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Intelligence for sustainable trade

Assessing tropical deforestation in Germany's agricultural commodity supply chains

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Trase is a partnership co-founded by the Stockholm Environment Institute and Global Canopy

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About Trase

Trase is a data-driven transparency initiative that revolutionises our understanding of the international trade and financing of agricultural commodities which drive tropical deforestation. Its unique supply chain mapping approach brings together disparate, publicly available data to connect consumer markets to deforestation and other impacts in producer countries. Trase's free online tools and actionable intelligence enable governments, companies, financial institutions and civil society organisations to take practical steps to address deforestation. Trase is a not-for-profit partnership founded in 2015 by the Stockholm Environment Institute and Global Canopy. www.trase.earth

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Executive Summary

Trase was commissioned by Germany's development agency (GIZ) on behalf of the Federal Ministry of Economic Cooperation and Development (BMZ) to assess Germany's association with tropical and subtropical deforestation via its trade and consumption of imported agricultural commodities and products. The study is intended to help inform the development of measures to achieve deforestation-free supply chains.

Understanding the extent to which imports are exposed to deforestation is important if Germany is to meet international commitments to address deforestation, such as the Amsterdam Declarations Partnership (ADP), develop and implement national guidelines on the promotion of deforestation-free supply chains, and prepare for emerging EU legislation through the proposed regulation on deforestation-free products.

Perceptions of Germany's exposure to deforestation risk may vary according to the length and complexity of trade and supply chain links considered between points of commodity production and the consumption of commodities in Germany's economy. In this study, Trase has used three perspectives which draw on different datasets and research techniques to provide useful insights into Germany's deforestation risk exposure:

- A direct trade perspective which attributes responsibility based on the assumption that point-to-point trade is important to the German economy;
- A re-export-adjusted perspective which captures the indirect trade pathways that are likely to be more representative of the total risk exposure of Germany's trade activities;
- A consumption-based perspective which reflects the total embedded impact of commodity use from the perspective of the products and services actually consumed in Germany.

Key Findings

Germany's economy is linked to significant amounts of deforestation risk

Between 2016-2018 – the three most recent years with available data – Germany's direct imports from commodity-producing countries were linked to 58,500 hectares (ha) of tropical deforestation – an area two-thirds the size of Berlin. However, the deforestation risk associated with Germany's total estimated consumption, including imports via other countries which may turn commodities into processed goods, is more than twice as large, at 138,000 ha of deforestation over the same period.

The risk from directly imported commodities has been decreasing over time – down 46% since 2005. However, this decrease was not seen in the total consumption perspective, showing that the deforestation embedded in more processed products is an increasingly important contribution to risk for Germany.

Deforestation risk is concentrated in a few commodities and countries

In the most recent three years of data (2016-2018), 94% of Germany's directly imported deforestation risk was linked to just five key commodities (in decreasing order of importance): soy (28%), coffee (26%), palm oil (19%), cocoa (18%) and cattle (3%).

In the most recent three years of data (2016-2018), more than 90% of the directly imported deforestation risk came from nine countries (in decreasing order of importance): Brazil (24%), Colombia (15%), Indonesia (13%), Malaysia (12%), Peru (8%), Paraguay (8%), Honduras (5%), Côte d'Ivoire (4%) and Papua New Guinea (2%).

The total consumption perspective highlights the same important commodities, but ranked differently

Palm oil products are the most important source of deforestation risk from a total consumption perspective (33%), followed by cattle products (24%), soy (17%), coffee (5%) and cocoa (5%). The jump up the ranking of cattle products compared to the direct trade perspective is particularly striking.

The most important commodities and countries have varied over time, with some hotspots emerging in the most recent years

- For example, 2012 saw a significant spike in Germany's directly imported risk (at 36,800 ha, it was more than double the 2018 value of 14,700 ha). This was mostly driven by increased imports and deforestation intensity of Paraguayan soy.
- The importance of coffee as a source of risk has been increasing markedly, and in 2018 was more important than soy and palm oil combined from a direct trade perspective. This is partly due to a surge in coffee deforestation risk from Colombia.
- Across all commodities, Colombia has emerged as a deforestation-risk hotspot in the most recent years, and was a greater source of directly imported risk than Brazil or Indonesia in 2018. This was linked to increased deforestation risk from Colombian coffee and palm oil.
- Palm oil risk is increasing from a consumption-based perspective – this contrasts with a declining risk from the direct trade perspective, and highlights the important role of palm oil as an embedded commodity in products likely flowing into Germany via indirect supply chain pathways.
- The risk from cattle has started to increase in recent years, mostly linked to Brazil, where deforestation rates associated with cattle production have been rising (rather than an increase in trade or consumption of Brazilian beef).

The impact of adjusting for re-exports varies between commodities

We also considered Germany's imported risk after adjusting for re-exports: taking into account commodities that are imported into Germany via other 'intermediary' countries and commodities that are shipped to Germany before being exported elsewhere.

When compared to Germany's direct import deforestation risk, adjusting for re-exports lowered Germany's deforestation risk exposure overall by around 20%, but this result varied depending on the commodity. It made relatively little difference for soy, slightly decreased the risk for palm, roughly doubled the risk from cattle, and nearly halved the risk from cocoa and coffee.

This is consistent with Germany acting as an important trade and processing hub of cocoa and coffee products. However, this analysis is likely to slightly underestimate impacts because not all trade could be assigned a source country (and therefore linked to deforestation risk) in the re-export adjustment process. This is particularly the case for palm oil, where a large proportion of palm kernel cake was of unknown origin.

Germany imports deforestation risk via intermediary countries and re-exports risk to other countries

Delving into the indirect routes by which deforestation risk reaches Germany shows that the Netherlands (and to a lesser extent Belgium) were important intermediary countries. For example, after adjusting directly imported deforestation for re-exports, Trase data shows that 25.9% of Germany's palm oil deforestation risk from Indonesia, and 19.5% of its soy deforestation risk from Brazil, came via the Netherlands.

Germany itself has a key role as a re-exporter to other countries, particularly for soybean cake (where the key recipients are Denmark, Czechia and Austria) and green coffee beans (where the key recipient is Poland, followed by the USA and the Netherlands).

Risk is even more concentrated in specific locations at the subnational level

Trase data shows that more than half (61.6%) of the Brazilian soy deforestation risk directly imported into Germany between 2016-2018 came from three municipalities in the Matopiba region: Formosa do Rio Preto, Alto Parnaiba and Urucui.

Re-exports typically made little difference to which subnational regions are associated with deforestation – with one exception

Compared to direct imports, adjusting for re-exports generally produced a greater distribution of commodity deforestation risk, but the top subnational regions stayed the same for every example we explored. This suggests that Germany can work jointly with intermediary partners in its supply chain to explore the potential for sustainable production interventions in key shared production frontiers.

An exception is Indonesian palm oil. Although the top three kabupaten (municipalities) stayed the same, all of which are in Sumatra, the deforestation risk from Indonesian Borneo (Kalimantan) increased dramatically after adjusting for re-exports – from 0.5% to 20.5% of the total palm oil deforestation risk – and total palm oil deforestation risk from Indonesia increased by 46%. This is likely because the Netherlands (a key intermediary that handles a quarter of the palm oil deforestation risk ultimately imported into Germany) sources more of its palm oil from Kalimantan.

Germany's deforestation risk is larger than for France and Italy

Although dwarfed by the deforestation associated with China's consumption (1,148,200 ha), the deforestation associated with Germany's overall consumption between 2014 and 2018 (229,600 ha) is larger than any other ADP signatory country, with France (189,300 ha) and Italy (161,700 ha) in second and third place respectively.

However, when taking into account the quantities of commodities being traded (the deforestation risk intensity), China's consumption had a lower deforestation risk per tonne than any of the ADP countries, including Germany.

Recommendations

Based on the results, Trase makes the following recommendations:

- **Germany should look to establish an ongoing and annual monitoring system for its deforestation-risk exposure, to track the change in deforestation risk over time.** This could involve direct trade, re-export-adjusted and consumption-based components depending on the uses for the information, such as monitoring progress linked to current or forthcoming commitments.
- **Results should be provided for discussion with relevant commodities roundtables such as the Forum for Sustainable Palm Oil (FONAP) and the German Initiative on Sustainable Cocoa (GISCO).** This may provide a starting point for more detailed analysis to understand the extent to which individual supply chains are linked to high-risk areas of production.
- **Results should also be discussed with stakeholders in regions of production, particularly as part of multi-partner dialogues.** Further analysis in high-risk regions may identify opportunities for investment to ensure deforestation-free supply both for Germany and across landscapes as a whole.
- **Germany should continue to work with other important regions of consumption on joint steps to reduce supply chain risk.** This includes the ADP, of which several members are important re-export partners to Germany, and China as the major global consumer across several deforestation-risk commodities.

- **An assessment should be made of commodities which are of lower absolute risk but still appear as important in Germany's indirect risk exposure.** These include cassava, rice, cotton and others which are not actively considered under existing commodity discussions, but may be important drivers of regional deforestation.
- **Further methodological enhancements are likely to be valuable when conducting similar assessments in future and should be prioritised.** These include: harmonise methods for re-export-adjustment and consumption-based accounting, and conduct intercomparisons across methods; integrate Trase data into consumption-based accounting frameworks; understand and resolve the presence of 'unknown' sources, particularly for palm kernel oil.

Introduction and background

Purpose

Trase was commissioned by Germany's development agency (GIZ) on behalf of the Federal Ministry of Economic Cooperation and Development (BMZ) to assess Germany's association with tropical and subtropical deforestation via its consumption of imported agricultural commodities and products to inform the development of measures to achieve deforestation-free supply chains.

These efforts by Germany come at a time when wider initiatives are being developed by some leading national governments in Europe and at the EU level through the proposed regulation on deforestation-free products (EC regulation proposal COM 2021/0366, EC 2021). GIZ recognises that Germany needs to take account of these initiatives in the development of its own measures to facilitate coordinated action.

The primary aim of this work is to provide stakeholders in Germany with a detailed understanding of the 'deforestation risk' that the country is exposed to via its consumption of a range of imported commodities associated with tropical and subtropical deforestation in producer countries. This work is designed to enhance knowledge of Germany's deforestation risk exposure and inform the development of a potential monitoring and reporting framework. The analysis combines information on global and regional deforestation with trade and consumption data to provide an overview of the scope and nature of Germany's exposure to deforestation in supply chain activities.

The work involved the development and implementation of a number of models and datasets. Details of the methods used to derive the data are described in the Methodological Summary below. These methods were guided by consultation with stakeholders to understand priorities for data development and harmonisation. This engagement process, along with a more extensive discussion of the methods and their wider implications, are contained in the Annexes. The main report summarises the results for Germany, highlighting hotspots of tropical and subtropical deforestation risk in supply chains, Germany's supply chain linkages and changing trends in exposure.

Commodity-driven deforestation and policy commitments

It is well-established that the primary driver of tropical and subtropical deforestation is agricultural production (e.g. Curtis et al. 2018). Yet assessing the role that the commodity trade plays in deforestation is challenged by the complexity and lack of transparency in global supply chains (Gardner et al. 2019). Furthermore, the dynamics of land use change are complex. Land can be converted directly to increase agricultural production, or via indirect land use dynamics (Meyfroidt et al. 2018). For this reason, various supply chain mapping methods exist to attribute deforestation occurring upstream in producer countries to downstream countries of consumption.

For a country that depends on economically important commodities that are not produced at scale domestically, understanding the extent to which imports are exposed to deforestation is paramount. A key reason is that many countries, including Germany, have made commitments to address deforestation which recognise that responsibility for the environmental impacts associated with commodity production should be shared between producer and consumer countries.

These commitments include the 2014 New York Declaration on Forests (UNDP 2014), the Amsterdam Declarations Partnership (ADP 2021) and the German Federal Government´s Guidelines on the Promotion of Deforestation-Free Supply Chains of Agricultural Commodities. Several multi-stakeholder initiatives aim at fostering greater sustainability in agricultural supply chains, including eliminating deforestation from supply chains. These include Germany's Initiative for Sustainable Agricultural Supply Chains (INA), which is a collaboration between civil society and the public and private sectors. Further commitments have been made through commodity-specific platforms such as the Forum for Sustainable Palm Oil (FONAP) and the German Initiative on Sustainable Cocoa (GISCO).

Importantly, the EU may introduce legislation that prohibits the importation of agricultural commodities such as soy, beef and palm oil produced on land deforested after 2020. An ability to monitor and review commodities consumed in Germany and across the EU is important in guiding the policy and the EU and Member State responses to it.

Supply chain perspectives

This study has been prepared by Trase, a partnership founded by the Stockholm Environment Institute and Global Canopy (www.trase.earth). Since its creation in 2015, Trase has become an authoritative source of information on the supply chains connecting agricultural commodity production and associated tropical deforestation in producer countries with commodity imports by consumer countries. Trase data covers over 60% of global trade in forest risk commodities, including soy, beef and palm oil.

Trase provides data on subnational commodity deforestation risks in supply chains, links to commodity traders and volumes of imports into countries. Trase data is limited to selected landscapes and to the point of first import. However, Trase can extend the scope of its analysis by including datasets which provide additional information about the global nature of deforestation and its drivers. This extended analysis includes the use of commodities downstream in supply chains beyond the point of first import, providing several alternative, complementary perspectives on deforestation risk that is not available with Trase data alone.

Direct or indirect trade

The deforestation associated with Germany can be conceptualised in several ways that are determined by the 'boundaries' that one places around the supply chains of interest.

First, it may be based on the direct trade relationships that exist between Germany and countries that use deforestation to expand production. In this case, we can make a direct attribution of responsibility for deforestation based on the assumption that direct imports are important to the German economy and could be directly influenced by the government and other supply chain participants.

Second, the association with deforestation can be conceptualised in terms of an extension of the system boundary which also captures the indirect supply chain pathways that are likely to be more representative of the total risk exposure of the German economy, and would be subject to different considerations when it comes to policy or private sector responses.

Re-export and consumption-based perspectives

For these indirect pathways, two main perspectives are provided in our analysis. One is based on a consideration of trade activities only, but also considers the re-export of primary and/or derived materials via intermediate countries such as the Benelux region, a major importer of overseas materials into Europe, or flows into Germany that are exported to other countries. This ensures that commodity flows via these countries are assigned back to their point of origin and potential impact. The other perspective offers a full 'consumption-based account' which reflects the total embedded impact of commodity use from the perspective of the products and services actually consumed in Germany.

National and subnational-scale analysis

In addition to these three perspectives (one direct and two indirect; see Methodological Summary for descriptions of implementation), it is necessary to undertake assessment at two scales of analysis. Where Trase data is available, subnational-scale assessments of deforestation linkages can be made; otherwise, one can fall back on national-scale datasets to provide assessments of risk exposure. The methodological details of the implementation are described in more detail below and in Annex 2. For our analysis we use the state-of-the-art Pendrill et al. (2022) dataset to provide our global, national-scale assessment.

Our analysis of Germany's tropical and subtropical deforestation risk in supply chains aims to provide a comprehensive overview across these different scales and perspectives, via the utilisation of a number of datasets and methods which have been harmonised to the extent possible within the scope of this project (see Discussion).

Previous studies have attempted to quantify the deforestation risk associated with the German economy. These include analysis conducted for the UK government, which resulted in estimates for Germany and several other countries (Croft et al., 2021), the European Union (COWI 2018), the University of Freiburg (Pokorny et al., 2019), FERN (FERN 2015, Polsterer 2019), IDH/IUCN (IDH & IUCN NL, 2019) and academic studies (Pendrill et al., 2019a, 2019b, Hoang & Kanemoto, 2021).

We summarise the results from the previous studies that provide alternative quantified information on commodity deforestation risk (i.e. provide relevant statistics that are not taken from Trase) in the Results section to allow comparison with the analysis in this study for BMZ/GIZ.

Methodological Summary

This study provides a breakdown of Germany's tropical and subtropical deforestation risk, and associated role in the supply chain of key commodities, across two scales of spatial risk analysis (national risk assessment, and subnational risk assessment of producing countries) and three trade-linked perspectives: direct trade relationships; trade that accounts for re-exports in materials and their primary (and for some commodities, secondary; see Annex 2 for details) derivatives; and a consumption-based perspective which allows estimates of the full trade and processing activities linked to the commodities and their use within final consumption activities in the economy. A summary of these approaches is found in Table 1. Note that the consumption-based approach also involves the re-export adjustment process, and so could be seen as an extension of the re-export approach. However, the re-export approach is not simply an extension of the direct trade approach, because of steps introduced to reconcile trade data across import and export records as part of the re-export adjustment process. This should be borne in mind when interpreting results from across the three perspectives offered.

Name	Description	Considerations linked to applications in this study	
		Commodity coverage	Other notes
Direct trade: National scale	Bilateral trade (point A to point B) of agricultural commodities derived from FAO production and export statistics for harvested and transformed commodities. Applied to Pendrill et al. 2022 statistics to determine deforestation in supply chains.	79 primary (harvested) crop commodities (plus selected transformed derivatives), plus cattle products available from FAO/Pendrill at al. 2022. Time-series 2005-2018	Covers trade as reported by FAO. Trade in derived commodities entails application of equivalence factors to link to the production of the harvested commodity. Assumption made that direct trade origin reflects location of production.
Direct trade: subnational scale	Bilateral trade (point A to point B) of selected high deforestation-risk agricultural commodities and countries of origin derived from Trase data. Point of origin is at appropriate jurisdictional level in line with that available from the Trase platform.	Soybean (Brazil: 2006-2018; Paraguay: 2014-2017; Argentina: 2016-2018). Palm Oil (Indonesia: 2015). Cattle (Brazil: 2015-2018; Paraguay: 2015-2019).	Results presented for Trase data with associated subnational deforestation.

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Name	Description	Considerations linked to applications in this study	
		Commodity coverage	Other notes
Re-export-adjusted: subnational scale	Bilateral trade (point A to point B), but based around a reconciled trade data set (constructed from both import and export records) and then corrected for indirect pathways (i.e. re-exports) of agricultural commodities derived from FAO statistics for harvested and transformed commodities. Data are balanced across reported production, utilisation and trade, as well as opening and closing stocks.	Commodities as for national-scale direct trade. Time series: 2014-2018	Re-export-adjusted data attempts to account for the role of 'intermediate' trade partners between points of origin and destination. It includes direct trade also, but additional steps taken in the re-export adjustment process (to reconcile differences between import and export records) mean that the standalone direct trade analysis (above) is not directly 'nested' within re-export-adjusted data. Re-export-adjusted data account for (i.e. exclude from a German risk perspective) commodities imported into Germany and then subsequently exported (in either the same or subsequently derived form). Derived commodities are linked to sourcing of parent commodities, thus country of origin refers to the point of harvest of the primary commodity. The balancing stage, and especially the incorporation of opening and closing stocks, requires allocation of some production to an 'unknown' origin where this balancing requires additional supply.
Re-export-adjusted: subnational scale	As per the approach for national scale re-export-adjusted, but overwriting focal countries' trade with that reported by Trase (i.e. the reconciliation process is still performed across the global dataset, but Trase data is automatically preserved), retaining the subnational specificity of origin.	Soybean (Brazil: 2006-2018; Paraguay: 2014-2017; Argentina: 2016-2018). Palm Oil (Indonesia: 2015).	Subnational re-export-adjusted results for German risk do not include commodities imported into Germany and subsequently exported in the same form. Any derived commodities produced outside of Trase focal countries are not linked to sourcing of the parent commodities, and therefore trade of such derived forms are not captured with assignment to the point of harvest of primary commodity. Beyond the point of first import there is a lack of traceability of the supply chains, and the model depends on a mass balance approach (i.e. assumptions of proportionality are applied).
Consumption-based	These results take the data from the national-scale re-export-adjusted trade data and feed this into an MRIO framework to provide estimates of the full supply chain through to final consumption. Results capture direct and indirect consumption, including that embedded within goods and services.	Commodities as for national-scale direct trade. Time series: 2014-2018	Data estimate total production necessary – and the points of production – to fulfil German consumption, regardless of form and number of processing steps. Some 'unknown sources' are retained, however, given dependency on re-export-adjusted data.

Table 1: Summary of perspectives and scales analysed in this study along with brief methodological explanations, coverage (time series and commodity) and selected notes relevant to the interpretation of results.

Direct trade

For direct trade estimates at subnational scale, we utilise Trase data (available from supplychains.trase.earth) for trade connections to points of import for those commodities where Trase provides associated commodity-linked deforestation estimates. Trase combines information such as customs records, shipping data, tax information, processing and production statistics to complete supply chain mapping for total exports from a country of commodity production, retaining information on the subnational origin of materials and the trading actors involved in supply chains. This data is compiled in the form of decision trees and modelling steps (with the dependence on modelling varying by data availability across different country-commodity contexts). In some cases, links between export and origin cannot be made with sufficient confidence. In these instances, trade is reported as being of unknown origin.

The time series coverage of data available from Trase varies depending on the commodity (see Table 1). Trase is limited in its global commodity coverage and geographic scope, covering commodities identified as being associated with high levels of tropical deforestation and only deployed where sufficient information exists (e.g. via data disclosure at country or industry level). A more detailed description of the way in which Trase develops supply chain maps for deforestation-risk commodities is provided in Annex 2.

For national estimates at the global scale, we use agricultural production statistics from the Food and Agriculture Organization's crop and livestock products dataset and direct trade estimates (export quantities) from the FAO's detailed trade matrix dataset. Commodities in both datasets are classified according to the FAO's commodity codes. Deforestation intensity (hectares per tonne of product) was obtained for each FAO product using the open access data from Pendrill et al. (2022). The Pendrill data provides estimates of tropical and subtropical deforestation associated with production of agricultural and forestry commodities by country and year for the 2005-2018 period.

Deforestation intensity is calculated for each combination of producer country, commodity and year, by dividing deforestation estimates by associated material production estimates from the FAO. These intensities are then multiplied by the quantities exported to Germany to estimate the deforestation risk linked to traded production. Whilst in reality some (or in extreme cases all) of this supply could be comprised of imports rather than domestic production, an assumption is therefore implicitly made that all exports are composed of domestically produced commodities[1].

1. More complex methods to account for 're-export' activities that account for cases where this assumption is not valid, are included as a separate component of the analysis in this study (re-export-adjusted results).

Many important agricultural commodities are traded in processed forms, rather than (or in addition to) their harvested forms. Soy, for example, is often traded in the form of soy cake or soy oil, as well as raw soybean. In the case of palm oil, the harvested commodity (oil palm fruit) is almost always traded in the form of palm oil, palm kernel cake and palm kernel oil, rather than in its raw form.

Given that the deforestation attribution data from Pendrill et al. (2022) is for raw commodities, to capture the deforestation risk of these more processed products, we first need to calculate the export quantities in raw commodity equivalents. Failing to do so would underestimate the deforestation risk where, for example, the raw commodity has become more concentrated in its derived forms or where processing steps result in loss via waste.

A description of our approach to converting derived commodities back to their raw equivalents is included in Annex 2. Similar to the above, we make the assumption for the direct trade analysis that derived products are linked to the production of the primary product (and therefore associated deforestation risk) in the same country; for example, that soy cake imported from Brazil is linked with the production of soybean (and any associated deforestation) in Brazil.

Re-export analysis

Direct trade analysis may not reflect the eventual destination of materials as reported by the baseline trade statistics. One reason is that products may be 're-exported' either in the same or immediately derived forms. Such re-export activities can make up an important part of the supply chain which would otherwise be masked from the deforestation assessments of a focal country. For example, within Europe, the port of Rotterdam is a major regional re-export 'hub', and export records from the Netherlands therefore include exports of products such as soy and palm oil. Rotterdam also operates major processing facilities and so, while these processed products may have been produced in the Netherlands, their production does not reflect the origin of the deforestation connected to the raw, harvested product. For this reason it is useful to try to account for the re-export activities of countries as derived from international trade flows in order to understand where a country's deforestation risk may be linked to trading intermediaries.

The starting point for the estimate of re-export activities is the direct trade information mentioned above (Trase or FAO depending on the scale adopted). However, this data source comprises both import and export data for all trading countries of the world, and therefore within our re-export adjustment process we undergo a reconciliation process to try and best mitigate problems such as data gaps (e.g. countries not reporting) and erroneous reporting (by using the most reliable information for each reported transaction). This reconciled trade data is then compared to additional utilisation information, such as opening and closing commodity stocks and requirements for additional uses, such as for feed and seed, as well as processing into derived forms.

Any negative balance here (i.e. a deficit of available supply to meet export requirements and/or other uses) is assigned to an appropriate stock, but is allocated as 'unknown origin'. The absence of origin information in such cases means that it is possible for a portion of recorded trade to not be connected to an associated deforestation intensity.

For national re-export activities, we take the approach of first estimating re-exports linked to the trade in primary commodities from these sources, adopting methods similar to those developed by Kastner et al (2011). After this first step of adjusting the trade of primary commodities to account for re-export activities, we take into account the aforementioned processing of these products into their derived forms using the FAO's supply utilisation accounts for 2014 onwards. This results in estimates of the production of derived product forms, which are then subjected to the data reconciliation and re-export-adjusted trade step to estimate their final points of imports. In certain cases, this is repeated again for second-order derived forms.

These methods allow the analysis of trade, incorporating estimates of re-export activities, for both primary commodities and derived commodities that they are used for. Importantly, via the methods employed, estimates can also be derived of the relative importance of different types of supply chains (i.e. supply chain length) as well as the role that countries who act as potential intermediaries play in the overall trade activities. An in-depth description of the methods employed to generate this data is provided in Annex 2. As well as capturing direct and indirect pathways to Germany (or for any other focal country of interest), these results also account for what comes into Germany and then leaves via re-exports to other countries.

For Trase-linked re-export activities, a similar approach is adopted. Trase data is taken as 'perfect' for this purpose, i.e. within the reconciliation step the data from Trase is accepted automatically within the global trade system and overrides any conflicting information reported by other parties.[2] Given a lack of subnational utilisation and processing data of the type used for the national-scale implementation, and in order to preserve the Trase data within a broader framework, the production of derived commodity forms downstream is not linked to sourcing profiles of the parent commodity. Results are therefore only capturing the flows of commodities in the form they originally left the focal country, and not those which might be transformed subsequent to leaving the focal country. For example, soybean, soy oil or soy cake leaving Brazil and destined for Germany, regardless of trade pathway, is captured; soybean leaving Brazil, being processed by an intermediary country and then traded to Germany as soy oil or cake is not. Likewise, soybean imported into Germany, which is then processed and exported as oil or cake, is not 'removed' from the imported volume, unlike in the re-export-adjusted version at national scale.

2. For the purposes of the re-export methods, it is simplest to treat the Trase countries at the national scale, but the subnational linkages between country of origin and country of first import are retained and factored into the results. This approach is appropriate since any movement beyond the reported country of import loses traceability and thus mass-balance assumptions around proportional use are required. Data regarding domestic utilisation and activities are not available at a similar resolution to the Trase results; however, these are not necessary for the focal countries since the Trase results are preserved and thus provide all of the required information for supply and total domestic demand.

Consumption-based accounting

Environmentally extended consumption-based accounting aims to derive estimates of the impacts associated with 'final demand' activities by consumers (e.g. households, government) which account for all the upstream dependencies necessary to meet that final consumption activity. In other words, a consumption-based perspective attempts to allocate impacts through to the 'true' point of consumption rather than intermediate points of demand. The fact that consumption-based accounts consider all upstream dependencies has some important implications for the interpretation of results, in that commodities can be utilised upstream in the supply chain whilst not having any physical presence in the materials finally purchased by consumers. A hypothetical example might be rice fed to factory workers as part of their employment in facilities which manufacture electronic components. Here, the rice is utilised in the supply chain, but not as an 'ingredient' in the product eventually consumed. Another example might be soy used in animal feed linked to the production of leather for the German market.

Consumption-based accounts undertaking global impact assessments typically rely on multi-regional input-output (MRIO) models which detail (usually in monetary terms) the inter-industry transactions (including international trade) taking place across global economies. MRIOs comprise country-level input-output tables often compiled via national statistics agencies, in which data is harmonised to ensure a balanced representation of the global economic system. After environmental impacts are assigned to the sectors driving them (e.g. deforestation linked to appropriate agricultural sectors), matrix algebra can be used to derive the associated impacts of consumption in regions of production.

A limitation of traditional MRIO methods is often their sectoral and geographic resolution. Typically, the process of compiling MRIOs results in relatively coarse sectors which can aggregate multiple production or processing activities, and regions of economic activity which can span multiple countries. While MRIOs continue to improve in their specificity, for the treatment of deforestation-risk commodities this presents a potential problem as deforestation can be limited to a small number of commodities in a relatively small number of regions. A lack of commodity-specificity in traditional MRIOs results in these commodities being modelled alongside the flows of other materials which, for example, may not provide a deforestation risk.

In response to this limitation, the SEI input-output trade analysis (IOTA) framework utilises a 'hybrid' approach. It first models (using the re-export methods described above[3]) trade in primary commodities, initial processing and trade in derivatives in physical units before inserting the resultant supply into appropriate sectors of the MRIO database. This allows the MRIO model to then distribute the initial trade and processing steps through to points of final consumption. Ultimately, this approach allows commodity and geographic detail to be retained initially (improving the specificity with which commodities are assigned to markets) before then allowing the (coarser) monetary transactions to distribute these flows through to final demand.

3. i.e. the outputs of the application of re-export-adjusted methods are a direct input into the IOTA framework in this study.

This approach ensures that commodity-specific production and trade information is linked through to all final consumption activities. However, specific elements of supply chain traceability are lost. For example, one cannot say with confidence that individual physical flows will be linked to specific consumption end-points. Rather the IOTA framework - and indeed traditional MRIO methods - provide estimates of the overall balance of global risk and responsibility.

In these results, we have hybridised the re-export statistics derived above with the

EXIOBASE MRIO model to produce a consumption-based account between 2014 and 2018 of tropical and subtropical deforestation likely to be driven by supply chains to Germany. An alternative set of results, derived using the GTAP MRIO dataset, are included in Annex 3 for comparison purposes. EXIOBASE was selected over GTAP for the main report due to the presence of time-series information in EXIOBASE that overlapped with the other results.

Results from IOTA are implemented only for the national-scale analysis (i.e. for physical trade and processing derived at national scale from FAO); subnational integration of Trase data into IOTA has been scoped out as part of this project however, and a summary of proposals for that integration can be found in Annex 4.

Deforestation data

The deforestation data used in this study, which is joined to trade information to estimate deforestation in Germany's imports or consumption activities, varies depending on the spatial resolution of the analysis.

National-scale tropical and subtropical deforestation data is utilised alongside our national-scale trade analysis, with the data sourced from Pendrill et al. (2022). The data is derived from a simple 'land-balance' model, with observed forest loss (from the Global Land Analysis and Discovery (GLAD) lab in the University of Maryland) first attributed to different land use types. Here, based on FAO statistical records, cropland expansion first takes place into pastures (in any cases where there is gross pasture loss according to FAO), then into areas identified as having forest loss. Plantation forest expansion is also accounted for. In essence, forest loss is attributed across expanding cropland, pasture or plantations based on their areas of overall increase, capped at the total forest loss in the region. Forest loss attributed to cropland expansion is further attributed to individual crops or crop groups in proportion to their relative expansion in the harvested area. Forest loss attributed to pasture is linked to cattle grazing.

Here, while data on forest loss is spatially specific (as it is derived from remote sensing), attribution to individual crops/crop groups is conducted non-spatially based on overall records of planted area and not the physical location/expansion of specific crops and their interface with areas of deforestation. Pendrill et al. (2022) use a combination of a three-year attribution period and five-year amortisation step to also annualise their deforestation information, allowing the summation of deforestation estimates across multiple years without double counting.

Trase's subnational trade data links commodity land use expansion to deforestation information derived from spatially explicit data obtained through remote sensing. The indicator estimates, from the perspective of the focal commodity, how much of this commodity production area overlaps with recently deforested areas within a given jurisdiction (to match the spatial resolution of Trase's supply chain maps). 'Recently' refers to a specified allocation period (e.g. five years) for which a 'lag' period is also defined, referring to the minimum time period between deforestation activity and the earliest possible harvest of the commodity (for more information see Annex 2). Deforestation estimates associated with commodity land use expansion are then linked to Trase's commodity supply chains to estimate the deforestation risk of an actor (company or country) associated with the sourcing of the commodity in a given jurisdiction. Trase annualises the commodity deforestation risk for each year, meaning that annual estimates of deforestation derived from Trase represent a portion of the initial deforestation activity spread across several subsequent years (determined by the allocation period). This means deforestation estimates can be summed across years without risk of double-counting the original deforestation activity.

Methodological assumptions and considerations

It is useful to draw attention to some methodological assumptions and limitations of the analysis conducted which should be borne in mind when interpreting results. More detail on specific method and model details are available in Annex 2 and associated supporting references, but a summary of key aspects is provided below:

- **Given the different methods employed to calculate deforestation in commodity supply chains, we do not attempt in this study to make comparisons between data derived from Trase subnational analysis and the equivalent information derived from the national deforestation dataset.** Ultimately, the difference in methods adopted relates to the scale of analysis. As described above, Trase does not have global coverage and does not seek to adopt methods which are fully consistent across country contexts (often technically not possible due to differences in available data inputs) and can therefore utilise local, more detailed information. The Pendrill et al. (2022) dataset provides a globally consistent dataset, but as a result (due to gaps in information on spatial crop dynamics) requires the use of a simpler crop-attribution method.
- **The exact methodological details used to provide subnational deforestation data and supply chain maps differ due to the availability of data in those landscapes.** While Trase aims to provide the best available assessments of deforestation in commodity supply chains, data availability varies considerably. For example, in Brazil, the soy and beef results are highly data-driven, relying less on optimisation modelling approaches overall. We therefore have higher confidence in the specificity of the Brazilian data in contrast to, for example, Argentinian or Paraguayan contexts which rely more on assumptions and mathematical modelling to make links between departments and ports of export.
- **The granularity and modelling-dependency of the assessments used to make connections between material sources and points of import and consumption differs across the three perspectives contained in this study.** Trase is highly data driven and based on per-shipment trade data, seeking to provide accurate subnational material flows with high specificity between production regions and points of first import. Similarly, but at a national scale, FAO trade information

provides point-to-point records of material transactions between countries. However, for the ‘downstream’ perspectives, this supply chain specificity becomes reduced due to additional dependency on model-derived information required to balance and redistribute initial trade flows, and rather relies on mass balance assumptions of proportionality. It is important to reiterate that re-export-adjusted trade pathways and consumption-based accounts are derived via computations based on reconciled trade data and a ‘mass-balance’ approach to assigning supplies to exports. These results should be treated, therefore, as estimates of potential trade pathways. Shipment-specific and/or industry-specific information would be required to validate the role of intermediaries in Germany’s trade pathways; this information is not, to our knowledge, publicly accessible for use across multiple commodities and trades.

Results

The following results provide detail of the deforestation risk associated with Germany's supply chains from three complementary perspectives and across two scales of analysis – national and subnational (see Methodological Summary for additional details). The perspectives are:

- a direct trade perspective (derived from Trase's subnational supply chain mapping data, or from national production and trade statistics derived from FAO);
- a re-export-adjusted perspective (reliant on trade-data reconciliation steps and additional modelling, and covering the trade and processing of harvested and directly transformed commodities) applied both at national and subnational scales;
- a consumption-based perspective (employing the IOTA multi-regional input-output framework and covering the use of materials at all stages of the supply chain) which is applied at national-scale only.

We first summarise the overall connection between tropical and subtropical deforestation risk and Germany's supply chains, employing only national-scale analysis in this overview. Then, for specific commodities of interest, we provide additional detail on the geographic sources and supply chains for these commodities, along with subnational analysis derived from Trase, where this is available. At the end of this section, we include a brief comparison with other studies that have attempted to quantify the link between deforestation and Germany's supply chain.

Note: For all results, deforestation statistics are linked to either Trase or Pendrill et al. (2022) deforestation assessments and therefore include deforestation in tropical and subtropical regions only. For brevity in the remainder of this report, we refer just to 'deforestation' when referencing results.

Deforestation risk overview

Direct trade

Our national-scale analysis indicates that total deforestation associated with the direct imports of Germany was 14,700 hectares (ha) in 2018, down 46% from 27,200 ha in 2005, and down 60% from a peak of 36,800 ha in 2012 (Figure 1). Soybeans, palm oil, cocoa and coffee imports are linked to the largest amount of deforestation over our time series.

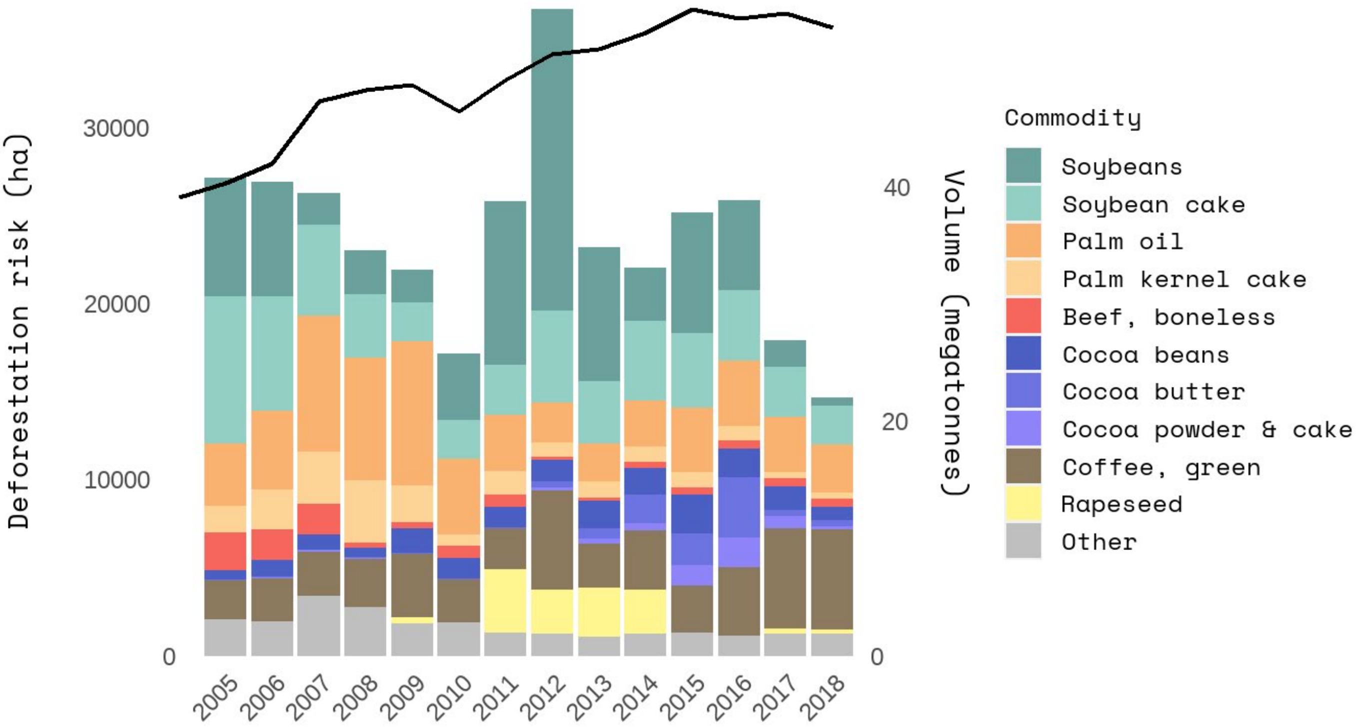

Figure 1: Germany's commodity deforestation risk from direct imports over time, by commodity. The 10 individual commodities shown were the largest contributors to deforestation risk over the entire time series (2005-2018). Commodities not in this top 10 were classified as 'Other', shown in grey at the bottom of the chart. The total trade volume (mass of raw material equivalents across all commodity sources, regardless of their association – or not – with deforestation) is also shown by the black line and right-hand axis.

Historically, soy and oil palm products have switched positions as the single largest driver of Germany's direct deforestation risk, but recently coffee has been linked to more deforestation than soy and oil palm products combined (Figure 2). This is partly due to a surge in coffee deforestation risk from Colombia (where both exports to Germany and deforestation intensity have recently increased), and a fall in soy and palm risk (due to declines in both deforestation intensity and trade quantities from key producer countries: Indonesia for palm oil, and Paraguay and Brazil for soy; see specific commodity results later in the report for more detail). Soy is particularly associated with the peak in deforestation in 2012, driven by a spike in deforestation intensity and trade of Paraguayan soy.

Deforestation linked to cocoa production was a large contributor to the overall impact in 2015 and 2016, but has since fallen again. Impacts associated with beef imports have fallen from previous levels, largely due to a fall in Brazilian beef imports after 2007. Direct trade impacts linked to beef are relatively small compared with other commodities. Rapeseed imports were associated with deforestation between 2011 and 2014, and a small contribution remained in 2018[4].

4. Additional discussion of the rapeseed deforestation risk and its origin is provided below.

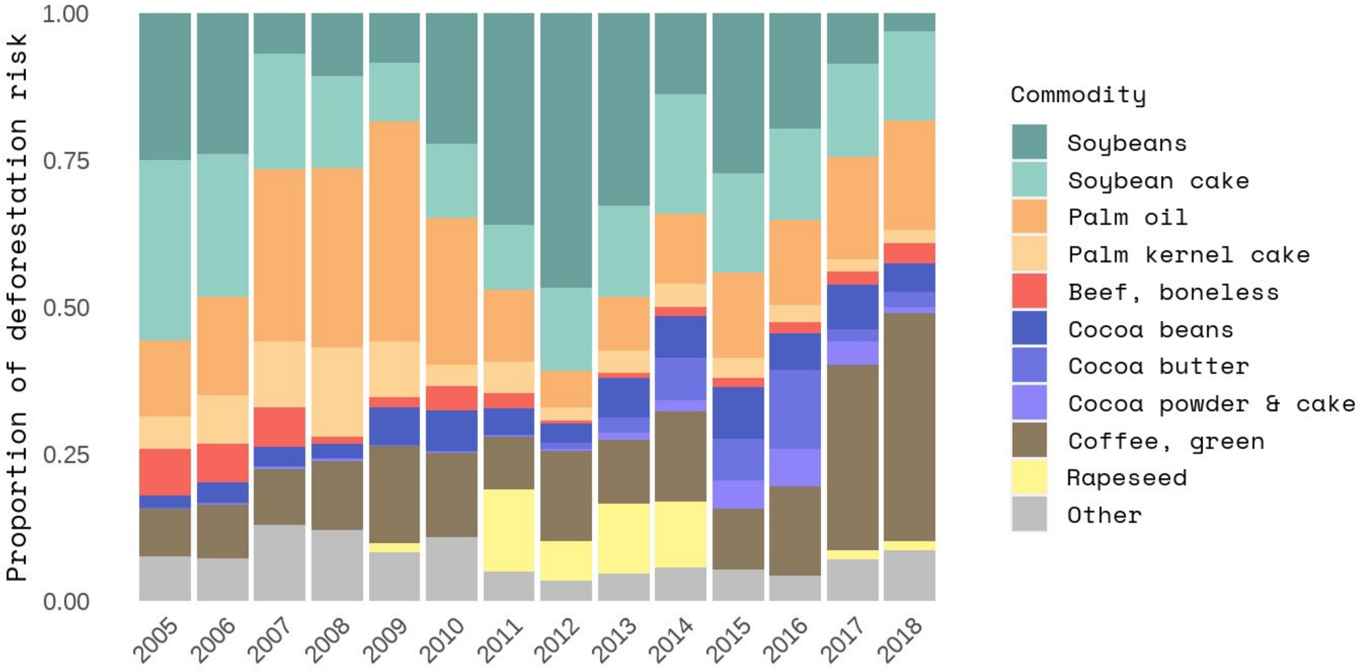

Figure 2: The relative contribution of key commodities to Germany's direct trade commodity deforestation risk over time.

Overall, key deforestation hotspots for the three most recent years in the dataset (2016-2018) are focused in Colombia and Brazil in Latin America, and Indonesia and Malaysia in Southeast Asia (Figure 3). Peru, Paraguay, Honduras, and Côte d'Ivoire are also notable hotspots.

DIRECT TRADE DEFORESTATION RISK, ALL COMMODITIES 2016-2018

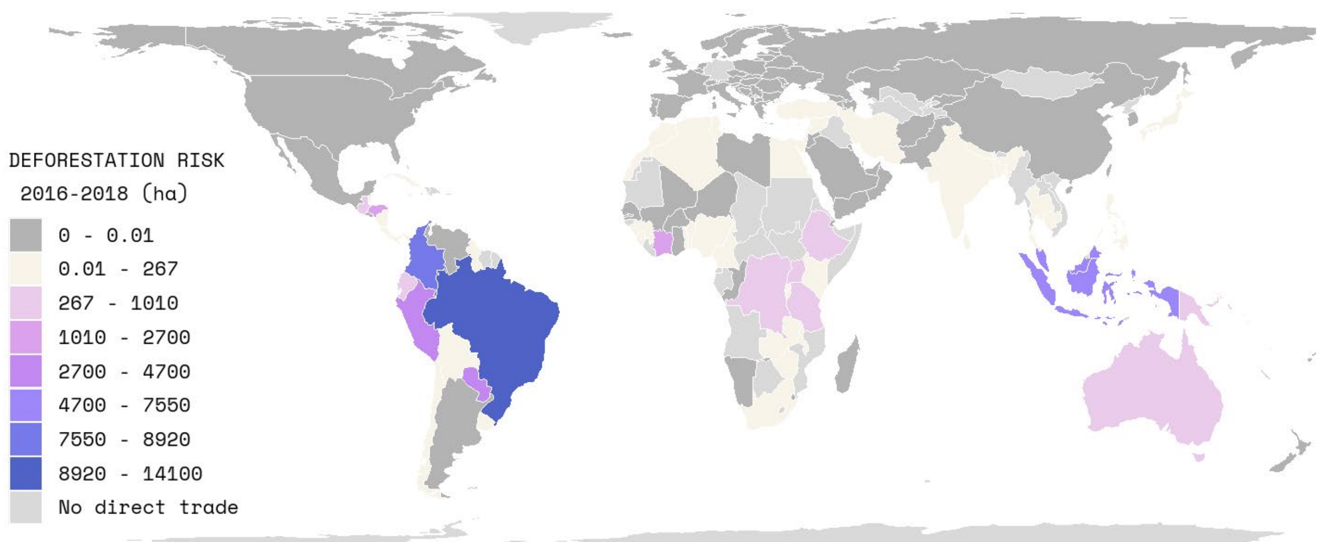

Figure 3: direct trade commodity deforestation risk (ha) by country, summed across all commodities, for the three most recent years in the national-level dataset (2016-2018).

Countries with the highest commodity deforestation risk linked to Germany's direct imports have, however, varied over time (Figure 4). Although Brazil and Indonesia have consistently been important contributors over the time series, Paraguay was actually the largest source of deforestation linked to Germany's imports between 2011 and 2013 due to a spike in both trade quantities and deforestation risk of Paraguayan soy (see soy section below for more detail).

