the top panels, there are large differences in the absolute amount of deforestation attributed to beef and soy production between the studies, with the earlier study attributing almost half as much deforestation to beef, and instead more to soybeans. This is explained by the approach taken for attributing deforestation emissions to land-uses in the earlier study. A ‘legacy’ approach is adopted whereby emissions resulting from biomass decay following deforestation are attributed to production on the deforested land year-by-year. This contrasts with the later study which adopts a more commonly applied ‘committed emissions’ approach, where all impacts over time are allocated to the land-use that first replace forests. Furthermore, the earlier study adopts differing assumptions around land-use dynamics where cropland—assumed to be soybean cultivation—accounts for a large share of the land-use in the years directly following deforestation, but then is replaced by pastures. This leads to much of the emissions being attributed to soybean cultivation. Empirical data[24,25], however, suggest land-use dynamics to be rather the opposite, with pasture being the dominant proximate driver and soybeans then expanding on pastures over time.

Supplementary Note 4: EU footprint comparison

Cuypers et al. 2013[26] included full consumption results derived from the use of the GTAP MRIO model. Underpinning data was provided, via personal communication, for the year 2004; available for the EU27 as an aggregated group. Given the relative age of this dataset in comparison with more contemporary studies, and the lack of country-specific information, these data are not included in the main Review. However, in Supplementary Table 3, results are compared against those studies that allow aggregation of countries to the EU27, for the closest comparable year (2005). Cuypers et al. 2013 results indicate a somewhat higher estimate of deforestation for the EU27, and the globe, compared to other studies. The share of the EU27 compared to global deforestation is comparable to results obtained from hybridized full consumption studies, with others indicating a somewhat lower EU27 share of the global footprint.

Supplementary Table 3. Comparison between Cuypers et al. 2013 full consumption (GTAP) results and those of other studies for aggregated EU27 countries*. For comparison purposes, results exclude forestry deforestation where present in underpinning datasets.

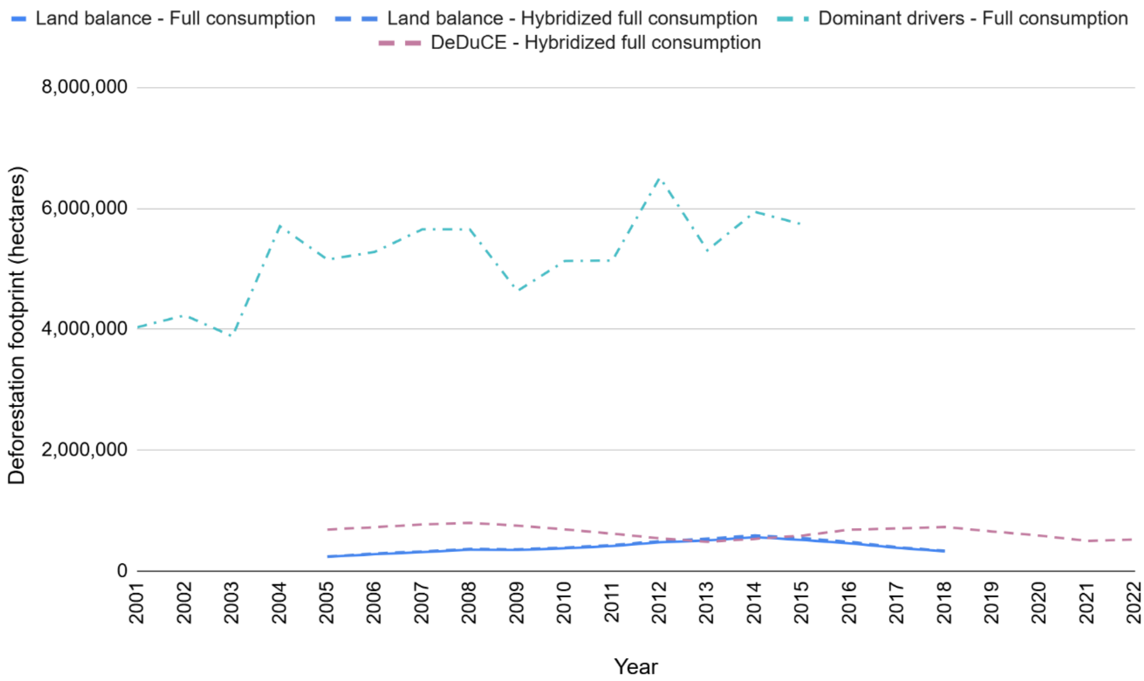
Study	Reference year	EU27 Deforestation Footprint (ha)	Global Deforestation Footprint (ha)	EU27 percentage of global total
Cuypers et al. 2013 – Full consumption	2004	705,961	7,011,386	10.1
Land balance – Apparent consumption	2005	344,762	4,680,534	7.4
Land balance – Full consumption	2005	381,906	4,858,328	7.9
Land balance – Hybridized full consumption	2005	486,398	5,233,871	9.3
DeDuCE – Apparent consumption	2005	357,941	4,624,889	7.7
DeDuCE – Hybridized full consumption	2005	472,775	4,746,124	10.0

