What is the DeDuCE model?

The Deforestation Driver & Carbon Emission (DeDuCE) model aims to identify deforestation—the permanent replacement of natural forests by other land-uses—across the globe to expanding croplands, pastures, and forest plantations. It then links this deforestation to the commodities produced on the deforested land and estimates the carbon dioxide emissions resulting from this land-use change.

The model does so by overlaying satellite data on forest loss with maps of specific crops (e.g., soybeans, oil palm, cocoa, and rubber) or of broader land-uses (e.g., croplands, forest plantations, and pastures) or deforestation drivers. Through a procedure that prioritizes data with higher spatio-temporal accuracy and detail, the model identifies where deforestation occurs and attributes this directly to a commodity using spatial data (e.g., soybeans) or to a broader land-use (e.g., agriculture or cropland). Where deforestation cannot be spatially attributed to a specific commodity, the model uses non-spatial agricultural and forestry statistics to assess commodity-driven deforestation in a two-step procedure: first, deforestation attributed to broad land-uses (e.g., agriculture or commodity production) is further subdivided between cropland, pastures, and forest plantations based on their relative (gross) expansion in a region (typically at country-level); second, deforestation attributed to cropland expansion (either based on cropland maps or statistics) is further allocated between different crop commodities in proportion to their respective increase in harvested area.

Finally, the model estimates carbon losses due to deforestation using maps of forest carbon stocks—in above- and below-ground biomass, dead wood, litter, and soils—and accounts for the carbon sequestered in the replacing land use. Furthermore, carbon dioxide emissions from peatland drainage are estimated by overlaying the identified deforestation data with a map of the global extent of peatlands.

As a result, the DeDuCE model provides over 9,100 unique deforestation and carbon footprint estimates—encompassing 176 countries and 184 commodities—for the period 2001 to 2022. The dataset also provides a quality index for each country-commodity deforestation estimate, reflecting the accuracy and detail of the underlying data producing a given deforestation footprint. The higher the quality index, the more likely it is that the attribution represents direct deforestation for that commodity, identified using spatial data; a low index, on the other hand, reflects attribution using national-level statistics (sometimes of poor quality) and should be interpreted as a measure of risk that a given commodity is associated with deforestation.

How does the DeDuCE model differ from the Pendrill et al. dataset?

The DeDuCE model builds on the methodology developed by Florence Pendrill and colleagues in their previous estimates of commodity-driven deforestation across the tropics[1], notably in the use of the same underlying forest loss data and the use of a land-balance model to attribute deforestation to specific land-uses and agricultural commodities where spatial data is lacking.

However, while the Pendrill et al. data exclusively relied on the land-balance approach, the DeDuCE model predominately attributes deforestation based on spatial land-use data from

[1] The latest version of the Pendrill et al. data can be found here, and the original methodology is described here.

satellite remote sensing, including maps of key forest-risk commodities and land-uses in major deforestation frontiers in Latin America and Southeast Asia. This means that the DeDuCE model provides a more accurate picture of both the extent of commodity-driven deforestation and the specific commodities driving deforestation in different regions. Furthermore, the use of spatial data also enables a more accurate assessment of commodity-specific carbon emissions due to deforestation. As a result, some of the most significant differences between the DeDuCE and Pendrill et al. datasets are seen where the former utilizes commodity-specific maps, such as for soy in Latin America, palm oil in Indonesia, rubber across Southeast Asia, and cocoa in West Africa.

In addition, the DeDuCE model extends the Pendrill et al. data both temporally (up until 2022) and geographically (from the tropics to the whole world[2]). Updates to the underlying agricultural statistics from FAO also contribute to differences between the datasets, especially towards the end of the Pendrill et al. data time-series, where lags in reporting of both total agricultural land-use and harvested area data for crops likely lead to underestimates of expansion and estimates of commodity-driven deforestation. This is also evident in the new dataset, and we strongly caution against drawing policy conclusions based on trends in the data for the last few years of the time-series (especially for years 2021-2022, where the lack of spatial data affects accuracy).

How is deforestation embedded in the production, trade and consumption of commodities assessed?

We also assess the links between the production commodities driving deforestation and consumption of these, both domestically in the countries of production and globally, through international trade. To do this, we first spread (or amortize) the forest loss due to expanding agriculture and forest plantations over five years, reflecting the fact that once land is cleared, it will typically produce commodities over multiple years. The deforestation footprint is thus distributed across a timeframe that mirrors the enduring impact of the land-use—here, the average amount of deforestation for a given commodity in the five years prior—and is then linked to two complementary approaches to modeling international trade.

The first approach uses data on bilateral trade of agricultural commodities (only) in physical units from FAOSTAT to examine how products travel through multiple countries before reaching their final destination, considering intermediate steps like processing and re-exports along the supply chain for a given commodity. However, due to the limited coverage of processed food products in FAOSTAT, it does not always trace embodied deforestation all the way to final consumption but may stop where a product is used as an input to more processed food products (for instance, the use as a feed for animal products).

The second approach uses a comprehensive model of the world economy—a so-called hybrid-multi-regional input-output model (MRIO)—to trace the physical and then monetary flows of embodied deforestation globally all the way to final consumption, regardless of supply chain complexity. Despite its power, the method sacrifices resolution on the demand side: initial physical trade flows are assigned to more aggregated economic activities (and in some cases to multi-country regions of consumption) to attribute deforestation through to final demand.

[2] Though it is worth noting that outside the tropics, where expansion of forestry rather than agriculture is the main driver of forest loss, the accuracy of deforestation attribution is typically lower due to lack of spatial data that can help discern clearing of primary forests from rotational clearing in managed forests.

Specific commodity-footprints, however, are retained. These two models provide complementary insights into deforestation embodied in trade: The physical trade model provides insights into the first stages of the supply-chain for forest-risk commodities (which might be more straightforward to target through supply-chain policies). The hybrid trade model results reveal the total deforestation footprint of consumer country economies, but as such also include very complex and indirect links between final consumption and deforestation, that can be more difficult to address through policy (other than by reducing total consumption).

Resources

Documentation of the DeDuCE model can be found here:

Preprint of the manuscript describing the DeDuCE model in more detail.	https://doi.org/10.31223/X5T69B
DeDuCE model code	https://github.com/chandrakant6492/DeDuCE
DeDuCE model results (including input data)	https://zenodo.org/records/10674962
Access & visualization of the DeDuCE results, as well as the data on deforestation embodied in trade and consumption.	https://www.deforestationfootprint.earth/
Data file containing deforestation attribution, associated carbon emissions, and deforestation.and.emissions.embodied. in.trade.and.consumption.	https://zenodo.org/records/10633818