Most recently, deforestation associated with Colombia has emerged as a key hotspot, whereas it has been a relatively minor contributor for most of the time series (largely driven by increases in both the deforestation intensity and trade quantities of Colombian coffee and palm oil). Malaysia has also been an important source, particularly in 2014-2016, but risk dropped again in 2017 and 2018.

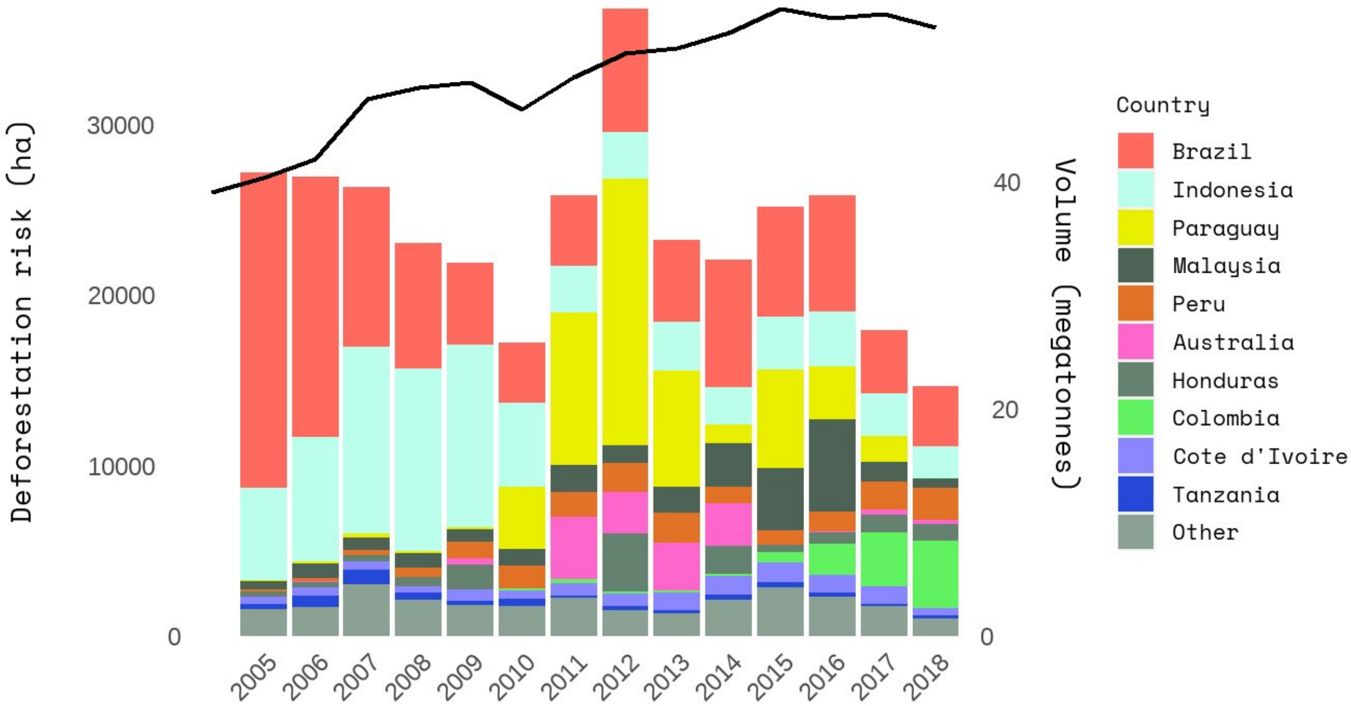

Figure 4: Direct trade commodity deforestation risk (ha) by country, summed across all commodities, between 2005 and 2018. The total trade volume (mass of raw material equivalents across all country sources, regardless of their association – or not – with deforestation) is also shown by the black line and right-hand axis. The ten highest-ranked countries in terms of deforestation risk over the entire time series are shown, all other countries are grouped into the 'other' category at the bottom of the figure.

Re-export analysis

Our re-export-adjusted analysis at national scale (which takes into account the role of intermediate trades in harvested commodities and their directly transformed derivatives) presents some striking differences to the commodity deforestation risk estimates for Germany across the 2014-2018 time series, with overall risk estimates lower than those estimated from consideration of direct imports (see Figure 5, compared with Figure 1). While it is important to note that other methodological differences (e.g. steps to reconcile trade data, and presence of 'unknown' sources of origin in reconciled accounts) may explain differences in results and not solely re-export behaviour, across the three most recent years (2016-2018), the total combined commodity deforestation risk was 58,500 ha from our direct trade perspective, but 45,900 ha from a re-export-adjusted perspective (a difference of 21%).

Soy risk appears roughly equivalent: for the period 2016-2018, the direct trade deforestation risk from soy commodities was 16,200 ha, and with a re-export perspective was 16,300 ha. However, the contributing commodities to the soy risk change when adopting the re-export perspective, so that indirect imports of soy cake account for 33.3% of Germany's commodity deforestation risk over the three most recent years (Figure 6). There is also a more prominent role for soybean oil in the re-export-adjusted deforestation risk (and less for raw soybeans), but soybean cake is dominant overall.

The relative contribution of oil palm products to the deforestation risk is similar in both the direct trade and re-export perspectives (19.4% compared to 19.9% respectively for 2016-2018, although palm oil trades are subject to high levels of 'unknown' origin in the dataset). However, palm kernel derivatives (palm kernel oil and palm kernel cake) are more prominent in the re-export-adjusted deforestation profile than within the direct trade results.

Coffee appears to have a lower relative and absolute contribution to the total commodity deforestation risk in comparison with the direct trade analysis making up 26.1% of direct trade deforestation risk, but 15.6% of re-export-adjusted risk), suggesting a role for Germany as a 're-exporter' of coffee products. The relative contribution of cocoa also fell (from 17.8% to 13.6%, for the direct trade and re-export perspectives respectively in 2016-2018).

Cashew nuts appear in the re-export-adjusted data as making an important contribution to deforestation in Germany's supply chains, contributing 5.2% to total deforestation over the 2016-2018 period compared to 0.56% in the direct trade analysis. However, cashew nut deforestation risk decreased by 74% from 2017-2018 in the re-export-adjusted risk, due to a drop in both the trade quantity and deforestation intensity of cashew nuts between those two years. Cashew nut deforestation contributed only 2.42% (262 hectares) of deforestation in 2018.

Rapeseed has a much less prominent role in comparison with the direct trade-based risk. Deforestation over 2016-2018 contributed 0.03% to total deforestation in the re-export-adjusted deforestation profile, compared to 0.87% in the direct trade risk.

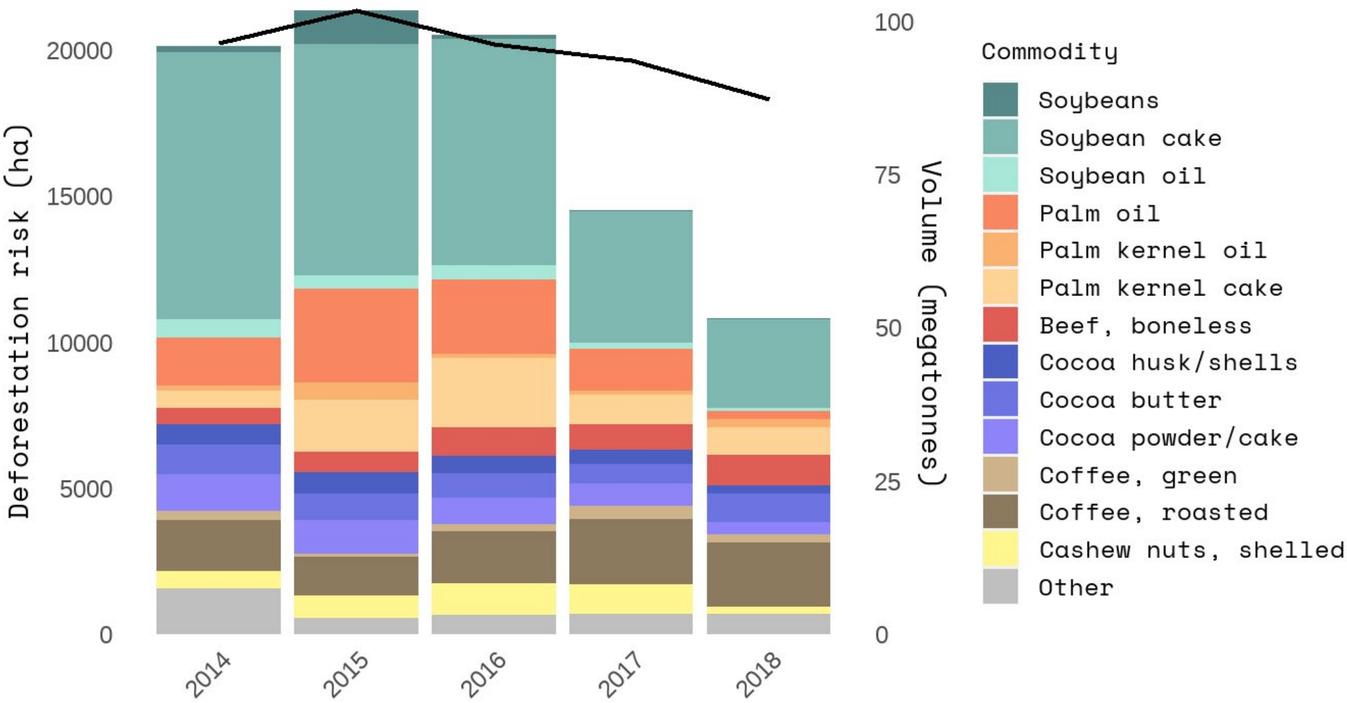

Figure 5: Top commodities in terms of overall commodity deforestation risk (ha), after adjusting for re-exports. The total trade volume (mass of raw material equivalents across all country sources, regardless of their association – or not – with deforestation) is also shown by the black line and right-hand axis. Note that 20.5% of this total trade volume was of unknown origin and therefore could not be linked to deforestation risk. Results are shown individually for key commodities, with the risk from all other commodities combined into the 'other' category at the bottom of the figure.

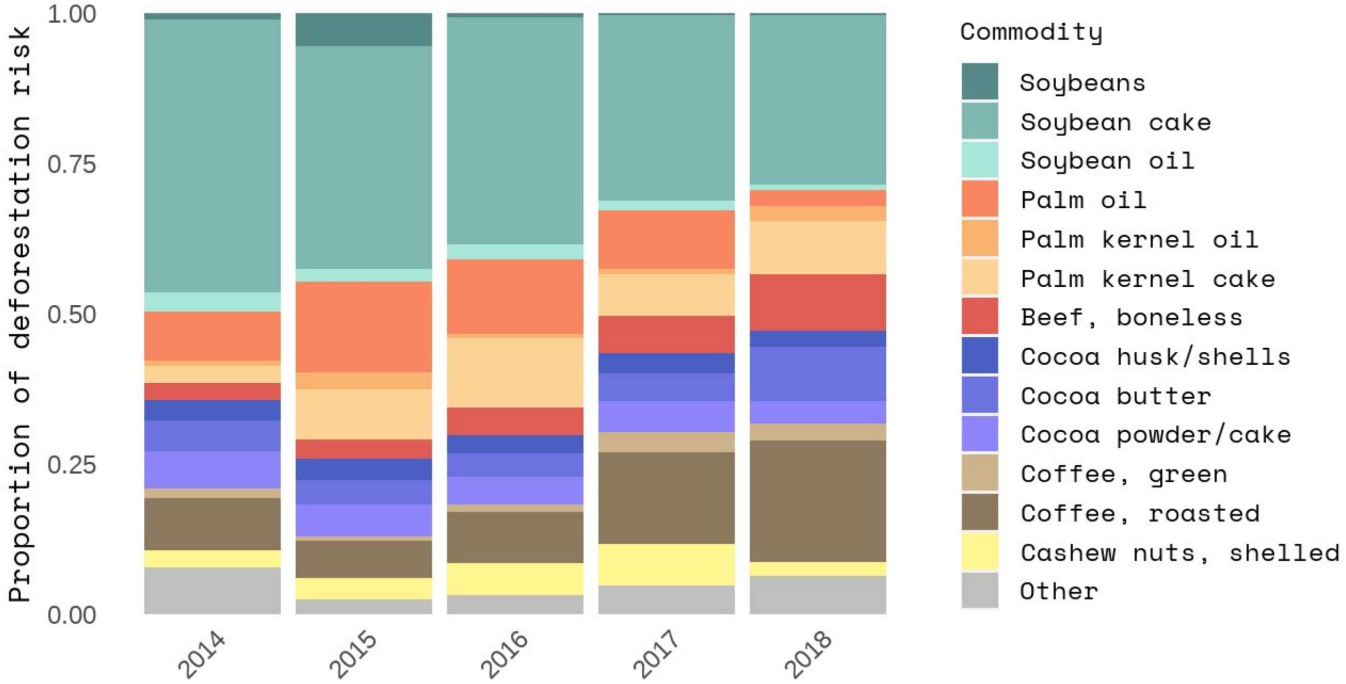

Figure 6: The relative contribution of key commodities to Germany's commodity deforestation risk over time, after adjusting for re-exports. Results are shown for key commodities, the risk from all other commodities is grouped into the 'other' category shown at the bottom of the figure. Note that 20.5% of the total traded quantity was of unknown origin and therefore could not be linked to deforestation risk.

The deforestation hotspots linked to Germany via re-exports appear broadly similar to those of direct exports, although there are some important differences; for example, the more prominent role of deforestation in Côte D'Ivoire and a reduced role for Malaysia. (Figures 7, 8).

RE-EXPORT ADJUSTED DEFORESTATION RISK, ALL COMMODITIES 2016-2018

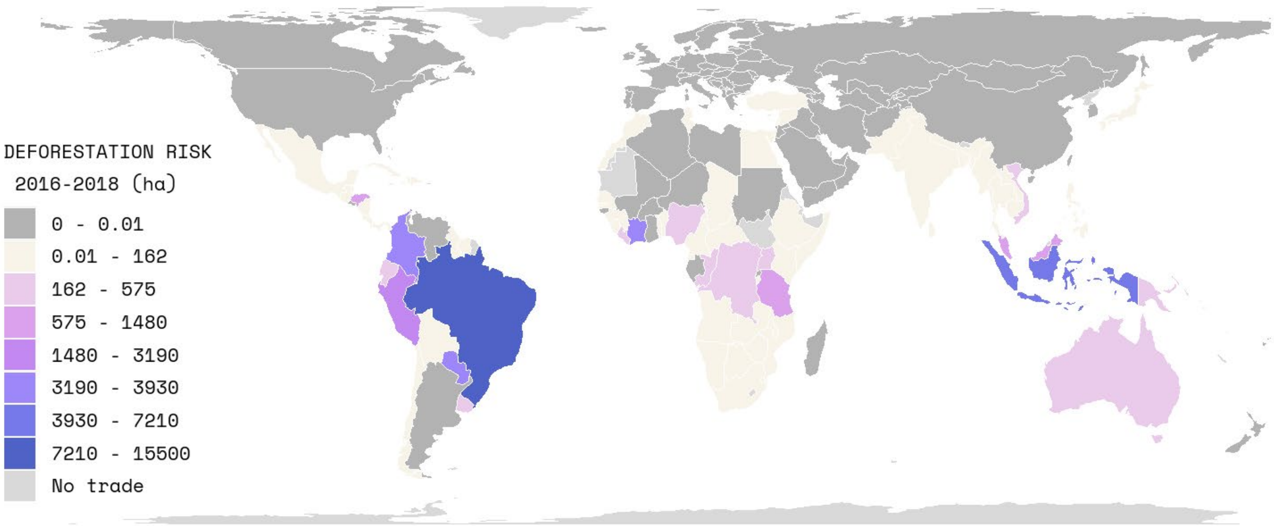

Figure 7: Map of global commodity deforestation risk from German imports after adjusting for re-export behaviour for the three most recent years with available data (2016-2018). Note that 20.5% of the total traded volume was of unknown origin and therefore could not be linked to deforestation risk.

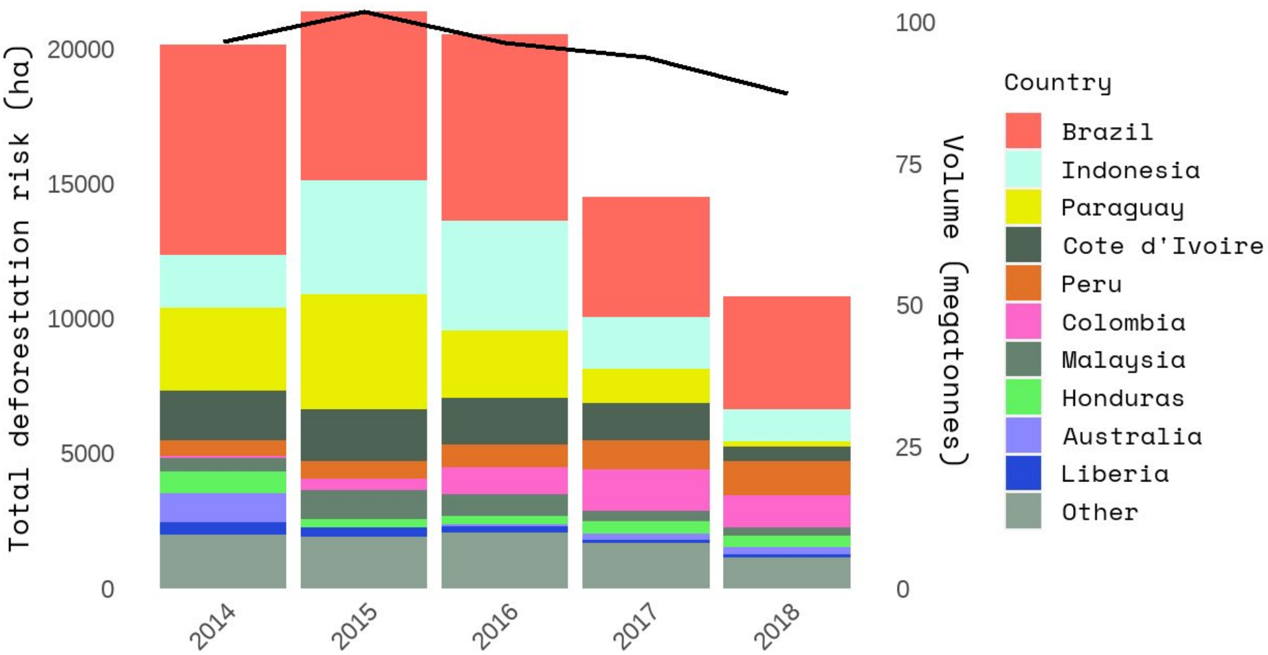

Figure 8: Re-export-adjusted commodity deforestation risk from the top 10 countries (ha). The total trade volume (mass of raw material equivalents across all country sources, regardless of their association – or not – with deforestation) is also shown by the black line and right-hand axis. Results are shown for the top ten commodities in terms of deforestation risk over the entire timeseries, with all other countries grouped together in the 'other' category. Overall, 20.5% of this re-export-adjusted trade volume was of unknown origin and therefore could not be linked to deforestation risk.

Deconstructing the re-export pathways provides insight into the paths taken from point of origin through to Germany. Figure 9 summarises the relative directness of these trade routes and provides context with a breakdown of Germany's domestic sourcing (i.e. supply for Germany's use which originates domestically); this includes domestic production of the focal commodity within Germany, opening stocks, and commodities of unknown origin necessary to meet reported demand for both exports and/or domestic use. It should be noted that this data refers to the quantities that remain in Germany after it has exported any commodities.

The sourcing of palm kernel cake and green coffee are dominated by relatively direct trade flows, while fresh cattle hides (which will not typically be traded) are produced domestically. In the case of cocoa products, the beans are sourced via imports, but a significant proportion of derived commodity supply is satisfied by domestic processing. Note that a large proportion of Germany's supply of palm kernel oil is associated with unknown origin.

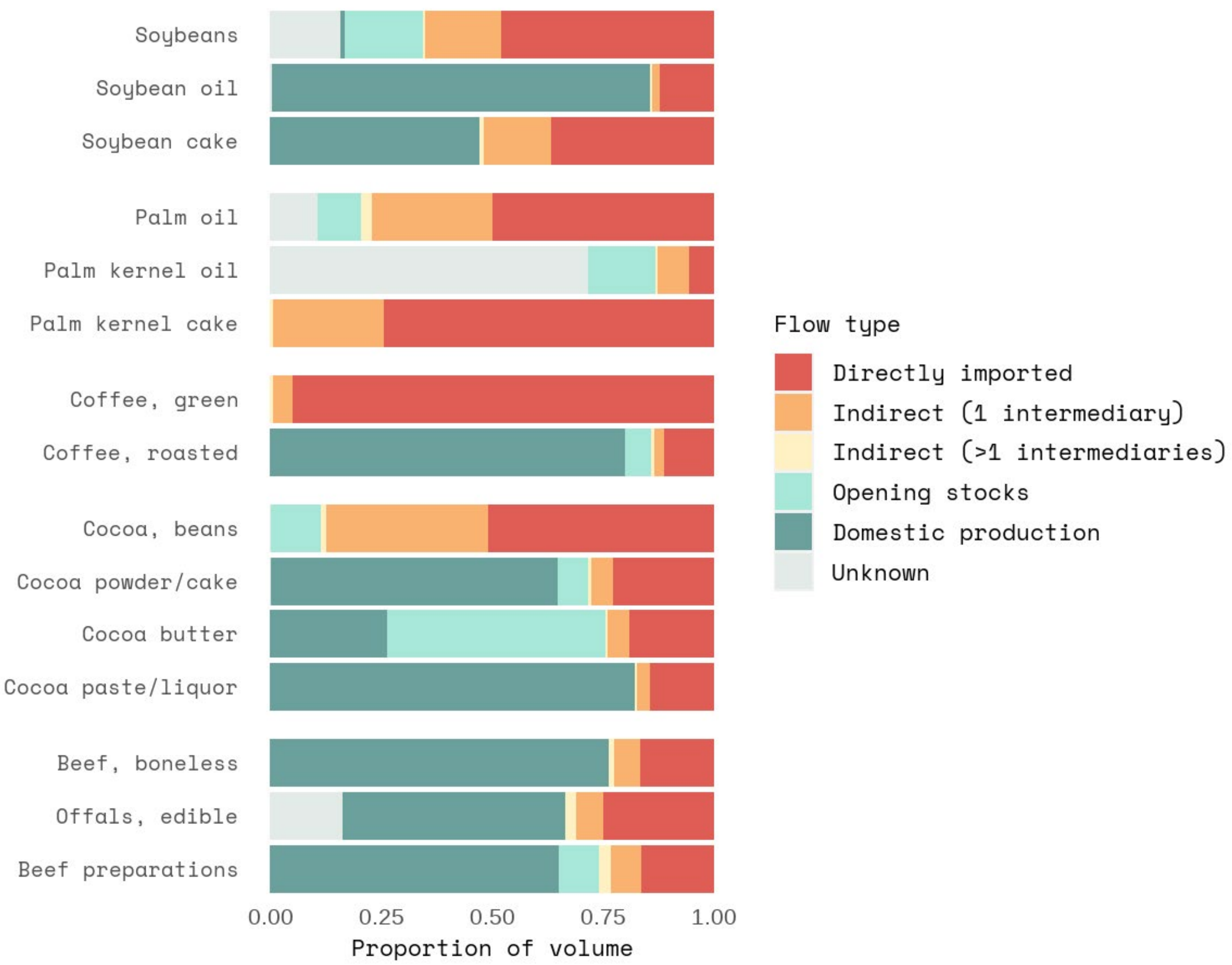

Figure 9: High-level breakdown of German supply pathways for selected high-deforestation-risk commodities in 2014-2018. This includes three types of trade: direct trade, indirect trade (with one intermediary between point of origin and Germany) and other indirect trade (i.e.trade with more than one intermediary). There are also two 'domestic' sources of supply to Germany: opening stocks (stocks carried over from previous year) and domestic production. Additionally, there may be the presence of supply introduced to balance the accounts and assigned 'unknown' origin.

Consumption-based accounts

Our consumption-based analysis at national scale[5] indicates that, at 137,600 ha between 2016 and 2018, the commodity deforestation risk of national consumption is substantially higher than that indicated by direct trade or re-export-adjusted analysis (58,500 ha and 45,900 ha respectively). This is a relatively typical result when considering risk from the perspective of countries which are likely to be net consumers of products produced overseas, reflecting the fact that much of Germany's supply chain impacts will be 'embedded' within processed products which are imported (but which are not captured with the re-export or direct trade analyses, since these only consider the products directly derived from harvested materials).

5. Note that it is possible to further break down results from consumption-based assessment into the risk associated with particular economic sectors. This has not been conducted for the purposes of this study.

Another observation is that the decreasing trend in the total agricultural commodity deforestation risk illustrated in the direct and re-export results (while still observable to a degree) is nowhere near as striking (Figure 10), suggesting an increase in exposure to deforestation from products imported in processed forms or linked to other upstream production processes.

One can also observe that there are some significant changes in which commodities are important to Germany's overall deforestation (Figure 11). Firstly, products such as palm oil and cattle, which were present in the other accounts, increase in relative importance; particularly cattle products which increase substantially (accounting for almost a quarter (23.5%) of Germany's consumption-based deforestation risk between 2016 and 2018, but just 2.7% and 7% of Germany's direct trade and re-export-adjusted risk over the same period). Indeed, impacts associated with soybean were relegated to third place in 2018 in comparison to the re-export results (where soybean was the largest contributor to the risk), with palm oil and then cattle products occupying first and second place.

Cocoa and coffee have a substantially lower contribution to the share of the commodity deforestation risk (4.7% and 5.3% respectively between 2016-2018) compared to direct and re-export-adjusted results. Cashew nuts, which were also an important component of risk in the re-export results, persist in the consumption results (2% of Germany's consumption-based risk 2016-2018). Also included in the consumption results are maize (3.9%), rice (4.5%), cassava (1.4%) and seed cotton (0.8%), which are also important drivers of global deforestation risk according to Pendrill et al. (2022). Again, the fact that these are present in the consumption-based risk profile is representative of the more indirect relationship that Germany will have with these products via international supply chains.

An outcome of the inclusion of these more indirect dependencies within the consumption-based results is that the distribution of risk (Figure 12) is now much more geographically widespread in comparison to the re-export and direct trade risk results, with more countries in Latin America, Africa and Southeast Asia appearing as important hotspots of risk. For the first time, Mozambique, Angola and the Democratic Republic of the Congo (DRC) appear in the top ten countries associated with Germany's commodity deforestation risk (Figure 13). Despite these differences, some patterns in the consumption results are consistent with the direct trade and re-export-adjusted perspectives; for example, the declining prominence of Paraguay as a source of deforestation and the growing importance of Colombia.

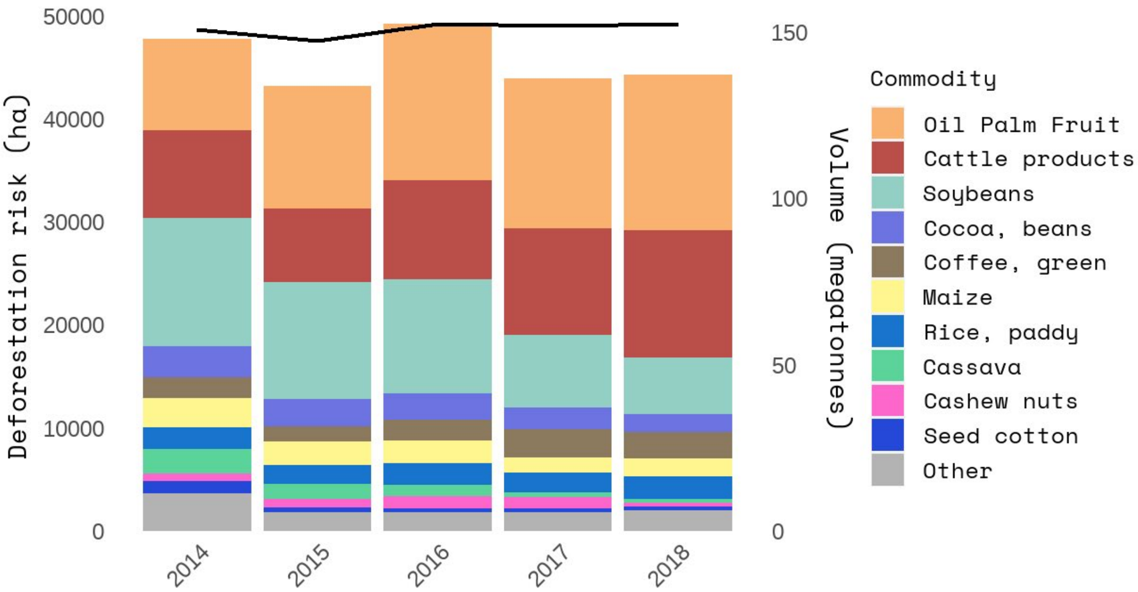

Figure 10: Commodity deforestation risk in Germany's national consumption, by primary commodity. The total production associated with German consumption (mass of raw material equivalents across all country sources, regardless of their association – or not – with deforestation) is also shown by the black line and right-hand axis. Results are shown for the top ten commodity types (ranked by deforestation risk over the entire time series), all other commodities are grouped together in the 'other' category. Note that 19.5% of the total volume linked to German consumption was of unknown origin and therefore could not be linked to deforestation risk.

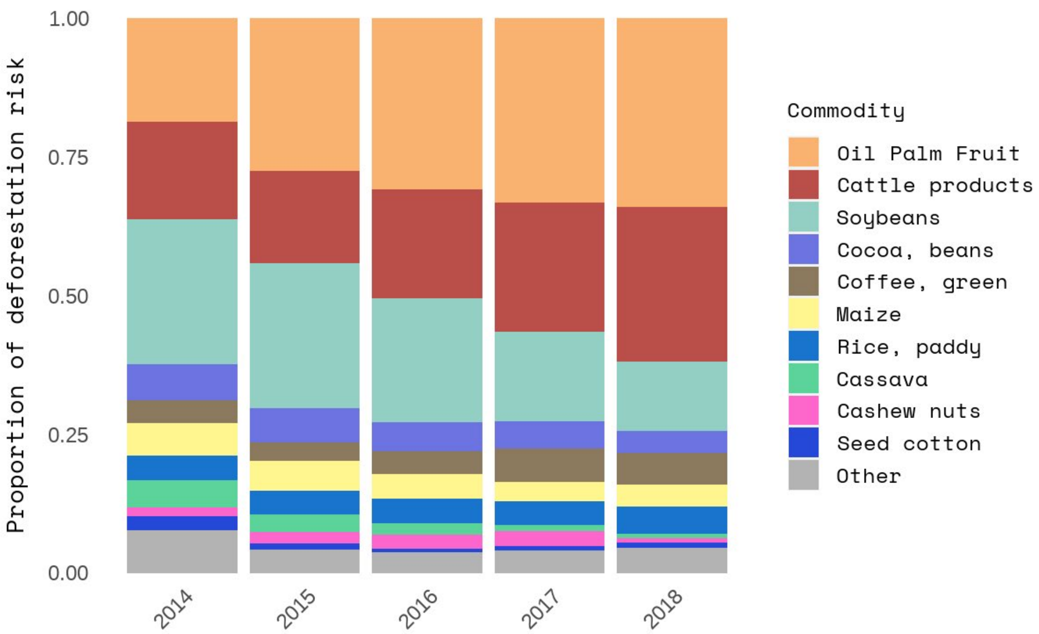

Figure 11: Proportion of commodity deforestation risk associated with Germany's consumption of agricultural commodities by primary commodity. The top ten commodities in terms of deforestation risk over the timeseries are shown; all other commodities are grouped together in the 'other' category. Note that 19.5% of the total volume linked to German consumption was of unknown origin and therefore could not be linked to deforestation risk.

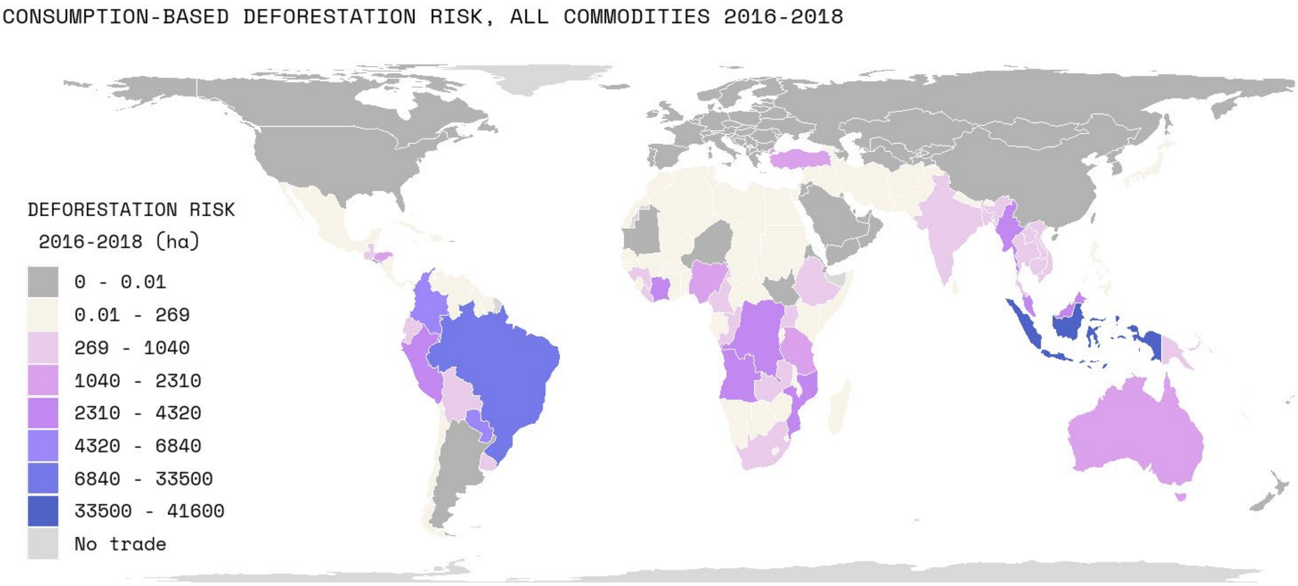

Figure 12: Map of global commodity deforestation risk for Germany from a consumption perspective for the three most recent years with available data (2016-2018). Note that 19.5% of the total production volume linked to German consumption was of unknown origin and therefore could not be linked to deforestation risk.

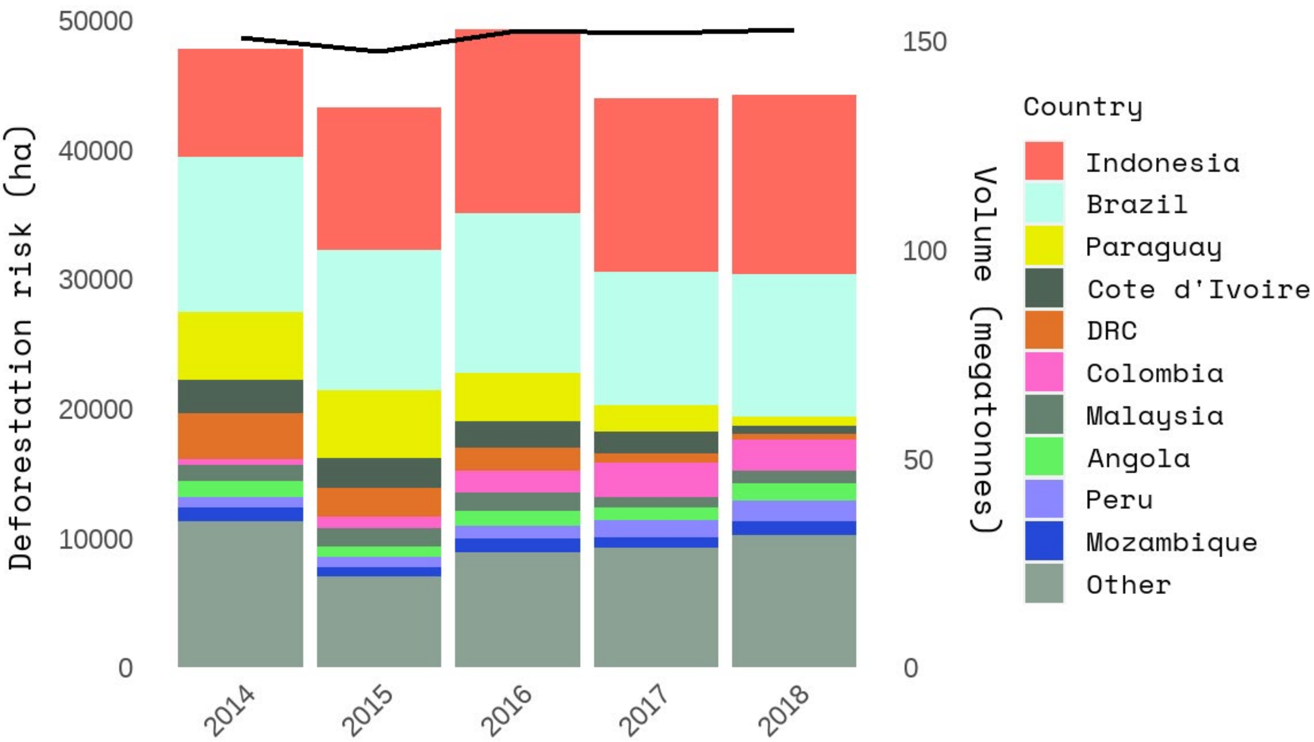

Figure 13: Consumption-based commodity deforestation risk from the top ten countries (in terms of overall risk over the five-year period). Countries not in the top ten are grouped into the 'other' category. The total production for German consumption (mass of raw material equivalents across all country sources, regardless of their association – or not – with deforestation) is also shown by the black line and right-hand axis. Note that 19.5% of the total volume associated with German consumption was of unknown origin and therefore could not be linked to deforestation risk.

Germany's commodity deforestation risk compared to other countries

The deforestation associated with Germany's overall consumption between 2014 and 2018 (229,600 ha) is larger than any other signatory country to the Amsterdam Declarations Partnership (ADP), with France (189,300 ha) and Italy (161,700 ha) in second and third place respectively (Figure 14, Panel A). However, this risk is dwarfed by the deforestation associated with China's consumption (1,148,200 ha). This ranking changes for the other two perspectives: while China still dominates, the Netherlands and Spain outrank Germany in terms of deforestation risk from the direct trade and re-export-adjusted perspectives, with the Netherlands associated with a particularly large amount of deforestation from the direct trade perspective.

Taking into account the quantities of commodities being traded (i.e. hectares of deforestation risk per tonne traded, or deforestation risk intensity) reveals a different pattern. While China has the highest risk intensity from a direct trade perspective, in the re-export and consumption-based analyses the deforestation risk per tonne was lower for China than for the ADP signatory countries, including Germany (Figure 14, Panel B). These results are broken down by commodity in subsequent sections of this report.

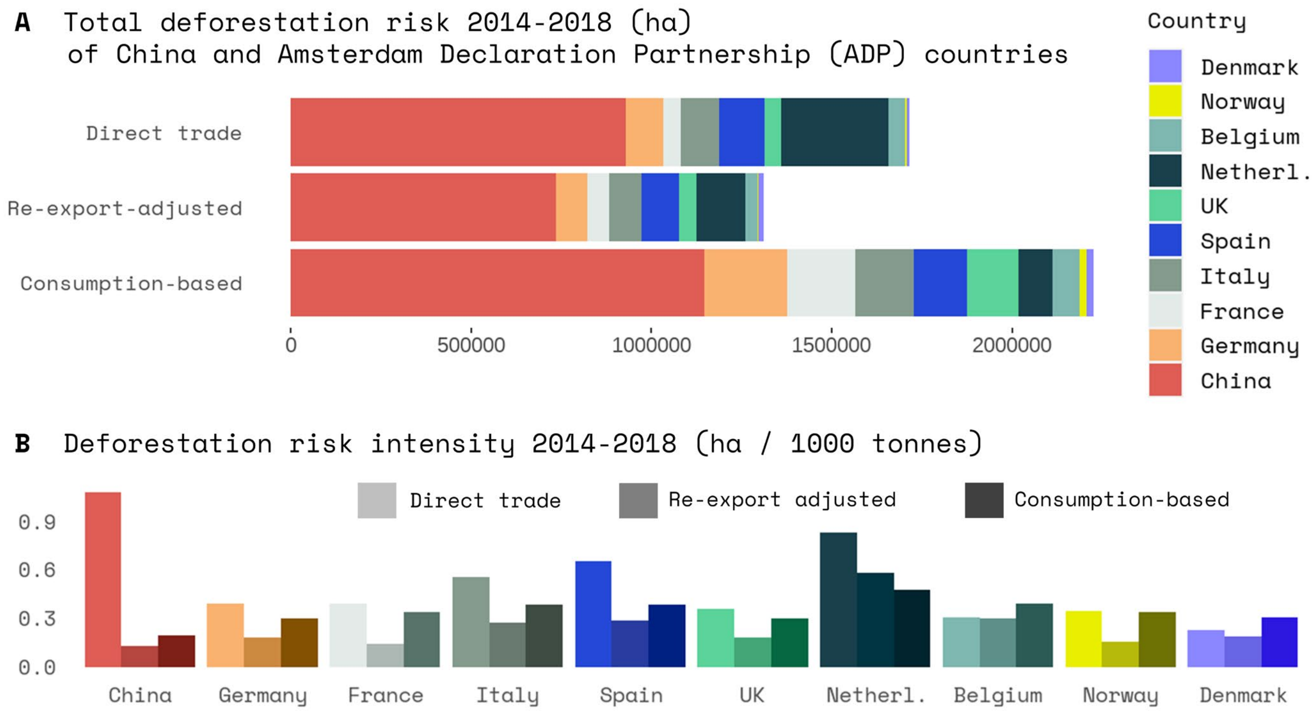

Figure 14: Total commodity deforestation risk (A) and intensity (B) associated with Germany's agricultural supply chains, the other ADP signatory countries, and China for the 2014-2018 period). Results are shown for all three perspectives (direct trade, re-export-adjusted trade, and consumption-based). Countries are arranged in descending order according to their overall consumption-based commodity deforestation risk.

Commodity-specific results

Soybean

Germany's imports of soy products, or production linked to German consumption, was associated with 16,200-23,600 hectares of deforestation in 2016-2018, depending on the supply chain perspective chosen[6]. Soy deforestation risk was significantly higher from a consumption-based perspective (23,600 ha) than from a direct trade (16,200 ha) or re-export-adjusted perspective (16,300 ha). The majority of this risk came from Brazil in the most recent years (71.7-76.4%), although Paraguay was also an important source (22.2-27.8%) (Figure 15). A combination of irreconcilable trade records and the closing/opening stock phenomenon means that 18% of re-export-adjusted soy trade into Germany is of 'unknown' origin, suggesting that the re-export risk (and consumption-based results) is likely to be slightly underestimated.

The time series data reveals a generally decreasing trend in soy deforestation risk from all three perspectives, with direct trade risk in 2018 down 82% from 2005 (Figure 16). The importance of Paraguay in particular has declined in recent years: the direct trade data shows how it was important in driving a peak of 22,400 ha of soy deforestation in 2012; the decline since then is explained by both a large drop both in the quantity of soy sourced from Paraguay and its deforestation intensity (which peaked in 2012). The trends for Brazil are partly explained by very high soy deforestation intensities before 2008, along with reduced imports from Brazil in the most recent two years.

Soy deforestation in Argentina has historically been linked to German direct imports, but very low deforestation intensities since 2010 (rather than a lack of trade) mean that Argentina does not appear significant more recently.

6. Please refer to the Methodological Summary section, the summary of approaches provided in Table 1, and particularly to the "Methodological assumptions and considerations" for a description of the methods and associated assumptions used to derive the results in this study. Results are designed to be indicative of hotspots of commodity deforestation risk, but should be interpreted on the basis of the methods employed which are not traceability assessments.

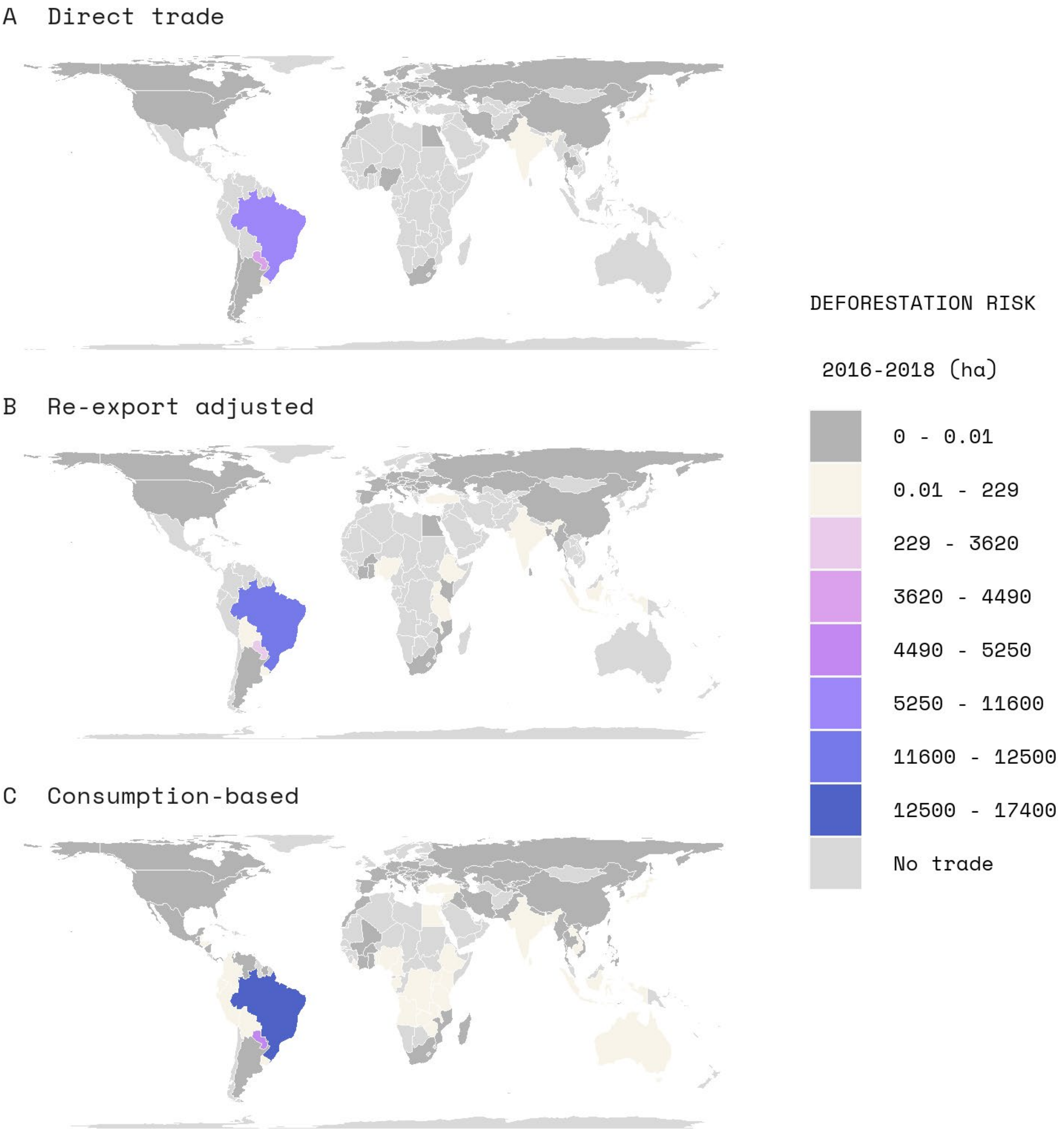

Figure 15: Maps of soy deforestation risk by source country, from the three supply chain perspectives: direct trade (A), re-export-adjusted trade (B) and a consumption-based approach (C). Values are summed across the three most recent years with available data (2016-2018). Note that 18% of the traded volume in (B) and 13% in (C) were of unknown origin and therefore could not be linked to deforestation risk.