*EU27 countries in 2013; including the UK but excluding Croatia. For DeDuCE – Hybridized full consumption, results for the UK are bundled with the 'RoW Europe' regional aggregation, i.e. individual results for the UK are not available in the specific dataset used[2]; these results are therefore inflated slightly compared to those of the true EU27.

Supplementary Note 5: Forestry deforestation footprints

Supplementary Figure 1 shows the estimated deforestation footprint associated with forestry where this information is available from the underpinning global datasets included in this Review. The estimates associated with the dominant drivers[3] dataset - capturing all forest loss, including in planted and managed forests, even where this does not constitute deforestation - are substantially higher than those obtained from results using the land balance[1] or DeDuCE[2] deforestation attribution estimates, which solely capture deforestation due to the expansion of dedicated tree plantations (and not clearing of natural forests for timber, which according to some definitions also classify as deforestation). Please refer to the main text of the Review for further explanation of these differences.

Supplementary Figure 1. Deforestation footprint associated with forestry.



Supplementary Note 6: Comparisons of domestic versus exported consumption

Table 2 provides data from two studies that provide estimates of the percentage of deforestation occurring within a country that is consumed domestically versus exported. The Mittempergher et al 2023[27] study apportions estimates of national deforestation derived from FAO 2020 FRA[28] data to broad economic sectors in a manner that is comparable with the 'dominant drivers' study but with distributions based on information from other studies[29,30] rather than that provided by Curtis et al. 2018[13]. The Mittempergher et al. 2023[27] study does not provide the underpinning data directly, so we extract values from their published figures ('Graphique 2a' in the report) using plot digitization. Deforestation estimates and percentages exported are then compared with the DeDuCE 'hybridized full consumption' dataset using the GTAP version of the consumption model[18] (see *Supplementary Information: Vietnamese timber* for additional explanation of this variant).

Supplementary Note 7: Agricultural commodity footprint comparison

Supplementary Table 4 shows the agricultural commodity-specific deforestation footprint associated with common countries analysed in this Review (the same countries uses in Figure 3 and Table 1 of the main text), illustrating that – while similar key crops are identified across studies using different attribution and consumption approaches – different model assumptions can affect their perceived importance as deforestation drivers. For example, cassava ranks highly in full consumption-derived results but does not appear as high in apparent consumption results. This highlights the importance of understanding the differences between the apparent or full consumption approaches offered by studies. Specifically, in the case of cassava, relatively small volumes are exported from producing regions with the highest deforestation footprints (although exports can be high from countries such as Thailand or Vietnam which have lower deforestation associated with production[18,20]). Instead, in these regions, will enter local economies and then the resultant outputs from these economies, including products not physically containing cassava, may be exported. The cassava footprint will then form a component of a downstream country's footprint because there is embedded use of this material in the producing-country's economy (for example within meals for workers, or for animal feed[31] or biofuels[32]). The 'directness' of supply chains has implications for policy; for example, trade-linked policies is likely insufficient for cassava-linked deforestation, and a broader set of policy measures is therefore required to tackle its generally more domestically-driven expansion[33,34]. Across studies there are also several commodities that appear in the top fifteen agricultural drivers but are not typically the focus of deforestation-linked policy discussions. These include high-value products such as cashew nuts, staples such as rice, cassava and wheat, and other important crops such as beans and sugarcane.