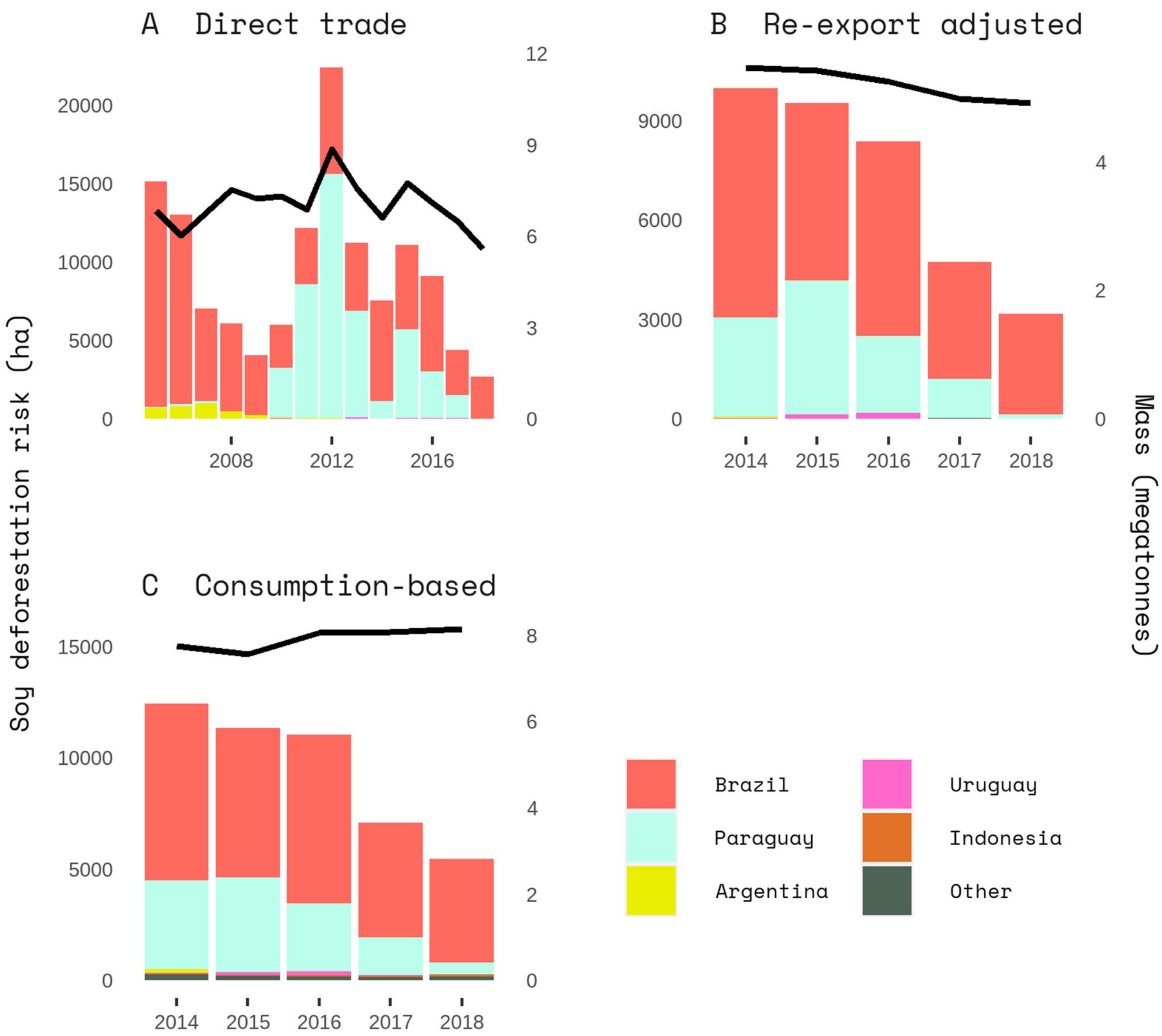

Figure 16: Soy deforestation risk over time by source country, from three supply chain perspectives: direct trade (A), re-export-adjusted trade (B) and a consumption-based approach (C). Results are shown for the top five countries across the three perspectives in terms of deforestation risk, with all other countries grouped in the 'other' category. The total trade volume/production linked to consumption (mass of raw material equivalents across all country sources, regardless of their association – or not – with deforestation) is also shown by the black line and right-hand axis. Note that 18% of the traded volume in (B) and 13% in (C) were of unknown origin and therefore could not be linked to deforestation risk.

Germany's role in soy trade pathways

Breaking down trade pathways to isolate individual routes and their associated volumes provides insights into both the key countries acting as intermediaries between point of production and German import, and also the role of Germany itself as an intermediary in other countries' sourcing.

Due to computational requirements and data tractability, these pathways are only deconstructed for supply chain paths with three nodes in which Germany appears as a destination or intermediary, or – for selected derived commodities – a source. While this does not provide complete coverage of all possible trade flows, these supply chain pathways capture potential routes of greatest significance[7], whereas longer chains are typically more numerous, fragmented and less important in terms of traded mass.

For soybean imports into Germany via an intermediary (Table 2), the Netherlands and Belgium are key pathways, but selected other countries (e.g. Canada, Romania, Poland, Italy, United States) are also re-exporters. Trade of soybean oil via intermediaries appears to be of relatively small volumes. For soybean cake, the Netherlands dominates as an intermediary, but Italy and Denmark are also notable, with Luxembourg and Austria also relevant to flows of cake which originate from the Netherlands. Where Germany acts as an intermediary in the supply chains of third parties (Table 3), it appears it has a relatively important role in the trade pathway of soybean to Portugal. Smaller volumes are again involved for soybean oil, but destinations include Poland, Algeria and India. Germany has a large role in the re-export of soybean cake to Denmark, Czechia and Austria. Where Germany acts as a source of derived soybean commodities (Table 4), for soybean oil the Netherlands, Poland, Algeria, India and Belgium are important destinations, and for soybean cake (exported in larger quantities) neighbouring countries of Denmark, Czechia, Austria, France and Poland are important.

7. It is important to reiterate that re-export-adjusted trade pathways are derived via computations based on reconciled trade data and a 'mass-balance' approach to assigning supplies to exports. These results should be treated, therefore, as estimates of potential trade pathways. Shipment-specific and/or industry-specific information would be required to validate the role of intermediaries in Germany's trade pathways; this information is not, to our knowledge, publicly accessible for use across multiple commodities and trades.

Soybean			Soybean oil			Soybean cake		
Origin	Intermediate Country	Mass (tonnes)	Origin	Intermediate Country	Mass (tonnes)	Origin	Intermediate Country	Mass (tonnes)
United States	Netherlands	545,000	**Paraguay**	Netherlands	936	**Brazil**	Netherlands	433,000
	Belgium	14,600					Italy	2,260
	Canada	12,200					Denmark	396
Brazil	Netherlands	210,000	**Netherlands**	UK	543	**Argentina**	Netherlands	52,100
	Belgium	18,400		Belgium	151		Italy	15,800
	Romania	2,930					Denmark	1,600

Soybean			Soybean oil			Soybean cake		
Origin	Intermediate Country	Mass (tonnes)	Origin	Intermediate Country	Mass (tonnes)	Origin	Intermediate Country	Mass (tonnes)
Ukraine	Netherlands	15,600	**Norway**	Netherlands	317	**Paraguay**	Netherlands	19,400
	Poland	2,050		Sweden	201		Italy	1,480
	Italy	318					Denmark	233
Paraguay	Netherlands	17,400	**Argentina**	Netherlands	393	**China**	Netherlands	16,000
	Brazil	270					Denmark	219
	Italy	239					Italy	178
Canada	Netherlands	5,830	**Hungary**	Austria	269	**Netherlands**	Luxembourg	2,520
	Belgium	2,660					Belgium	1,750
	United States	1,440					Austria	473

Table 2. Three-node trade relationships for Germany's trade of soybean, soybean oil and soybean cake, 2018, where Germany is the destination country. The five most important countries of origin by mass (value reported, not converted to raw material equivalents) shown, with top three re-export pathways (intermediary countries) associated with these origins (where mass is at least 100 tonnes). According to our reconciled re-export-adjusted data, in total, 2.6 million tonnes of soybeans, 46,000 tonnes of soybean oil, and 2.1 million tonnes of soybean cake were imported into Germany in 2018 (excluding quantities re-exported elsewhere).

Soybean			Soybean oil			Soybean cake		
Origin	Destination Country	Mass (tonnes)	Origin	Destination Country	Mass (tonnes)	Origin	Destination Country	Mass (tonnes)
United States	Portugal	31,100	**Netherlands**	Poland	2,360	**Brazil**	Denmark	122,000
	Poland	6,640		Algeria	1,901		Czechia	42,300
	Austria	2,550		India	1,450		Austria	28,200

Table continues onto next page

Brazil	Portugal	6,150	**Serbia**	Poland	387	**Nether-lands**	Denmark	68,800
	Poland	1,310		Algeria	311		Czechia	23,800
	Austria	505		India	237		Austria	15,900
Canada	Portugal	3,700	**Hungary**	Poland	168	**India**	Denmark	12,200
	Poland	790		Algeria	135		Czechia	4,210
	Austria	304		India	103		Austria	2,800
Ukraine	Portugal	1,230	**Austria**	Poland	108	**Argen-tina**	Denmark	11,100
	Poland	262					Czechia	3,840
	Austria	101					Austria	2,560
Austria	Portugal	673	**Italy**	Poland	107	**Russia**	Denmark	5,500
	Poland	144					Czechia	1,900
							Austria	1,270

Table 3. Destination of soybean, soybean oil and soybean cake where Germany is an intermediary in three-node trade relationships, 2018. The five most important countries of origin by mass (value reported, not converted to raw material equivalents) shown, with top three destinations (where mass is at least 100 tonnes). Note that destinations and proportions are the same for each point of origin due to mass-balance treatment of flows (see Methodological Summary). In total, 66,700 tonnes of soybeans, 16,900 tonnes of soybean oil and 549,000 tonnes of soybean cake were imported into Germany before being re-exported elsewhere in 2018.

Soybean oil			Soybean cake		
Origin	Second destination	Mass (tonnes)	Origin	Second destination	Mass (tonnes)
Netherlands	Netherlands	13,700	**Denmark**	Denmark	302,000
	Morocco	8,640		China	1,610
	United Kingdom	8,270		Sweden	1,050
Poland	Poland	34,100	**Czechia**	Czechia	105,000
	Czechia	363		Slovakia	5,040
				Austria	675
Algeria	Algeria	27,400	**Austria**	Austria	69,800
	Mauritania	135		Czechia	3,830
				Slovakia	985
India	India	20,900	**France**	France	40,800
				Turkey	172
Belgium	Belgium	13,600	**Poland**	Poland	39,200
	Angola	1,310		France	131
				Slovakia	102

Table 4. Destination of soybean oil and soybean cake where Germany is an origin in three-node trade relationships for the supply of third-party countries, 2018. The five most important immediate destinations by mass (value reported, not converted to raw material equivalents) are shown (where mass is at least 100 tonnes), plus up to three onward destinations. Note that in cases where there is no onward trade, the second destination is the same as the initial destination. In total, 221,000 tonnes of soybean oil and 784,000 tonnes of soybean cake were produced from soybean crushing in Germany in 2018 before being subsequently exported.

Germany's soy deforestation risk compared to other countries

From a consumption-based perspective, Germany's total soy deforestation risk for the period 2014-2018 (47,400 ha) outranks all other ADP signatory countries, but is considerably smaller than that of China (409,300 ha) (Figure 17, Panel A). Germany's soy deforestation risk also outranks other ADP countries with the re-export-adjusted trade perspective, closely followed by France, Spain and the Netherlands. Germany's soy deforestation risk from direct trade (34,807 ha) remains larger than that of France (29,300 ha) but is smaller than Spain's (41,210 ha), and considerably smaller than that of the Netherlands (73,200 ha). In each of the perspectives, China's soy deforestation risk is more than double that of all the ADP countries combined.

Although the total soy deforestation risk associated with Germany's consumption is larger than other assessed ADP countries, the risk intensity (Figure 17, Panel B) is generally similar to other countries: typically smaller across the three perspectives than that of France and the Netherlands, but larger than that of China and the UK. Germany's soy risk intensity was fairly consistent across the three perspectives, in contrast with some countries like Belgium, where the direct imports had a very low risk intensity but a much higher intensity from a re-export-adjusted or consumption-based perspective.

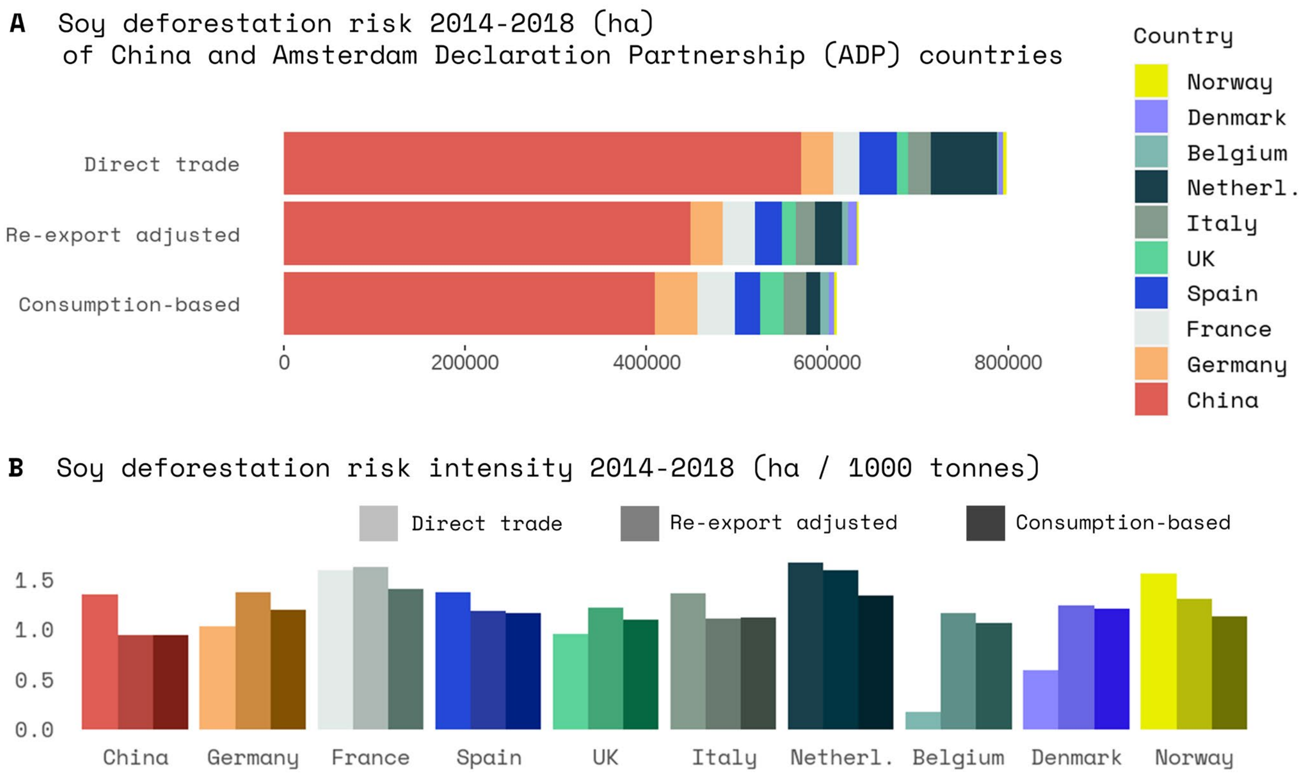

Figure 17: Tropical and subtropical soy deforestation risk (A) and risk intensity (B), compared between selected countries. Results are shown for all three perspectives (direct trade, re-export-adjusted trade and consumption-based). Countries are arranged in descending order according to their consumption-based soy deforestation risk.

Soy deforestation risk at the subnational level

For Brazil, data for the three most recent available years (2016-2018) reveals that soy deforestation linked to German imports was highly concentrated in the Matopiba region, both from a direct trade and re-export-adjusted perspective (Figure 18). The three municipalities with the greatest deforestation risk (Formosa do Rio Preto, Alto Parnaiba and Urucui), accounted for 61.6% of the total soy deforestation risk directly imported to Germany from Brazil, and 49.5% after re-export adjustment. In general, the re-export-adjusted results show a more distributed pattern of risk.

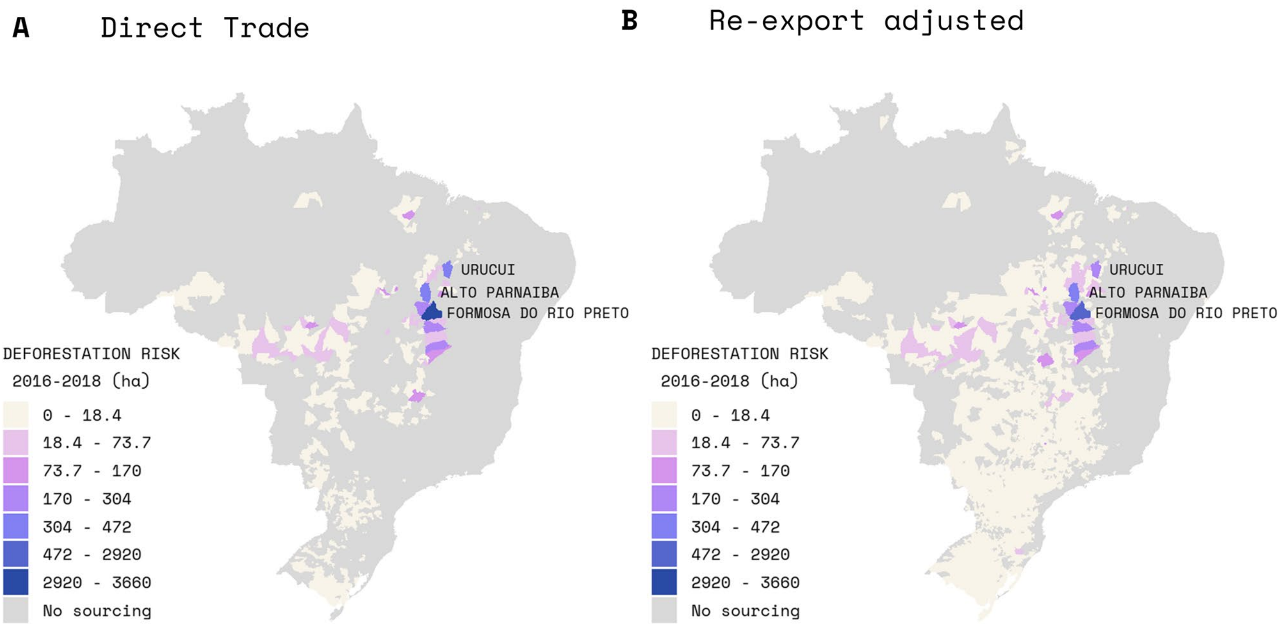

Figure 18: Subnational patterns of soy deforestation risk in Brazil associated with German imports, summed over the period 2016-2018 (the most recent three years with Trase data). Results are shown from a direct trade (A) and re-export-adjusted (B) perspective.

Trends over time in these subnational sources of deforestation risk are presented at a coarser (state) level (Figure 19). The state of Bahia has been the most important source of soy deforestation risk for Germany over the time series, making up 63.1% and 53.3% of the 2016-2018 risk from the direct trade and re-export-adjusted perspectives, respectively. However, in the most recent years, both the absolute risk from Bahia and its relative contribution have declined. Historically, the longer time series available with the direct trade data shows that Mato Grosso was a significant contributor (13.8%) to the risk profile before 2010, although appears less important in subsequent years. Over the time series, Tocantins and Maranhao have also been important sources of risk, from both the direct trade and re-export perspectives. In the re-export-adjusted results, Tocantins became a slightly more important source of risk (11% with re-exports vs 9% with direct trade), as did Mato Grosso (in third place with 10% of the risk with re-exports, compared to fifth place with 7% of the risk with direct trade).

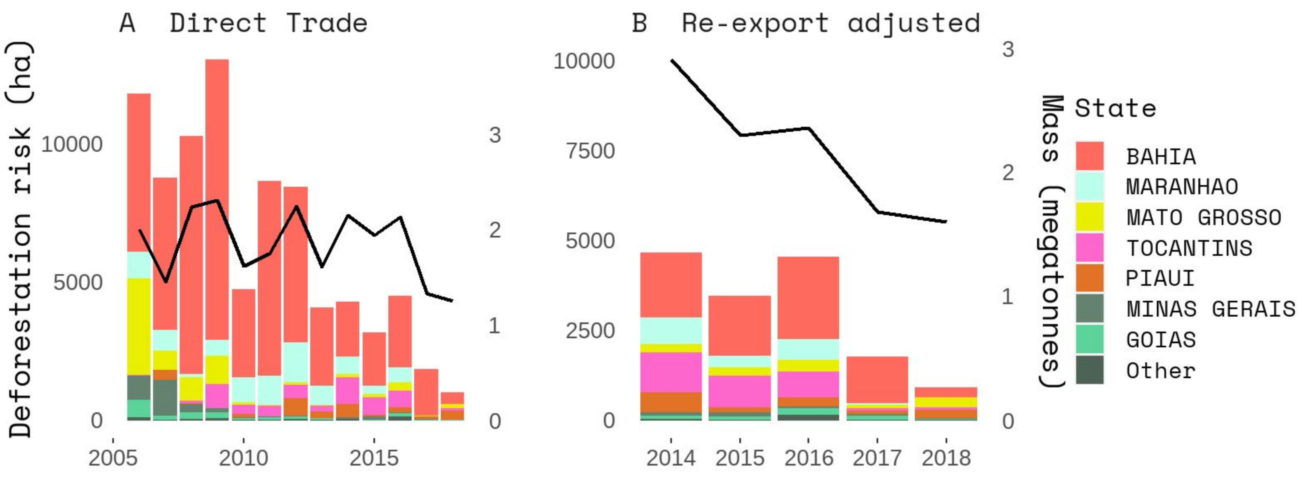

Figure 19: Brazilian soy deforestation risk linked to German imports over time, by state. Results are shown from a direct trade (A) and re-export-adjusted (B) perspective, for the top seven states (ranked by deforestation risk over the timeseries), all other states are grouped together in the 'other' category. The total trade volume (mass of raw material equivalents, regardless of their association – or not – with deforestation) is also shown by the black line and right-hand axis.

For soy directly imported into Germany from Brazil, in the most recent year (2018) the exporting trader Bunge is associated with the highest deforestation risk (745 ha)[8]. This is down from a peak of 8,500 ha in 2009 (Figure 20). Other traders highlighted as exporting soy deforestation risk from Brazil into Germany in 2018 were ADM (98 ha) and Amaggi (63 ha), among others. Although risk decreased significantly over the time series, Bunge is associated with the highest risk of any exporter in every year in the time series, usually followed by ADM.

8. These figures are based on the best publicly available data of companies' sourcing patterns and areas of deforestation risk. Trase supply chain maps show which traders are likely to be sourcing from these areas, however a lack of traceability means it is not possible to prove causal links. To do so would need additional assessment

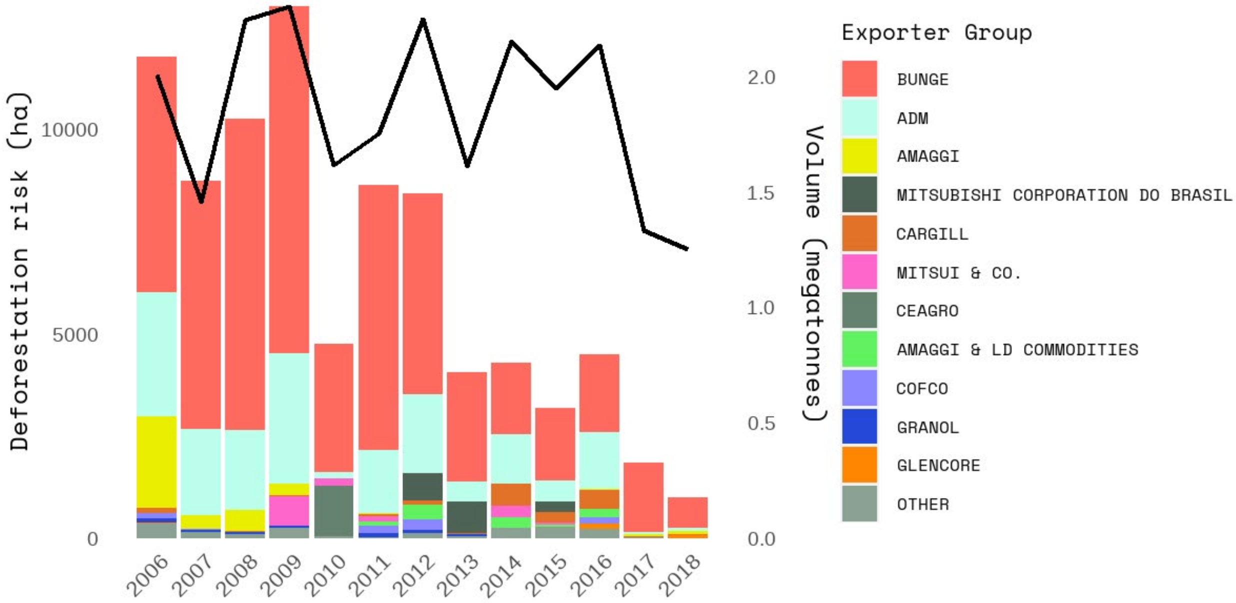

Figure 20: Brazilian soy deforestation risk (linked to German direct imports only) over time, by exporter group. The deforestation associated with any exporters not individually labelled are grouped together into the 'other' category. The total trade volume (mass of raw material equivalents, regardless of their association – or not – with deforestation) is also shown by the black line and right-hand axis.

The re-export-adjusted analysis reveals that the key intermediary country for the German supply of soy from Brazil is the Netherlands, which makes up 19.5% of the supply on average across the time series (Figure 21). Note that, as described in the Methodological Summary and in contrast to results at national-scale, re-export-adjusted Trase data does not account for the additional deforestation risk that might be expected with soy that originates in Brazil, but which is processed into soy oil or cake by intermediaries before reaching Germany.

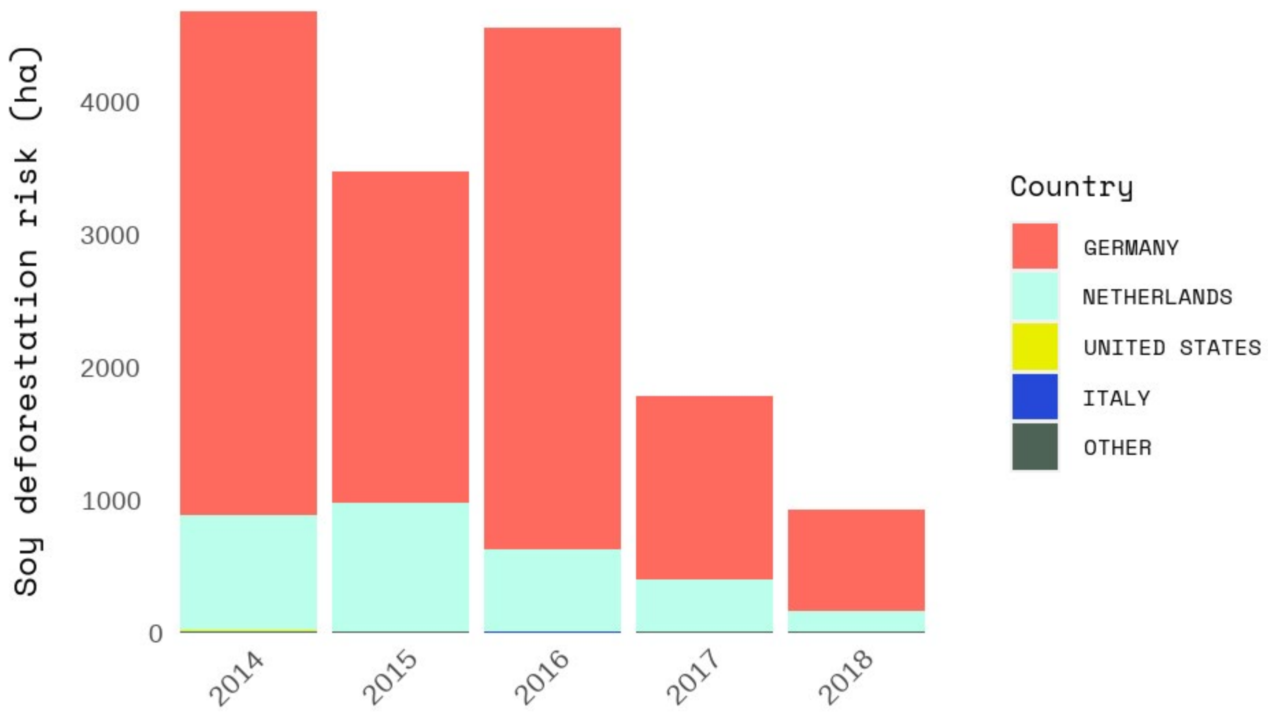

Figure 21: Soy deforestation risk imported into Germany from Brazil via other countries. Results are shown for the top four countries in terms of deforestation risk, with all other countries grouped into the 'other' category. Values for Germany represent direct imports to Germany that were not re-exported elsewhere, and are included to show the relative role of intermediaries (such as the Netherlands) as sources of deforestation risk compared to directly-imported risk).

Argentina was associated with negligible soy deforestation risk[9] for Germany in the national-scale dataset (Figure 16, above), but small amounts of soy deforestation are linked with German imports in the Trase data (this results from methodological differences; see Methodological Summary). For the latest year of Argentina data (2018), soy deforestation risk associated with direct exports to Germany is just 10 ha (direct trade) or 13 ha (re-export-adjusted), a considerable fall of 79-87% since the first year of the time series (2016) which saw 73 or 62 ha respectively. This fall is largely explained by a decrease in deforestation risk to Germany from a single province, Santiago del Estero, which made up the bulk of the soy deforestation risk in 2016, but saw a decline of 87-92% by 2018 (Figure 22). The province with the second largest soy deforestation risk, Chaco, has seen a slight decline over the three year period from both perspectives, but relative to other provinces accounts for the greatest portion of risk from Argentina in the most recent year. The prominence of Chaco province in the re-export-adjusted data is also higher than in the direct trade results (28.9% compared to 21.4 %)

9. This deforestation risk is also confined just to the Chaco region of Argentina.

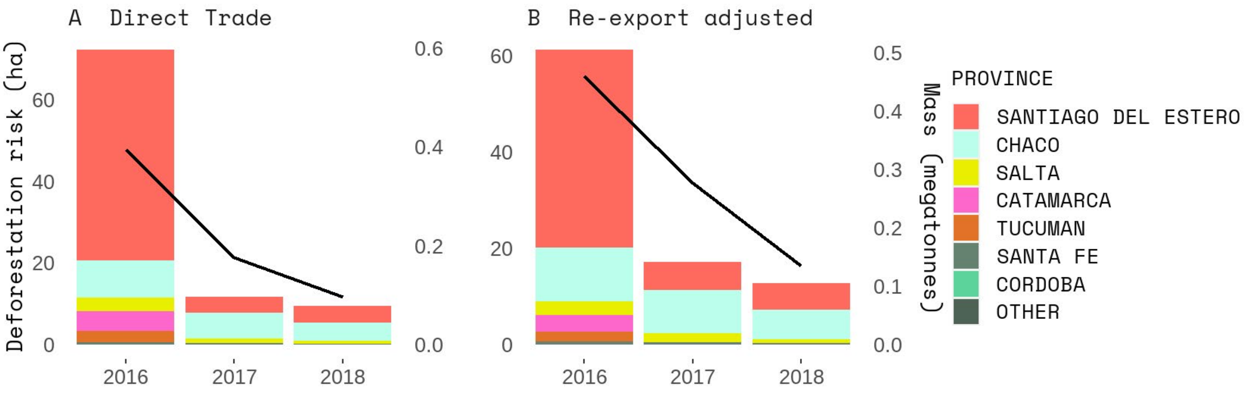

Figure 22: Soy deforestation risk associated with German imports of soy products from Argentina (2016-2018), by province. Results are shown from a direct trade (A) and re-export-adjusted (B) perspective, for the top seven provinces in terms of deforestation risk (with all others grouped into the 'other' category). The total trade volume (mass of raw material equivalents, regardless of their association – or not – with deforestation) is also shown by the black line and right-hand axis.

At the trader level, in 2016, Viluco SA is associated with the highest soy deforestation risk for direct trade between Argentina and Germany (55 ha), with other traders associated with much lower deforestation (Figure 23)[10]. However, different traders are linked to the low amounts of soy deforestation risk in 2017 and 2018, with the risk accounted for entirely by Aceitera General Deheza SA and Bunge (in 2017), and Glencore (in 2018).

10. These figures are based on the best publicly available data of companies' sourcing patterns and areas of deforestation risk. Trase supply chain maps show which traders are likely to be sourcing from these areas, however a lack of traceability means it is not possible to prove causal links. To do so would need additional assessment.

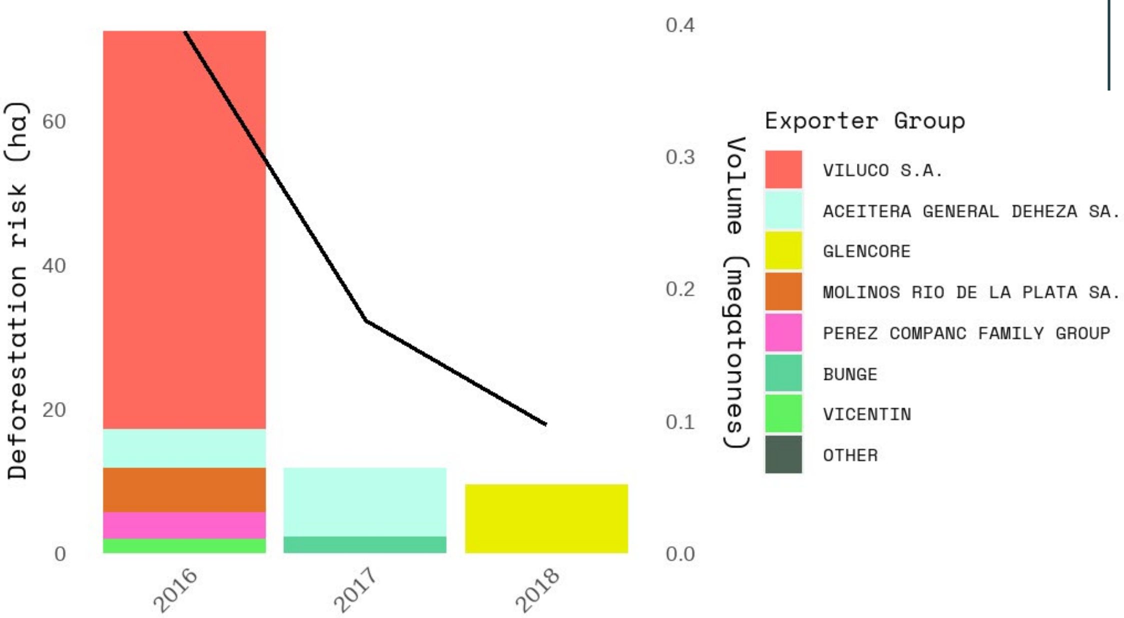

Figure 23: Soy deforestation risk associated with Argentinian exports to Germany, by exporting trader group for the period 2016-2018. The total trade volume (mass of raw material equivalents, regardless of their association – or not – with deforestation) is also shown by the black line and right-hand axis.

As in the case of Brazil, the re-export analysis revealed that the key intermediary country for the German supply of soy from Brazil is the Netherlands, which is an intermediary for 20.2% of the deforestation risk on average across the time series. Supply via Italy also makes up a portion of the risk (3.4%).

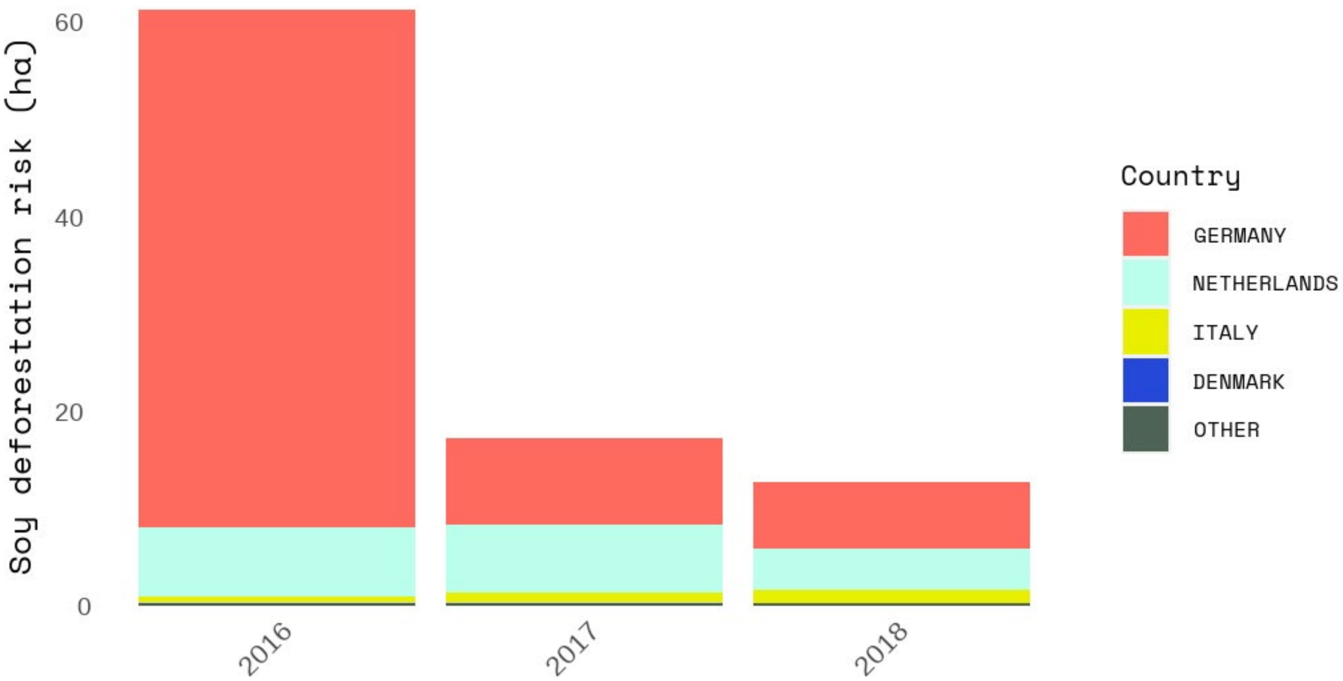

Figure 24: Soy deforestation risk imported into Germany from Argentina via other countries. The top four countries (in terms of deforestation risk) are labelled individually with all others grouped into the 'other' category. Values for Germany represent direct imports to Germany that were not re-exported elsewhere, and are included to show the relative role of intermediaries (such as the Netherlands) as sources of deforestation risk compared to directly imported risk).

At the subnational level in Paraguay, across the most recent three years with data (2016-2018), the departments of San Pedro (367 and 603 ha, from the direct trade and re-export-adjusted analyses respectively), Canindeyu (174 and 285 ha) and Alto Parana (95 and 151 ha) were associated with the greatest soy deforestation risk for Germany (Figure 25 and 26). These three departments accounted for 78.3% or 78.6% of the total risk from the two perspectives. Deforestation risk was highest in 2015 and 2016 from both perspectives, with the rise in 2015 partly attributable to a rise in risk from Canindeyu, while the peak in 2016 is largely due to a surge in risk from San Pedro.

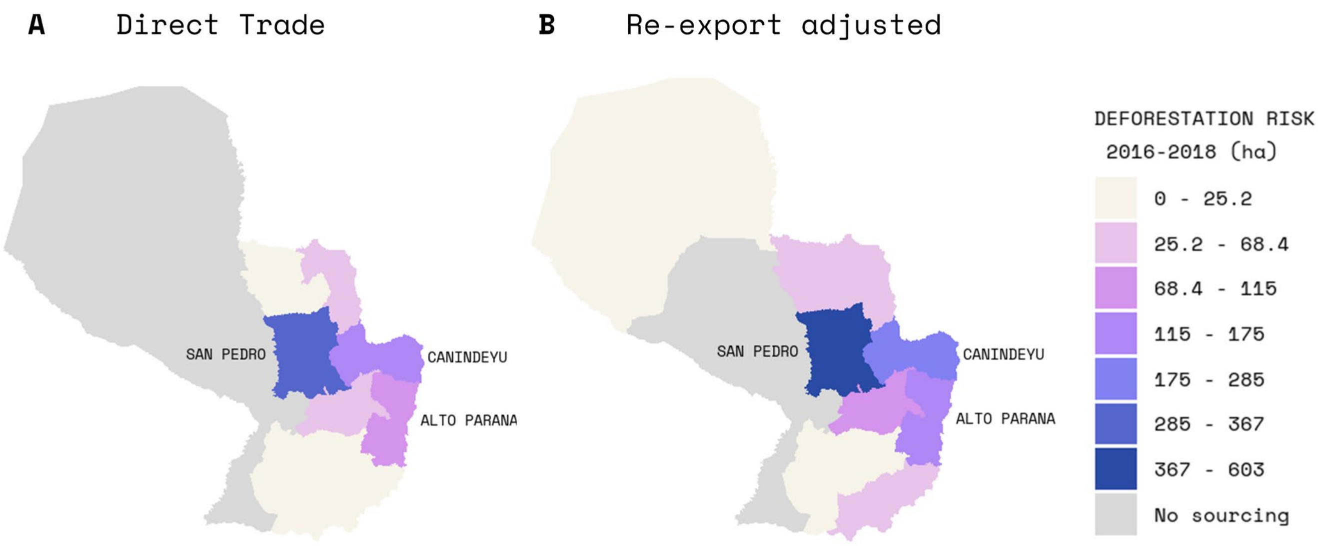

Figure 25: Department-level results of soy deforestation risk imported into Germany from Paraguay for the three years (2016-2018). Results are shown from a direct trade (A) and re-export-adjusted trade (B) perspective. Although direct trade Trase data are available for the year 2019, the period 2016-2018 window is shown here for both perspectives to enable direct comparison. Note that there was no direct trade of soy from Paraguay to Germany in 2018 or 2019.

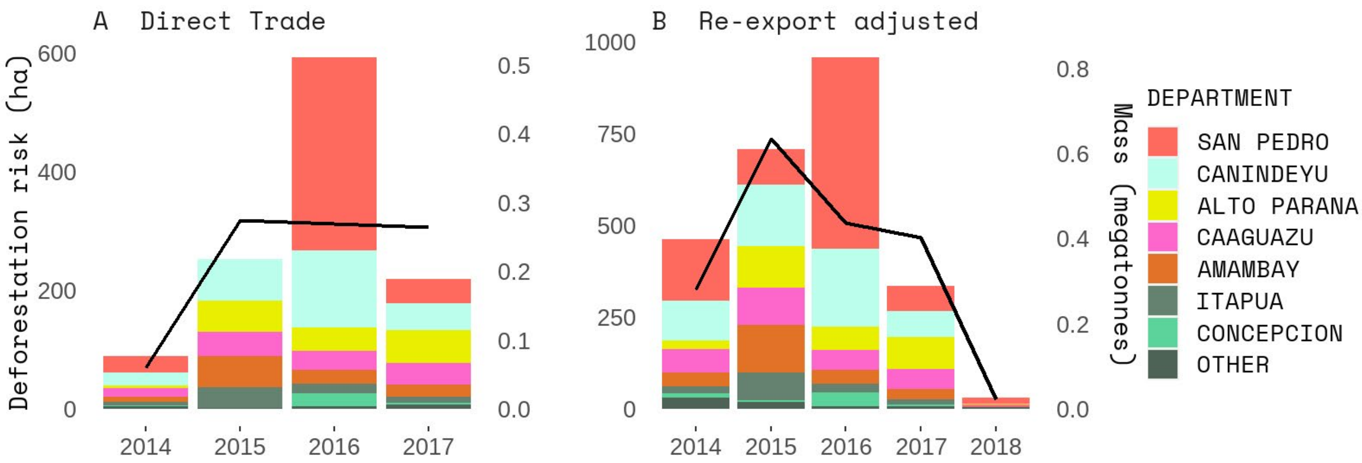

Figure 26: Soy deforestation risk associated with German imports from Paraguay, by department. Results are shown for direct trade (A) and re-export-adjusted trade (B) perspectives. In A, the time series ends in 2017 because there was no direct trade of soy from Paraguay to Germany in 2018 or 2019 (the most recent years with Trase data). In B, the time series ends in 2018 as this is the most recent year with re-export-adjusted trade data. The total trade volume (mass of raw material equivalents, regardless of their association - or not - with deforestation) is also shown by the black line and right-hand axis.

Over the time series, exporting trader ADM is associated with the highest soy deforestation risk for direct trade between Paraguay and Germany (823 ha), with other traders associated with much lower deforestation (Figure 27)[11]. This prominent role of ADM is consistent throughout the time series, although the importance of other traders has varied. COFCO in particular was responsible for a substantial proportion of the soy deforestation risk in 2015 and 2016, but not in 2014 or 2017.

11. These figures are based on the best publicly available data of companies' sourcing patterns and areas of deforestation risk. Trase supply chain maps show which traders are likely to be sourcing from these areas, however a lack of traceability means it is not possible to prove causal links. To do so would need additional assessment.