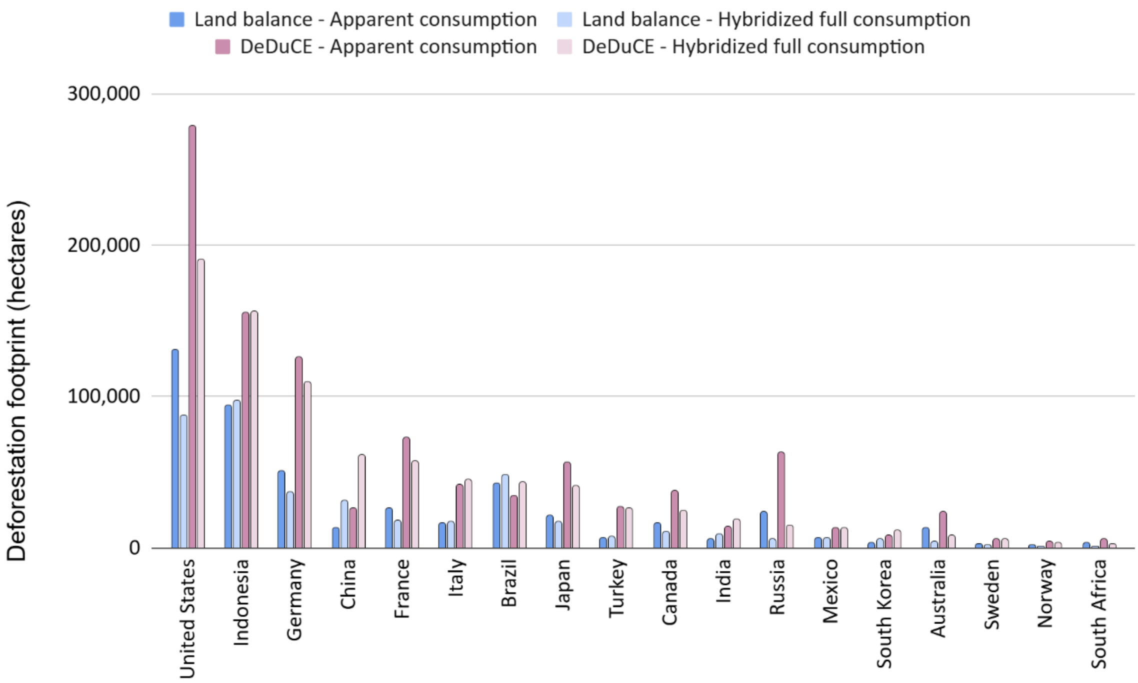
The presence of alternative commodity-specific estimates of deforestation footprint also has implications for decision makers in terms of understanding their respective responsibilities. Exploring country-level results for cocoa (Supplementary Figure 2), for example, reveals that for the US, Germany and France, the apparent consumption footprint (using both DeDucE[2] and land balance[1] estimates) is higher than the full consumption footprint. This reflects the fact that imports into these countries are processed into more complex chocolate products before being exported for consumption elsewhere.

Supplementary Table 4 | **Top fifteen agricultural commodities (plus 'other' agricultural commodities, aggregated) contributing to the deforestation footprint of common countries** (same countries considered as in Figure 3 and Table 1, main text). Summed deforestation between 2005-2018.