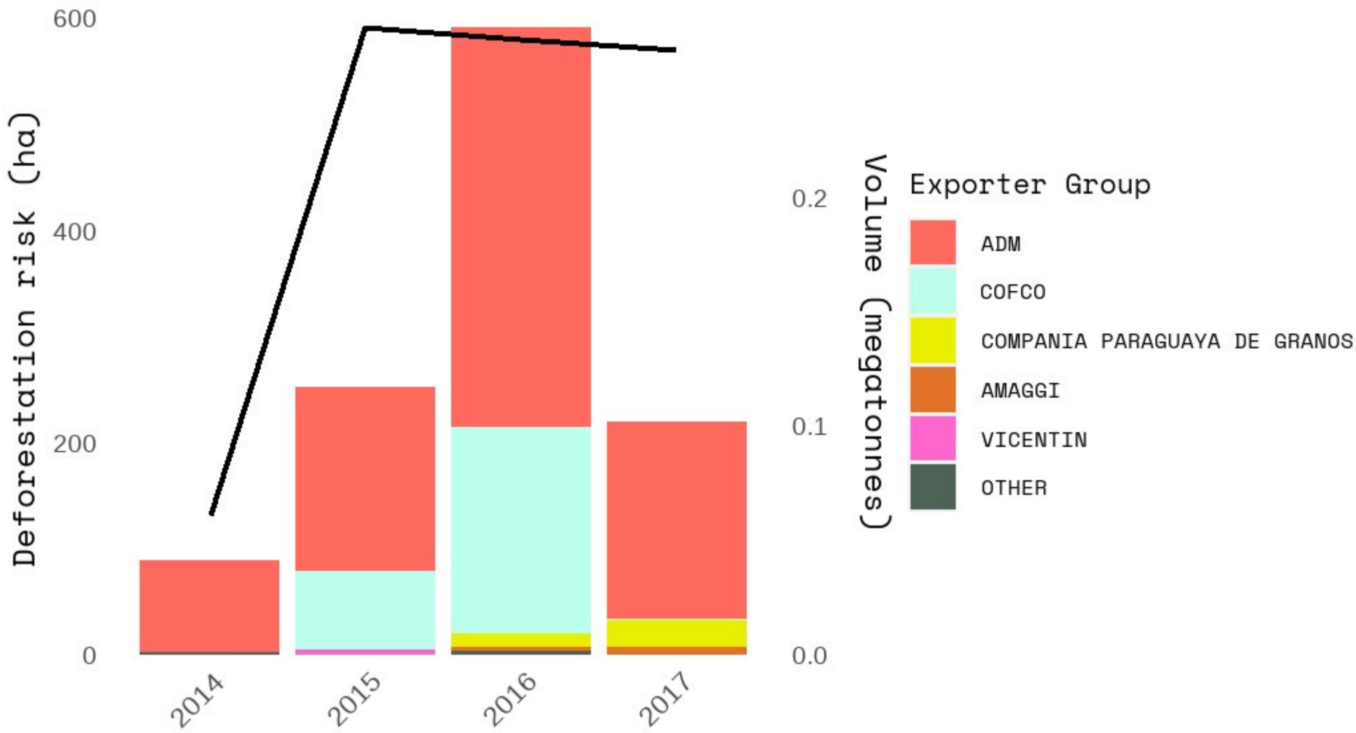

Figure 27: Paraguay soy deforestation risk associated with direct imports to Germany, broken down by exporter group. Exporters not in the top five in terms of deforestation risk over the timeseries are grouped together in the 'other' category. There was no direct trade of soy from Paraguay to Germany in 2018 or 2019. The total trade volume (mass of raw material equivalents, regardless of their association - or not - with deforestation) is also shown by the black line and right-hand axis.

As with Brazil and Argentina, the key intermediary country for the German supply of soy from Brazil is the Netherlands, which is an intermediary for 25.2% of the soy deforestation risk on average across the time series (Figure 28). As with Argentina, Italy also contributes a small component of the risk (1.1%). In 2014, risk from a re-export perspective was considerably higher than from a direct trade perspective; in this year a large proportion of supply is via the Netherlands (73.0%). Notably, also, whilst there is no direct trade in 2018, we do observe a small amount of soy deforestation risk imported indirectly via re-exports; mainly via the Netherlands.

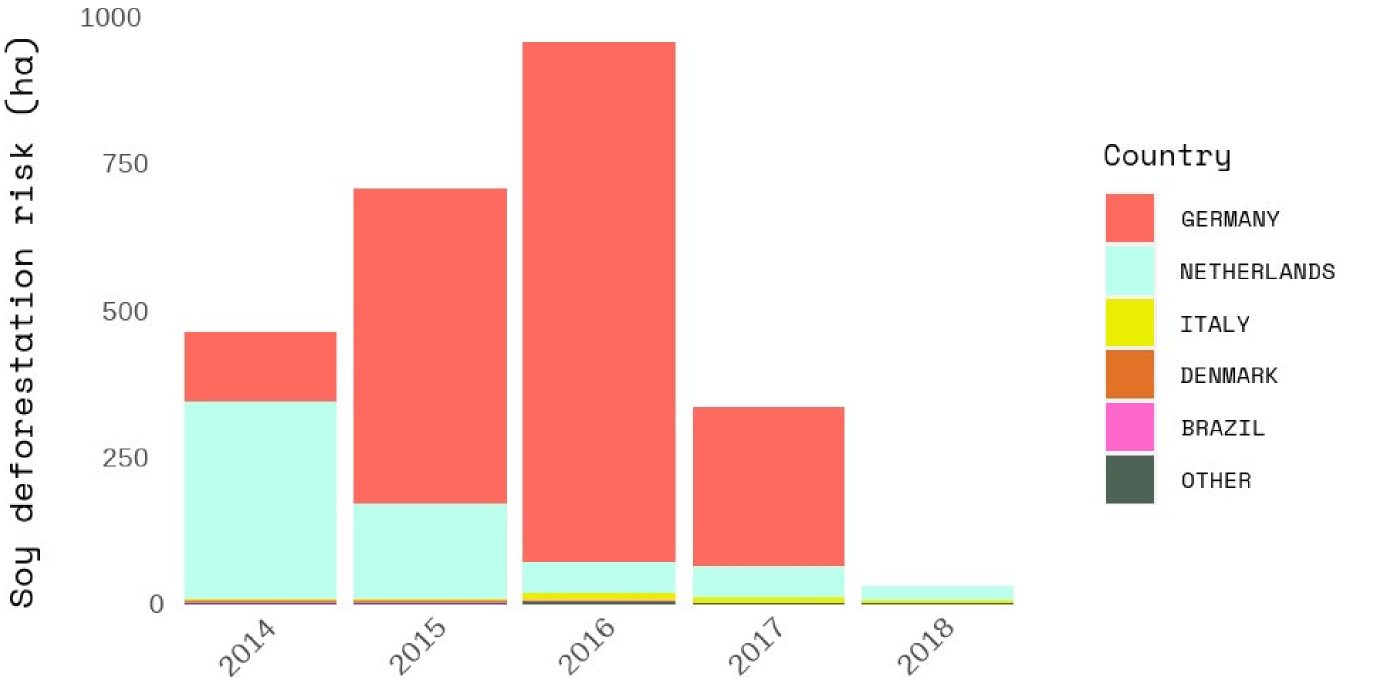

Figure 28: Soy deforestation risk imported into Germany from Paraguay via other countries. Countries not in the top five in terms of deforestation risk over the timeseries are grouped together in the 'other' category. Values for Germany represent direct imports to Germany that were not re-exported elsewhere, and are included to show the relative role of intermediaries (such as the Netherlands) as sources of deforestation risk compared to directly-imported risk)

Palm Oil

Between 2016-2018, German imports of oil palm products, or production linked to German consumption, was associated with 9,140-44,800 ha of deforestation risk, depending on the perspective taken[12]. Overall palm oil deforestation risk was considerably higher from a consumption-based perspective (44,800 ha), than either the direct trade (11,400 ha) or re-export-adjusted trade (9,140 ha) perspectives. It is important to note that 42.5% and 21.2% of trade in oil palm products, in the re-export and consumption-based approaches respectively, is currently classified in our analysis as of 'unknown' origin (largely associated with trade in palm kernel oil, see Figure 9), and therefore results are likely significantly underestimated given the fact that oil palm will mainly be grown in deforestation-risk frontiers. The most important sources of risk across the three perspectives were Indonesia, Malaysia and Colombia, and to a smaller extent Papua New Guinea and Brazil (Figure 29).

12. Please refer to the Methodological Summary section, the summary of approaches provided in Table 1, and particularly to the "Methodological assumptions and considerations" for a description of the methods and associated assumptions used to derive the results in this study. Results are designed to be indicative of hotspots of commodity deforestation risk, but should be interpreted on the basis of the methods employed which are not traceability assessments.

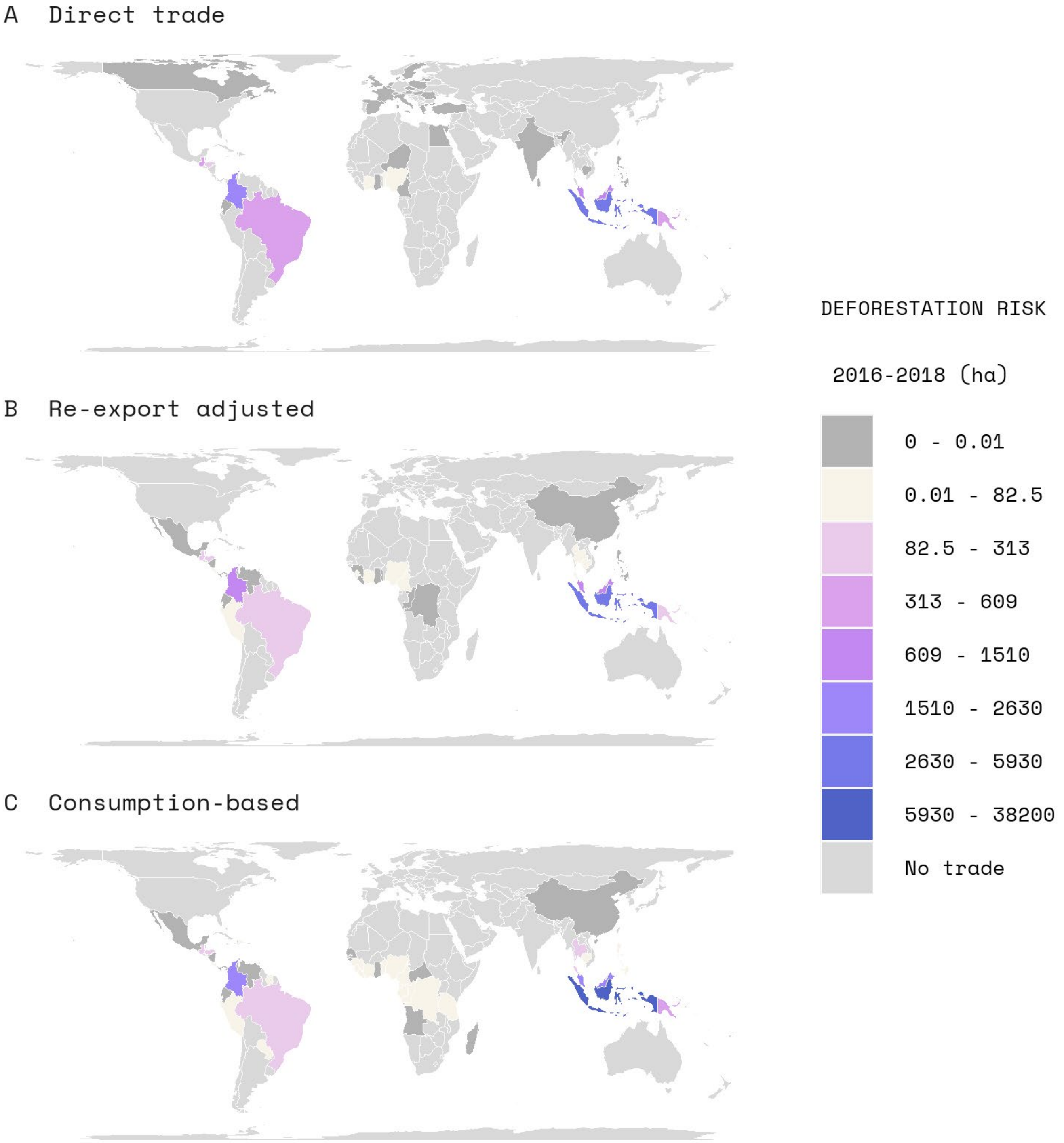

Figure 29: Maps of palm oil deforestation risk by source country, from the three supply chain perspectives: direct trade (A), re-export-adjusted trade (B) and a consumption-based approach (C). Values are summed across the three most recent years with available data (2016-2018). Note that 42.5% of the total volume traded to Germany in (B), and 21.2% of the volume of oil palm products consumed by Germany in (C), were of unknown origin and therefore could not be linked to deforestation risk.

The longest time series is available for the direct trade perspective, which reveals that palm oil deforestation risk for Germany peaked in 2007 at 11,100 ha, and since then has generally declined, with 2018 imports linked to 3,260 ha of deforestation risk (Figure 30). A decline in recent years is also seen in the re-export-adjusted results. However, the consumption-based results show that deforestation risk to Germany has actually increased more recently, suggesting there is an increasing risk from oil palm products that are more highly processed or embedded in upstream supply chains.

The primary source of this palm oil deforestation risk for Germany across all three perspectives has been Indonesia, but Malaysia has also been an important contributor. The significant peak in directly imported risk from Indonesia around 2007 was due to a combination of high trade quantities and high deforestation intensity. Indonesian production dominates the consumption results to an even higher degree than in the direct trade and re-export-adjusted results.

The direct trade results for Germany reveal that palm oil deforestation risk from Colombia has increased in recent years, and at 1,280 ha, was similar to Indonesia (1,360 ha) in the most recent year (2018). This is explained by a recent surge in the deforestation intensity of Colombian palm oil since 2014, along with an increase in the quantity of Colombian palm oil directly exported to Germany over the same period. From the re-export and consumption-based perspectives, the contribution of Colombia is lower. The emergence of Papua New Guinea as a source of risk in recent years is driven by the emergence of palm oil trade with Germany since 2014 (which was absent beforehand) rather than a recent increase in deforestation intensity. For Brazil, the emergence of risk in the last few years was driven by an increase in both, particularly around 2014-2016.

Figure 30: Palm oil deforestation risk over time by source country, from three supply chain perspectives: direct trade (A), re-export-adjusted trade (B) and a consumption-based approach (C). Countries not in the top ten in terms of deforestation risk across the three perspectives are grouped together in the 'other' category. The total trade volume/ production linked to consumption (mass of raw material equivalents across all country sources, regardless of their association - or not - with deforestation) is also shown by the black line and right-hand axis. Note that 42.5% of the total volume traded to Germany in (B), and 21.2% of the volume of oil palm products consumed by Germany in (C), were of unknown origin and therefore could not be linked to deforestation risk.

Germany's role in trade pathways of oil palm products

For palm oil trade into Germany via an intermediary (Table 5), the Netherlands is the key pathway, with Italy also being a notable re-exporter. Selected other countries (e.g. Belgium, the UK, Honduras and Brazil) are also re-exporters to Germany. Re-export of palm kernel cake is largely via the Netherlands, although Malaysia appears as a re-exporter of cake with Indonesian origin. Where Germany acts as an intermediary in the supply chains of third parties (Table 6), it appears it has a relatively important role in the trade pathway of palm oil to Poland, with Denmark and the Netherlands also appearing as destinations. Germany has a role in the re-export of palm kernel cake to Poland, Denmark and Belgium.

Palm Oil			Palm Kernel Cake		
Origin	Intermediate Country	Mass (tonnes)	Origin	Intermediate Country	Mass (tonnes)
Indonesia	Netherlands	31,100	**Indonesia**	Netherlands	65,600
	Italy	11,900		Malaysia	1,090
	Belgium	1,370			
Malaysia	Netherlands	20,400	**Malaysia**	Netherlands	4,520
	Italy	4,480			
Papua New Guinea	Netherlands	11,300	**Slovenia**	Netherlands	2,350
	UK	508			
	Belgium	486			
Guatemala	Netherlands	7,220			
	Belgium	451			
	Honduras	430			

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Palm Oil			Palm Kernel Cake		
Origin	Intermediate Country	Mass (tonnes)	Origin	Intermediate Country	Mass (tonnes)
Colombia	Netherlands	6,460			
	Brazil	1280			

Table 5. Three-node trade relationships for Germany's trade of palm oil and palm kernel cake, 2018, where Germany is the destination. Five most important countries of origin by mass (value reported, not converted to raw material equivalents) shown, with top three re-export pathways (intermediary countries) associated with these origins (where mass is at least 100 tonnes). According to our reconciled re-export-adjusted data, in total, 295,000 tonnes of palm oil and 348,000 tonnes of palm kernel cake were imported into Germany in 2018 (excluding quantities re-exported elsewhere).

Palm Oil			Palm Kernel Cake		
Origin	Destination Country	Mass (tonnes)	Origin	Destination Country	Mass (tonnes)
Indonesia	Poland	27,500	**Malaysia**	Poland	3,350
	Denmark	6,900		Denmark	3,190
	Netherlands	2,780		Belgium	3,130
Netherlands	Poland	15,200			
	Denmark	3,820			
	Netherlands	1,540			
Malaysia	Poland	7,510			
	Denmark	1,880			
	Netherlands	757			

Table continues onto next page

Palm Oil			Palm Kernel Cake		
Origin	Destination Country	Mass (tonnes)	Origin	Destination Country	Mass (tonnes)
Guatemala	Poland	6,080			
	Denmark	1,520			
	Netherlands	613			
Honduras	Poland	5,540			
	Denmark	1,390			
	Netherlands	559			

Table 6. Destination of palm oil and palm kernel cake where Germany is an intermediary in three-node trade relationships, 2018. Five most important countries of origin by mass (value reported, not converted to raw material equivalents) shown, with top three destinations (where mass is at least 100 tonnes). Note that destinations and proportions are the same for each point of origin due to mass-balance treatment of flows (see Methodological Summary). In total, 166,000 tonnes of palm oil and 15,900 tonnes of palm kernel cake were imported into Germany before being re-exported elsewhere in 2018.

Germany's palm oil deforestation risk relative to other countries

As with soy, Germany's total palm oil deforestation risk (2014-2018) from a consumption-based perspective (65,639 ha) was larger than any other ADP signatory country, but significantly lower than risk associated with China (356,000 ha) (Figure 31, Panel A). Italy (61,000 ha) and Spain (59,600 ha) were close behind Germany in terms of consumption-based risk. However, from both the direct trade and re-export-adjusted perspectives, Germany's palm oil deforestation risk was much lower than that of Spain, Italy and the Netherlands. The risk associated with oil palm products directly imported into the Netherlands is particularly striking (169,600 ha), approaching that of oil palm products imported directly into China (194,300 ha).

Risk intensity was often lower for German palm oil imports and consumption than the other assessed countries (Figure 31, Panel B), with German risk intensity notably lower than that of China, Italy, Spain and the Netherlands under the direct trade and re-export-adjusted trade perspectives. Risk intensity was highest with the consumption-based perspective, a pattern also true for the UK, France, Belgium, Denmark and Norway.

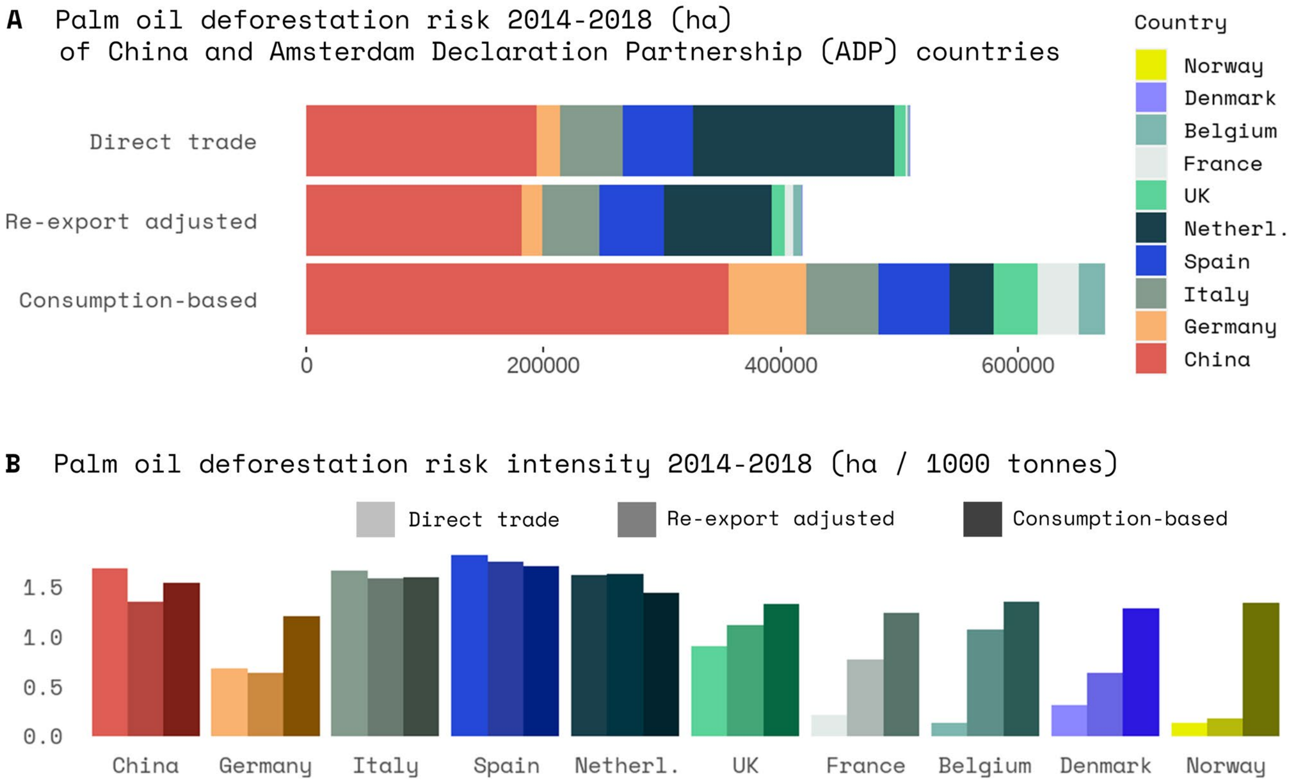

Figure 31: Germany's palm oil deforestation risk (A) and risk intensity (B) compared with selected other countries (ADP signatories and China) for the period 2014-2018. Countries are arranged in descending order of palm oil deforestation risk from a consumption-based perspective. Results are shown for all three perspectives.

Subnational results for palm oil deforestation risk

At the subnational level, Trase data is available for the year 2015, and covers palm oil only (unlike the national-level data above, which also includes palm kernel oil and palm kernel cake). The kabupaten (municipalities) associated with the greatest direct palm oil deforestation risk in 2015 were Musi Banyuasin (279 ha), Rokan Hulu (131 ha), and Banyuasin (127 ha). These three kabupaten accounted for 45% of the total palm oil deforestation risk directly imported to Germany from Indonesia. Almost all of this risk was associated with production in Sumatra, especially in the north and east of the island (Figure 32, Panel A).

Our re-export-adjusted results have a larger overall deforestation risk – at 1,700 ha, total risk is up 46% compared to the direct trade results – and also indicate that the distribution of deforestation risk is much broader (Figure 32, Panel B). The top three kabupaten are the same, but now account for only 30.7% of the total risk. Kalimantan also emerges as an important source of re-export-adjusted risk, which is not identified as a source of risk in direct trade results. In the direct trade results, kabupaten in Kalimantan made up just 0.5% of the overall deforestation risk (6 ha), but 20.5% of the risk in the re-export-adjusted results (348 ha). The most important kabupaten from direct and re-export-adjusted perspectives are summarised in Figure 33.

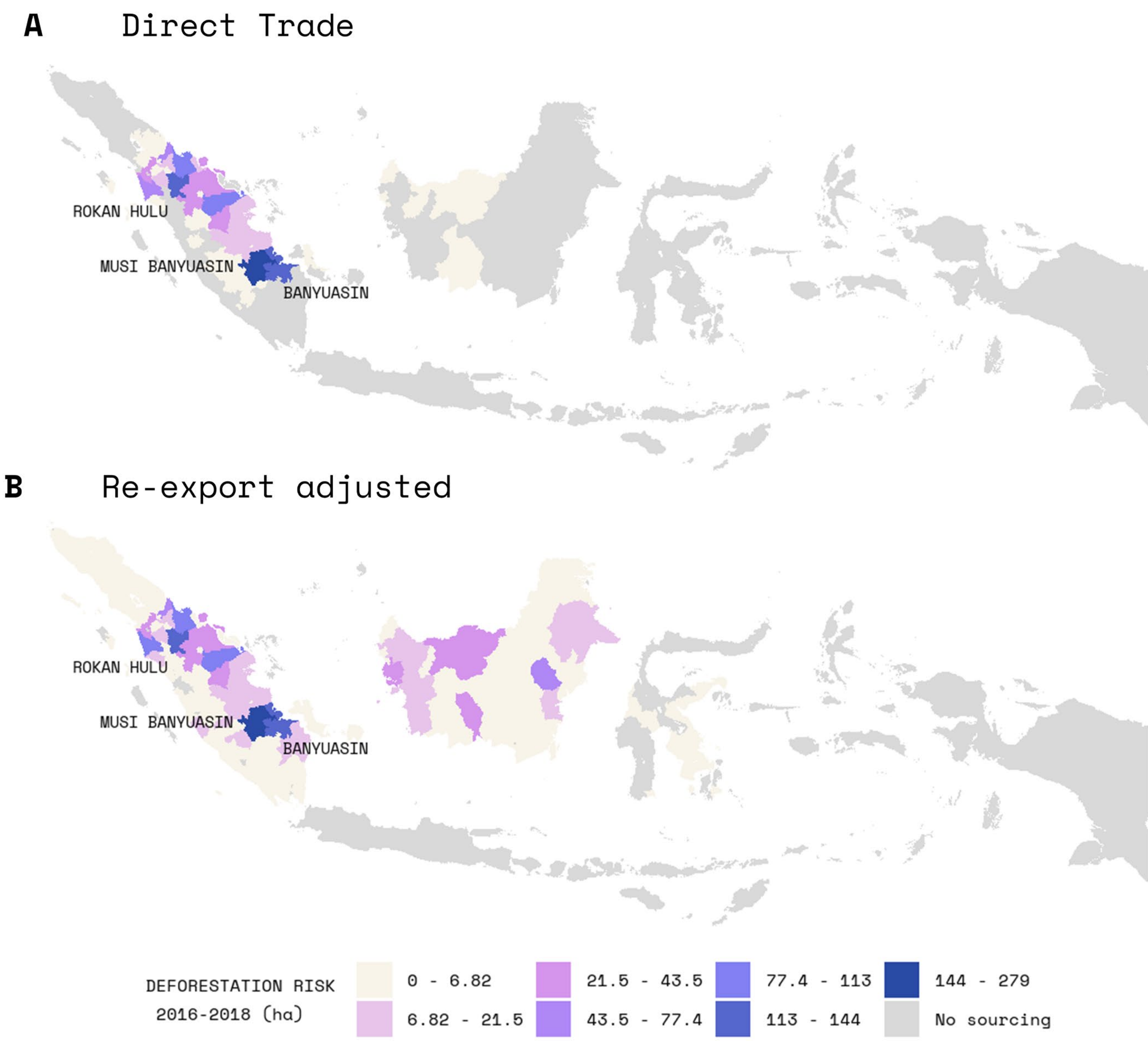

Figure 32: Palm oil deforestation risk associated with German imports from Indonesia in 2015. Results are shown from a direct trade (A) and re-export-adjusted trade (B) perspective.

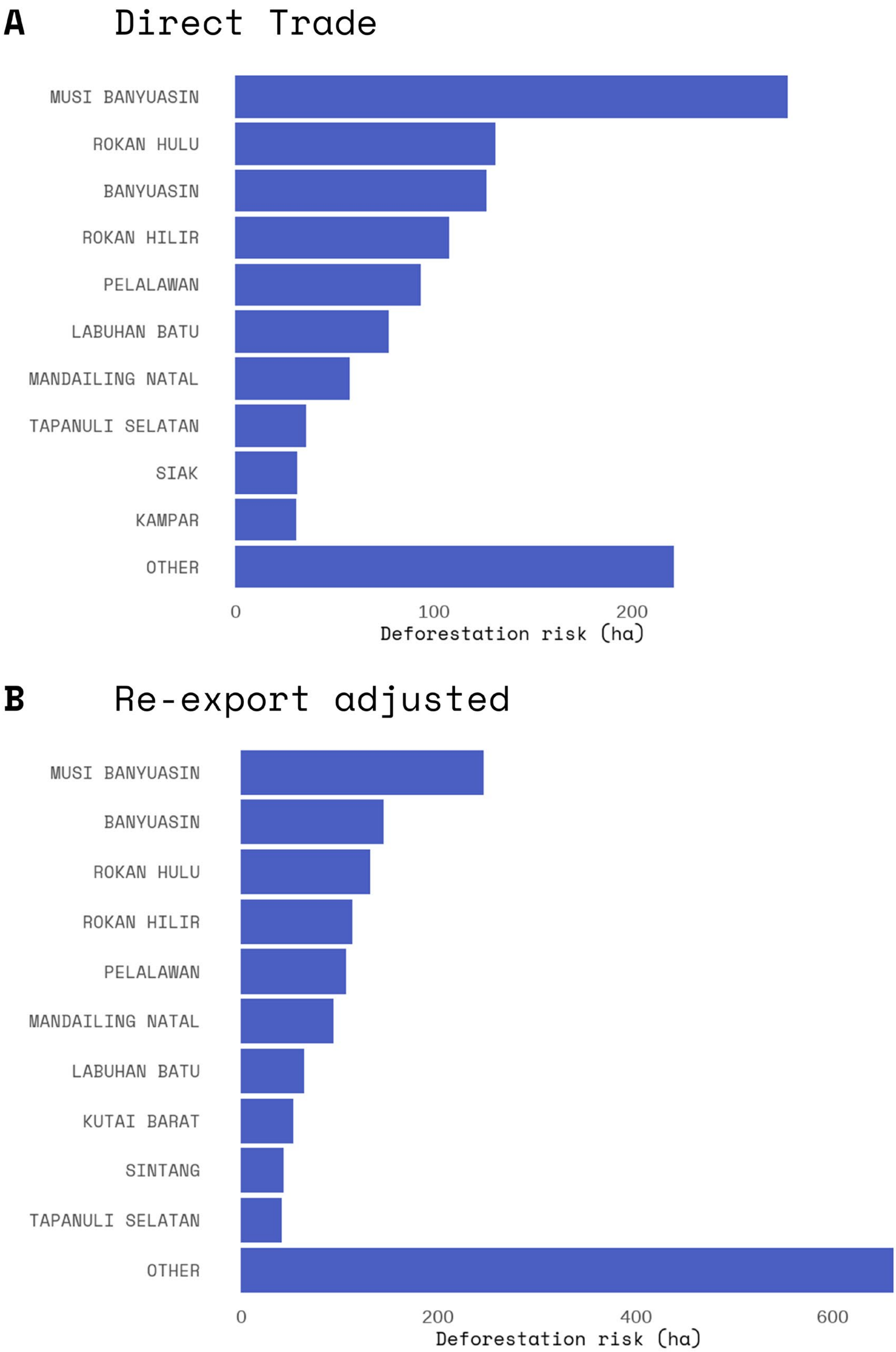

Figure 33: Palm oil deforestation risk associated with palm oil sourced from Indonesia in 2015, broken down by kabupaten (municipality), from a direct trade (A) and re-export-adjusted (B) perspective. The top ten kabupaten for each perspective are shown, with the rest grouped together in the 'other' category.

More than half of the palm oil deforestation risk associated with direct imports in 2015 was linked to two trader groups: Cargill (339 ha) and Royal Golden Eagle (317 ha) (Figure 34)[13]. Smaller, but still significant, amounts of deforestation risk were associated with SIPEF (146 ha), Musim Mas (136ha) and Sinar Mas (110ha). Cargill had the highest deforestation risk despite not being highest in terms of export volume (shown by black crosses in Figure 34), showing that deforestation risk was particularly concentrated in the exports of this major trader. In comparison, SIPEF had less than half the deforestation risk of Cargill despite exporting 59% more palm oil.

13. These figures are based on the best publicly available data of companies' sourcing patterns and areas of deforestation risk. Trase supply chain maps show which traders are likely to be sourcing from these areas; however, a lack of traceability means it is not possible to prove causal links. To do so would need additional assessment.

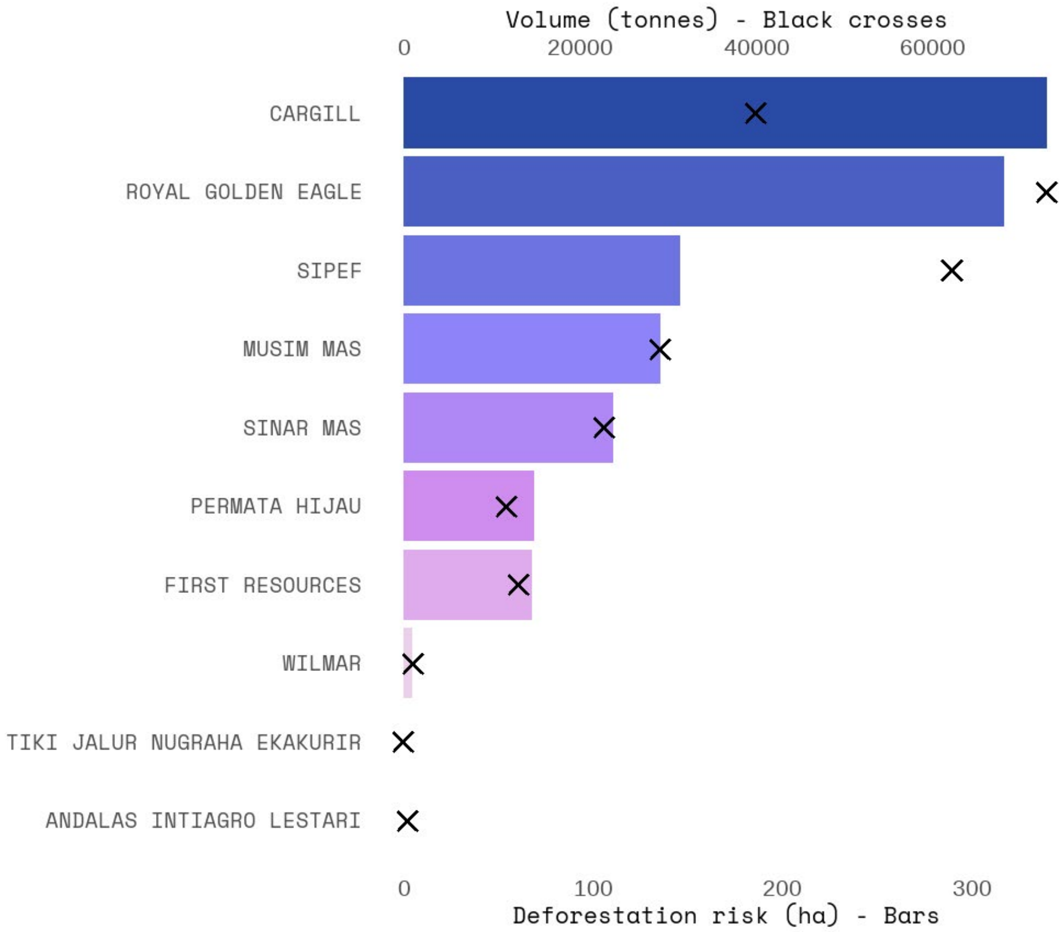

Figure 34: Palm oil deforestation risk (ha, shown in coloured bars) and export volume (tonnes, shown by black 'X') of palm oil trade between Indonesia and Germany in 2015, by exporter group.

The key intermediary country for the German supply of palm oil from Indonesia is the Netherlands, which makes up 25.9% of the deforestation risk in 2015 (Figure 35). Italy (8.1%), Papua New Guinea (5.4%), Brazil (3.7%) and Malaysia (2.2%) are also notable intermediaries. Note that, as described in the methods and in contrast to results at national scale, re-export-adjusted Trase data does not account for the additional deforestation risk which might be expected with palm oil that originates in Indonesia, but which is processed by intermediaries before reaching Germany.

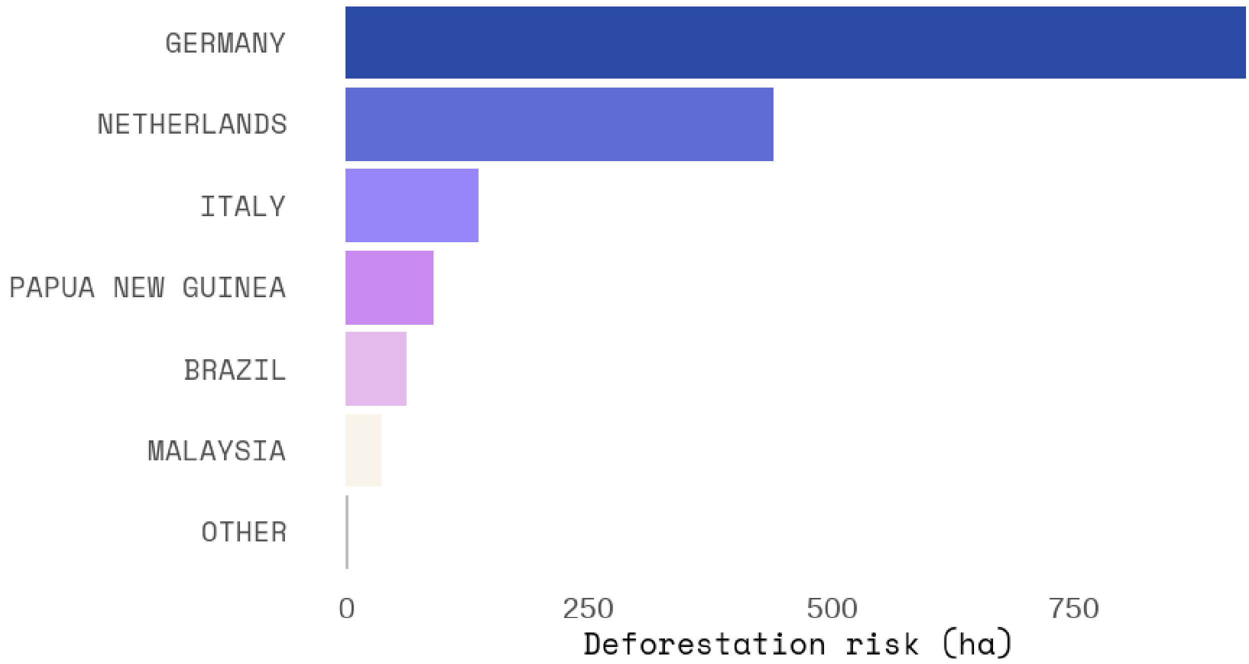

Figure 35: Palm oil deforestation risk imported into Germany from Indonesia via other countries, 2015. The top five countries in terms of deforestation risk are shown, with any others grouped together in the 'other' category. Values for Germany represent direct imports to Germany that were not re-exported elsewhere, and are included to show the relative role of intermediaries (such as the Netherlands) as sources of deforestation risk compared to directly imported risk).

Cattle

Between 2016-2018, imports of cattle products or production linked to German consumption was associated with 1,630 ha (direct trade), 3,200 ha (re-export-adjusted) or 32,100 ha (consumption-based) of deforestation risk[14]. In all three perspectives (Figures 36 & 37), Brazil is the most significant source of cattle deforestation risk, but this was particularly the case in the direct trade and re-export-adjusted approaches, where it was the source of 80% and 81% respectively of the total risk between 2016-2018. While still important from a consumption perspective, Brazil's prominence was lower here, accounting for 39% of the risk. This is explained by a much more distributed source of risk in the consumption-based approach (Figure 36, Panel C), notably including Angola, Mozambique, Turkey, Nigeria, Colombia and Tanzania. Paraguay and Australia are associated with relatively small amounts of risk in all approaches. Note that in the re-export-adjusted and consumption-based approaches, 4% and 5.7% of cattle products traded to / consumed by Germany are assigned 'unknown' origin.

The longer time series available for the direct trade data reveals that cattle deforestation risk from this perspective has fallen considerably from historical levels, with the 2018 figure of 600 ha down 80% from 2,960 ha in 2005. Since 2013, however, deforestation risk associated with cattle product imports has started to increase once more, and this pattern features in all three perspectives. The significant decline between 2005 and 2012 is due to a major drop in Brazilian beef imports to Germany between 2007-

14. Please refer to the Methodological Summary section, the summary of approaches provided in Table 1, and particularly to the "Methodological assumptions and considerations" for a description of the methods and associated assumptions used to derive the results in this study. Results are designed to be indicative of hotspots of commodity deforestation risk, but should be interpreted on the basis of the methods employed which are not traceability assessments.

2008, but also a steady decline in deforestation intensity until 2012. The increase in more recent years from Brazilian cattle appears to be linked to steadily increasing deforestation intensity rather than increasing trade quantities from Brazil (although trade quantities summed across all countries have been increasing, as indicated by the black line in Figure 37).

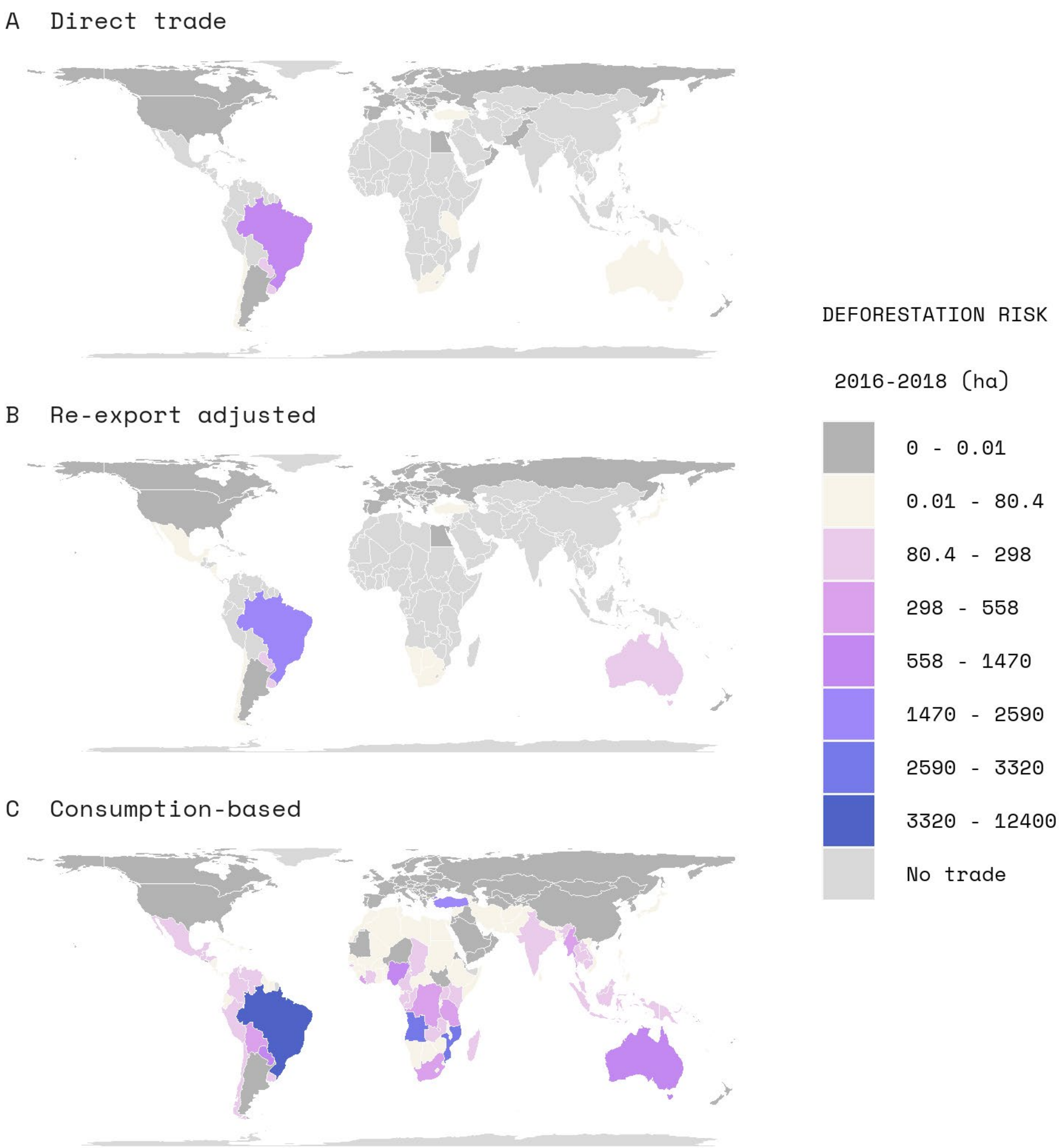

Figure 36: Maps of cattle deforestation risk by source country, from the three supply chain perspectives: direct trade (A), re-export-adjusted trade (B) and a consumption-based approach (C). Values are summed across the three most recent years with available data (2016-2018). Note that 4.0% of the total volume traded to Germany in (B), and 5.7% of the volume of cattle products consumed by Germany in (C), were of unknown origin and therefore could not be linked to deforestation risk.

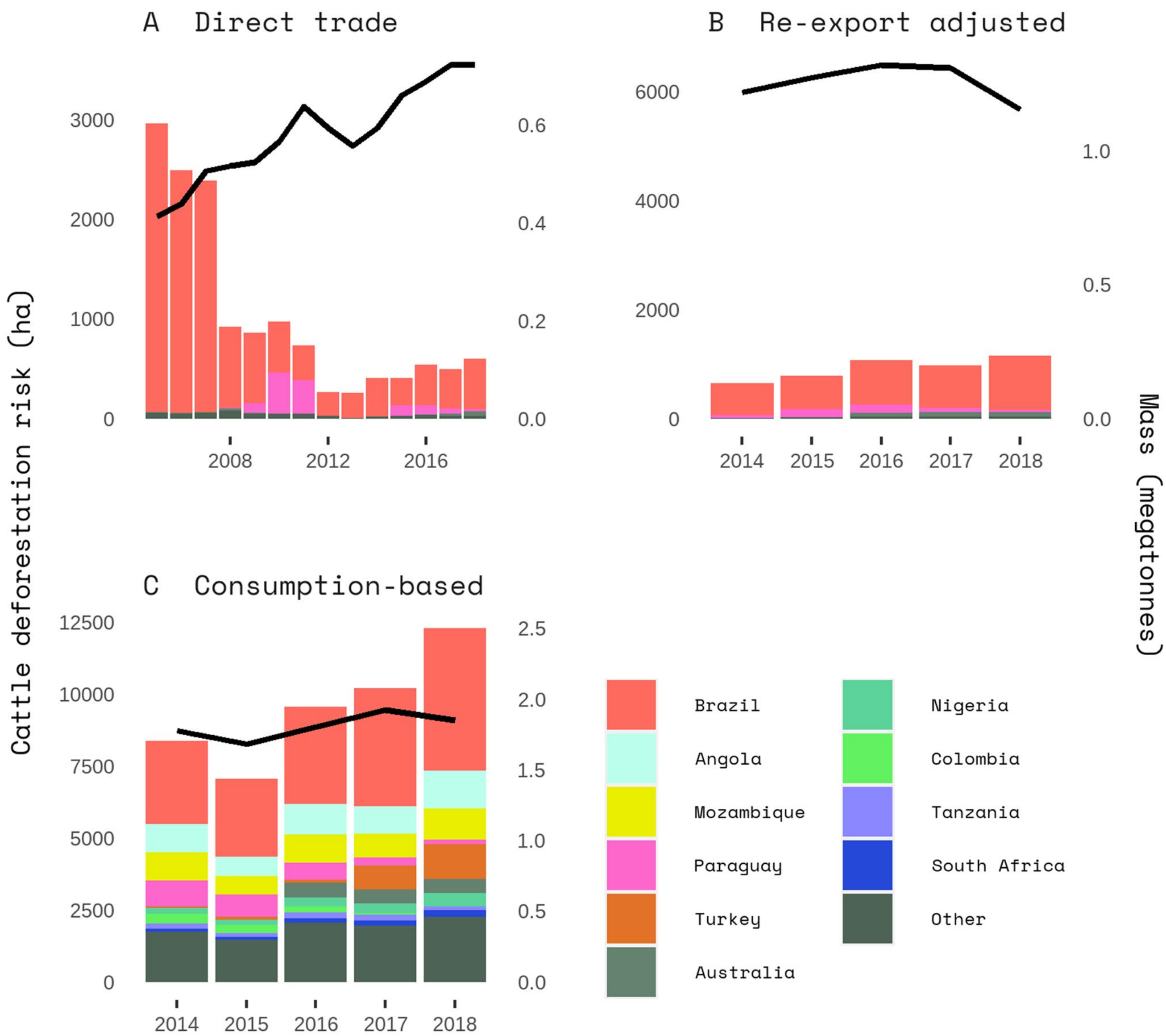

Figure 37: Cattle deforestation risk over time by source country, from three supply chain perspectives: direct trade (A), re-export-adjusted trade (B) and a consumption-based approach (C). The top ten countries (in terms of deforestation risk across all three perspectives) are shown, with the rest grouped together in the 'other' category. The total trade volume/production linked to consumption (mass of raw material equivalents across all country sources, regardless of their association – or not – with deforestation) is also shown by the black line and right-hand axis. Note that 4.0% of the total volume traded to Germany in (B), and 5.7% of the volume of cattle products consumed by Germany in (C), were of unknown origin and therefore could not be linked to deforestation risk.

Germany's role in cattle product trade pathways

For cattle meat imported into Germany via an intermediary (Table 7), the Netherlands is the key pathway, but quantities are relatively low. Selected other countries in Europe (e.g. France, Denmark, Italy and Belgium) are also re-exporters to Germany. Re-export of cattle offal is mainly split across Sweden, the UK, the Netherlands, Austria and Denmark. Re-export of cattle fat is relatively minor, but takes place via Belgium, Denmark, France and Austria. Note that there are no significant flows from deforestation-linked origins via these three-step re-export-adjusted pathways.

Where Germany acts as an intermediary in the supply chains of third parties (Table 8), it appears that again volumes are relatively small, but that it has a relatively important role in the trade pathway of cattle meat to the Netherlands, Italy and France. Germany acts as a re-exporter of cattle offal to France, the UK and Côte d'Ivoire. For cattle fat, Germany has a role in the re-export to Austria, Belgium and the Netherlands.

Cattle meat			Cattle offal			Cattle fat		
Origin	Intermediate Country	Mass (tonnes)	Origin	Intermediate Country	Mass (tonnes)	Origin	Intermediate Country	Mass (tonnes)
Belgium	Netherlands	1,940	**Ireland**	Sweden	725	**France**	Belgium	803
	France	242		UK	415			
Poland	Netherlands	1,030	**Belgium**	Netherlands	1,180	**Iceland**	Denmark	237
	Denmark	464						
	Italy	325						
Spain	Netherlands	643	**Netherlands**	Austria	637	**UK**	Belgium	179
France	Italy	305	**France**	Denmark	109	**Spain**	France	132
	Denmark	212						
	Belgium	196						

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Cattle meat			Cattle offal			Cattle fat		
Origin	Inter-mediate Country	Mass (tonnes)	Origin	Inter-mediate Country	Mass (tonnes)	Origin	Inter-mediate Country	Mass (tonnes)
United Kingdom	Nether-lands	700				**Italy**	Austria	153

Table 7. Three-node trade relationships for Germany's trade of cattle meat, cattle offal and cattle fat, 2018. Five most important countries of origin by mass (value reported, not converted to raw material equivalents) shown, with top three re-export pathways associated with these origins (where mass is at least 100 tonnes). According to our reconciled re-export-adjusted data, in total, 128,000 tonnes of cattle meat, 31,800 tonnes of cattle offal and 14,600 tonnes of cattle fat were imported into Germany in 2018 (excluding volumes that were re-exported elsewhere).

Cattle meat			Cattle offal			Cattle fat		
Origin	Desti-nation Country	Mass (tonnes)	Origin	Desti-nation Country	Mass (tonnes)	Origin	Desti-nation Country	Mass (tonnes)
France	Nether-lands	953	**Austria**	France	1,200	**Denmark**	Austria	541
	Italy	381		UK	718		Belgium	371
	France	203		Côte d'Ivoire	588		Nether-lands	289
Nether-lands	Nether-lands	926	**Nether-lands**	France	366	**France**	Austria	223
	Italy	370		UK	219		Belgium	153
	France	198		Côte d'Ivoire	179		Nether-lands	119
Poland	Nether-lands	922	**Poland**	France	227	**Belgium**	Austria	103
	Italy	368		UK	136			
	France	197		Côte d'Ivoire	111			

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Cattle meat			Cattle offal			Cattle fat		
Origin	Destination Country	Mass (tonnes)	Origin	Destination Country	Mass (tonnes)	Origin	Destination Country	Mass (tonnes)
Denmark	Netherlands	716	**UK**	France	185			
	Italy	286		UK	111			
	France	153						
Belgium	Netherlands	352	**Spain**	France	116			
	Italy	141						

Table 8. Destination of cattle meat, cattle offal and cattle fat where Germany is an intermediary in three-node trade relationships, 2018. Five most important countries of origin by mass (value reported, not converted to raw material equivalents) shown, with top three destinations (where mass is at least 100 tonnes). Note that destinations and proportions are the same for each point of origin due to mass-balance treatment of flows (see Methodological Summary). In total, 10,500 tonnes of cattle meat, 13,800 tonnes of cattle offal, and 2,990 tonnes of cattle fat were imported in Germany before being re-exported elsewhere in 2018.

Germany's cattle product deforestation risk compared to other countries

At 48,000 ha, Germany's cattle deforestation risk over the period 2014-2018 from a consumption-based perspective was larger than all other ADP signatory countries other than France (53,800 ha) (Figure 38, Panel A). Although Germany's risk was much smaller with a re-export-adjusted trade perspective (4,650 ha), across the ADP countries it was second only to the UK (10,600 ha). From a direct trade perspective, Germany's cattle deforestation risk was smaller still (2,460 ha), this time ranking below the UK (10,800 ha), Italy (9,400 ha) and the Netherlands (6,940 ha). Across all three perspectives, China was an important consumer or importer of cattle deforestation risk, particularly from the direct trade and re-export-adjusted perspectives.

In terms of risk intensity, Germany's exposure is similar to that of France, Germany, Italy, Norway and Denmark, as all have low risk intensity from a direct trade and re-export-adjusted perspective and relatively higher risk from a consumption-based perspective (Figure 38, Panel B). Cattle deforestation risk intensity was particularly high from a consumption-based perspective in Belgium and the Netherlands. China follows a different pattern to the European countries, with very high risk intensity from a direct trade perspective and lower risk from a consumption-based perspective.

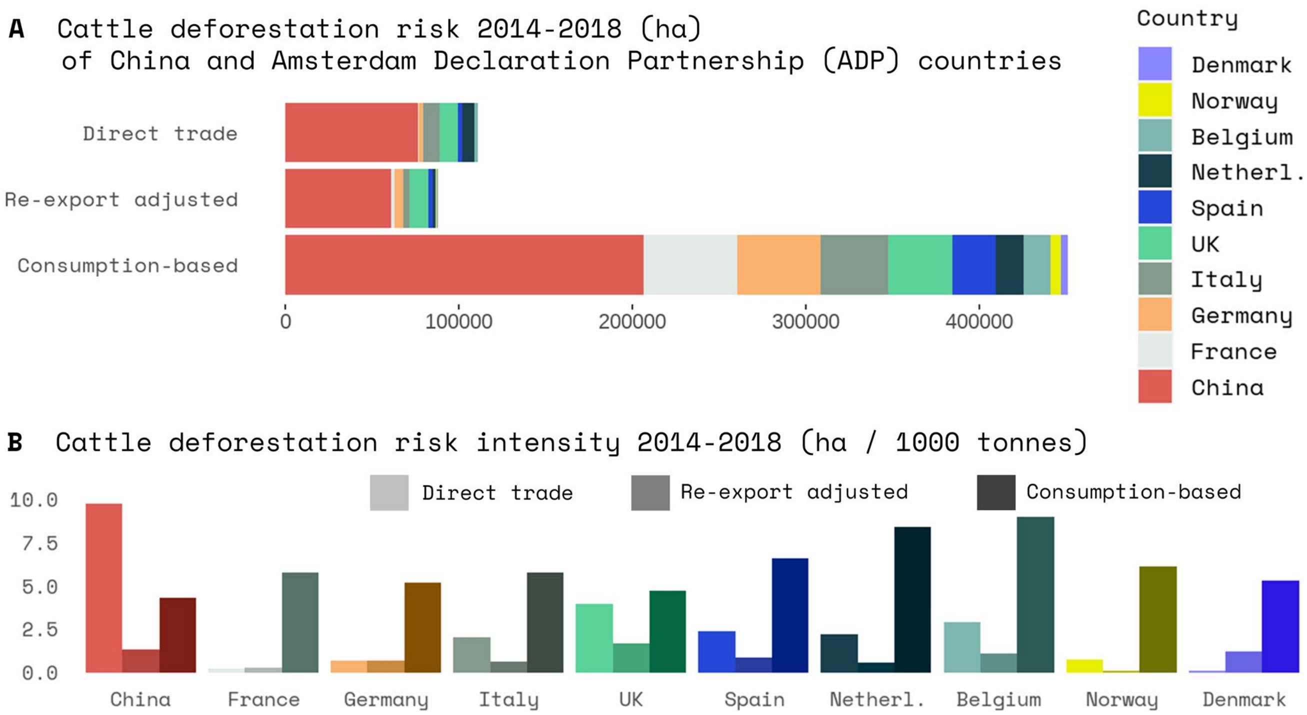

Figure 38: Cattle deforestation risk (A) and risk intensity (B) compared between selected countries (ADP signatories and China) for the period 2014-2018. Countries are arranged according to their consumption-based deforestation risk.

Subnational cattle deforestation risk

At the subnational level, our analysis with Trase data reveals that in Brazil most of the cattle deforestation risk is concentrated in central regions of the country, especially in the states of Mato Grosso, Goias and Minas Gerais (Figure 39). These three states contributed 44.5%, 29% and 14.5% respectively over the three years with Trase data (2015-2017). They are consistently all large contributors to Germany's direct trade risk throughout this period, although in 2015, Mato Grosso do Sul outranked Minas Gerais. In this three-year time series, cattle deforestation risk to Germany peaked in 2016 at 471 ha, where Mato Grosso had the highest deforestation risk at 224 ha, 47.6% of total deforestation risk. Deforestation linked to German direct sourcing from Minas Gerais increased over the three-year time series, in contrast to Mato Grosso do Sul where it decreased.

At a finer scale, the top three municipalities for Germany's direct trade linked cattle deforestation risk in 2015-2017 were Alto Araguaia (35 ha), Paranatinga (31 ha) and Caceres (25 ha) (Figure 40). All of these are found in Mato Grosso state. The top three municipalities only account for 11.4% of Germany's risk over the period, indicating that deforestation risk for Brazilian cattle is less spatially concentrated than it is for other contexts (such as Brazilian soy).

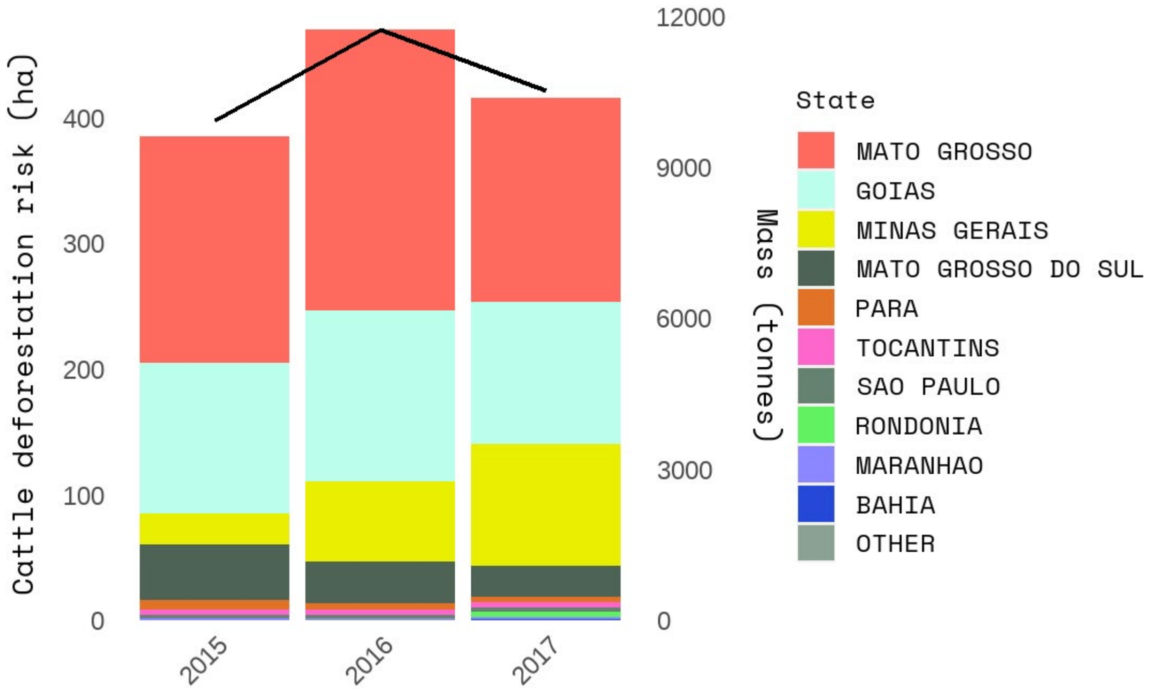

Figure 39: State-level cattle deforestation risk from Brazilian exports to Germany over the years 2015 - 2017. The top ten states (in terms of deforestation risk over the three years) are shown, with the remaining grouped together in the 'other' category. The total trade volume (mass of raw material equivalents, regardless of their association – or not – with deforestation) is also shown by the black line and right-hand axis.

BRAZILIAN CATTLE DEFORESTATION RISK - DIRECT TRADE 2015-2017

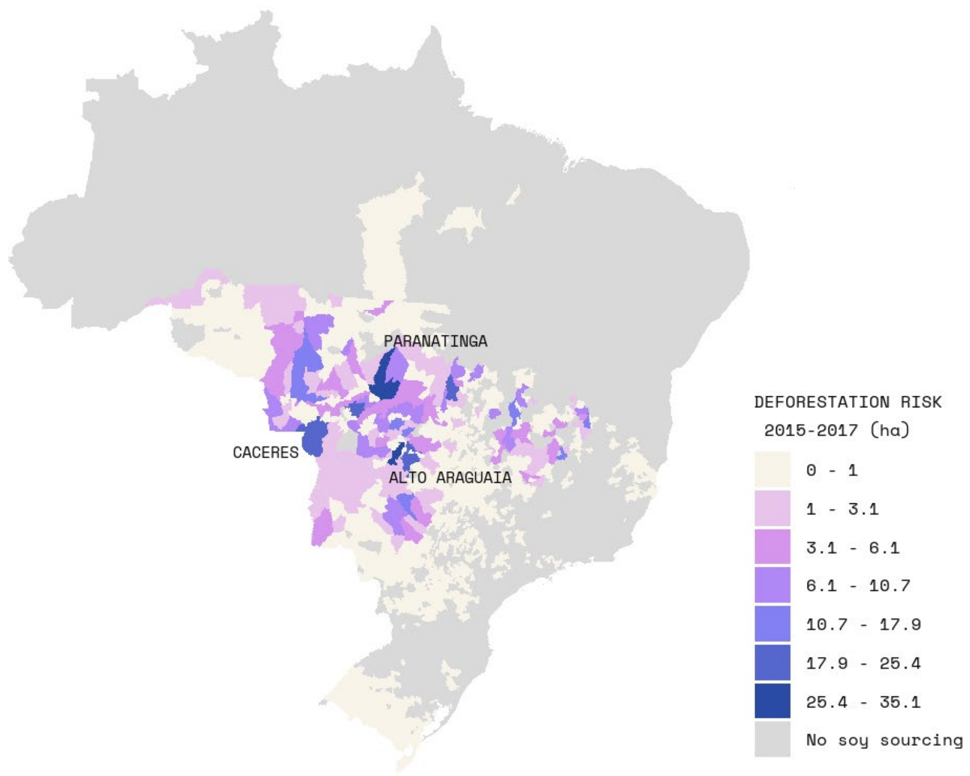

Figure 40: Municipality-level cattle deforestation risk from Brazilian exports to Germany (2015-2017).

Over the three year period with Trase data, exporter group Minerva was responsible for imports with the greatest share (37%) of Germany's cattle deforestation risk, followed by Marfrig Global Foods (31%) and JBS (19%) (Figure 41)[15]. The overall increase in risk between 2015 and 2016 is largely linked to a doubling (from 98 ha to 201 ha) of Minerva's cattle deforestation risk linked to Germany, while the subsequent fall in deforestation risk between 2016 and 2017 appears to be mostly associated with a drop in the deforestation risk linked to JBS.

15. These figures are based on the best publicly available data of companies' sourcing patterns and areas of deforestation risk. Trase supply chain maps show which traders are likely to be sourcing from these areas; however, a lack of traceability means it is not possible to prove causal links. To do so would need additional assessment.

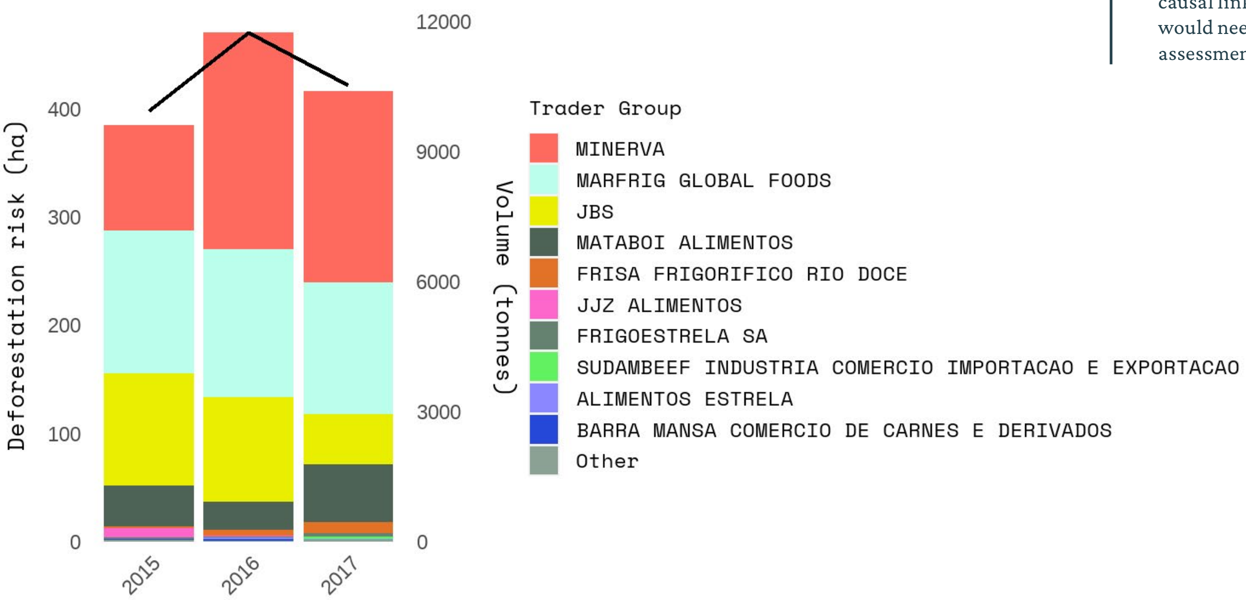

Figure 41: Brazilian cattle deforestation risk for Germany, by exporter group for the years 2015-2017. The top ten exporter groups (in terms of deforestation risk for trade between Brazil and Germany) are shown, with any others grouped together in the 'other' category. The total trade volume (mass of raw material equivalents, regardless of their association – or not – with deforestation) is also shown by the black line and right-hand axis.

For beef sourced from Paraguay by Germany, most of the recent subnational-level cattle deforestation risk is concentrated in three departments in the west of the country: Boquerón, Alto Paraguay and Presidente Hayes contributed 66.2%, 19.1% and 14.1% respectively to total German cattle deforestation risk over the period 2015-2019 (Figure 42). Fluctuations over this period, including a significant peak in 2016, were largely driven by variable deforestation risk in Boquerón, where deforestation grew rapidly from 237 ha in 2015 to its peak of 1800 ha in 2016. Figure 43 shows a map of cattle deforestation risk for the most recent three years. Together, Boqueron (1360 ha), Alto Paraguay (423 ha) and Presidente Hayes (333 ha) together constitute more than 99% of the cattle deforestation risk exported to Germany from Paraguay.

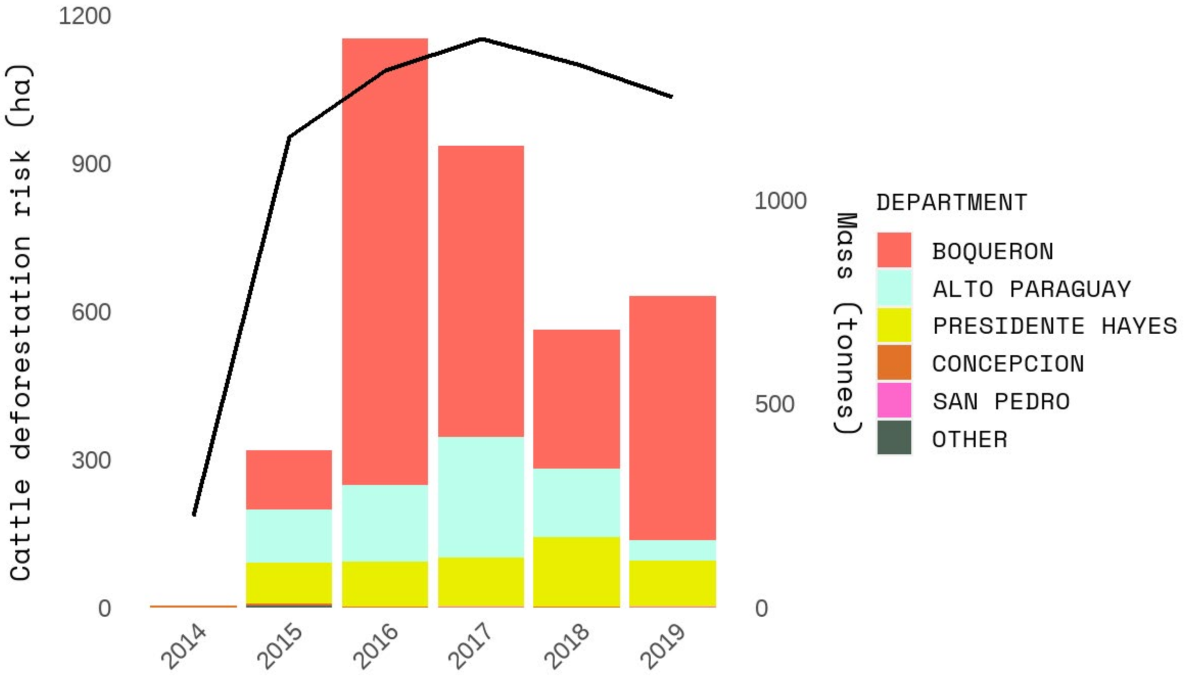

Figure 42: Department-level cattle deforestation risk from Paraguayan exports to Germany for 2015-2018. The top five departments are shown, with any others grouped together in the 'other' category. The total trade volume (mass of raw material equivalents, regardless of their association – or not – with deforestation) is also shown by the black line and right-hand axis.

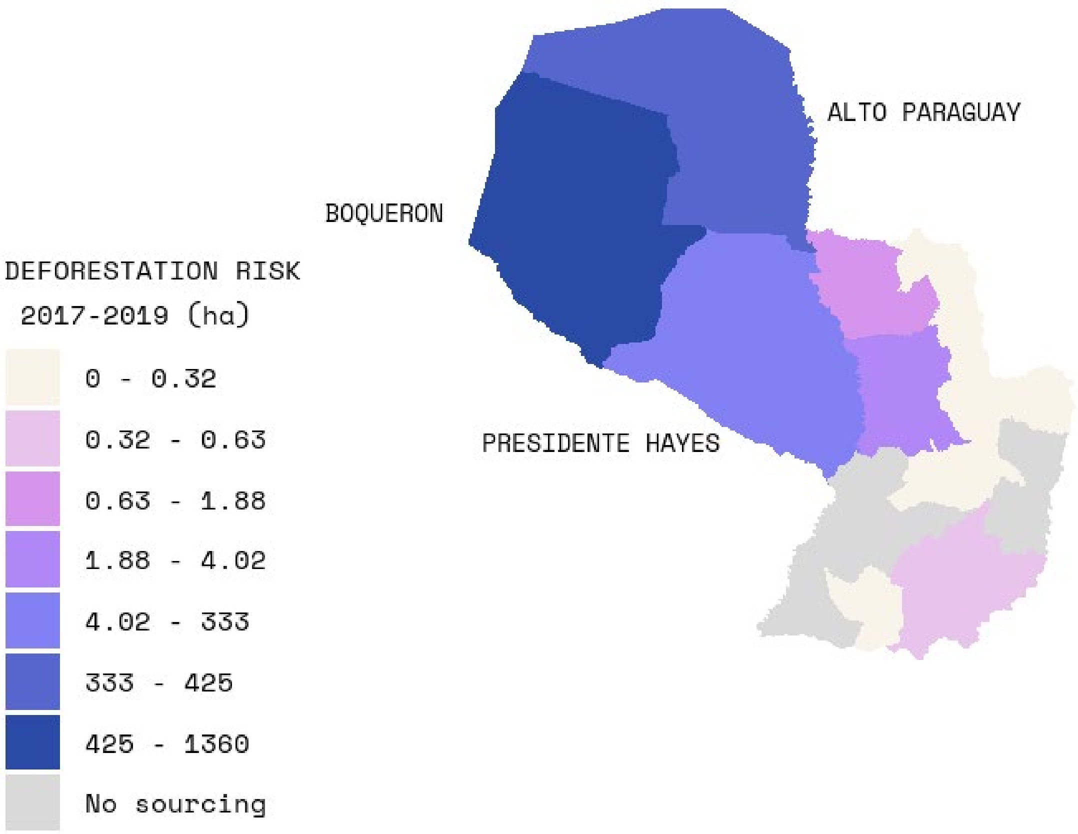

Figure 43: Cattle deforestation risk from Paraguayan departments for direct imports to Germany (2017-2019). The three departments with the greatest deforestation risk are labelled.

There has been some variability in the traders associated with Paraguayan cattle deforestation risk for Germany (Figure 44), although the largest proportion of that risk has been handled by Cooperativa Fernheim[16]. A more than ten-fold increase in their share of risk from 52 ha to 609 ha largely explains the significant rise in imported risk between 2015 and 2016. A drop in 2018 was also largely attributable to a significant decrease in the risk traded by this group. Minerva has consistently been the second most important trader group in terms of deforestation risk throughout the period 2015-2019. For the years 2015-2017, Frigorifico Guarani is linked to a sizable component of cattle deforestation risk, but this disappeared in the most recent two years. Cooperativa Chortitzer also played a significant role in 2018, but not other years.

16. These figures are based on the best publicly available data of companies' sourcing patterns and areas of deforestation risk. Trase supply chain maps show which traders are likely to be sourcing from these areas; however, a lack of traceability means it is not possible to prove causal links. To do so would need additional assessment.

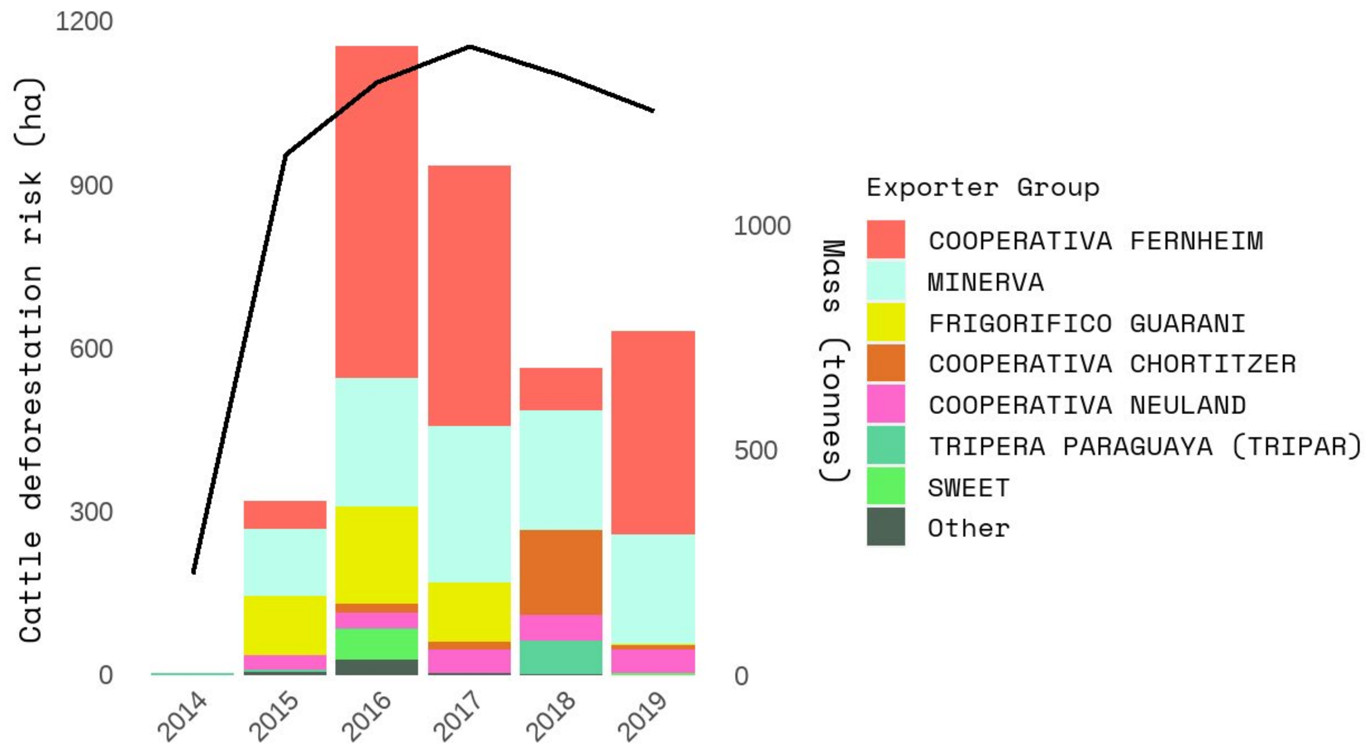

Figure 44: Direct trade cattle deforestation risk from Paraguayan beef exports to Germany, by exporter group. The top seven exporter groups (in terms of deforestation risk associated with cattle product trade from Paraguay to Germany over the entire time series) are shown, with any others grouped together in the 'other' category. The total trade volume (mass of raw material equivalents, regardless of their association – or not – with deforestation) is also shown by the black line and right-hand axis.

Cocoa

In 2016-2018, imports of cocoa products, or production linked to German consumption, was associated with 10,400 ha (direct trade), 6,230 ha (re-export-adjusted) and 6,480 ha (consumption-based) of deforestation risk[17].

Cocoa deforestation risk is spread across several countries of production; across the perspectives, the main sources of risk were Côte d'Ivoire, Peru, Ecuador and Indonesia (Figure 45), although the direct trade results show a large contribution from Malaysia, explaining why the direct trade figure is substantially higher than for the other two perspectives (Figure 46). This is attributable to a significant spike in cocoa deforestation intensity in Malaysia in 2016 and 2017. While cocoa trade between Malaysia and Germany peaked around the same time (mostly in the form of cocoa butter and to a lesser extent cocoa powder/cake), quantities remained relatively small (a peak of 11,300 tonnes cocoa bean equivalents in 2016).

Côte d'Ivoire has been a consistent source of risk across the time series and in each perspective. Although direct cocoa trade from Côte d'Ivoire has increased significantly (more than trebling between 2004 and 2018), this has been offset by a decline in deforestation intensity since 2013, leading to fairly minor changes in the overall German cocoa deforestation risk from this country. In contrast with the direct trade results, the re-export-adjusted and consumption-based results show a steadily decreasing trend in cocoa deforestation risk over time. This occurs partly due to slightly declining risk from Côte d'Ivoire, and occurs despite growing risk from Peru. Congo and Liberia emerge as important sources of risk in the re-export and consumption-based approaches, where they did not in the direct trade approach. 19.5% and 19.8% of total trades are classified as 'unknown' origin in the re-export and consumption-based results for cocoa.

17. Please refer to the Methodological Summary section, the summary of approaches provided in Table 1, and particularly to the "Methodological assumptions and considerations" for a description of the methods and associated assumptions used to derive the results in this study. Results are designed to be indicative of hotspots of commodity deforestation risk, but should be interpreted on the basis of the methods employed which are not traceability assessments.

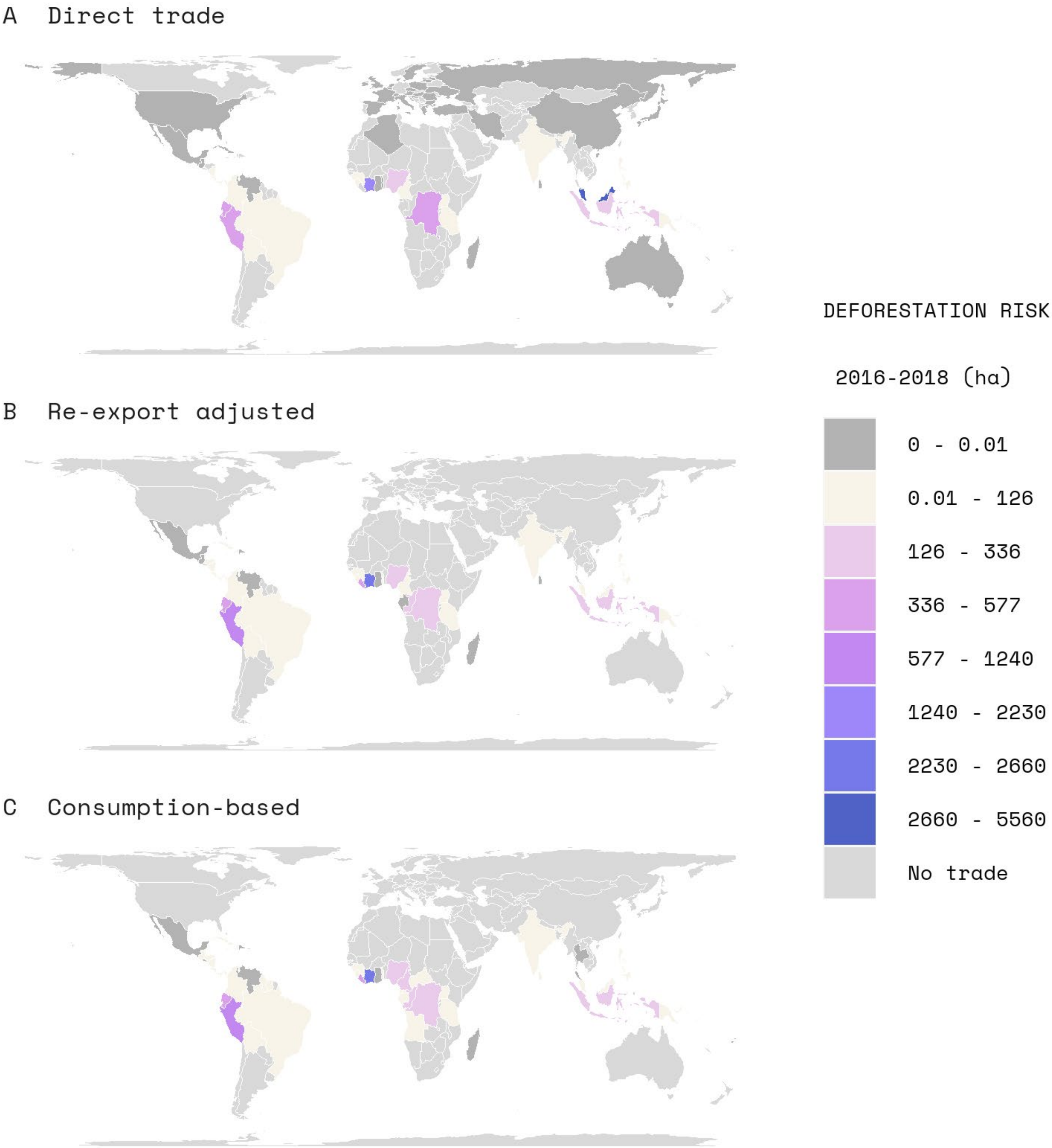

Figure 45: Maps of cocoa deforestation risk by source country, from the three supply chain perspectives: direct trade (A), re-export-adjusted trade (B) and a consumption-based approach (C). Values are summed across the three most recent years with available data (2016-2018). Note that 19.5% of the total volume traded to Germany in (B), and 19.8% of the volume of cocoa consumed by Germany in (C), were of unknown origin and therefore could not be linked to deforestation risk.

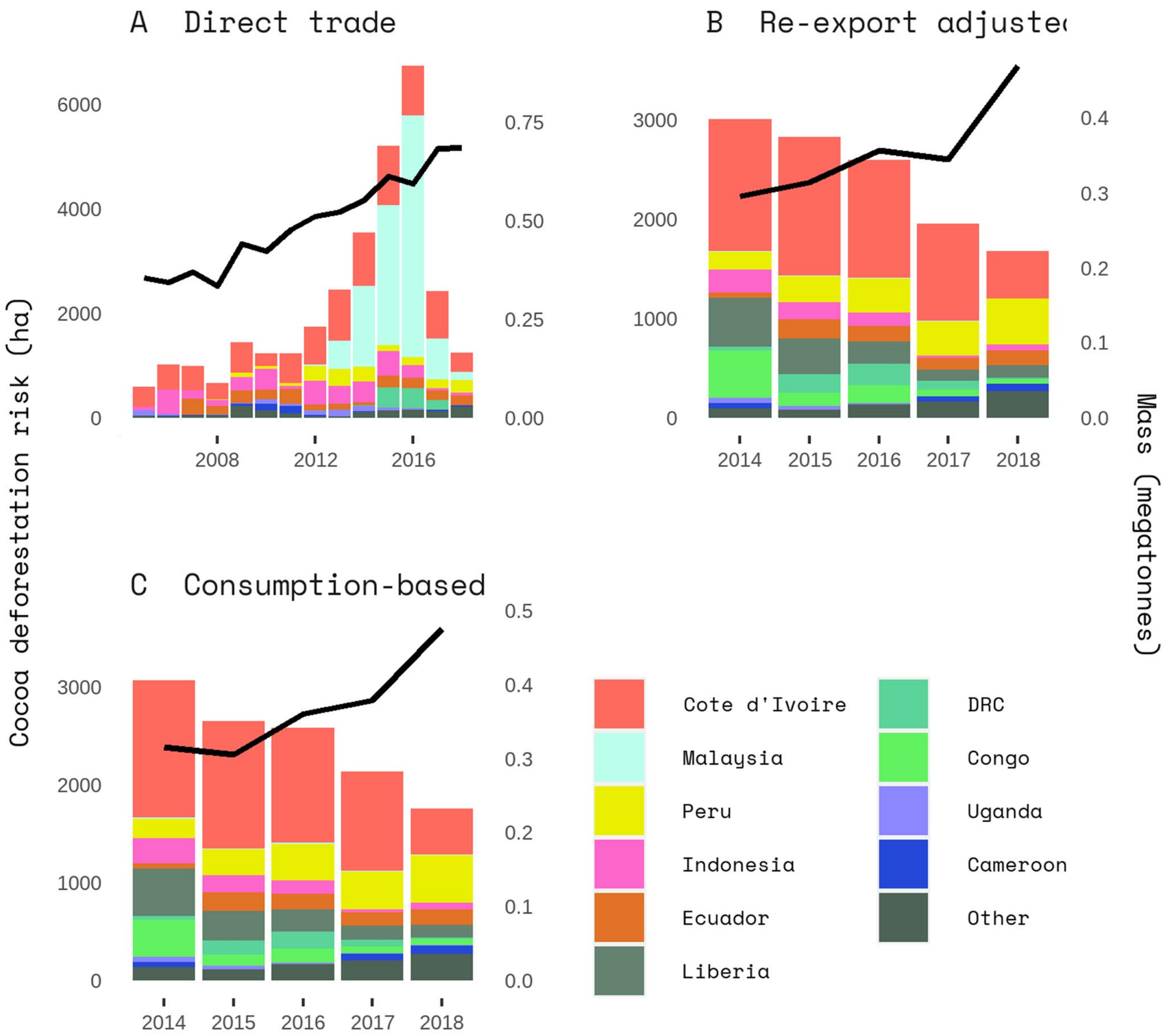

Figure 46: Cocoa deforestation risk over time by source country, from three supply chain perspectives: direct trade (A), re-export-adjusted trade (B) and a consumption-based approach (C). The top ten countries in terms of deforestation risk over all three perspectives are shown, with all other countries grouped together in the 'other' category. The total trade volume/production linked to consumption (mass of raw material equivalents across all country sources, regardless of their association – or not – with deforestation) is also shown by the black line and right-hand axis. Note that 19.5% of the total volume imported by Germany in (B), and 19.8% of the volume of cocoa consumed by Germany in (C), were of unknown origin and therefore could not be linked to deforestation risk.

Germany's role in cocoa trade pathways

For cocoa bean trade into Germany via an intermediary (Table 9), quantities are relatively high with the Netherlands and Belgium being key pathways. The UK appears as a re-exporter from Côte d'Ivoire, but with relatively small volume. Re-export of cocoa paste is in lower quantities and is mainly split across the Netherlands and France, with Poland, Switzerland and Belgium also re-exporters. For cocoa powder/cake, again quantities are relatively small, and the Netherlands is again the most important re-exporter, but Spain, France and Sweden also re-export to Germany. Where Germany acts as an intermediary in the three-stage supply chains of third parties (Table 10), it appears that volumes are relatively small, but that it has a role in the trade pathway of cocoa beans to Austria, the Netherlands, and Poland. Germany acts as a re-exporter of cocoa paste to Belgium, Italy and France. For cocoa powder/cake, Germany has a role in the re-export to France, Russia and Italy. Where Germany acts as a source of derived cocoa commodities (Table 11), for cocoa paste the Belgium, Italy, France, Poland and the Netherlands, and for cocoa powder/cake (exported in smaller quantities) France, Russia, Italy and Poland are important.

Cocoa beans			Cocoa paste			Cocoa powder/cake		
Origin	Inter-mediate Country	Mass (tonnes)	Origin	Inter-mediate Country	Mass (tonnes)	Origin	Inter-mediate Country	Mass (tonnes)
Côte d'Ivoire	Nether-lands	59,000	**Côte d'Ivoire**	Nether-lands	2,920	**Côte d'Ivoire**	Nether-lands	1,770
	Belgium	34,900		France	1,270		Spain	451
	UK	229		Poland	199		France	163
Ghana	Nether-lands	18,100	**Ghana**	Nether-lands	1,030	**Ghana**	Nether-lands	1,580
	Belgium	6,060		France	402		Spain	132
				Poland	191			
Nigeria	Nether-lands	14,700	**Nether-lands**	Switzer-land	654	**Nether-lands**	France	507
	Belgium	6,530		France	430		Sweden	161
				Belgium	193			

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Cocoa beans			Cocoa paste			Cocoa powder/cake		
Origin	Intermediate Country	Mass (tonnes)	Origin	Intermediate Country	Mass (tonnes)	Origin	Intermediate Country	Mass (tonnes)
Cameroon	Netherlands	13,000	**Cameroon**	France	332	**Belgium**	Netherlands	456
	Belgium	1,550						
Ecuador	Netherlands	3,570	**Belgium**	Switzerland	116	**Indonesia**	Netherlands	120
	Belgium	2,170						

Table 9. Three-node trade relationships for Germany's trade of cocoa beans, cocoa paste and cocoa powder/cake, 2018. Five most important countries of origin by mass (value reported, not converted to raw material equivalents) shown, with top three re-export pathways associated with these origins (where mass is at least 100 tonnes). According to our reconciled re-export-adjusted data, in total, 462,000 tonnes of cocoa beans, 49,400 tonnes of cocoa paste and 43,600 tonnes of cocoa powder/cake were imported into Germany in 2018 (excluding quantities that were subsequently re-exported elsewhere).

Cocoa beans			Cocoa paste			Cocoa powder/cake		
Origin	Destination Country	Mass (tonnes)	Origin	Destination Country	Mass (tonnes)	Origin	Destination Country	Mass (tonnes)
Côte d'Ivoire	Austria	831	**Netherlands**	Belgium	1,000	**Netherlands**	France	1,470
	Netherlands	312		Italy	740		Russia	1,440
	Poland	308		France	568		Italy	1,090
Netherlands	Austria	523	**Ghana**	Belgium	373	**Côte d'Ivoire**	France	542
	Netherlands	197		Italy	276		Russia	531
	Poland	194		France	212		Italy	402

Table continues onto next page

Cocoa beans			Cocoa paste			Cocoa powder/cake		
Origin	Desti-nation Country	Mass (tonnes)	Origin	Desti-nation Country	Mass (tonnes)	Origin	Desti-nation Country	Mass (tonnes)
Nigeria	Austria	286	**Switzer-land**	Belgium	295	**Ghana**	France	304
	Nether-lands	107		Italy	218		Russia	298
	Poland	106		France	168		Italy	226
Ghana	Austria	243	**France**	Belgium	281	**France**	France	279
	Nether-lands			Italy	208		Russia	273
	Poland			France	160		Italy	207
Ecuador	Austria	103				**Came-roon**	France	233
							Russia	228
							Italy	173

Table 10. Destination of cocoa beans, cocoa paste and cocoa powder/cake where Germany is an intermediary in three-node trade relationships, 2018. Five most important countries of origin by mass (value reported, not converted to raw material equivalents) shown, with top three destinations (where mass is at least 100 tonnes). Note that destinations and proportions are the same for each point of origin due to mass-balance treatment of flows (see Methodological Summary). In total, 4,890 tonnes of cocoa beans, 8,200 tonnes of cocoa paste and 23,200 tonnes of cocoa powder/cake were imported into Germany before being re-exported elsewhere in 2018.