	Land balance – apparent consumption		**Land balance – hybridized full consumption**		**DeDuCE – apparent consumption**		**DeDuCE – hybridized full consumption**	
Rank	*Commodity*	*Deforestation (hectares)*	*Commodity*	*Deforestation (hectares)*	*Commodity*	*Deforestation (hectares)*	*Commodity*	*Deforestation (hectares)*
1	Meat (cattle and buffalo)	16,273,120	Meat (cattle and buffalo)*	18,235,250	Meat (cattle and buffalo)	20,590,410	Meat (cattle and buffalo)*	22,252,280
2	Oil palm fruit	4,155,522	Oil palm fruit	3,858,812	Oil palm fruit	5,979,976	Oil palm fruit	5,651,872
3	Soybeans	3,027,382	Soybeans	3,280,216	Soybeans	2,480,715	Soybeans	2,790,072
4	Maize	1,521,909	Maize	1,719,494	Natural rubber	1,997,805	Natural rubber	1,739,970
5	Rice, paddy	1,228,263	Rice, paddy	1,481,690	Maize	1,256,257	Maize	1,557,577
6	Cocoa beans	478,159	Cassava	476,750	Cocoa beans	995,969	Rice	938,407
7	Natural rubber	467,469	Beans, dry	459,789	Sugar cane	509,869	Cocoa beans	832,296
8	Seed cotton	464,520	Seed cotton	444,895	Rice	506,730	Sugar cane	536,177
9	Beans, dry	379,783	Rubber, natural	413,516	Coffee, green	289,900	Cassava	456,311
10	Coffee, green	275,118	Cocoa, beans	408,014	Coconuts	266,482	Beans, dry	321,285
11	Roots and tubers	261,594	Coffee, green	271,850	Cashew nuts	239,361	Coffee, green	303,135
12	Cassava	260,128	Sugar cane	255,151	Wheat	226,171	Coconuts	284,499
13	Wheat	208,722	Cashew nuts,	245,113	Beans, dry	213,783	Wheat	256,831
14	Sugar raw centrifugal	182,659	Wheat	241,917	Seed cotton	154,141	Cashew nuts	238,060
15	Rapeseed	131,054	Rapeseed	142,316	Cloves	153,927	Groundnuts	172,200
	Other	1,434,990	Other	2,029,909	Other	2,191,453	Other	3,119,899

*plus associated co-products for studies using the hybridized full consumption approach

Supplementary Figure 2. Cocoa deforestation footprints for selected countries. Results (summed for the period 2005-2018) are ordered by total footprint according to the DeDuCE hybridized full consumption dataset. Deforestation estimates associated with apparent consumption of cocoa in countries such as Germany and the United States are markedly higher than their respective full consumption estimates, indicating that these countries are important exporters of chocolate-based products as well as being important consumers in their own right.



Supplementary Note 8: Comparisons to fine-scale studies

Supplementary Table 5 provides comparisons between deforestation attributed to agricultural commodities from fine-scale studies and equivalent estimates from the DeDuCE. These studies adopt different data sources to derive their deforestation estimates, and different assumptions are then used to attribute deforestation to focal commodities. Aggregation of DeDuCE data across years within Supplementary Table 5, to increase data-alignment for comparison purposes, should therefore be seen as illustrative rather than directly equivalent. However, comparisons reiterate the potential for the underpinning data choices to change – sometimes substantially – impact estimates.

Supplementary Table 5 | **Selected fine-scale commodity-specific studies and comparisons with estimates derived from DeDuCE[2].**