Cocoa paste			Cocoa powder/cake		
Initial destination	Second destination	Mass (tonnes)	Initial destination	Second destination	Mass (tonnes)
Belgium	Belgium	16,000	**France**	France	9,740
	Netherlands	613		United States	723
	France	537		Italy	403

Table continues onto next page

Cocoa paste			Cocoa powder/cake		
Initial destination	Second destination	Mass (tonnes)	Initial destination	Second destination	Mass (tonnes)
Italy	Italy	11,900	**Russia**	Russia	9,540
France	France	9,110	**Italy**	Italy	7,220
	Belgium	335		Canada	198
	Poland	142		Turkey	121
Poland	Poland	7,230	**Poland**	Poland	6,610
	France	769		Russia	112
Netherlands	Netherlands	5,320	**Netherlands**	Netherlands	867
	Belgium	272		United States	830
	France	120		France	205

Table 11. Destination of cocoa paste and cocoa powder/cake cake where Germany is an origin in three-node trade relationships for the supply of third-party countries, 2018. The five most important immediate destinations by mass (value reported, not converted to raw material equivalents) are shown (where mass is at least 100 tonnes), plus up to three onward destinations. Note that in cases where there is no onward trade, the second destination is the same as the initial destination. In total, 70,700 tonnes of cocoa paste and 85,600 tonnes of cocoa powder/cake were produced in Germany in 2018 before being subsequently exported.

Germany's cocoa deforestation risk compared to other countries

Comparing results between countries reveals that Germany was an important importer and consumer of cocoa deforestation risk across 2014-2018, with its total risk substantially larger than all other countries considered, from the consumption-based and re-export-adjusted perspectives (12,200 ha and 12,100 ha respectively; Figure 47, Panel A). While Germany's cocoa deforestation-risk exposure was even higher from a direct trade perspective (19,200 ha), this was much smaller than the risk associated with direct imports to China (46,800 ha) and the Netherlands (31,300 ha).

In terms of cocoa risk intensity, Germany's exposure is similar across all three perspectives, and comparable to that of other ADP countries, but less than that of e.g. Spain which has higher-than-average risk intensity across all perspectives (Figure 47, Panel B). Germany's direct trade risk intensity is also lower than that for Denmark, which has the second highest for direct trade behind China which has an extremely high direct trade intensity.

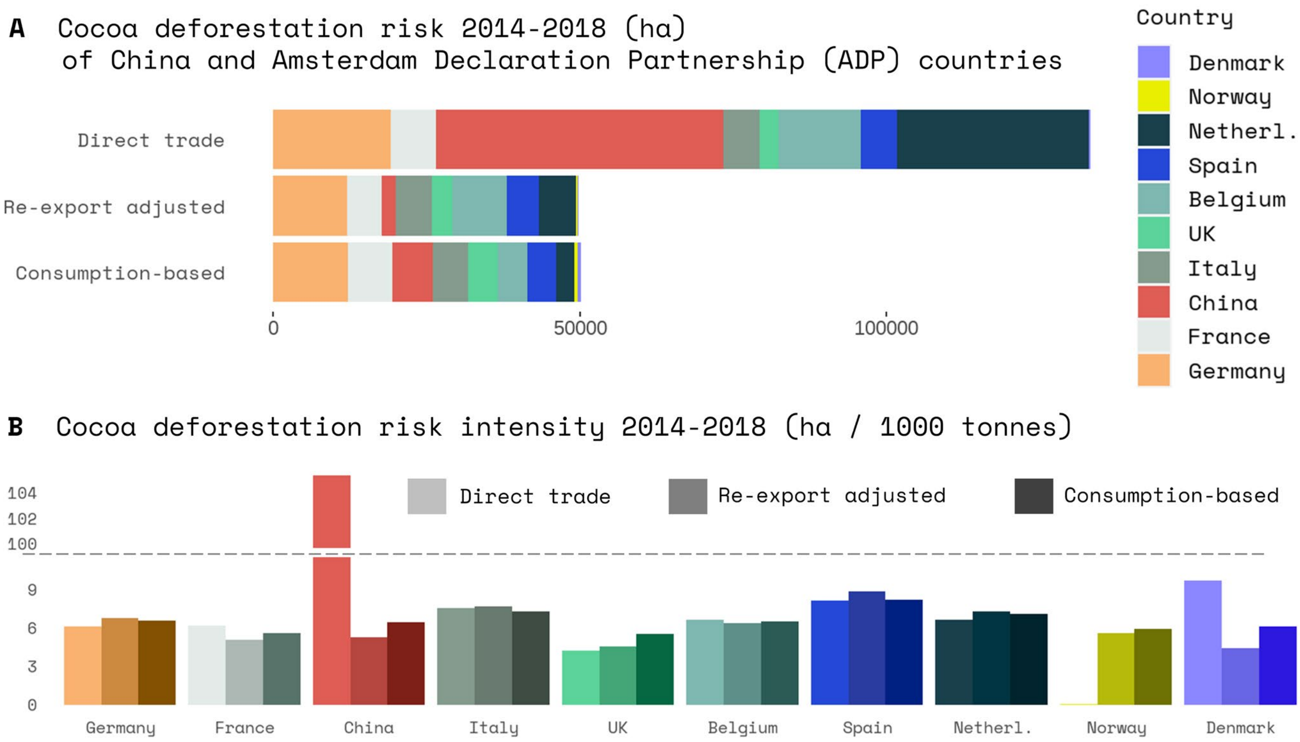

Figure 47: Comparison between selected countries in terms of cocoa deforestation risk (A) and risk intensity (B) for the period 2014-2018. Note: Broken y-axis to show the high risk intensity associated with direct imports of cocoa to China.

Coffee

In the three most recent years with available data (2016-2018), Germany's imports of coffee products, or production linked to German consumption, was linked to 7,180-15,290 ha of deforestation, depending on the supply chain perspective chosen (Figure 48)[18]. Direct trade coffee deforestation risk (15,290 ha) was approximately double that of the re-export (7,180ha) and consumption-based perspectives (7,270ha). In all three perspectives, Colombia was the greatest source of coffee deforestation risk in recent years, followed by Peru and Honduras.

The time series reveals that coffee deforestation risk to Germany was highest in the two most recent years (2017 and 2018), although the longer time series available for direct trade shows that levels were similarly high in 2012 (Figure 49). Coffee deforestation risk has generally increased over time, with direct trade risk in 2018 up 158% from 2005. Peruvian coffee deforestation has remained high, despite a decline in trade since 2012, due to a significant increase in Peurivan coffee deforestation intensity. Deforestation linked to coffee production in Colombia has rapidly risen to be the most important source in recent years, accounting for more German deforestation risk than Peru and Honduras combined in 2018, for all three perspectives. This is related to a major increase in coffee deforestation intensity since 2012, as well as an increase in Colombian coffee

18. Please refer to the Methodological Summary section, the summary of approaches provided in Table 1, and particularly to the "Methodological assumptions and considerations" for a description of the methods and associated assumptions used to derive the results in this study. Results are designed to be indicative of hotspots of commodity deforestation risk, but should be interpreted on the basis of the methods employed which are not traceability assessments.

imports since a low point in 2010. In contrast to Colombia, coffee deforestation linked to Indonesia has decreased over the time series. Both coffee trade quantities and deforestation intensities from Indonesia have fluctuated but generally declined over time, with both reaching their lowest value in 2018, explaining the low deforestation risk in the most recent year. In the re-export and consumption-based results, 13.5% and 14.1% of total trades are classified as ‘unknown’ origin.

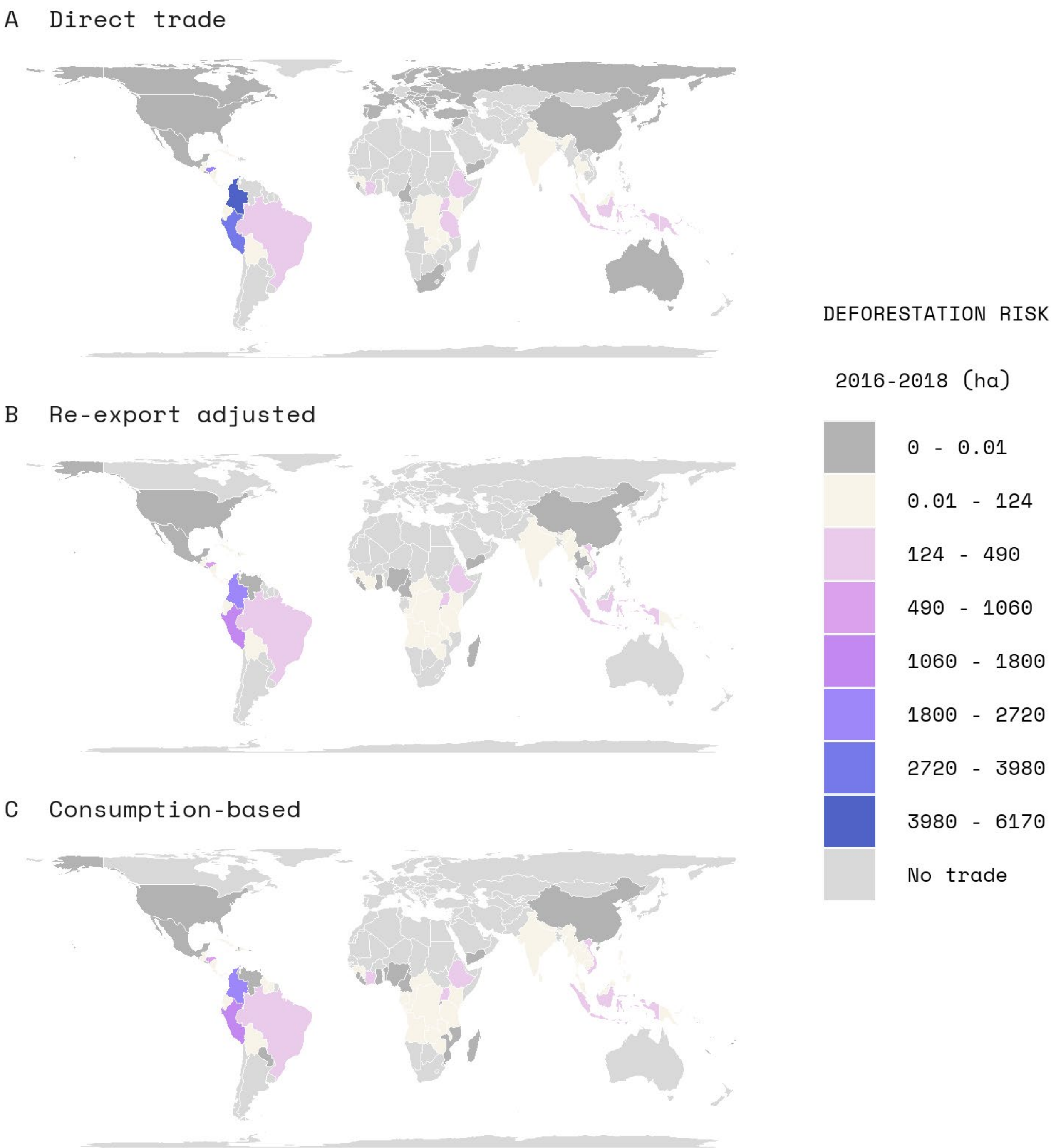

Figure 48: Maps of coffee deforestation risk by source country, from the three supply chain perspectives: direct trade (A), re-export-adjusted trade (B) and a consumption-based approach (C). Values are summed across the three most recent years with available data (2016-2018). Note that 13.5% of the total volume traded to Germany in (B), and 14.1% of the volume of coffee consumed by Germany in (C), were of unknown origin and therefore could not be linked to deforestation risk.

Figure 49: Coffee deforestation risk over time by source country, from three supply chain perspectives: direct trade (A), re-export-adjusted trade (B) and a consumption-based approach (C). The top ten countries in terms of deforestation risk across the three perspectives are shown, with all other countries grouped together in the 'other' category. The total trade volume/production linked to consumption (mass of raw material equivalents across all country sources, regardless of their association – or not – with deforestation) is also shown by the black line and right-hand axis. Note that 13.5% of the total volume traded to Germany in (B), and 14.1% of the volume of coffee consumed by Germany in (C), were of unknown origin and therefore could not be linked to deforestation risk.

Germany's role in coffee trade pathways

For green coffee imports to Germany via an intermediary (Table 12), India, China, Belgium and Colombia appear to be relatively important pathways, although quantities of imports are not hugely significant. China, Costa Rica and Viet Nam also appear as re-exporters. For roasted coffee, re-exported volumes to Germany are small. Where Germany acts as an intermediary in the supply chains of third parties (Table 13), it appears that volumes are relatively significant for green coffee and that it has a relatively large role in the trade pathways to Poland, the United States and the Netherlands. Germany acts as a re-exporter of roasted coffee to Poland, the Netherlands and France, but in relatively small volumes. Where Germany acts as a source of roasted coffee, Poland, the Netherlands, France, Slovakia and Austria are important destinations (Table 14).

Green coffee			Roasted coffee		
Origin	Intermediate Country	Mass (tonnes)	Origin	Intermediate Country	Mass (tonnes)
Viet Nam	India	2,730	**Italy**	Poland	319
	China	2,689		France	267
	Belgium	1,170		Austria	267
Brazil	Belgium	2,470	**Netherlands**	France	351
	Colombia	1,180		Czechia	160
	China	946		Belgium	106
Honduras	Belgium	1,760	**Switzerland**	France	563
	Colombia	778			
	Costa Rica	228			
China	Viet Nam	1,871	**France**	Italy	144
				Netherlands	101
Peru	Colombia	1,080	**Poland**	Czechia	157
	Belgium	543		Netherlands	120

Table 12. Three-node trade relationships for Germany's trade of green coffee and roasted coffee, 2018. Five most important countries of origin by mass (value reported, not converted to raw material equivalents) shown, with top three re-export pathways associated with these origins (where mass is at least 100 tonnes). According to our reconciled re-export-adjusted data, in total, 814,000 tonnes of green coffee beans and 50,600 tonnes of roasted coffee beans were imported into Germany in 2018 (excluding any that was subsequently re-exported elsewhere).

Green coffee			Roasted coffee		
Origin	Destination Country	Mass (tonnes)	Origin	Destination Country	Mass (tonnes)
Brazil	Poland	26,200	**Italy**	Poland	1,490
	United States	9,090		Netherlands	1,340
	Netherlands	7,100		France	1,280
Viet Nam	Poland	22,000	**Poland**	Poland	255
	United States	7,620		Netherlands	229
	Netherlands	5,950		France	218
Honduras	Poland	8,250	**Netherlands**	Poland	237
	United States	2,860		Netherlands	213
	Netherlands	2,230		France	202
Peru	Poland	4,670	**Switzerland**	Poland	217
	United States	1,620		Netherlands	195
	Netherlands	1,270		France	185
Colombia	Poland	4,370	**France**	Poland	140
	United States	1,510		Netherlands	126
	Netherlands	1,180		France	120

Table 13. Destination of green coffee and roasted coffee where Germany is an intermediary in three-node trade relationships, 2018. Five most important countries of origin by mass (value reported, not converted to raw material equivalents) shown, with top three destinations (where mass is at least 100 tonnes). Note that destinations and proportions are the same for each point of origin due to mass-balance treatment of flows (see Methodological Summary). In total, 248,000 tonnes of green coffee beans and 19,700 tonnes of roasted coffee beans were imported into Germany before being re-exported elsewhere in 2018.

Roasted coffee

Initial destination	Second destination	Mass (tonnes)
Poland	Poland	17,400
	Ukraine	1,720
	Czechia	1,410
Netherlands	Netherlands	15,600
	France	3,390
	Belgium	833
France	France	14,800
	Spain	339
	Netherlands	253
Slovakia	Slovakia	5,250
	Austria	2,690
	Hungary	2,510
Austria	Austria	10,900
	Hungary	227

Table 14. Destination of roasted coffee where Germany is an origin in three-node trade relationships for the supply of third-party countries, 2018. The five most important immediate destinations by mass (value reported, not converted to raw material equivalents) are shown (where mass is at least 100 tonnes), plus up to three onward destinations. Note that in cases where there is no onward trade, the second destination is the same as the initial destination. In total, 180,000 tonnes of roasted coffee was produced in Germany in 2018 before being exported.

Germany's coffee deforestation risk compared to other countries

Relative to other countries, Germany is an important importer and consumer of coffee 2014-2018, with a total coffee deforestation risk higher than any of the other countries we assessed (the other ADP signatory countries and China) from all three perspectives (Figure 50, Panel A). From the direct trade and re-export-adjusted trade perspectives, Germany's total coffee deforestation risk (21,400 ha and 10,700 ha, respectively) was significantly larger than the next two highest ranked countries, Belgium (12,300 ha and 5,830 ha) and Italy (9,100 ha and 5,600 ha). From the consumption-based perspective, France (6,760 ha) was the second highest country after Germany (10,700 ha), followed by Italy (5,540 ha).

Germany's coffee deforestation risk intensity (Figure 50, Panel B) was similar across all three perspectives and comparable to the other countries assessed.

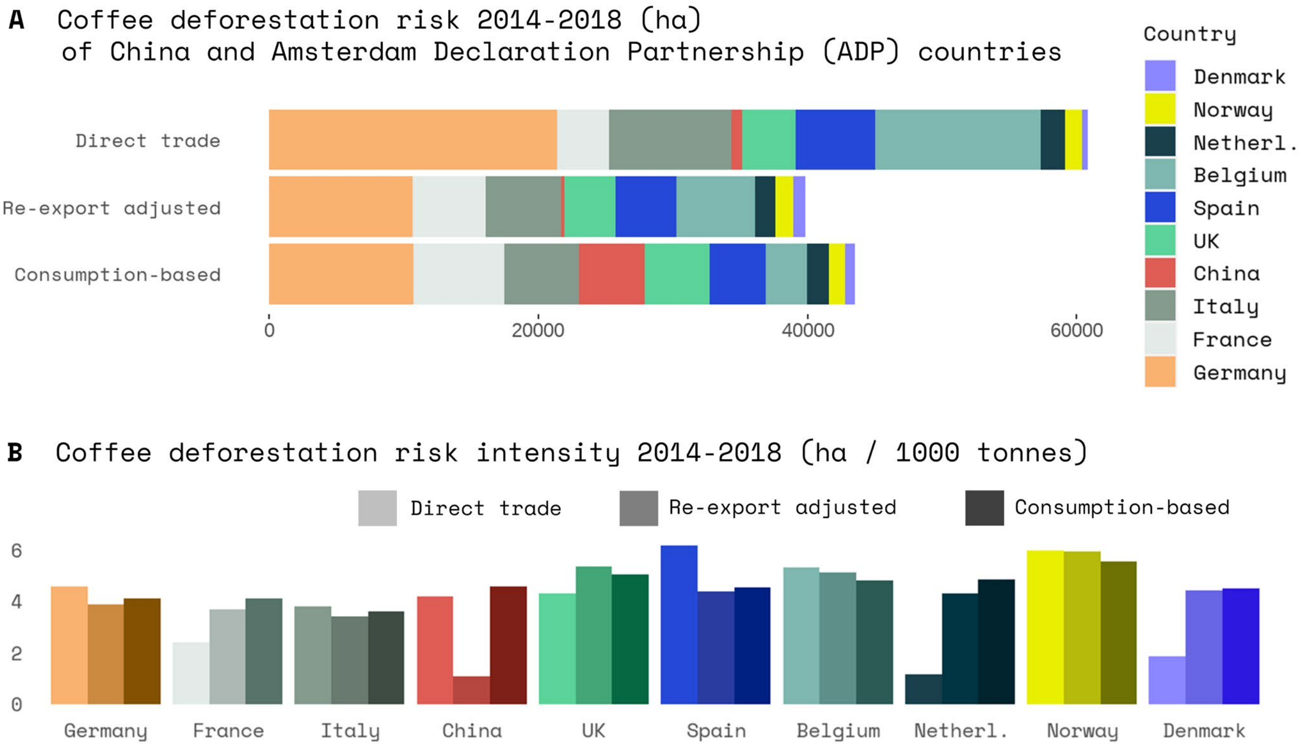

Figure 50: Coffee deforestation risk (A) and risk intensity (B) compared between selected countries (2014-2018) for all three perspectives (direct trade, re-export-adjusted trade, and consumption-based).

Other commodities

Rapeseed

Our national-scale analysis indicates that commodity deforestation risk associated with the direct trade of rapeseed products to Germany was 234 ha in 2018[19]. Several years had zero deforestation risk from rapeseed (2005-2008, 2010 and 2015-2016), while in other years, risk was relatively large, peaking at 3,600 ha in 2011. The overwhelming majority of this risk is associated with rapeseed imported from Australia (Figure 51), with more than 12,000 ha of deforestation risk since 2005 – the second most important country over the entire time series was Chile with just 2.6 ha. It should be noted that, because the source of this deforestation-linked rapeseed is principally Australia, these results must be interpreted with regard to an important methodological constraint associated with the national-scale deforestation analysis: In the Pendrill et al. (2022) dataset, deforestation is attributed (for most countries) based on national non-spatialised crop expansion statistics. For large countries, including Australia, this increases the likelihood that deforestation is attributed to crops that may be produced outside of deforestation frontiers and therefore not a direct driver of deforestation activities.

19. Please refer to the Methodological Summary section, the summary of approaches provided in Table 1, and particularly to the "Methodological assumptions and considerations" for a description of the methods and associated assumptions used to derive the results in this study. Results are designed to be indicative of hotspots of commodity deforestation risk, but should be interpreted on the basis of the methods employed which are not traceability assessments.

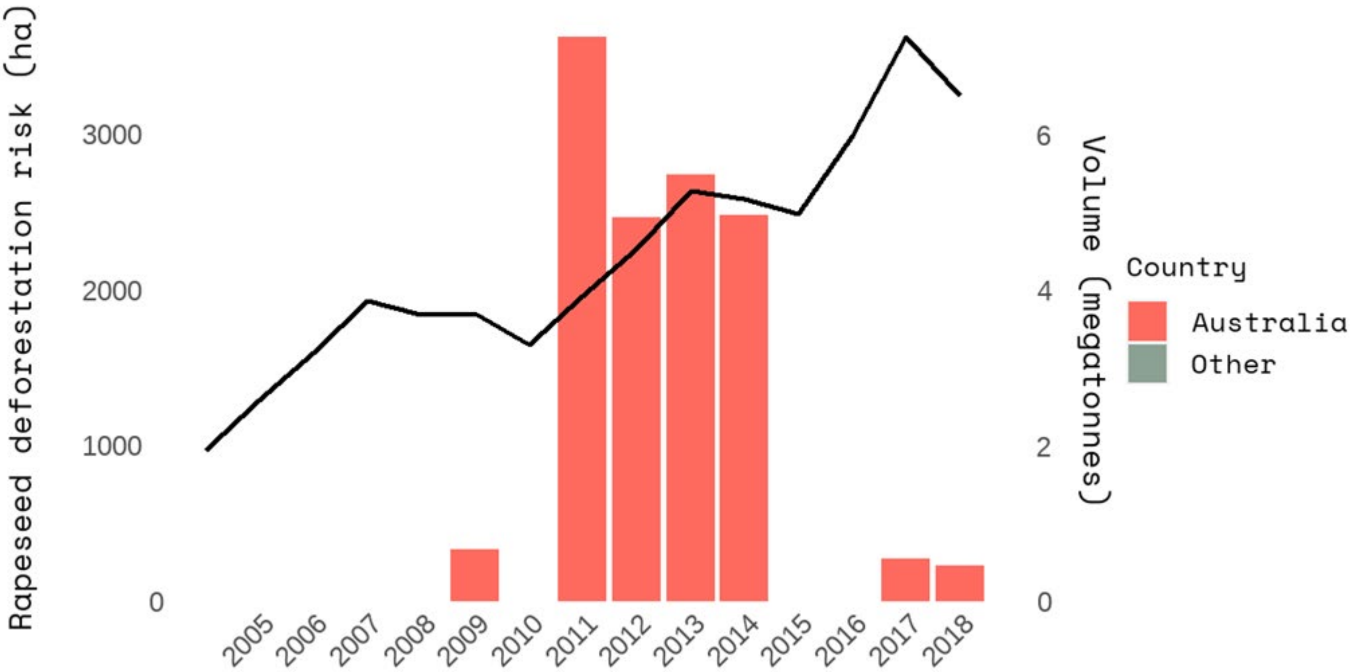

Figure 51: Rapeseed deforestation risk associated with direct imports to Germany (2005-2018). As the overwhelming majority of risk was associated with rapeseed sourced from Australia, all other countries are grouped together in the 'other' category. The total trade volume (mass of raw material equivalents, regardless of their association – or not – with deforestation) is also shown by the black line and right-hand axis.

Cashew nuts

In the re-export-adjusted analysis, cashew nuts appear as one of the top ten most important sources of deforestation risk for Germany. Sources of this risk are predominantly Côte d'Ivoire, Indonesia and Tanzania (Figure 52 & 53). Cashew nut deforestation risk increases initially in the time series, but falls back substantially in 2018. This is linked to a steady decline in Côte d'Ivoire deforestation intensity over the time series, and a drop in trade quantities from Indonesia and Tanzania for 2018.

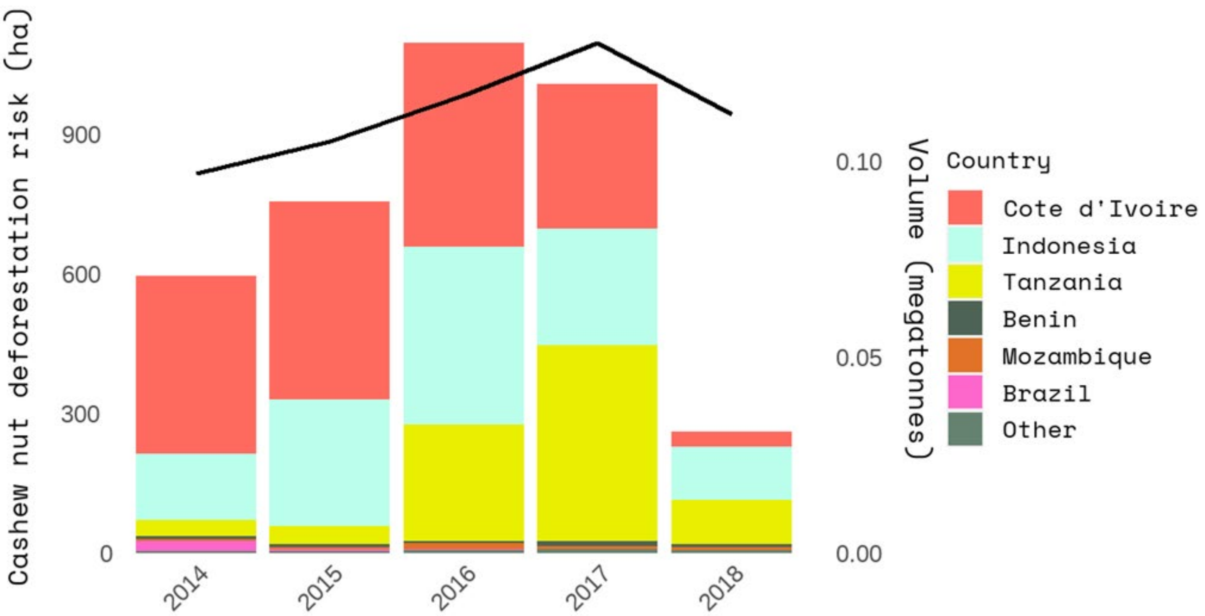

Figure 52: Re-export-adjusted cashew nut deforestation risk associated with imports to Germany. The top six countries in terms of cashew nut deforestation risk across the time series are shown, with all others grouped together in the 'other' category. The total trade volume (mass of raw material equivalents, regardless of their association – or not – with deforestation) is also shown by the black line and right-hand axis.

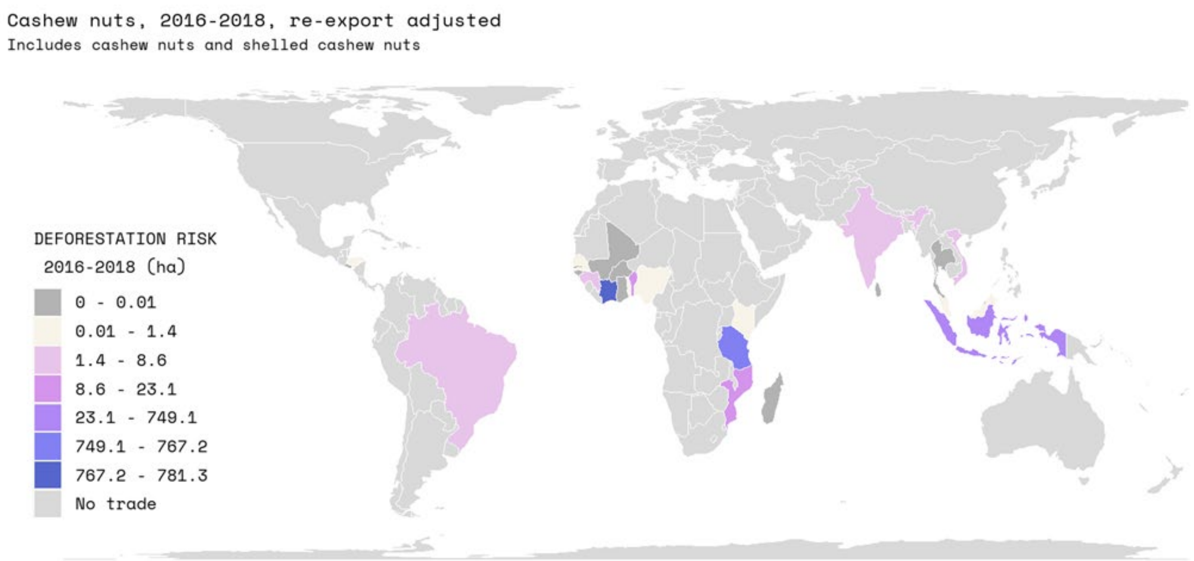

Figure 53: Cashew nut deforestation risk associated with German imports after adjusting for re-exports for the period 2016-2018.

Cashew nuts are also highlighted in the consumption-based analysis. Sourcing patterns are similar to those in the re-export analysis, although the overall risk from consumption is somewhat larger than from re-export-adjusted trade (Figure 54). Consumption-based deforestation risk for Germany peaked in 2016 at 1,240 ha, with Tanzania accounting for the largest amount of risk over the most recent three years (Figure 55). Indonesia and Côte d'Ivoire were also important sources of deforestation.

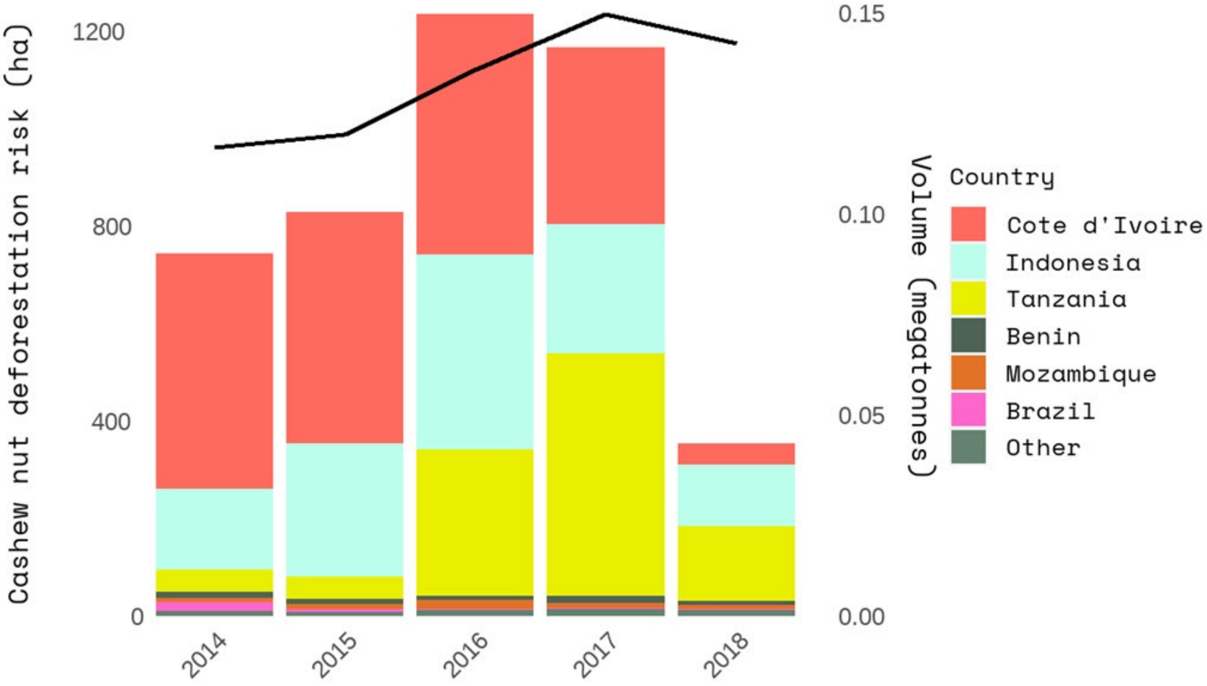

Figure 54: Cashew nut deforestation risk of production associated with German consumption 2014-2018 by producer country. The total production linked to German consumption (mass of raw material equivalents, regardless of their association – or not – with deforestation) is also shown by the black line and right-hand axis.

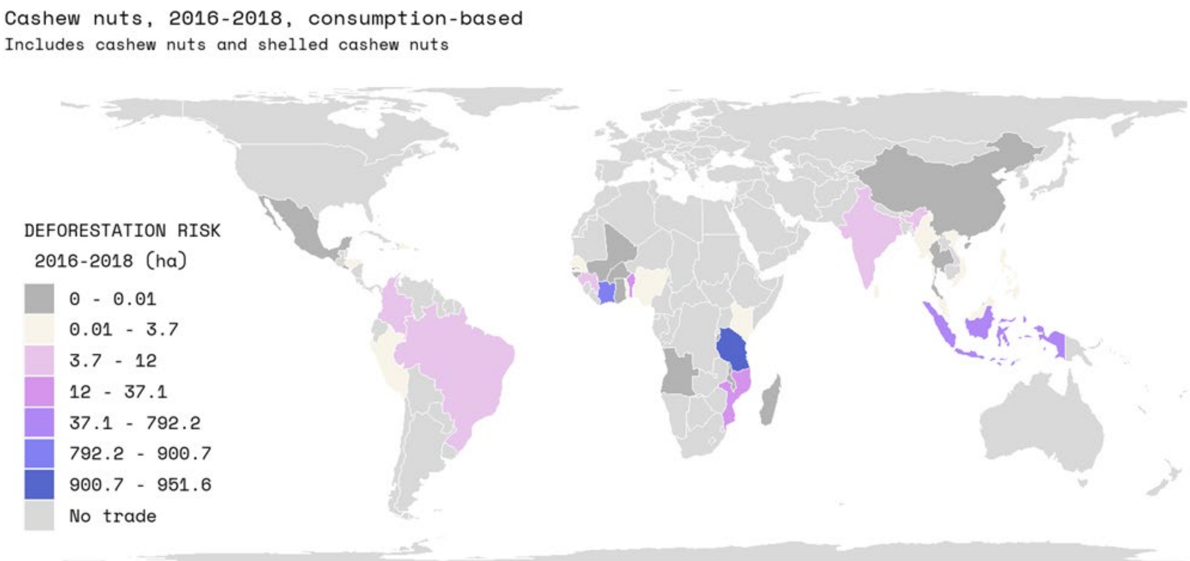

Figure 55: Cashew nut deforestation risk associated with production linked to German consumption for the period 2016-2018.

Maize

The consumption-based analysis revealed that production of maize linked to German consumption has been another source of deforestation risk, and generally decreased over the five years with available data, from a peak of 2,800 ha in 2014 to 1,490 ha in 2017 (Figure 56). At the beginning of the time series, the DRC was the greatest source of this deforestation risk, with 947 ha in 2014, but this fell by more than 96% down to 31 ha in 2018. Although trade quantities from the DRC have fallen over time, the majority of this decreased risk is due to a drop in deforestation intensity since a peak in 2014. Brazil has remained another major source of maize deforestation risk, making up 50% of Germany's consumption-based risk in 2018. Figure 57 shows sources of maize deforestation risk for Germany's consumption for the period 2016-2018.

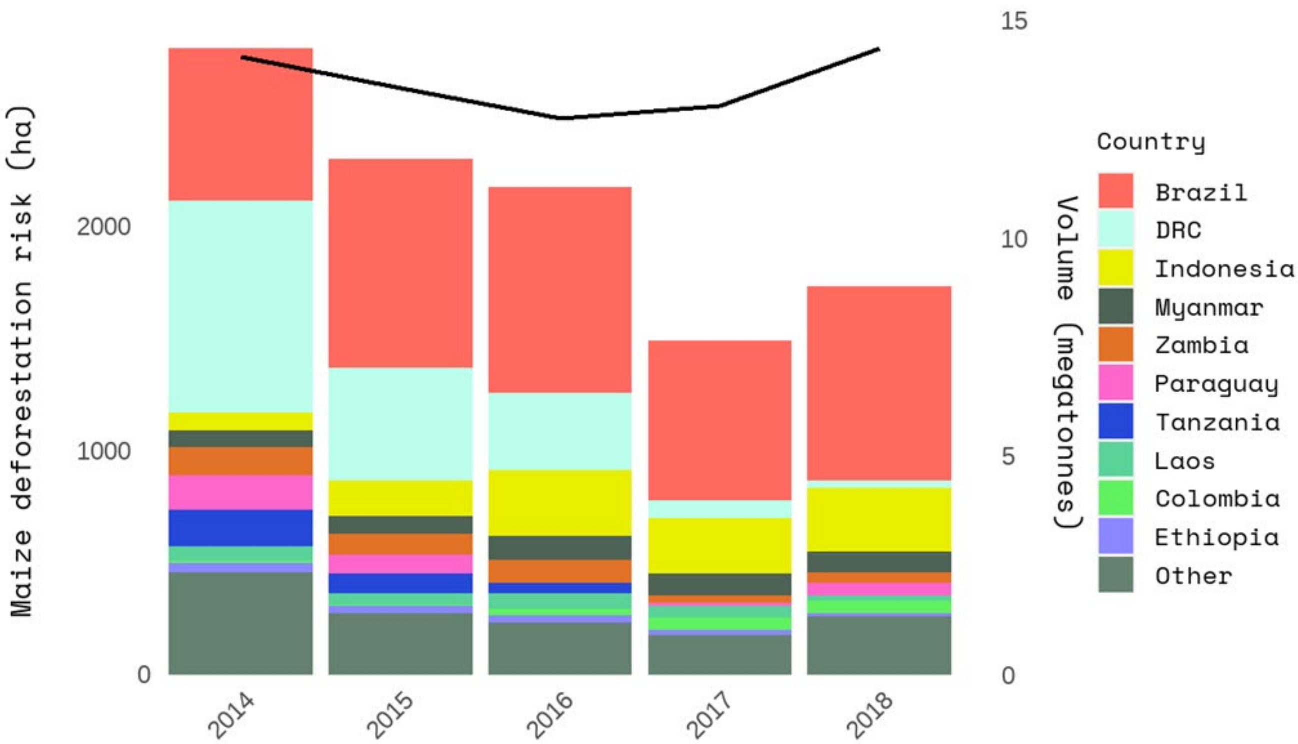

Figure 56: Maize deforestation risk of production associated with German consumption 2014-2018 by producer country. The top ten countries in terms of maize deforestation risk over the timeseries are shown, with all others grouped together in the 'other' category. The total production linked to German consumption (mass of raw material equivalents, regardless of their association – or not – with deforestation) is also shown by the black line and right-hand axis.

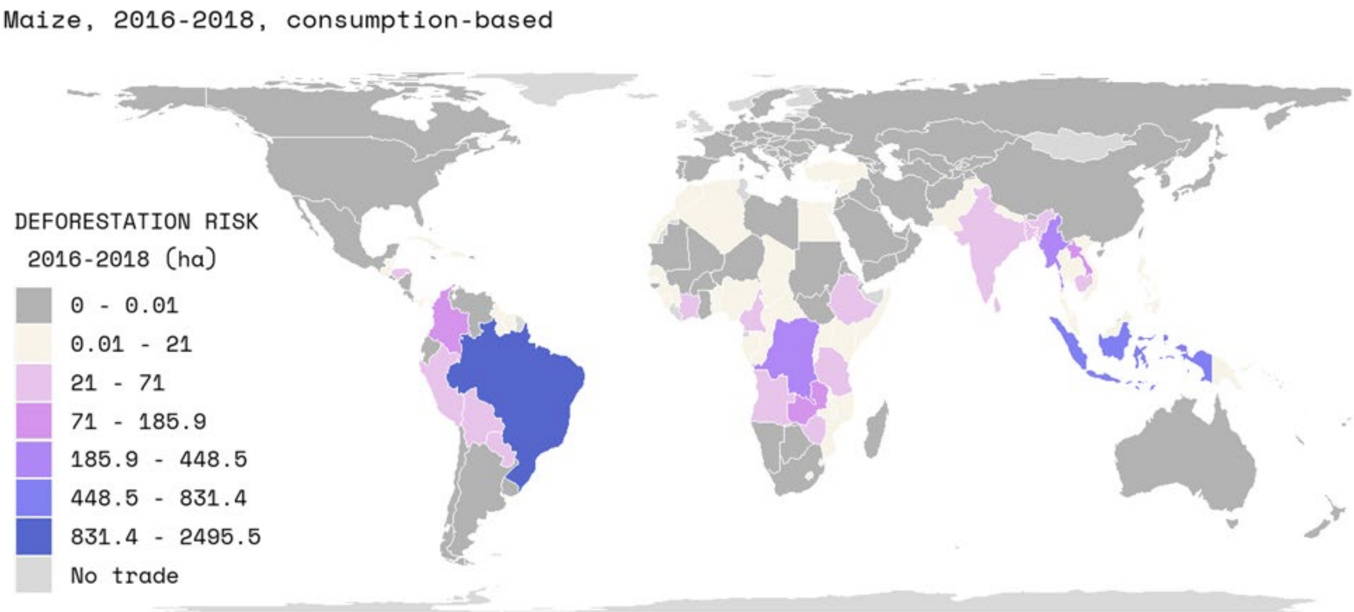

Figure 57: Maize deforestation risk associated with production linked to German consumption for the period 2016-2018.

Cassava

Production of cassava over recent years linked to German consumption is also associated with deforestation risk, largely in the DRC (Figure 58). However, declining risk from the DRC has led to a significant decrease in Germany's risk exposure over the time series (2014-2018), largely due to a significant fall in the deforestation intensity of DRC cassava production. Smaller amounts of consumption-based deforestation risk were associated with cassava production in Cambodia and other countries mostly in Southeast Asia and Africa. Figure 59 shows sources of cassava deforestation risk for Germany's consumption for the period 2016-2018.

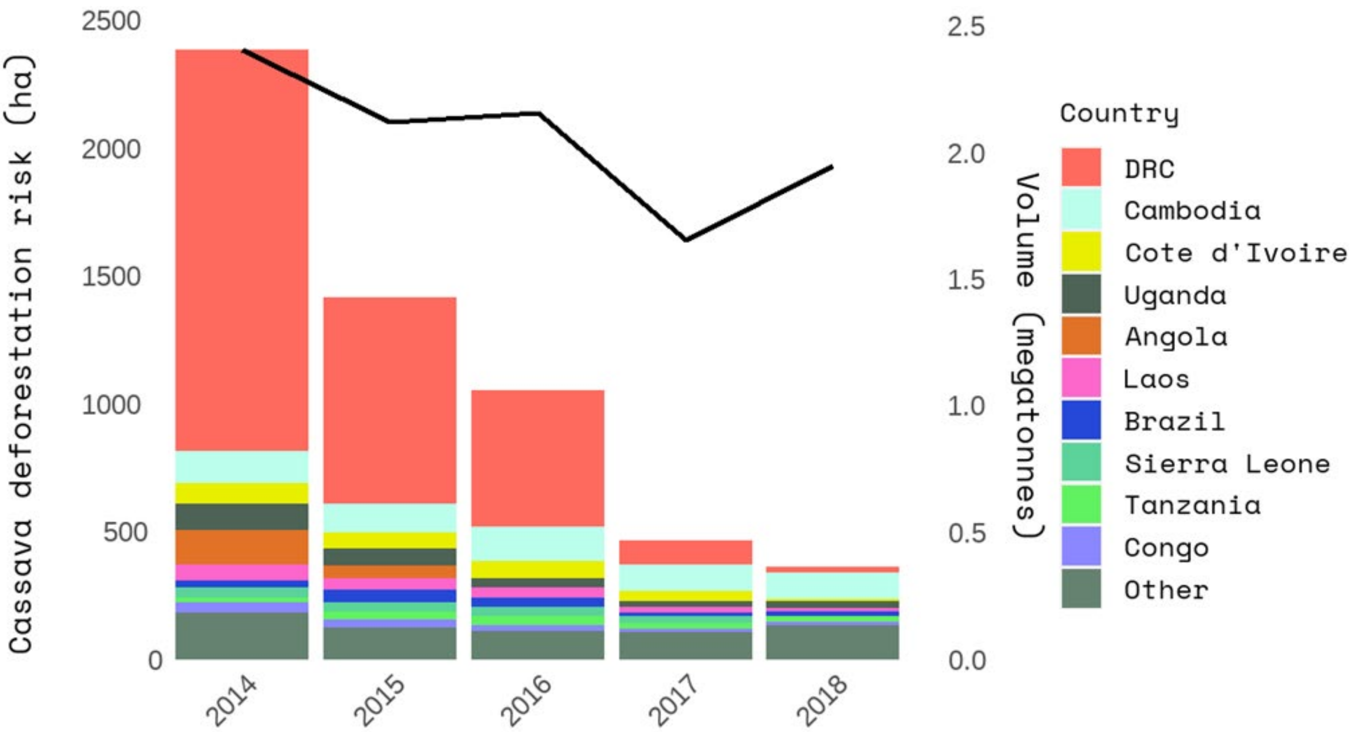

FIgure 58: Cassava deforestation risk of production associated with German consumption (2014-2018) by producer country. The top ten countries in terms of cassava deforestation risk over the timeseries are shown, with all others grouped together in the 'other' category. The total production linked to German consumption (mass of raw material equivalents, regardless of their association – or not – with deforestation) is also shown by the black line and right-hand axis.