Source methodology	**Commodity & Country of Production**	**Deforestation estimate (total, year(s))**	**Comparative DeDuCE deforestation estimate (unamortized)**	**Methods notes**
Trase[35,36]	Cocoa, Cote D'Ivoire	1,452,227 ha, 2021	675,826 ha, (2007-2021)	Trase uses a 4-year lag between cocoa planting and the first harvest and aggregated deforestation at the location of cocoa production across 15 years. For comparison purposes, unamortized data from DeDuCE is summed over 2007-2021
Trase[37]	Soy, Paraguay	41,439 ha, 2019	39,945 ha, (2015-2019)	Trase uses a 1-year lag between forest loss and soy harvest and aggregated deforestation at the location of soy production across 5 years. For comparison purposes, unamortized data from DeDuCE is summed over the period 2015-2019
Trase[38]	Soy, Brazil	416,578 ha, 2020	603,340 ha, (2016-2020)	Trase uses a 1-year lag between forest loss and soy harvest and aggregated deforestation at the location of soy production across 5 years. For comparison purposes, unamortized data from DeDuCE is summed over the period 2016-2020
Trase[39,40]	Beef, Brazil	948,667 ha, 2020	1,289,948 ha, 2020 (pasture-linked deforestation)	For cattle, Trase uses the average pasture-linked deforestation from the previous 5 years, divided by the average production in the same municipality over the same time period. Trase also accounts for five years of pasture deforestation overall, assuming that animals are fed for five years before being slaughtered.
TRACAST[41]	Avocado, Mexico	14,614 ha, between 2001 and 2017	10,671 ha, between 2001 and 2017	20% of total deforestation in Michoacán State is linked to deforestation (based on identification of avocado plantations from Landsat and cross-referencing with GFW data. Note that DeDuCE, in contrast, covers the whole of Mexico.
TRACAST[42]	Rubber, Sri Lanka	19,600 ha, between 2006 and 2016	3,901 ha, between 2006 and 2016	Study covers ten districts in Sri Lanka. DeDuCE, in contrast, covers the whole of Sri Lanka.
TRACAST[43]	Palm Oil, Guatemala	24,609 ha, between 2009 and 2019.	64,696 ha, between 2009 and 2019.	Study covers 54,000km^2 across three departments responsible for 75% of Guatemala's palm oil production. DeDuCE, in contrast, covers the whole of Guatemala.

In the main text we provide estimates for China's deforestation footprint derived from Trase. Providing further example of the potential for rather extreme differences in estimates to arise between studies, Trase estimates that in 2021 alone, the US - via its direct imports only - was associated with 224,452 ha of deforestation linked to cocoa in Côte d'Ivoire[44]. The footprint of the Netherlands is even higher at 347,908 ha. This compares with apparent consumption estimates for cocoa from DeDuCE[2] for 2021 from *all* source countries of 21,322 ha and 4,344 ha respectively. The different trade perspective (direct trade vs. re-export adjusted apparent consumption) is not sufficient to explain such stark differences in footprint estimates. Instead, a combination of a lack of amortization in Trase (production-linked deforestation estimates are based on the total deforestation that occurs within a specified time-window, rather than amortizing across years of production as per DeDuCE and different underpinning tree loss datasets generate these differences.

In the main text we provide an estimate of the deforestation linked to Mexican avocado production that can be linked to exports to the US. The TRACAST-based study[41] doesn't provide this estimate directly, so we derive this from statistics provided in the paper. The Supplementary Information of the paper provides estimates of the mass of 2018 exports of avocados by twenty traders, which totals 381,874 tonnes. The authors state that this makes up 75% of exports, so total exports to the US are thus estimated at 509,165 tonnes. Total production of avocados in 2018 is stated by the authors at 1,674,855 tonnes, and thus ~30% of production is destined for US-export. The authors estimate that 14,614 ha of deforestation are associated with avocado production between 2001 and 2017 (Supplementary Table 5). This results in an average rate per year of 859.6 ha, meaning that the US-driven estimate can be derived as 261.3 ha per year.

Supplementary References

1. Pendrill, F., Persson, U. M., Kastner, T. & Wood, R. Deforestation risk embodied in production and consumption of agricultural and forestry commodities 2005-2018. Zenodo https://doi.org/10.5281/zenodo.5886600 (2022).
2. Singh, C., Persson, U. M., Croft, S., Kastner, T. & West, C. D. Commodity-driven deforestation, associated carbon emissions and trade 2001-2022. Zenodo https://doi.org/10.5281/zenodo.10633818 (2024).
3. Hoang, N. T. & Kanemoto, K. Mapping the deforestation footprint of nations reveals growing threat to tropical forests. *Nat. Ecol. Evol.* **5**, 845–853 (2021).
4. Pendrill, F. *et al.* Agricultural and forestry trade drives large share of tropical deforestation emissions. *Glob. Environ. Change* **56**, 1–10 (2019).
5. Kastner, T., Kastner, M. & Nonhebel, S. Tracing distant environmental impacts of agricultural products from a consumer perspective. *Ecol. Econ.* **70**, 1032–1040 (2011).
6. Kastner, T., Erb, K.-H. & Haberl, H. Rapid growth in agricultural trade: effects on global area efficiency and the role of management. *Environ. Res. Lett.* **9**, 034015 (2014).

7. Stadler, K. *et al*. EXIOBASE 3: Developing a Time Series of Detailed Environmentally Extended Multi-Regional Input-Output Tables. *J. Ind. Ecol.* **22**, 502–515 (2018).
8. Croft, S. A., West, C. D. & Green, J. M. H. Capturing the heterogeneity of sub-national production in global trade flows. *J. Clean. Prod.* **203**, 1106–1118 (2018).
9. Croft, S. *et al. Technical Documentation for an Experimental Statistic Estimating the Global Environmental Impacts of UK Consumption*. https://webarchive.nationalarchives.gov.uk/ukgwa/20220901105721mp_/https://data.jncc.gov.uk/data/91efc19d-f675-426f-9333-ed0195cc729d/JNCC-Report-695-FINAL-WEB.pdf (2021).
10. Singh, C. & Persson, U. M. Global patterns of commodity-driven deforestation and associated carbon emissions. *Earth ArXiV Pre-Print* (2024) doi:https://doi.org/10.31223/X5T69B.
11. Schwarzmueller, F. & Kastner, T. Agricultural trade and its impacts on cropland use and the global loss of species habitat. *Sustain. Sci.* **17**, 2363–2377 (2022).
12. Croft, S. *et al. Technical Documentation for an Official Statistic in Development Estimating the Global Environmental Impacts of Consumption: 2023 Version*. https://data.jncc.gov.uk/data/7a4063c9-a221-4ca1-ab6a-3b2fae544b32/jncc-report-746.pdf (2023).
13. Curtis, P. G., Slay, C. M., Harris, N. L., Tyukavina, A. & Hansen, M. C. Classifying drivers of global forest loss. *Science* **361**, 1108–1111 (2018).
14. Lenzen, M., Moran, D., Kanemoto, K. & Geschke, A. Building eora: a global multi-region input–output database at high country and sector resolution. *Econ. Syst. Res.* **25**, 20–49 (2013).
15. Global Forest Watch. Tree Cover Loss by Dominant Driver 2023. https://data.globalforestwatch.org/documents/ff304784a9f04ac4a45a40f60bae5b26 (2024).
16. Meyfroidt, P. & Lambin, E. F. Forest transition in Vietnam and displacement of deforestation abroad. *Proc. Natl. Acad. Sci.* **106**, 16139–16144 (2009).
17. Global Forest Watch. Tree Cover Loss. https://data.globalforestwatch.org/documents/gfw::tree-cover-loss/explore (2024).
18. JNCC & SEI. The Global Environmental Impacts of Consumption (GEIC) Indicator. https://commodityfootprints.earth/ (2024).

19. Andrew, R. M. & Peters, G. P. A Multi-Region Input–Output Table Based on the Global Trade Analysis Project Database (GTAP-MRIO). *Econ. Syst. Res.* **25**, 99–121 (2013).

20. UN FAO. FAOStat Database. https://www.fao.org/faostat/en/#data (2024).

21. Global Forest Watch. Vietnam Deforestation Rates & Statistics. https://www.globalforestwatch.org/dashboards/country/VNM?category=undefined (2024).

22. Bausano, G., Masiero, M., Migliavacca, M., Pettenella, D. & Rougieux, P. Food, biofuels or cosmetics? Land-use, deforestation and CO2 emissions embodied in the palm oil consumption of four European countries: a biophysical accounting approach. *Agric. Food Econ.* **11**, 35 (2023).

23. Karstensen, J., Peters, G. P. & Andrew, R. M. Attribution of CO2 emissions from Brazilian deforestation to consumers between 1990 and 2010. *Environ. Res. Lett.* **8**, 024005 (2013).

24. Arima, E. Y., Richards, P., Walker, R. & Caldas, M. M. Statistical confirmation of indirect land use change in the Brazilian Amazon. *Environ. Res. Lett.* **6**, 024010 (2011).

25. Richards, P. D., Walker, R. T. & Arima, E. Y. Spatially complex land change: The Indirect effect of Brazil's agricultural sector on land use in Amazonia. *Glob. Environ. Change Hum. Policy Dimens.* **29**, 1–9 (2014).