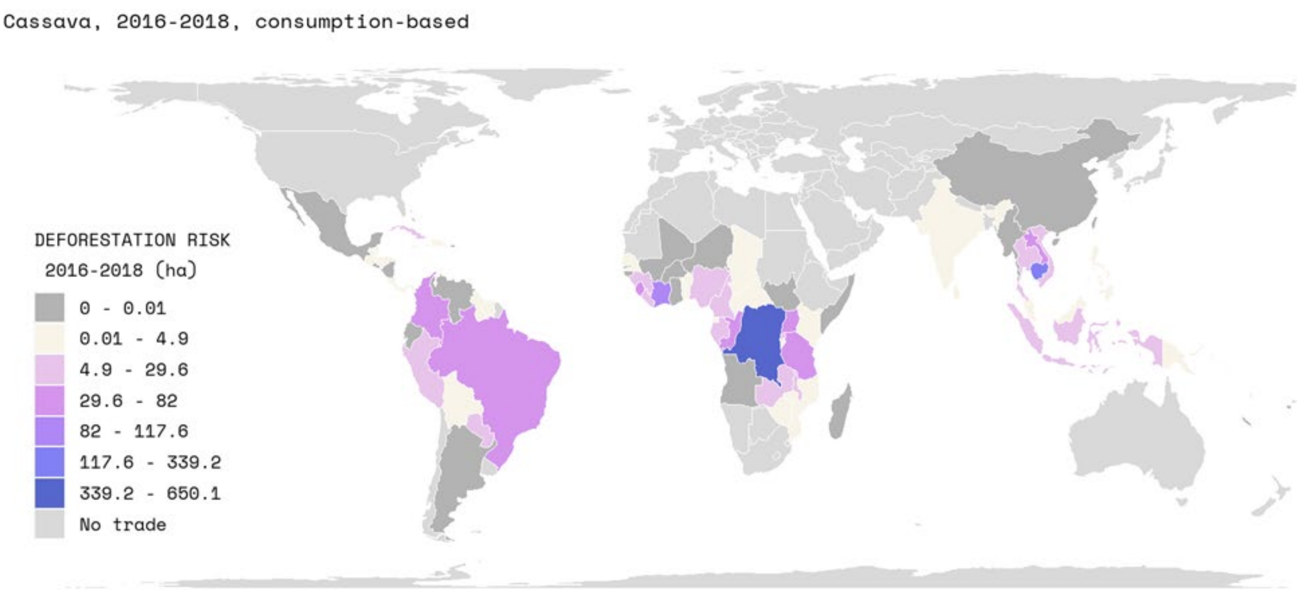

Figure 59: Cassava deforestation risk associated with production linked to German consumption for the period 2016-2018.

Paddy rice

Paddy rice has remained a consistent source of around 2,000 ha per year of deforestation risk for German consumption over the five year period 2014-2018 (Figure 60). However, this consistency masks dynamic changes at the national level, with rice deforestation risk in the DRC – an important source of risk in 2014 – down 88% by 2018. Laos, the second largest source of risk in 2014, also shrank in its importance by the end of the time series (down 75%). In contrast, Myanmar rapidly became a significant source of rice deforestation risk over the five years, and in the latest year (2018) accounted for 46% of Germany's consumption-based rice deforestation-risk exposure. The falls in risk from the DRC and Laos are due to decreases in deforestation intensity in each country; quantities linked to German consumption have remained consistent over the five year period. The rise in Myanmar between 2015 and 2017 is due to a sharp rise in deforestation intensity, while the increase between 2017 and 2018 is explained by a 30% increase in production linked to German consumption and only a slight increase in deforestation intensity. Figure 61 shows sources of paddy rice deforestation risk for Germany's consumption for the period 2016-2018.

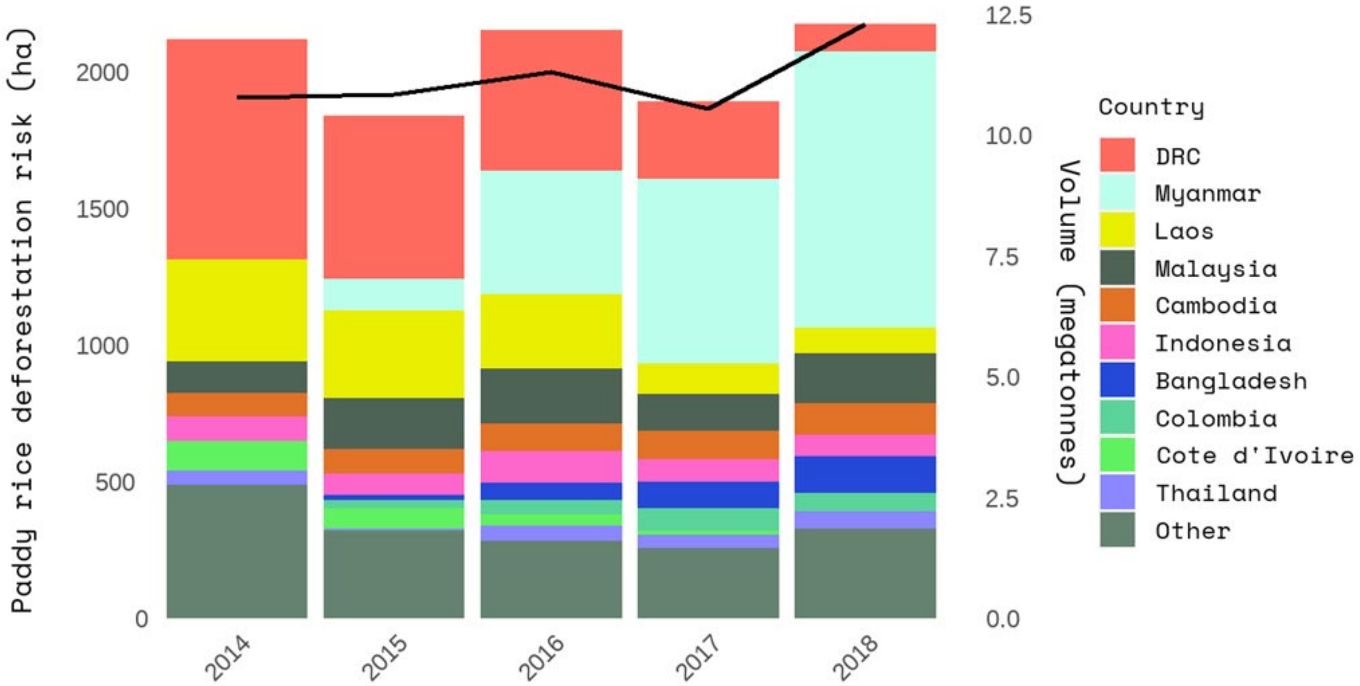

Figure 60: Paddy rice deforestation risk of production associated with German consumption (2014-2018) by producer country. The top ten countries in terms of deforestation risk over the timeseries are shown, with all others grouped together in the 'other' category. The total production linked to German consumption (mass of raw material equivalents, regardless of their association – or not – with deforestation) is also shown by the black line and right-hand axis.

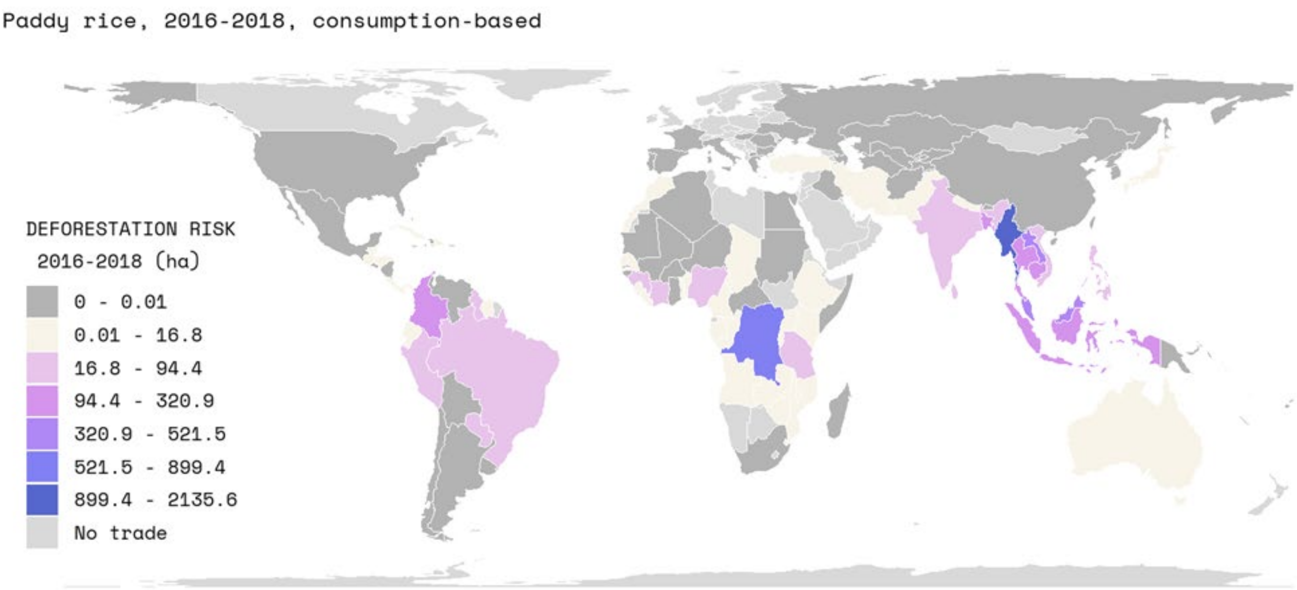

Figure 61: Paddy rice deforestation risk associated with production linked to German consumption for the period 2016-2018.

Seed cotton

Cotton was another source of deforestation risk for Germany highlighted in our consumption-based analysis. Risk was concentrated in cotton sourced from Brazil, West Africa and Southeast Asia, and at 1,180 ha was significantly higher in 2014 than in subsequent years. In 2014, Zambia, Australia and Côte d'Ivoire were the largest sources of deforestation risk, but were associated with very little risk by 2018 (Figure 62). Production in Zambia linked to German consumption fell by around 40% between 2014-2015 but remained at this level thereafter; the subsequent drop in risk from Zambia is due to a lack of deforestation attributed to cotton after 2016. Similarly, production in Australia linked to German consumption actually increased throughout the period, but there was little or no deforestation attributed to Australian cotton production after 2014, explaining the lack of risk. The decline in risk from Côte d'Ivoire is also related to a drop in deforestation intensity rather than a drop in production linked to German consumption. Brazil's contribution to Germany's risk exposure generally increased throughout the period, totalling 188 ha (or 43% of the risk) in 2018. This increase is explained by rising deforestation intensity and slightly increasing production linked to German consumption. Figure 63 shows sources of seed cotton deforestation risk for Germany's consumption for the period 2016-2018.

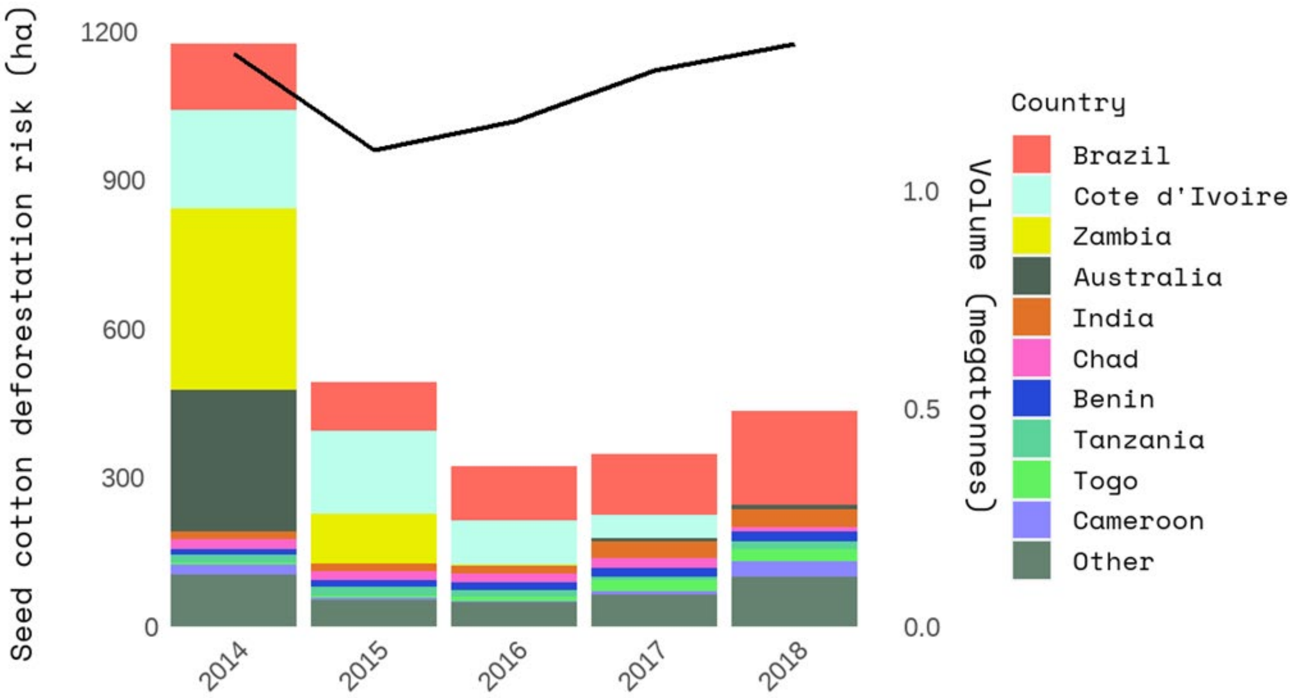

Figure 62: Seed cotton deforestation risk of production associated with German consumption (2014-2018) by producer country. The top ten countries in terms of deforestation risk over the time series are shown, with all others grouped together in the 'other' category. The total production linked to German consumption (mass of raw material equivalents, regardless of their association – or not – with deforestation) is also shown by the black line and right-hand axis.

Seed cotton, 2016-2018, consumption-based

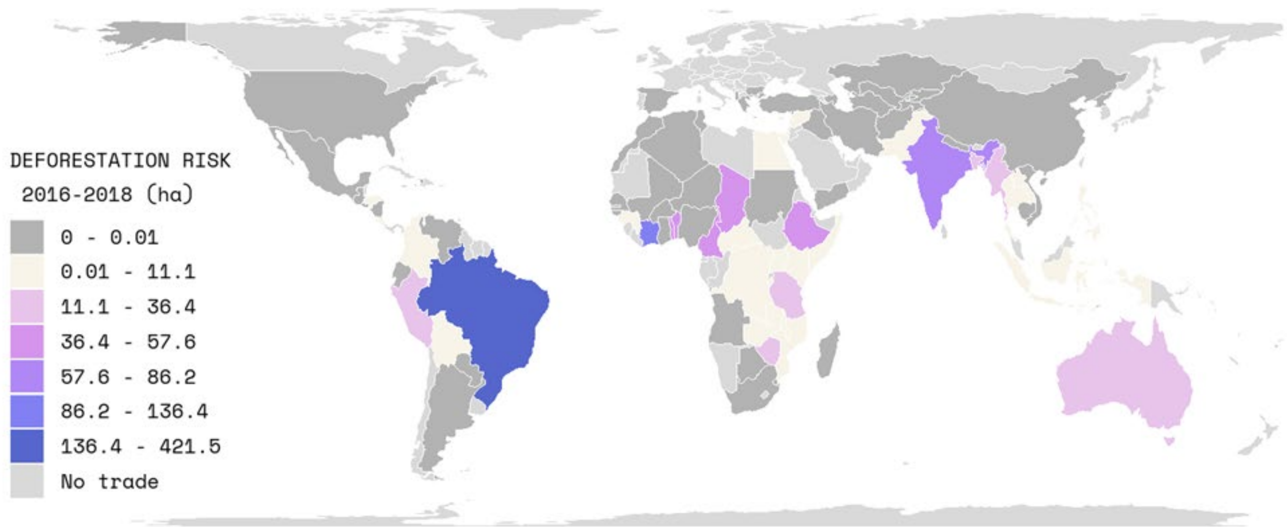

Figure 63: Seed cotton deforestation risk associated with production linked to German consumption for the period 2016-2018.

Comparative results from other studies

A number of previous studies have quantified estimates of Germany's commodity deforestation risk. Table 15 presents these to allow basic comparison with our own results.

The European Soy Monitor (IDH & IUCN NL, 2019) does not directly provide deforestation statistics, but does quantify total import dependencies for soy in terms of direct imports and estimates for consumption (although their methods for consumption are not in alignment with the modelling approach conducted for this study). Their 2017 direct import estimate of 5.8 million tonnes is slightly lower than our estimate of 6.5 million tonnes across soy and its oil and cake derivatives (all in raw soy equivalents). However, their consumption estimate of 3.5 million tonnes is significantly lower than our estimate of 8.1 million tonnes; likely a reflection of the nature of the supply chain models employed in our analysis which aim to capture complete final demand for commodities across all forms of consumption.

The indicator set developed for the UK government (Croft et al. 2021) conducts only a consumption-based analysis, but uses the same modelling framework (IOTA) and deforestation dataset (Pendrill et al. 2022, although only to 2017) as employed in this study. However, a key difference is that the re-export-adjustment treatment of physical trade within the hybrid physical-financial modelling framework is different; work for the UK indicator set employed methods to account for the production, trade and re-export of only harvested commodities, whereas work in this study significantly advanced this method to also encapsulate onward processing and trade of derived commodities in physical terms before hybridisation with the monetary MRIO model[20]. Comparing results for the year 2017, we observe that while this analysis indicates 44k ha, the data from the UK indicator work indicates Germany is linked to 46.2k ha of deforestation risk. For palm oil, this study indicates 14.6k ha of commodity deforestation risk for Germany in 2017, in comparison to 12.9k ha from the UK indicator work. For cattle, the results are 10.3k ha and 9.36k ha respectively. For soybeans, 7.1k ha and 4.65k ha. For coffee, 2.68k ha and 4.65k ha. For cocoa, 2.14k ha and 2.73k ha.

20. Note that - as also described in the Methodological Summary - a product of this is that we have also assigned some trade flows to 'unknown' sources. These are not associated with deforestation in our results which may underestimate deforestation risk in such cases.

The Pendrill et al (2022) dataset includes the authors' own approaches to link deforestation to trade activities. Their approaches do account for re-exports, but are based on a different methodological implementation to those adopted in this study for our re-export-adjusted results. Our estimate of 10.8k ha for the total 2018 deforestation risk for Germany, compares to the trade-linked estimate in Pendrill et al (2022) of 19.1k ha. For palm oil, this study indicates 1.5k ha of deforestation risk for Germany in 2018, in comparison to 5.3k ha from the Pendrill et al (2022) trade-linked estimates (see Figure 9: our study assigns most (>1.2m tonnes in palm oil fruit equivalents) palm kernel oil to unknown sources which likely explains a large portion of this difference in results). For cattle the results are 1.2k ha and 1.3k ha respectively. For soybeans, 3.2k ha and 3.8k ha. For coffee, 2.5k ha and 3.9k ha. For cocoa, 1.7k ha and 1.8k ha. While Pendrill et al (2022) also provide consumption-based results, they do so aggregated to coarse sectors rather than at commodity level, so we do not attempt direct comparison here.

We estimate a consumption-based commodity deforestation risk for Germany of 43.2k ha in 2015, which is significantly below the approximately 200k ha from Huang & Kanemoto (2021). Huang & Kanemoto (2021) use a consumption-based approach in the form of a different, non-hybridised, monetary MRIO (Eora) with the deployment of quite different methods for attributing deforestation to production sectors.

Where commodity-specific comparators are available, while the absolute results differ, we make similar conclusions about the relative importance of several key commodities to the overall deforestation risk associated with Germany. In our consumption-based analysis, 84% of the total commodity deforestation risk in 2017 comprised products of palm oil, soy, cattle, coffee and cocoa, compared to 74% in the UK indicator results. From a re-export perspective, these commodities comprise 92% of the total risk estimate in our study in 2018, compared to 84% in trade-linked results from Pendrill et al. (2022).

Study (and reference)	Perspective adopted	Deforestation risk estimates (ha)	Mass estimates (tonnes)	Notes
European Soy Monitor (IDH & IUCN NL, 2019)	Direct trade Domestic consumption	N/A – no accompanying deforestation statistics supplied; analysis focuses on %age of mass certified as deforestation free.	In 2017: Soybeans (imports) – 5.8M In 2017: Domestic consumption (estimated) – ~3.5M	Covers soy only. Domestic consumption estimated via e.g. estimates of use in livestock industry and accompanying consumption statistics. Estimates 3.5 million tonnes of meal used in animal feed consumed in Germany, and 2,000 tonnes of oil consumed in biodiesel.
Indicator set developed for the UK government, including tropical and subtropical deforestation (Croft et al. 2021, www.commodity footprints.earth)	Consumption-based	15,600	In 2017: Oil palm fruit – 8.04M Cattle – 2.12M Soybeans – 6.15M Coffee – 476k Cocoa – 450k	The indicator developed here utilises the IOTA framework also applied for this study. However, the methods employed in this study are different, particularly due to the inclusion of bilateral trade of derived commodities in physical units. Note all masses are expressed in raw material equivalents e.g. oil palm fruit not the mass of palm oil itself.

Table continues onto next page

Study (and reference)	Perspective adopted	Deforestation risk estimates (ha)	Mass estimates (tonnes)	Notes
Deforestation risk embodied in production and consumption of agricultural and forestry commodities 2005-2018 (Pendrill et al. 2022)	Re-export-adjusted	22.1k total in 2017/ 19.1k total in 2018: Oil palm fruit (2017/2018) – 6.6k / 5.3k Cattle – 1.2k / 1.3k Soybeans – 4.2k / 3.8k Coffee – 4.1k / 3.9k Cocoa – 2.9k / 1.8k	Not provided	Re-export-adjusted metrics follow similar, but not identical methods/assumptions as those adopted in this study. Re-export-adjusted cattle data includes meat, but not leather products.
	Consumption-based	52.1k total in 2017/ 53.7k total in 2018: Oil seeds (2017/2018) – 18.5k / 19.0k Cattle – 17k / 18.7k Crops not elsewhere classified – 7.1k / 6.3k Vegetables, fruit, nuts – 5.3k / 4.6k		Uses EXIOBASE model, but not in a 'hybrid' format (i.e. not linked to physical trade/processing steps). Data is aggregated into coarser sectors of production/ consumption.
Mapping the deforestation footprint of nations reveals growing threat to tropical forests (Huang & Kanemoto, 2021)	Consumption-based	Imported tropical deforestation area (2015): 200k (estimated) across all commodities	Not provided	Uses the Eora MRIO model, which is linked to measures of both tropical and temperate deforestation (tropical results shown on left only, for alignment with this study), with linkages made to the MRIO via estimates of crop distribution and coarse deforestation driver classifications.

Table 15. Other studies that quantify the deforestation risk associated with Germany's trade or consumption. Table contains detail on the perspective adopted in the study, results and relevant explanatory notes.

Discussion

Summary of Germany's deforestation in agricultural supply chains

This study reveals the direct, re-export-adjusted and consumption-based relationships that Germany has with commodities linked to tropical and subtropical deforestation. Our analysis provides a global, but coarse, overview of where commodity deforestation risk in Germany's supply chains is likely to be highest (and how this has changed over time), along with more granular 'hotspotting' of risks where this information is available via Trase.

We are unaware of any similar assessments for Germany (e.g. see Table 15) that have provided the breadth and detail covered in this study. While transparency in global supply chains, issues with data consistency and a dependence on models mean that work remains to improve our knowledge of commodity-linked deforestation in Germany's supply chains (and those of other countries), this study and its underpinning datasets provide a rich source of information in assessing Germany's role in this challenging space.

Overall, our results suggest that Germany's contribution to tropical and subtropical deforestation has decreased over the period analysed. However, although a decrease is shown in both direct and re-export-related results, consumption-based results suggest this trend is marginal, if existent at all. A decrease for its more 'direct' trade relationships is encouraging from the perspective of Germany's deforestation risk, although the results suggest that work is required to reduce deforestation risk for indirect and embedded supply chain pathways.

Additionally, recent trends in deforestation have suggested that: i) deforestation is again increasing in some areas (e.g. Brazil; Silva Junior et al. 2020, INPE 2021); ii) other consumer markets may be experiencing an increase in deforestation risk given changing patterns of trade and consumption, and; iii) ultimately, deforestation-risk exposure for Germany is still a current and active risk in its supply chains.

Moreover, common across the results and perspectives is the relative importance of particular commodities and particular source regions, which aligns with prior assessments. For example, critical soy-producing countries with important rates of deforestation are Brazil and Paraguay; for palm oil, Indonesia dominates (although Malaysia and Colombia are also important); for cattle, Brazil, Paraguay and Australia are hotspots of concern; for cocoa, the distribution of risk is broader, with Côte d'Ivoire, Peru, Ecuador and others being of importance; and similarly for coffee, while a wider variety of countries are sources of risk, Colombia, Peru and Honduras stand out.

There are exceptions in the general trend of decreasing risk for Germany. For example:

- While overall risk has reduced for beef, the most recent years of the time series suggest that deforestation linked to this commodity is again increasing, particularly in those supplies from Brazilian production systems. This recent increase appears to be due to increasing deforestation intensity associated with the production of Brazilian cattle products rather than increasing trade or consumption;
- Also of potential concern is a large spike in historical deforestation in Paraguay for 2012, which – accompanied by a concurrent upturn in trade from Paraguay in the period – dominated Germany's soy deforestation risk, and is indicative of the volatility of the commodity-deforestation context, with the potential for rates of deforestation and commodity expansion to rapidly change year on year;
- For our consumption-based results for palm oil products, we see an increasing deforestation-risk trend, in contrast to the results from the direct trade and re-export analysis, with the risk also substantially higher for palm oil from a consumption-based perspective; indicative of palm oil's important role as an 'embedded' product in materials likely flowing into Germany via indirect supply chain pathways;
- Results for cocoa are mixed, but direct trade analysis has suggested an increasing trend in cocoa deforestation risk over the time series. However, direct, re-export and consumption results for cocoa all indicate a decreasing deforestation risk trend for Germany in recent years;
- Direct and re-export-adjusted results for coffee suggest an overall increasing coffee deforestation risk, particularly linked to production in Colombia.

A number of commodities appear in the national-scale results which might be classed as 'unusual suspects' when it comes to the relative level of attention that they receive in dialogue around deforestation. In our direct trade results, rapeseed appears as an important commodity for selected years, due to a connection with deforestation in Australia. However, the very large size of the Australian land mass and an associated lack of spatial attribution of deforestation to crops within the Pendrill et al. (2022) dataset means that this result may primarily be a product of the methods employed rather than a reflection of the importance of rapeseed as a deforestation-risk commodity. In contrast, cashew nuts do not appear particularly prevalent in the direct trade analysis, but do appear as an important commodity in our re-export-adjusted analysis, linked to deforestation in Côte d'Ivoire, Indonesia and Tanzania particularly.

The 'stickiness' (i.e. the stability and longevity) of supply chain relationships between Germany and production regions is an important component to consider when discussing deforestation risk. While a handful of commodities make up Germany's total risk, it is clear their relative contribution is quite variable year on year. For example, at various times throughout the direct trade time series, soy, palm oil and coffee dominate risk estimates overall.

As indicated above, analysis across perspectives at the national level also suggests that a few key countries dominate across the time series, but inter-annual variability is also present that reflects both changes in the deforestation activity and changes in sourcing patterns.

Delving into the subnational data from Trase allows us to analyse the stickiness of relationships in more detail, and at this scale we would expect variability to be higher. Nonetheless, across key commodities we observe some persistent relationships to deforestation. For Brazilian soy, for example, sourcing from particular regions dominates the overall deforestation risk, and in turn some trading companies are more associated with this risk than others. Also striking, however, is that there is a high level of variability across some of the trading companies. This is true for Brazil, where several smaller/less well-known companies are periodically associated with deforestation risk linked to Germany. It is even more apparent in Argentina which (while Trase provides only a short time series) has a very different complement of trader deforestation risk year on year. This is an indication of how complex stakeholder engagement is likely to be in the context of managing Germany's supply chain risk. While some key traders are priorities for engagement to further understand their exposure to deforestation risks at corporate level, an important component of supply (and hence risk) is associated with different organisations at different times.

Germany's role in international supply chains

Alongside exploring Germany's overall exposure to risk, we have also assessed the role of its economy in the supply chains of tropical and subtropical deforestation risk commodities. Our analysis reveals that, from a consumption-based perspective, Germany's recent commodity deforestation risk (2014-2018) is higher in absolute terms than any other signatories to the Amsterdam Declarations Partnership, but significantly lower in absolute terms than China's risk.

However, Germany's deforestation risk intensity (as for other ADP countries) is actually higher overall than China's. For specific commodities, a similar pattern of Germany being the most important consumer from a consumption-based risk perspective across ADP countries is observed (although France has a higher consumption-based risk for cattle), but the ranking of Germany in comparison with other countries varies from direct or re-export-adjusted trade perspectives. Germany has the largest consumption-based risk of any country analysed (i.e. including China and other ADP countries) for cocoa and coffee.

Germany's consumption-based risk results are also significantly higher than its direct or re-export-adjusted risk, illustrating that much of Germany's link to deforestation is through more complex supply chain paths. A component of the risk from this consumption-based perspective will be associated with products which are consumed far upstream in Germany's supply chain (see Methodological Summary for more detail) and may not be physically present in materials ultimately consumed in Germany.

The degree to which Germany may act to address these components of risk will therefore depend on the context of such upstream dependencies and, for example, existing dialogues that it may have with industry in third-party countries.

Deconstructing selected re-export pathways also provides further information on the role Germany has as a destination or intermediate country of transit in the supply chains of others. In this study we have presented the re-export pathways of harvested and derived commodities associated with three-node supply chains where Germany is the origin, re-exporting intermediary or destination. This analysis reveals the importance of certain EU countries which act as re-exporters to Germany, particularly the Netherlands and Belgium. It is clear also that Germany has a key role itself as a re-exporter to other countries (or serves as a 'hub' of sorts), particularly for soybean cake (where the key recipients are Denmark, Czechia and Austria) and green coffee (where the key recipient is Poland, followed by the USA and the Netherlands). Germany is also a key point of origin for the export of derived commodities (such as soybean cake, soybean oil, cocoa paste, cocoa powder/cake and roasted coffee) to other (mainly) European countries.

Finally, the re-export-adjusted subnational (Trase) data for soy and palm oil further supports the importance of the Netherlands as an important intermediary (and indirect source of deforestation risk for Germany). For soybeans from Brazil, Argentina and Paraguay, however, the distribution of risk after accounting for re-exports, while slightly wider, is similar to Germany's direct commodity deforestation risk. This contrasts with palm oil from Indonesia where risk linked to Germany via re-exports is much higher in Kalimantan, whereas risk was mostly restricted to Sumatra from a direct trade perspective. For palm oil from Indonesia, Italy, Papua New Guinea, Brazil and Malaysia appear as notable re-exporters in addition to the Netherlands.

Policy and practical context

Overall, our analysis shows that Germany plays an important role in the trade and consumption of agricultural commodities linked to tropical and subtropical deforestation. It is thus critical that Germany applies its political and economic influence to work with producers, supply chain actors and consumers to continue to reduce this risk over time. While much of Germany's risk is via direct trade, a significant proportion of risk exposure is associated with indirect supply chain pathways. Germany also clearly plays an important role in the supply chains of other trade partners; efforts to reduce deforestation in its supply chains will therefore have spillover effects on other economies. Additionally, Germany's deforestation risk is significantly lower than other world economies such as China (although its deforestation intensity for our consumption-based results is higher overall). These facts imply that a variety of approaches are likely to be necessary for Germany to reduce its deforestation-risk exposure and – more importantly – exert influence and support to reduce deforestation in regions of production.

There are several initiatives already in progress that can support such objectives. Firstly, the forthcoming introduction of the regulation on deforestation-free products (EC regulation proposal COM 2021/0366, EC 2021) provides an important opportunity for Germany to work in tandem with other EU member states on the removal of deforestation from EU supply chains. Careful assessment is, however, required of the commodities and locations that might be considered to be of the highest risk. The current legislative proposals seek to exert more stringent requirements on actors sourcing from these regions, implying that more detailed risk assessment will be needed in those areas alongside investment to ensure landscape-scale production becomes more sustainable (e.g. to reduce the likelihood of switching of some supply chains to low-risk areas while conversion for other markets continues) as identified by Germany's INA initiative.

Analysis such as that conducted for this study can help identify areas and commodities of low or high risk and how they may be changing. This type of analysis also provides a starting point for discussion and the more detailed deforestation risk assessment that would be needed when working with, for example, commodity-specific roundtables (e.g. FONAP, GISCO) which may seek to build upon the economy-wide analysis here by conducting more detailed traceability assessments in regions of concern. It is important to note, however, that the definition of deforestation currently adopted by the EU regulatory proposals (the FAO Forest Resources Assessment definition) is not in alignment with the deforestation metrics used in this study, which also only focus on tropical and subtropical regions. Further work would be needed to harmonise assessments going forward, and/or to explore commodity-linked land-use changes in other non-forested ecosystems not covered by deforestation metrics.

Additionally, it is important to note that – while our analysis reveals that most of Germany's commodity deforestation risk is associated with palm oil, soy, cocoa, coffee and cattle products which are well-established commodities of deforestation concern and are associated with international platforms working on deforestation-free production and supply chains – there are a number of commodities which appear significant to the German risk assessment. These include cashew nuts, maize, rice, cassava and cotton. Given the fact that these commodities appear important particularly within the consumption-based results, the nature of the linkage to the German economy is likely to be quite complex (e.g. much of the risk might be embedded in materials which are not directly associated with imports of the harvested commodity). Additional efforts to understand the supply chain linkages of these commodities would help to determine the extent to which German companies are associated with the supply chains of these materials, and/or whether efforts should be focused on working directly in regions of commodity production.

Advances and limitations

The analysis conducted here combines several state-of-the-art approaches to assessing an economy's deforestation-risk exposure. In particular, we have provided a dataset which contains a detailed account of the trade and consumption of tropical and subtropical deforestation risk commodities. Methods development conducted for this study has included several significant advances to the capabilities of the Trase team's analytical tools including: a) new approaches to reconciling trade records; b) comprehensive development of re-export-adjustment steps covering the main FAO commodities and their derivatives, including the deconstruction of these supply chains; c) use of Trase bilateral trade data with re-export adjustments to model connections to subnational locations via re-exports. In the development of these advances, we played close attention to the feedback received in a stakeholder consultation process conducted for this project (see Annex 1 for summary).

There are, however, aspects of the work conducted that need to be considered and understood when interpreting the findings:

1. **Comparability across scales:** Deforestation metrics are compiled using approaches which vary depending on the scale of the analysis. Subnational data from Trase is also based on country-specific export reports and – while aligned – will not match precisely with international records. For these reasons, comparison of absolute deforestation risk across national and subnational records presented in this study is not advised.
2. **Comparability across perspectives:** While seeking to be complementary, there is not full alignment between the analysis conducted across all three direct trade, re-export-adjusted and consumption-based accounts. For example, in our direct trade analysis, to ensure alignment with the 'raw' datasets provided by Trase and FAO (which other analysts may be more directly familiar with), we utilise trade statistics based on export records of reporting countries. For our re-export and consumption-based analysis – because they rely on modelling steps which depart from raw statistics – we took the step of reconciling both export and import records to deal with data mismatches. Reconciled direct trade statistics would be possible to compute, but has not been conducted for this report. Likewise, the methodological differences explain why our results may differ from prior estimates of Germany's deforestation risk (Table 15); for example the calculation of re-export-adjusted analysis conducted for this study differ from those conducted in e.g. Pendrill et al (2019, 2022).

3. **Results do not provide traceability, nor measures of deforestation impact:** All the results presented here are based on techniques that required models or analytical assumptions. These are described in more detail in Annex 2, but include for example, the fact that assumptions need to be made about the mix of sources in a country's ongoing exports, and the fact that for national deforestation risk assessment it is necessary to rely on non-spatial attribution. The presence of 'unknown' sources in Trase supply chain maps, and 'unknown origin' within the national-scale re-export and consumption-based accounts, also means that deforestation risk for Germany (and other countries) may be underestimated in some cases. This appears particularly to be the case for palm kernel oil (see Figure 9). Specific assessment of deforestation risk is further complicated by the variety of indirect forms of land use change that might be linked to agricultural production. As a consequence, the data does not provide a traceability assessment and/or an assessment of the impact of the German supply chain, but rather risk assessment based on tried-and-tested techniques for linking production-to-consumption systems for international economies. Identification of traders or intermediary countries of sources of deforestation risk, does not imply that such stakeholders are directly implicated in deforestation activities; additional assessment would be needed to establish causal links.

Recommendations

We have the following recommendations for GIZ/BMZ and for the further development of deforestation risk analysis:

- **Germany should look to establish an ongoing and annual monitoring system for its deforestation-risk exposure, to track the change in deforestation risk over time.** This could involve direct trade, re-export-adjusted and consumption-based components depending on the determined uses for the information (which could, for example, include monitoring progress linked to current or forthcoming commitments and/or assessing the emergence of new commodities of risk). For this study, the deforestation data available for use is not fully aligned with the proposed use of the FAO Forest Resources Assessment definition of deforestation with incoming regulation on deforestation-free products (EC regulation proposal COM 2021/0366, EC 2021), but further work should be conducted to seek alignment going forward.
- **Results should be provided for discussion with relevant commodities roundtables such as FONAP and GISCO.** Such results may be a starting point for more detailed analysis to validate results and/or understand the extent to which individual supply chains of importance to Germany are linked to high-risk areas of production.
- **Results should also be discussed with stakeholders in regions of production, particularly as part of multi-partner dialogues.** Further analysis in high-risk regions may identify opportunities for investment to ensure deforestation-free supply both for Germany and across landscapes as a whole.

- **Germany should continue to work with other important regions of consumption on joint steps to reduce supply chain risk.** This includes the Amsterdam Declaration Partnership (ADP), of which several members are important re-export partners to Germany, and China as the major global consumer across several deforestation-risk commodities.
- **An assessment should be made of the role of commodities which are of lower absolute risk but still appear as important in Germany's indirect risk exposure.** These commodities include cassava, rice, cotton and others which are not actively considered under existing commodity discussions, but may be important drivers of regional deforestation.
- **Further methodological enhancements are likely to be valuable when conducting similar assessments in future and should be prioritised.** These include: a) further work to harmonise methods for re-export-adjustment and consumption-based accounting, and to conduct intercomparisons across methods; b) integration of Trase data into consumption-based accounting frameworks (see Annex 4); c) additional work to understand and resolve the presence of 'unknown' sources linked to opening and closing commodity stocks reported by FAO; particularly for palm kernel oil.

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Annex List

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Annex 1

Summary of consultation and implications for methods deployed in this report

Studies similar to this one are ongoing with other national governments that have also committed to monitoring commodity deforestation risk linked to their imports and/or consumption activities, as well as related initiatives being led by civil society organisations, research teams and private sector coalitions.

Therefore, a core consideration in this study has been alignment with other stakeholder groups, in order to contribute to a continual improvement in coherence between research activities and common understanding across different datasets and approaches that are being used; to facilitate comparability and coordinated actions.

For this reason, the first phase of the study focused on the development of a standard – but flexible – methodological framework for applying Trase data and associated methods used in the GIZ study and other use cases. GIZ and Trase have actively encouraged interested parties' involvement in informing the development of methods and a common understanding of their applications, including an open consultation with stakeholders on the implications that methodological choices have on their own use cases.

This Annex provides a summary of the implications of our consultation process for methods which have been deployed in this report, and for the longer term development of Trase and Trase-linked approaches. A more detailed technical report is available on request from Trase, and additional detail on the methods themselves is available in the main report and Annex 2. Below (in bold) we include the specific topics included within our external consultation process, followed by a summary of the conclusions drawn from consultation responses in terms of adjustments (if any) required to Trase methodological development.

1. Deforestation allocations, cut-off dates and thresholds applied within Trase methods

Together with Trase's supply chain mapping, Trase's commodity deforestation risk indicator estimates the exposure of an actor (company or country) to the risk of sourcing a specific commodity from an area recently deforested. The indicator captures, from the perspective of the focal commodity coverage, how much of this area overlaps with areas that have been recently deforested. It uses a number of parameters, which were included in the scope of the consultation:

i) Allocation period - which describes (considering the dynamics of the commodity) the period of time in which the deforestation was potentially motivated by the target commodity - e.g. five years for soy

ii) Lag period - to reflect the minimum time needed between a deforestation event and the first harvest of a crop or establishment of pastures for animal rearing - e.g. one year for annual crop commodities

The exact methods employed within Trase are context-specific.

Our conclusions on the implications for Trase of consultation responses, are by topic:

1.1 The allocation period over which deforestation can be associated with export activity.

- We will maintain flexibility on a per-context basis given that no clear consensus emerged on adopting alternative lengths from our external respondents. These will continue to be based on reasonable allocation periods associated with local land use and commodity-production dynamics.
- We will be adjusting the allocation periods for palm oil in an upcoming release (expected in 2022); acknowledging that the current implementation (which was limited at the time by data availability) is not satisfactory.

1.2. The application of any cut-off dates to deforestation associated with downstream companies or countries that are linked to deforestation.

- We will, as a priority, initiate discussions internally within Trase (and then seek external inputs as appropriate) for how cut-off dates should be incorporated into the Trase data, platform and/or associated outputs/resources. The importance of Trase's capacity to work to provide data which is compatible with the introduction of cut-off dates (set e.g. by incoming EU regulation), was a strong and recurring theme across many respondents/responses in the survey. Careful consideration is required as to how this will work alongside allocation periods. Discussions on this topic remain ongoing within Trase at the time of report publication.

1.3. Whether or not deforestation impacts associated with trade should be assessed on annual records or an average over an e.g. three or five year period - to reflect the fact that one 'snapshot' of risk might not reflect longer-term relationships.

- No firm consensus emerged on this point from our external engagement, and ultimately it is likely that this choice will be context dependent. A suggestion was made to combine annual assessments with considerations of trends, which is something that we will bear in mind in our risk assessments going forward, along with potential analyses which can assess the 'stickiness' of relationships over time. The final report aimed to adopt these recommendations, in that in the main report we provided timeseries information along with a more recent snapshot (typically summed commodity deforestation risk across the most recent three years of data availability).

- Ultimately, the most important aspect here is likely to be transparency around which periods have been adopted (and also the implications of the choice) so that results can be interpreted within these conditions. For this reason, we have provided a relatively exhaustive methodological description in the report and Annexes - along with a description of caveats and the implications of assumptions adopted - and would welcome anyone who seeks further information to email info@trase.earth.

1.4. How should Trase approach 'impact spreading', i.e. the annualisation of risk so that a deforestation event is not double-counted across multiple export years?

- We will continue to annualise Trase data given the clear consensus that this is a sensible approach. This report continues to use annualised data. For some use cases it may be useful to use non-annualised results to communicate the fact that e.g. a single year's exports might ultimately be linked to deforestation 'in sum'. Again, this will require careful and transparent communication to ensure comprehension.
- Given the support received overall from stakeholders, we will continue to explore if our allocation process can be improved (where data allows) to account for a problem of 'unallocated' deforestation (that can occur in cases where production does not take place in all years within an allocation period) that can arise in the existing implementation. These discussions have continued throughout the duration of this project and we expect changes to be made to the way in which Trase handles unallocated deforestation in future Trase releases.
- We will also explore whether providing a 'per jurisdiction' metric is possible which indicates commodity-linked deforestation before attribution to the supply chain takes place.

1.5. Is it useful to introduce any standard risk 'thresholds' on data provision, either from the perspective of a minimum threshold of production risk (i.e. does 0.1 ha/1000 tonnes mean anything?) or several thresholds to reflect high/medium/low risk sources.

- We will not - at this stage - pursue the adoption of a standard minimum risk threshold, given the mixed views expressed about this in our consultation. However, we committed to continue to scope out how thresholds may be applied. This discussion has continued throughout the project and we have been working in close collaboration with the Accountability Framework Initiative and Proforest to present proposals for a relative-risk threshold-based approach for prioritisation of high deforestation-risk areas. We expect external communication of these proposals within the next few months.

1.6. How should deforestation information be attributed to different crops which are produced in the same fields in rotation (e.g. soy/maize)? Should double-counting be avoided or embraced?

- Prior to this consultation process Trase took the view that allocating the same deforestation risk to soy and maize (i.e. double-counting) was the best mechanism to highlight the 'shared' responsibility of these crops to deforestation[1]. However, for applications which require commodities to be combined within an analysis (e.g. a 'total deforestation risk of consumption'), we would have to undertake an allocation. However, several stakeholders raised concerns about this, and a clear conclusion is that we should give some further consideration to the approach which Trase adopts based on these concerns. Ultimately, as for other areas, whichever approach is adopted will require careful and transparent communication to avoid data mis-use. These discussions have been taking place during the project, within the Trase team, particularly with regard to the treatment of maize deforestation risk for Brazil where data teams have been analysing the maize production data to ascertain the feasibility of allocations to maize within soy-maize cropping systems. These investigations are set to continue throughout 2022.

1. Note that at the time of writing, no deforestation is allocated to maize and therefore there is no double-counting associated with Trase' soy deforestation data at subnational scale. For the national scale results used in this study, different methods are utilised to assign deforestation to commodities, which also do not double-count risks.

1.7. How should Trase treat the provision of data between years when there has been an underpinning change in methods (e.g. due to data restrictions); should Trase present differences in data quality within releases via 'flags' that indicate different data matching methods?

- Methods are likely to continue to be updated over time, including in response to changes in the data landscape. We prioritise using the best available data on an ongoing basis, which means that our time-series data are likely to remain inconsistent between certain releases in their compilation. As for other items, methodological transparency is the most important step that we will take as a team to avoid misinterpretation of data.
- There was some interest in the introduction of data flags[2] into the dataset to allow users to assess the reliability of supply chain map components. We are aware that these data flags can be useful - and discussions have begun internally with respect to their presentation in the dataset - but we do not have near-term plans to introduce these into the dataset given priorities at the time related to data updates.

2. E.g. inclusion of metadata supporting data points which described levels of confidence in results.

2. Methods to adjust bilateral trade data to account for re-exports

Techniques to estimate re-export corrected data are now well established, and commonly based on methods developed by Kastner et al. (2011). These methods reassign export activities accordingly to estimate their true origin. However, subtle differences emerge depending on the precise implementation of these methods and the assumptions adopted.

i) The mix and availability of supply to meet demand - resolving re-exports depends on an assessment of this and requires decisions about how to handle situations where demand exceeds supply. The approach to re-exports taken by the Trase team includes constraining a re-export algorithm based on available supply to ensure a ‘balanced system’ (i.e. overall, no more is sourced from somewhere than is reportedly produced and/or imported there).

ii) Mismatches between international export and import records - choices must be made about which to use, or whether records should be combined to fill gaps/create a reconciled record, which may act as another point of difference between datasets using conceptually similar techniques.

Whilst most applications of re-export corrected trade flows to date have simply sought to determine the true origin of traded material, the Trase team has recently developed an approach that also disentangles the intermediate pathways allowing the estimation of the paths via which material might flow from origin to destination.

Our conclusions on the implications for Trase of consultation responses, are by topic:

2.1. Whether to constrain re-export adjustments by (e.g. FAO) production quantities.

- The methods developed for the study involved an extensive re-development of the methods used to handle the re-export phenomenon present in trade activities. Full details are available in the main report and Annex 2 but, in summary, entailed i) re-balancing steps across import and export records to reconcile mismatches; ii) new methods to link harvested and derived commodities together within a harmonised production and trade model; iii) new methods to incorporate information on closing and opening stocks now available from FAO. These methodological developments resulted in the introduction of a new category of trade flows within the results delivered in this study: that of trade of products of ‘unknown’ origin necessary to ensure supply meets reported demand. Essentially, here a decision was made to preserve trade information for the purposes of the re-export adjustment step at national level. This means the deforestation risk estimates will potentially be underestimated where ‘unknown origin’ flows are present. In contrast, for our Trase (subnational) re-export adjustment, Trase production and trade data are used as the constraint (i.e. are fixed) in the model. Further work would be beneficial to undertake sensitivity analysis of alternative parameterisations, and to undertake additional work to see if flows from unknown origin can be re-assigned to potential source regions (e.g. breaking down components of closing stocks by estimates of origin).