26. Cuypers, D. *et al. The Impact of EU Consumption on Deforestation: Comprehensive Analysis of the Impact of EU Consumption on Deforestation*. https://pure.iiasa.ac.at/id/eprint/14868/1/1.%20Report%20analysis%20of%20impact.pdf (2013).

27. Mittempergher, D., Vergez, A. & Puydarrieux, P. Commerce international et déforestation : méthode et calcul d'une empreinte déforestation des nations. *Rev. Déconomie Dév.* **33**, 5–53 (2023).

28. UN FAO. *Global Forest Resources Assessment 2020*. https://openknowledge.fao.org/handle/20.500.14283/ca9825en (2020).

29. Hosonuma, N. *et al.* An assessment of deforestation and forest degradation drivers in developing countries. *Environ. Res. Lett.* **7**, 044009 (2012).

30. Sy, V. D. *et al.* Land use patterns and related carbon losses following deforestation in South America. *Environ. Res. Lett.* **10**, 124004 (2015).

31. Bizzuti, B. E. *et al.* Potential use of cassava by-product as ruminant feed. *Trop. Anim. Health Prod.* **53**, 108 (2021).

32. Fathima, A. A., Sanitha, M., Tripathi, L. & Muiruri, S. Cassava (Manihot esculenta) dual use for food and bioenergy: A review. *Food Energy Secur.* **12**, e380 (2023).

33. Jayathilake, H. M., Prescott, G. W., Carrasco, L. R., Rao, M. & Symes, W. S. Drivers of deforestation and degradation for 28 tropical conservation landscapes. *Ambio* **50**, 215–228 (2021).

34. Ordway, E. M., Asner, G. P. & Lambin, E. F. Deforestation risk due to commodity crop expansion in sub-Saharan Africa. *Environ. Res. Lett.* **12**, 044015 (2017).

35. Renier, C. *et al.* Transparency, traceability and deforestation in the Ivorian cocoa supply chain. *Environ. Res. Lett.* **18**, 024030 (2023).

36. Trase. *SEI-PCS Côte d'Ivoire Cocoa v1.1 Supply Chain Map: Data Sources and Methods*. https://resources.trase.earth/documents/data_methods/Cote_dIvoire_cocoa_methods.pdf (2024).

37. Croft, S., Tyldesley, M. & Ribeiro, V. Paraguay soy supply chain (2014-2019). Trase https://doi.org/10.48650/PP9Z-PA43 (2022).

38. Trase. *SEI-PCS Brazil Soy v2.6 Supply Chain Map: Data Sources and Methods*. https://resources.trase.earth/documents/data_methods/SEI_PCS_Brazil_soy_2.6._EN.pdf (2022).

39. zu Ermgassen, E. K. H. J. *et al.* The origin, supply chain, and deforestation risk of Brazil's beef exports. *Proc. Natl. Acad. Sci.* **117**, 31770–31779 (2020).

40. Trase. *SEI-PCS Brazil Beef v2.2 Supply Chain Map: Data Sources and Methods*. https://resources.trase.earth/documents/data_methods/SEI_PCS_Brazil_beef_2.2._EN.pdf (2023).

41. Cho, K., Goldstein, B., Gounaridis, D. & Newell, J. P. Where does your guacamole come from? Detecting deforestation associated with the export of avocados from Mexico to the United States. *J. Environ. Manage.* **278**, 111482 (2021).

42. Cho, K., Goldstein, B., Gounaridis, D. & Newell, J. P. Hidden risks of deforestation in global supply chains: A study of natural rubber flows from Sri Lanka to the United States. *J. Clean. Prod.* **349**, 131275 (2022).

43. VanderWilde, C. P., Newell, J. P., Gounaridis, D. & Goldstein, B. P. Deforestation, certification, and transnational palm oil supply chains: Linking Guatemala to global consumer markets. *J. Environ. Manage.* **344**, 118505 (2023).

44. Trase. Côte d'Ivoire cocoa. *trase.earth* https://trase.earth/explore/supply-chain/cote-d-ivoire/cocoa (2024).