2.2. Whether to use FAO or UN ComTrade trade data (or both) in the preparation of statistics.

- We did not consult directly on this question with stakeholders but responses in other areas suggested a general openness to providing results using different data sources for comparative purposes. In this project, we continued to use FAO data in the preparation of results, but remain open to exploring other trade records in future for comparative purposes.

2.3 Whether to apply re-export estimates only on primary commodities, or also (where possible, e.g. for soy and palm oil) on derived products.

- The majority of respondents suggested that it would be useful for us to provide results using both approaches, to allow comparison. Originally, it was our intention within this project to apply an approach for derived commodities only for soy and palm oil. However, the methodological development conducted for the project substantially surpassed this expectation, and we were eventually able to comprehensively include derived commodities across the full FAO agricultural commodity profile in our assessments (see Annex 5 for a commodity list). Comparison between methods employing this advanced approach and simpler implementations would be beneficial in future work.

2.4. Whether to use import or export records (or a combination of both) to compile re-export statistics

- There was general support for utilising a combination of records, and therefore we sought to undertake this for the GIZ project reporting. Our eventual implementation at national scale included a step to reconcile trade records from export and import sources. There are some implications related to the differences between Trase and IOTA implementations, however, in that Trase is an ‘export-oriented’ dataset and therefore we needed to consider how consolidated import/export records would sit alongside Trase export records. For this study, a decision was made to use Trase as the ‘authoritative’ source of information when Trase subnational data was applied within re-export adjusted methods; whilst largely the same reconciliation process was applied as in national-scale results, the methods were tweaked so as to not adjust Trase-derived data within this process.

3. Consumption-accounting / IOTA choices

Even correcting bilateral trade data for re-exports still just provides a partial picture compared with total consumption activities.

The prevailing approach to consumption-based accounting is via multi-regional input-output (MRIO) modelling. MRIO models provide a complete monetary representation of global economic activity, allowing consumption activity (final demand) to be linked to production, via intermediate financial flows. However, they typically do so at the expense of resolution; activity (e.g. production and processing) is typically aggregated to (often) broad economic sectors, and geographic regions may also be highly aggregated.

Via the use of 'environmental extensions', MRIO approaches have the potential to provide a whole-economy (i.e. full breadth and depth) perspective of the effects of consumption and trade activity on the environment. However, results are typically most useful for understanding where potential hotspots of environmental risk or pressure might exist at a relatively coarse level and - for example - across multiple sectors of the global economy.

To overcome the sectoral-resolution limitations of traditional MRIOs (which is important when considering that deforestation is associated with specific commodities, e.g. soy and palm oil, and not broader sectors, e.g. oilseeds in general) the Trase team have been developing methods to hybridise MRIO models with re-export adjusted bilateral trade statistics (see Croft et al. 2018). This technique has the advantage of retaining product-specificity alongside a whole-economy / consumption-based perspective. The resulting 'Input Output Trade Analysis' (IOTA) framework has underpinned a number of studies and has been deployed for the development of a UK indicator for overseas commodity impact (Croft et al. 2021) as well as for this study.

Our conclusions on the implications for Trase of consultation responses, are by topic:

3.1. Should re-export statistics be applied only on primary commodities or also (where possible, e.g. for soy and palm oil) on derived products, before being joined to the MRIO dataset?

- See response to 2.4, above.

3.2. Which MRIO datasets should be utilised as 'standard' in the framework?

- There was no strong preference stated for either MRIO dataset suggested; from a technical perspective both GTAP and EXIOBASE have relative strengths and weaknesses. Many respondents felt there was some utility in having results derived from both datasets. For the purposes of this study, it was eventually decided to utilise the EXIOBASE dataset given the presence of more recent data (to allow results for up to 2018 to be included) and an annual timeseries useful for exploring trends. GTAP in contrast has a most recent year of 2014, and does not have an annual timestep. A brief comparison of data derived from GTAP for the year 2014 is included in Annex 4, although the ability to only contrast with a single year means the direct utility of these results for intercomparison are somewhat limited. Future work should focus on undertaking more extensive intercomparisons between the two MRIO datasets.

3.3. How to deal with other arising choices when integrating Trase data alongside national statistics; there are various decision points required when harmonising disparate datasets.

- There are a number of ongoing conversations relevant to the need to further ‘harmonise’ datasets and incorporate new or alternative data as it emerges. Key ongoing discussions are likely to include, for example: i) how to respond to deforestation definitions (and associated data) derived from the FAO Forest Resources Assessment which is likely to be adopted in EU legislation; ii) if, how and when to adapt/update work in other contexts (e.g. development of the UK’s experimental statistic on oversea impact) which is based on simpler methods than those developed in this GIZ/BMZ study; iii) how to further harmonise Trase analysis, e.g. potential applications of the trade data reconciliation steps to direct-trade assessments and/or harmonisation of Trase contexts to facilitate application within MRIO frameworks such as IOTA (see Annex 4). Further future external consultation by Trase may be considered where we feel this is useful to inform these ongoing investigations.

Annex 2

Additional methodological detail

As described in the main project report, three trade perspectives have been provided, across two scales (subnational and national) to assess Germany's commodity deforestation risk. The methods employed are quite technical, involving data selection, alignment and computational steps which are subject to a variety of assumptions. These assumptions are particularly necessary to deal with mismatches or misalignments in the reported statistics on which the methods depend. This annex, therefore, serves to provide a more detailed description of the methods employed in the provision of data for the main report, highlighting key assumptions and their potential implications for the interpretation of results, and referring to other resources in case readers are interested in further details. We have tried to lay out these methods as clearly as possible, but are aware of their highly technical nature which may require expert knowledge to interpret. For this reason, if you have any questions related to the methods employed, we would be happy to discuss details further. Please contact info@trase.earth for enquiries.

Trase

Supply chain mapping

Trase allows international trade activities associated with tropical deforestation to be explicitly linked to sub-national regions of production (identifying the trading actors involved in supply chains in the process) and associated environmental risks.

The methodological approaches undertaken to map supply chain connections are known by the name 'Spatially Explicit Information on Production to Consumption Systems (SEI-PCS), but the precise details of the methods vary according to the commodity and country of interest. However, all Trase methods broadly follow the same standardised approach to combine per shipment trade data, official tax records, and asset and infrastructure ownership information.

The methods used to compile Trase's supply chain maps are covered in detail in a specific methodology document for Trase, which can be found here: http://resources.trase.earth/documents/Trase_supply_chain_mapping_manual.pdf

The result is a spatially explicit commodity supply chain map linking a locality of production (e.g. municipality in Brazil, kabupaten in Indonesia etc.) to a country of destination. For many environmental concerns this spatially explicit information is very important because impacts can be highly spatially heterogeneous.

Trase is conceptually very similar to bilateral trade information provided by organisations such as FAO and UNComTrade. However it is unique in its subnational resolution and incorporation of supply chain actors within the mapped trade flows and because of its incorporation of deforestation and related indicators.

A key point, which is important for the interpretation of results presented in the associated report, is that the precise methods applied in Trase vary by context. Typically, subnational Trase contexts will be released in 'Version 1' format. Subsequent research and data analysis may result in a 'Version 2' context, or iterative improvements to Version 1. For the results presented, we rely on outputs from both Version 1 and Version 2 methods

SEI-PCS Version 1 relies heavily on modelling approaches, typically using transportation costs and optimization models to allocate export volumes to individual production regions.

If sufficient data are available, this can be replaced with SEI-PCS version 2. Version 2 uses a much more data-driven approach to link production regions, commodity logistic hubs and export facilities, providing very robust supply chain maps with high levels of accuracy and multiple weights of evidence from a variety of official sources.

The table below provides the version numbers for each context used in the main report. The first number indicates the Version type. The second number indicates the major revision (e.g. 0 = original version, 1 = first revision and so on; major revisions typically indicate methodological updates to improve the supply chain maps). The third number indicates minor revisions (e.g. fixes to data errors, adding additional years etc).

Trase context	Version number
Argentina soy	1.0.1
Brazil beef	2.0.1
Brazil soy	2.5.0
Indonesia palm oil	1.1.0
Paraguay beef	1.2.0
Paraguay soy	1.2.2

Deforestation data

Where sub-national production information is available, Trase employs spatially explicit analysis to link deforestation activities to commodity land use expansion, and further links this to the supply chain (at the same resolution as the supply chain data) in the form of a deforestation risk metric. Trase provides information which details commodity production and associated deforestation for a given location of production through to the port of export and country of first import. Trase's commodity deforestation risk indicator estimates, from the perspective of the focal commodity, the exposure of an actor (company or country) to the risk of sourcing a specific commodity from an area recently deforested.

The parameter used to decide which years of deforestation will be included in the commodity risk analysis is termed the "allocation period" which describes (considering the dynamics of the commodity) the period of time in which the deforestation was potentially motivated by the target commodity. This allocation period varies depending on the crop/commodity. For example, in South America, we use an allocation period of five years for soy.

In addition to an allocation period, we also define a 'lag' period to reflect the minimum time needed between a deforestation event and the first harvest of a crop. We typically use a lag period of one year for annual crop commodities.

For beef, the dynamics of land use change and production are different. Whilst for soy we use only one year of the commodity coverage overlapped with the five previous years of deforestation, for beef, we calculate the deforestation risk by accounting for five years of pasture grazing and the five previous years of deforestation for pasture creation. We do this because the animals in South America are generally fed on pasture for up to five years before being slaughtered. We do not include a lag period for beef production (reflecting the fact that animal rearing can take place soon after deforestation).

For palm oil, deforestation risk data is only available for 2015, and data constraints determined that only two years (2011, 2012) of deforestation data were available. Here, an average of the deforestation taking place in these two years is assigned to 2015 exports, effectively incorporating a 3-4 year lag between deforestation and attribution to palm oil. The Trase palm oil context is in the final stages of being updated for later years, with revised methods based on improved data, but the data for the year 2015 alone was available for the BMZ/GIZ report.

Figure 1 illustrates the application of allocation periods and lag periods in the case of South American soy exports. For soy produced in 2019, we look backward in time and link it to deforestation that occurred anytime between 2014 and 2018, inclusive. The one year lag period determines the gap between the last possible deforestation event (2018) and the soy harvested in 2019, i.e. no deforestation within a harvest year is associated with production in that same harvest year.

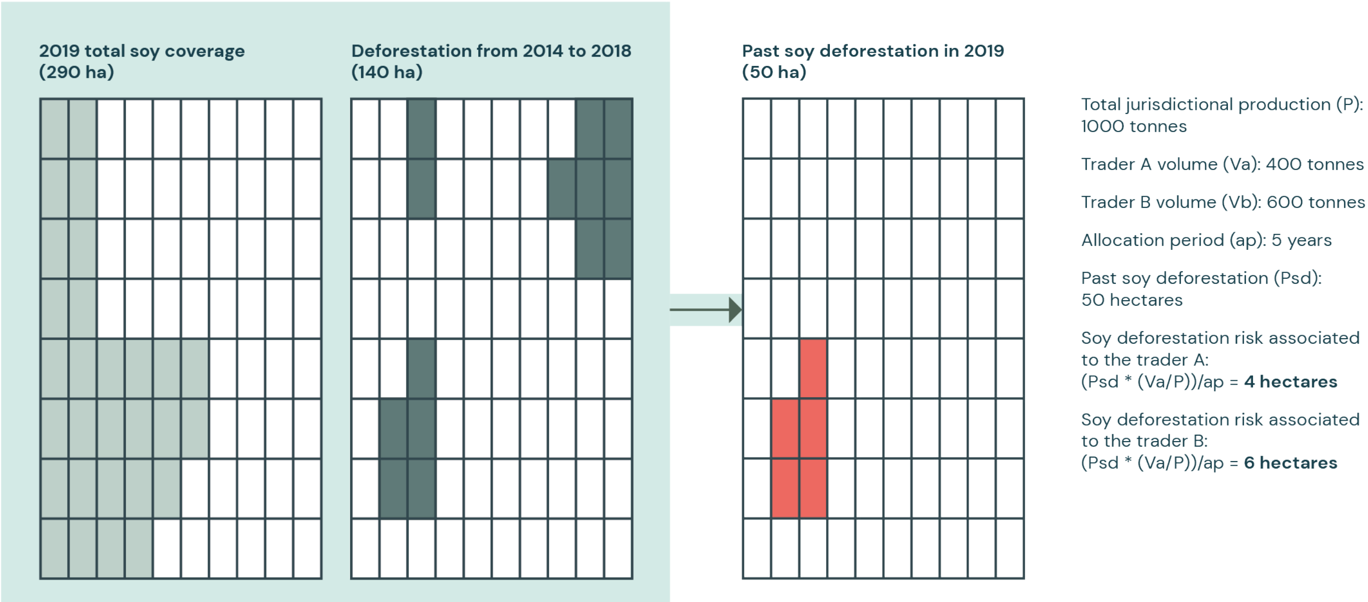

Figure 1. Representation of soy deforestation risk for 2019 commodity exports. First, deforestation is allocated to the commodity harvested and exported in 2019, if conversion of forest to commodity occurred in the preceding five-year allocation period (2014-2018 inclusive), considering a one year lag period between the closest possible year of detection of deforestation in 2018 and harvest of the commodity in 2019. Trase aggregates total deforestation at the jurisdictional level, before sharing it among actors in the supply chain of the 2019 exports. Each actor's share of this deforestation is directly proportional to that actor's share of total commodity exports. Because different years can have the same deforestation event included in the allocation period, the data are annualized by dividing by the allocation period to avoid double counting in the time series.

The adoption of an allocation period means that Trase does not assign all historical deforestation in a given area of land to commodities being produced on that land today. Rather, the indicators on the Trase platform are focused on recent deforestation (i.e. they assess the volume of the commodity that is associated with areas recently deforested), which indicates the role of the commodity, and subsequently the actors trading a given commodity, in the territorial deforestation occurring in recent history. We reason that this deforestation is a direct responsibility of the commodity's buyers, who demonstrably benefit from the clearance of land that enabled the supply of the product of interest. Adopting different allocation periods will affect the amount of deforestation being associated with the supply chain. It is difficult to predict exactly how longer or shorter allocations affect the deforestation risk without sensitivity analysis, as historical rates of deforestation and the crops grown in areas previously forested are dynamic over time.

Adoption of multi-year allocation periods means that consideration must be made as to how to deal with the association of deforestation to production and exports occurring over several years. For example, a deforestation event occurring in 2014 may be associated with soy production and export in 2019 (see Figure 1), but - due to the five year allocation period - also to soy exported in 2018, 2017, 2016 and 2015. Summing the same deforestation allocated to soy exports from a single parcel of land across multiple years would return a larger area than that initially deforested (five times larger in this example). If the objective is to compare changes in deforestation risk associated with soy exports over time (as done in the report), then it makes more sense to spread the initial deforestation event over the full allocation period (and therefore avoid double counting of deforestation across export years). To account for this, Trase annualises the deforestation risk for each year and each region by dividing the total deforestation by the allocation period (in other words, five years in the case of soy in South America). Trase aggregates total deforestation at the jurisdictional level, before sharing it among actors in the supply chain of exports. Each actor's share of this deforestation is directly proportional to that actor's share of total commodity exports from that jurisdiction (see Figure 1).

Full details of the allocation periods, lags and other methods used to allocate deforestation to the supply chain are contained in more detailed methodological information on the Trase website: https://schema-cms-api-pages127dfd1a-1100pd61xro1g.s3.amazonaws.com/280/blocks/1043/Trase_deforestation_risk_procedure_June2021.pdf

Pendrill et al. (2022) deforestation methods

The Pendrill et al. (2022) dataset (https://zenodo.org/record/5886600) is a well-recognised, peer-reviewed source of information on agriculture-attributed tropical and subtropical deforestation (and associated net CO2 emissions). It provides a time-series between 2005 and 2018, inclusive, with individual crop-commodity (plus beef and timber) production. Data from Pendrill et al. (2022) is freely available both in terms of attribution data (which can be linked to trade data by any user) and in terms of 'trade-linked' data which has been run through a re-export adjusted bilateral trade model (see Figure 2). The Pendrill et al. (2022) dataset provides estimates of tropical and subtropical deforestation embedded in supply chains, via the utilization of bilateral trade data which has been adjusted to account for re-export activities.

However, it is important to note that the trade methods adopted in the results available in the Pendrill et al. (2022) dataset differ in their detail from the methods employed in the results compiled for the BMZ/GIZ study. See the main report for further discussion on this, and below for further details on our treatment of the Pendrill et al. (2022) deforestation data.

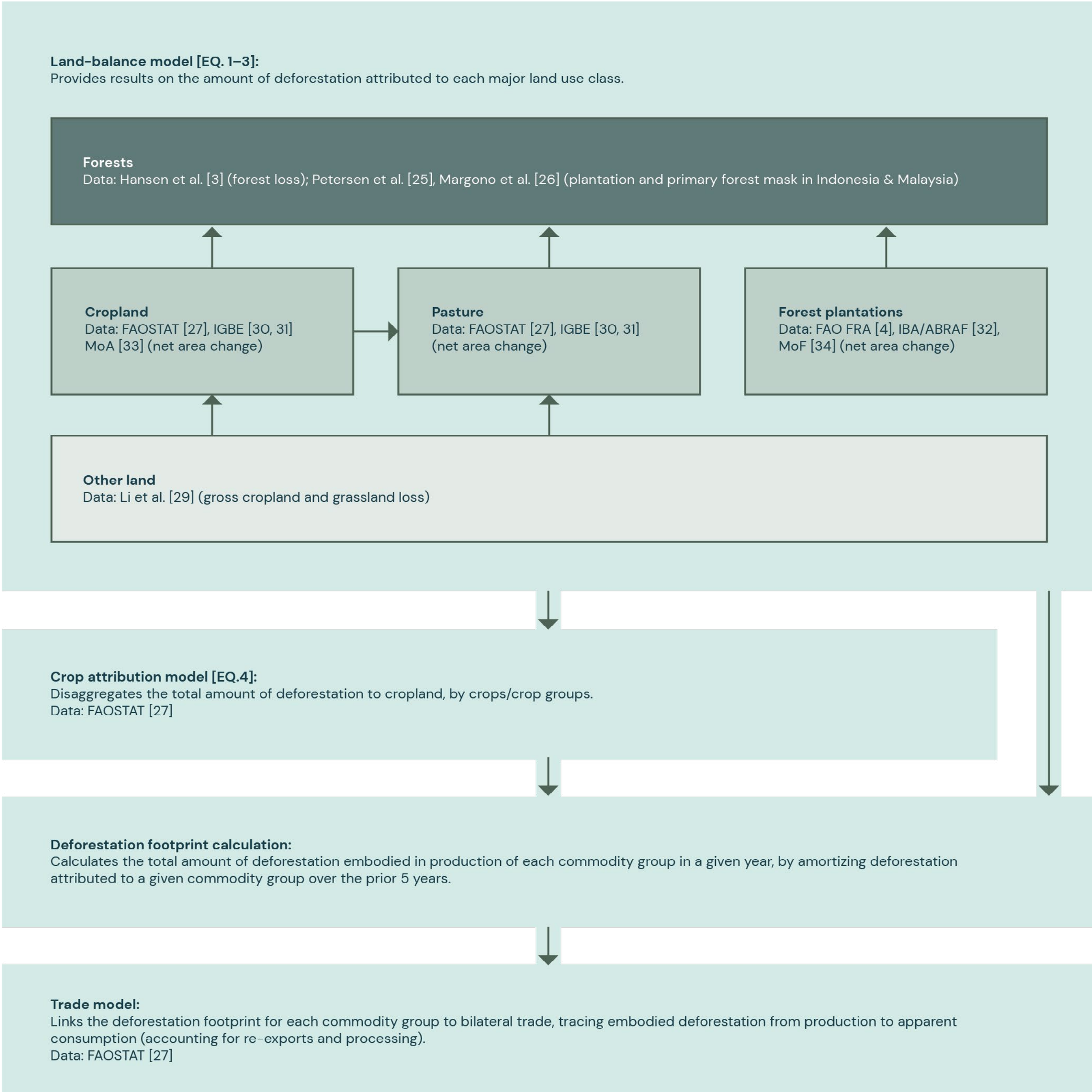

Figure 2. Reproduced figure from Pendrill et al. 2019 describing the methods sources for the linkage of bilateral trade data (bottom box; from FAOStat trade information) to deforestation activity. Crop-specific attribution is possible due to the granular information provided by bilateral trade statistics.

To generate the Pendrill et al. (2022) dataset, observed forest loss, from remote sensing data from the Global Land Analysis and Discovery (GLAD) lab in the University of Maryland (see Hansen et al. 2013 - at 30m resolution, with a threshold of 25% canopy cover used to define forest, and complete loss per pixel defined as ‘forest loss’), is attributed to agricultural and timber commodities using a simple land-balance model implemented at national scale (for Brazil and Indonesia, implementation is at sub-national level, but results remain nationally aggregated in the dataset).

In this land-balance model, cropland expansion, from FAOStat, takes place first into pastures (in cases where there is gross pasture loss), and then into forests (where there is gross forest loss), an assumption which is deemed to robustly reflect typical tropical landscape dynamics. In essence, forest loss is attributed across expanding cropland, pasture and managed forest plantations based on their area increase, but capped at total estimated forest loss in the focal region.

Forest loss attributed to forest plantations is attributed to 'wood products (forest plantations)'. Forest loss attributed to cropland expansion is further attributed to individual crops or crop groups in proportion to their relative expansion in the harvested area (also from FAO, except Brazil and Indonesia which use nationally-specific statistics). Forest loss attributed to pasture is linked to cattle grazing for meat (and, to a lesser extent, leather production)[3]. Note that, whilst data on forest loss is spatially specific (as it is derived from remote sensing), attribution to individual crops/crop groups is conducted non-spatially based on overall planted areas and not the physical location/expansion of specific crops (data on which is not globally available at this stage).

3. They do this according to a 95%, 5% distribution for meat and leather respectively, but this is easily adjusted when attributing to trade statistics. We use alternative allocations in our trade analysis – see details below.

Key points of difference in contrast to the Trase approach to linking deforestation to agricultural production (see above) are therefore the national (as opposed to subnational) scale of analysis and a lack of spatially-explicit linkage to crop distributions. A further contrast to the Trase deforestation data relates to the time lag and attribution steps adopted in Pendrill et al. (2022). approach. Because of observed time lags between deforestation and agricultural production, the authors choose to average changes in the area of cropland, pastures and crop groups over a period of three years following forest loss. Furthermore, to reflect the fact that the productive use of land for commodity production occurs for several years after forest conversion, the deforestation attributed to a given land use is spread equally over production from that land in the five years following the deforestation event. In other words, whilst both Trase and Pendrill et al. (2022) account for allocation periods and timelags in their approaches, they do so with different assumptions.

The Pendrill et al. (2022) dataset provides deforestation risk statistics per FAO primary commodity (e.g. crop). This can be used alongside production and trade information, also from FAO, to attribute tropical and subtropical deforestation risk to the supply chains of important commodities.

For complete methodological details, please refer to the peer-reviewed publication underpinning the data, available here: https://iopscience.iop.org/article/10.1088/1748-9326/ab0d41. Specific changes in methodology linked to recent data revisions are available as metadata in the results files themselves: https://zenodo.org/record/5886600

National scale direct exports

Deforestation intensities

For our global scale, national-level direct trade analysis[4], we first divided the deforestation statistics from Pendrill et al. (2022) (described above) for each producer country, year (2005-2018) and commodity by FAOSTAT production quantities (downloaded on the 24th January 2022), to calculate the deforestation intensity (ha per tonne) associated with each producer country, commodity and year combination.

4. Note that our direct-export data at subnational level was sourced directly from the Trase platform (see above)

Due to differences in the classification of cattle and leather products in the Pendrill et al. (2022) deforestation data and FAO production data, cattle and leather data were combined into a single "cattle products" category in both datasets to calculate the deforestation intensity. The production of buffalo products was also included in this calculation because the Pendrill et al. (2022) data combine cattle and buffalo into a single category, and so this was needed to avoid overestimating the deforestation intensity. Although we didn't consider the trade or consumption of buffalo products (see Annex 5 for details of commodity coverage), there was no trade of buffalo products to Germany between 2005 and 2018 according to FAO data.

Trade data, commodity equivalence factors and deforestation risk calculation

The Pendrill et al. (2022) deforestation data, and therefore the deforestation intensities calculated here, only cover primary (harvested) commodities, but many deforestation-risk commodities are traded in 'derived' forms, such as soybean cake and oil. In order to link the trade of these derived forms back to the primary commodity deforestation intensities, we used commodity equivalence factors to estimate the traded mass in primary commodity equivalents.

Primary commodity equivalence factors were calculated using the inverse of the sum of the relevant Technical Conversion Factors provided in the FAO Commodity Trees for a given processing step. This accounts for the loss of primary commodity in processing steps as waste or the concentration of raw commodity in more processed forms, but avoids double counting the primary commodity where processing steps result in multiple traded commodities. For example, when oil palm fruit is processed, on average 75% of the mass of the original fruit is lost, while 19% is retained as palm oil and 6% is retained as palm kernels, resulting in an equivalence factor of 4 (i.e. 1 / 0.25). In other words, to produce one tonne of palm oil and palm kernels (split in their appropriate ratios), four tonnes of oil palm fruit must have been processed. In the case of soy cake and oil, the primary commodity equivalents are almost identical to the mass of these more processed forms (the equivalence factor is 1.03), since the whole soy bean is used with very little waste. These equivalence factors were calculated for as many products as possible, up to second-tier derived commodities, where FAO trade data and conversion factors were available, and excluding products that are mixed with other ingredients. A full list of the primary and derived commodities utilised in this study and their equivalence factors is provided in Annex 5.

The deforestation intensities and primary commodity equivalence factors were then combined with FAO trade data from the FAOSTAT Detailed Trade Matrix, as follows: Trade records were downloaded and filtered to retain any products with a reported 'Export quantity' from any 'Reporter countries' to Germany (the selected 'Partner country') between 2005 and 2018. Commodities that we were unable to include because we could not link back to primary commodities in the Pendrill data via equivalence factors (see Annex 5 for detail of commodity coverage) were then removed. The trade quantities of the remaining commodities were then expressed in primary commodity equivalents by multiplying the trade quantity by the relevant equivalence factor. Finally, to calculate the deforestation risk associated with each trade record, these trade quantities (expressed as primary commodity equivalents) were multiplied by the deforestation intensity corresponding to that trade record's source country, commodity type and year. We make the assumption that exports are entirely composed of domestic production, and similarly, that derived commodities like soybean cake are entirely produced from domestically sourced soybeans. In reality, some domestic supply is likely to have been imported; this is addressed by our re-export adjusted methods described below, but for direct-export deforestation risk estimates this limiting assumption for our direct-trade analysis should be borne in mind where countries are known to be important processors of material imported from elsewhere.

Re-exports and associated reconciliation steps

Overview

Bilateral trade information (i.e. customs-based data on exports and imports) covers trade activity between points of export and import. The Trase supply chain data are of this type, i.e. they detail trade from point of export to point of first import. Equally, the Pendrill et al. (2022) deforestation attribution data described above can be readily linked to bilateral trade data provided by FAO.

A challenge with bilateral trade data is that they do not systematically account for 're-export' behaviour which means the origin of material is sometimes masked (e.g. Germany might report imports of soy from the Netherlands, despite the fact that the Netherlands is not a soy producer; this stage of trade originated in the Netherlands, but the commodity's origin is elsewhere).

Techniques to estimate re-export corrected data are now well established, and are commonly based on methods first introduced by Kastner et al. (2011). These methods reassign export activities accordingly to estimate their true origin. However, subtle differences emerge depending on the precise implementation of these methods and the assumptions adopted. For example, resolving for re-exports is dependent on the mix and availability of supply to meet demand, and decisions are required about how to handle situations where demand exceeds reported supply; the approach to re-exports taken by the Trase team includes establishing total supply and demand for each country, and supplementing any shortfalls with an additional supply to ensure a 'balanced system' (i.e. overall, each country has has the appropriate supply necessary to meet its export and domestic utilisation requirements). Additionally, given mismatches between

Re-export methods applied in this study

Within the analysis conducted for this project, the re-export results go beyond simply adjusting the trade results to account for re-exports implicit within the raw trade data.

The first methodological step is constructing full (to the extent data are available within the FAO database) commodity trees for the commodities to be included. This means not just making linkages between primary commodities and their derived forms (including equivalence factors), but also understanding the different processing stages and branches that determine the linkages between production of derived commodities in different places, and the material requirements to enable this.

FAO provides its trade information from two points of view; export records to destination countries provided by exporting countries as 'reporters', or import records from origin countries provided by importing countries as reporters. These records frequently do not match, however, and our consultation process (see Annex 1) indicated a preference from stakeholders to develop methods to overcome this problem. In this study, import and export data are therefore not drawn straight from the raw trade data provided by FAO. Rather than adopting a single set of trade records (i.e. utilising export records or import records), a reconciliation approach is adopted (Shaar 2019) which assigns a reliability to each country's reports based on the consistency (or otherwise) of its trade reporting with that of its partners. Where reported trade between two countries differs between reporting perspectives (i.e. if the exporter reports a different quantity of trade than the importer), the relative reliability index of each country's import and export reporting is used to choose the reported trade value from what is deemed the more reliable reporter. This approach accounts for absent reporters (i.e. countries that do not report any trade data), as well as attempting to correct bad reporting by unreliable actors.

The commodity tree structure and reconciled trade data described above enable the calculation of material requirements to meet reported demand, and accordingly (in the event of any outstanding imbalances) any balancing required to the datasets. Demand consists of export requirements, utilisation for food, feed and seed, as well as processing into derived commodities. It is this latter component of demand (processing) where the commodity tree structure is critically important, as the production of derived commodities can be used to understand, and link to, the requirements for raw commodities to be processed. There may also be requirements for carrying over stocks of commodities at the end of a year in the form of closing stocks. These closing stocks at the end of one year then become supply in the following year, along with domestic production and imports.

Ultimately, for the whole system to function correctly, it is the net balance of these sources of supply and demand that requires adjusting within the approaches taken to correct for re-export pathways across different commodity flows. If there is a surplus of supply in a country, this can just remain within this country for modelling purposes; if there is a deficit (i.e. demand for a country's stocks exceeds its supply), an additional component of supply assigned to “unknown” origin is added. For this reason, in the results provided in this study, in some instances we record the presence of ‘unknown’ sources of commodities in the results for Germany which are required to meet recorded trade demands. Without origin information, these cannot be associated with deforestation estimates, but this means that in some cases reported commodity deforestation risk is likely to be underestimated in our results.

With import-export mismatches in the FAO trade data reconciled, supply and demand for harvested and derived products quantified, and any required balancing addressed, these intermediate datasets can then be run through the re-export methods as described in Kastner et al. (2011) to account for re-export pathways within the reported trade activities. This returns a list of resolved origin-to-destination flows. A proportion of the flows from each origin are converted to “unknown” in line with any balancing that was required (e.g. if 10% of a country’s supply is assigned to unknown origin, then 10% of any supply sourced from this country is accordingly assigned as unknown). Likewise, domestic supply (from domestic production or imports) that is required for closing stocks or processing is removed from the resolved results and ring-fenced for the following year or converted into derived commodities, respectively. In the case of derived commodities, the re-export process is repeated from points of production, via the reconciled trade data, to points of destination. An additional step is then taken to link the origin of derived commodities (i.e. the point of processing of the parent commodity) back to the origin of the primary commodity. Finally, the resolved flows of derived commodities (from point of production of the corresponding primary commodity) are then converted back into raw primary equivalents.

The outcome of the process described above is a fully consistent representation of production, trade and utilisation, where all values are conserved. The approach comprehensively captures processing and movement stages of the trade system, linking points of final use and/or consumption back to the origin of the primary commodity.

There are, however, some key assumptions and limitations with this implementation that are important to understand in order to correctly interpret and utilise the corresponding results.

Firstly, the core component of the process, namely the adjustment of trade data to account for re-export activities, is based around a core assumption of proportionality associated with the make-up of a country’s trade; i.e. it is assumed that what a country exports in any given trade activity is comprised of the same proportions as its various forms of supply (be it domestic production, imports from other countries or sourcing from opening stocks). This means the exports from a given country to all other countries have the same make-up of origin. In reality, this ‘mass-balance’ approach will not reflect the true nature of re-export activity; many of these re-exports flows will likely be taking commodities from specific areas of origin and exporting them to specific areas of destination. However, in the absence of traceability data for commodities going into and out of countries, this broad assumption is the most sensible one to make, and a mass balance approach as adopted mitigates the need for more complicated, and unjustified, assumptions.

Another key assumption is in relation to closing and opening stocks, as well as any additional balancing, where there are a few important factors to consider in both the source data utilised and the implementation described above. Whilst countries do commonly utilise closing and opening stocks (especially around seasonal commodities), the data on this (from FAOSTAT) is often not compiled from explicitly reported data, but rather is a combination of imputed estimates and requirements to balance supply records. In some instances, it is known via anecdotal evidence that these “opening stocks” can also be capturing not inconsiderable volumes of illegal or unreported trade. Values provided by FAO, therefore, do not simply reflect carried over stock from the previous year, but rather are a statistical tool to allow the different components of reported data to match up (i.e. supply = demand). The additional balancing stages required within our methods (see above) then reflect the fact that some of the reported data is still (despite the presence of closing and opening stocks reported by FAO) inconsistent (i.e. in terms of quantities required for processing to produce reported levels of production of derived commodities), and also the fact that reconciled trade statistics can differ from in-country reported trade data. Whilst in some cases it would be possible to estimate the make-up (in terms of domestic production and imports from other countries) of closing, and thus opening, stocks, an “unknown” assignment would still likely be required for considerable portions of certain key commodities in important producing countries. Attempts to estimate the origin of opening stocks is a priority for the ongoing development of our methods, but in order to avoid the need for additional assumptions and computational complexity within this study, it was decided to assign all balanced opening stocks to an “unknown” origin.

The decision to retain flows of ‘unknown’ origin in our study does not affect the results in terms of total material requirements or trade, but does prohibit the assignment of the location of origin to these flows, and accordingly the risk assessment (i.e. deforestation) associated with this sourcing. The motivation for this is that all production, trade and utilisation is captured, but since some of the production is not being assigned to a producing country, it follows that deforestation data associated with its production can also not be assigned. This also means that, from a production perspective, some of the flows lose their visibility downstream; whilst the produced and traded volumes are still preserved, this break in the connections between origin and destination results in a loss of the associated deforestation risk within the system. This does not affect the results with known origin in terms of risk intensities and corresponding risk estimates, but does mean there is a scope to underestimate risks where significant sourcing is classified as unknown.

Another effect of this decision is that flows into a country, e.g. Germany, which are assigned to closing stocks and thus carried over into the following year, are removed from the sourcing and risks associated with the year of procurement and moved into the following year stripped of their origin and risk data. Again, this leads to a possible underestimation of associated risks.

Decomposition of re-export adjusted results

Whilst most applications of re-export corrected trade flows to date have simply sought to determine the true origin of traded material, the Trase team has recently developed an approach that also disentangles the intermediate pathways allowing the estimation of the paths via which material might flow from origin to destination.

Whilst this does not affect our results in terms of e.g. the origin of resolved flows and associated risks, it is important to understand the potential routes via which commodities and risk are indirectly imported into a country, and similarly to understand the role of a country as an intermediate trade partner. The former allows hotspotting of critical trade partners as potential proxy suppliers of embedded risk within imported commodities, whilst the latter bridges the gap between direct-import and re-export corrected perspectives and is critical for understanding roles within the supply chain that fall outside of the conventional origin/destination nodes.

This method utilises the properties of mathematical constructs present within conventional input-output modelling methods (which themselves form the foundation of the core re-export adjustment methods used in this analysis). These properties allow the linkages at different stages of the supply chain to be disentangled, and specified pathways to be extracted. If this process is performed over all permutations of interest (i.e. any permutations involving a specified number of supply chain steps and a given focal country), the results comprise a comprehensive list of associated trade pathways and corresponding trade volumes within this scope. Whilst this builds on established MRIO methods, their use in application to re-export adjusted trade data is a novel development for this study.

Consumption based accounting and IOTA

Overview

Consumption-based accounting, as the name suggests, is primarily interested in a consumption-based perspective rather than a production-based one, and so estimating the flows of goods and services for, and critically to, final consumption is essential in accurately trying to capture consumption driven impacts and dependencies.

Whilst correcting for re-exports in bilateral trade data improves the accuracy of origin-to-destination flows by accounting for intermediate trade, and in doing so has the potential to provide information on multi-step pathways, it is still only mapping the supply chain from origin to final point of import in primary, and sometimes immediately derived, product forms. This information can be highly useful (see Trase, for example), and the re-export adjustment is important for understanding the roles of countries such as the Netherlands in global supply chains. However, if an interest lies in understanding the impacts of one or more countries' total consumption activities (i.e. the goods and services consumed by households and governments, or for infrastructure), these types of data are often still a distance away from providing such information. The extent of this "distance" depends highly on the type of commodity, the countries in question, and the degree to which physical processing and further trade steps are taken into account in re-export linked methods, but it is easy to consider that consumption profiles of a widely used commodity such as oil palm could differ drastically from the trade patterns of the primary commodity and/or its direct derivatives.

The prevailing approach to consumption-based accounting is via the application of multi-regional input-output (MRIO) modelling. This approach is now well established in both academic and national statistical contexts, particularly for the purposes of carbon and material footprinting. Multi-regional input-output models provide a complete monetary representation of global economic activity, allowing consumption activity (final demand) to be linked to production, via intermediate financial flows. However, they typically do so at the expense of resolution; activity (e.g. production and processing) is typically aggregated to (often) broad economic sectors, and geographic regions may also be highly aggregated. There are various MRIO models available for use, with common choices including EXIOBASE and GTAP, which differ in their sectoral and geographic classifications and aggregations. The main advantage of MRIO approaches is that they have the potential to provide a 'whole economy' (i.e. full breadth and depth) perspective, via the use of 'environmental extensions', of the effects of consumption and trade activity on the environment. Results are typically most useful for understanding where potential hotspots of environmental risk or pressure might exist at a relatively coarse level and - for example - across multiple sectors of the global economy.

In order to overcome the sectoral-resolution limitations of traditional MRIOs (which is important when considering that deforestation is associated with specific commodities, e.g. soy and palm oil, and not broader sectors, e.g. oilseeds in general) the Trase team have been developing methods to hybridise MRIO models with re-export adjusted bilateral trade statistics (see Croft et al. 2018). This technique has the advantage of retaining product-specificity alongside a whole-economy/consumption-based perspective. The resulting 'Input Output Trade Analysis' (IOTA) framework has underpinned a number of studies, and is the consumption-based approach used in the report for BMZ/GIZ, and in the development of a UK indicator for overseas commodity impact (Croft et al. 2021). Below, a description is provided of the implementation of the IOTA framework in the BMZ/GIZ study.

IOTA framework methods applied for BMZ/GIZ report

The implementation of IOTA in this work takes the outcome of the processed re-export corrected trade flows (see above) as a direct input. These flows detail the linkages between production, via (often) multiple trade and processing stages, and the point of import of the primary and/or derived forms. The MRIO component (primarily in this work the EXIOBASE MRIO, but also the GTAP database is used as a comparator, see Annex 5) is then utilised to complete estimates of the structure of the supply chain. It is important to understand that financial expenditure is being used as a proxy for material purchases/dependencies; there are no explicit downstream data on the sale, purchase and utilisation of individual commodities within monetary MRIO structures.

Standard MRIO methods (Miller & Blair 2009) allow for calculations on the direct up- and down-stream relationships to estimate entire linkages and dependencies across the whole economy, i.e. in order for a sector to produce a unit of output, what activities much take place across the rest of the economy in order to facilitate this. When combined with final demand (expenditure) across the different sectors, in turn this can provide an estimate of global activity required for, and thus driven by, these purchases. An important point here is that this means that MRIO methods (or methods based on MRIO such as IOTA) account for all uses of material in supply chains, whether or not they are consumed directly in consumption activities. Use of materials in animal feed not constituting part of the final meat product is one example, as is - for example - the machinery used in the production of agricultural products. The consumption of materials can therefore be considered as a 'driver' of material use across and along supply chains.

Within IOTA, the financial MRIO data are hybridised with the production and trade data (from the re-export adjustment steps summarise above) to convert this from financial dependencies to material dependencies, and - via environmental extensions - the environmental risks associated with these materials. This hybridisation is executed by taking the processed trade data, and thus the quantities of different materials imported to each country, and replacing economic outputs within the MRIO with the material utilisation, all the while retaining the modelled connections to points of production.

In order to convert country level supply (i.e. the data outputs of the re-export adjustment steps) to sector level utilisations, the relative expenditure by in-country sectors on upstream "parent" sectors of the commodities in question are utilised within the IOTA framework. That is, if Country A exports a given quantity of a commodity to Country B, the commodity utilisation is distributed across Country B's economic sectors in proportion to these sectors' relative expenditure on the associated producing sector within Country A. From this point on, the sales and purchases between sectors within the MRIO can be converted into material flows (or, more specifically, material dependencies; see below), completing the supply chains from sectors in countries of import through to final purchases of goods and services (aka final demand). This hybridisation, and specifically the mapping of the physical flow data onto the financial MRIO framework, depends on concordance maps between both the different geographic classifications within the different datasets, but also the individual commodities and the associated sectors within the MRIO.

Each commodity form (i.e. each primary commodity and also each derived form explicitly captured within the production and trade data), goes through an individual hybridisation step, and thus each commodity has its own unique hybridised physical-financial MRIO representation of its supply chain. These are handled individually throughout the modelling process, and then recombined to provide primary-equivalent results. For example for soybean, the production and trade of raw soy - with any soy used for processing into soy oil and soy cake removed - is run through the system separately to soy oil and cake, which are each run independently whilst maintaining all of the linkages to primary production (and constraints in terms of material availability). Results are then combined to produce the complete supply chain estimates for the focal commodity (in this case soy).

Annex 3

Results for GTAP implementation within IOTA

All-commodity results

As part of this project, the project team took the step of using the GTAP MRIO model in the implementation of IOTA, in addition to the EXIOBASE model used in the main report. This implementation is only available for the year 2014, as this is the only year provided by GTAP aligned with the timeseries available for the version of IOTA used in this study. Key differences between EXIOBASE and GTAP include sectoral (EXIOBASE higher overall) and geographic (GTAP higher) resolution. The results summarised below indicate some substantial changes in the relative importance of certain commodities to Germany's consumption-based deforestation-risk, reflecting the different ways in which global economies and trade are represented within the MRIO datasets. It was outside of the scope of the project to conduct thorough intercomparison of results, or investigation of the drivers behind differences, but results are provided to highlight the fact that MRIO model choice is an important consideration when conducting consumption-based risk assessment, with potentially important implications for overall conclusions. Additional intercomparison work is therefore recommended going forward. The absence of timeseries information, and data more recent than 2014, made GTAP unsuitable for use in the main report, and intercomparison across a longer timeseries would be highly desirable to check how consistently differences between the two datasets are represented.

The GTAP implementation of IOTA, available for the year 2014, produces some differences to the EXIOBASE implementation used in the main report. The total deforestation risk associated with German consumption increases by 21%, from 47,800 ha to 57,600 ha (Figure 1). This is due to an increase in the risk associated with cassava (up 120%), maize (up 206%) and soy products (up 28.7%), and occurs despite a significant fall in the deforestation risk associated with oil palm products (down 49.9%). Notably, when IOTA is implemented using GTAP, cassava and maize overtake oil palm products in their importance to Germany's risk exposure.

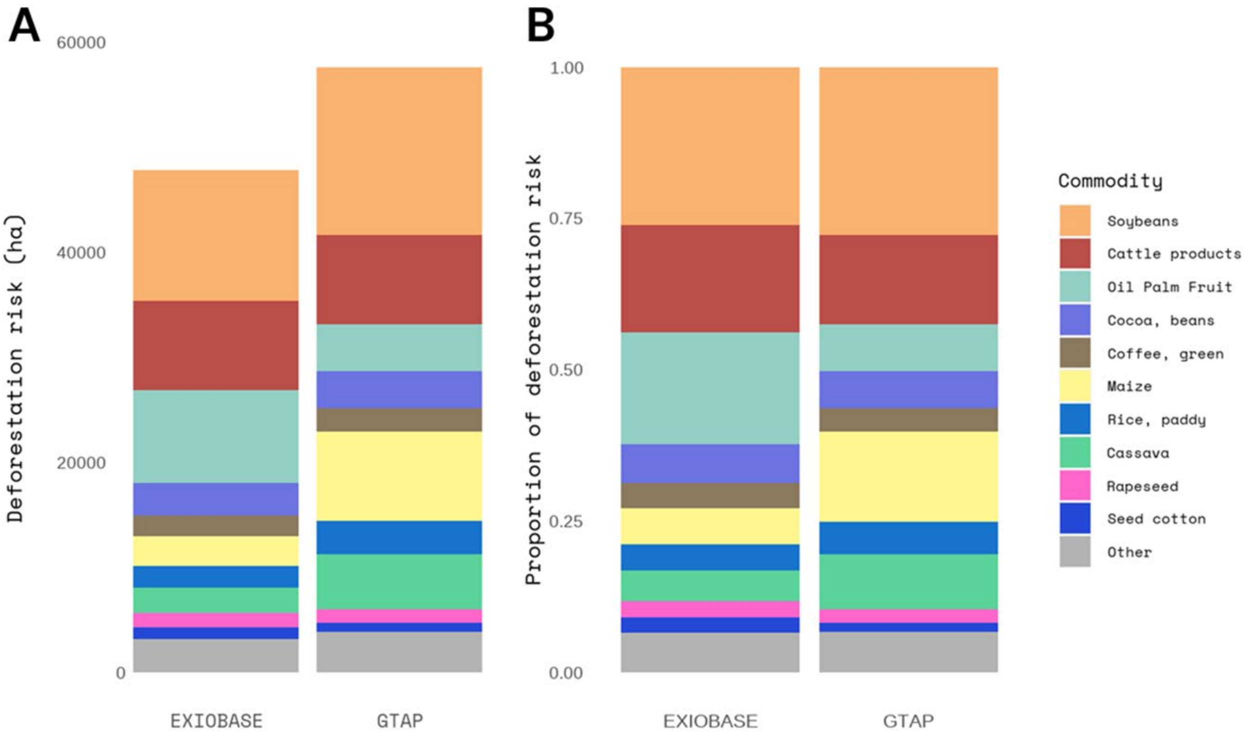

Figure 1. Comparison of the deforestation risk (A) and proportion of deforestation risk (B) associated with key commodities using both the EXIOBASE and GTAP implementations of IOTA. Data are for the year 2014, the only year available for both models. The ten commodities shown are the top 10 in terms of deforestation risk across both approaches.

The national-level distribution of risk (Figure 2 & 3) is similar for both MRIO implementations; Brazil remains the key source of risk with both EXIOBASE and GTAP, although the risk from Brazil is much larger with GTAP (21,854 ha, compared with 12,033 ha). There are some other notable differences, with the risk associated with Indonesia reduced by 54.3% with GTAP (largely due to the decrease in risk linked to palm oil), but the risk associated with DRC and Colombia increased by 125% and 28.8% respectively.

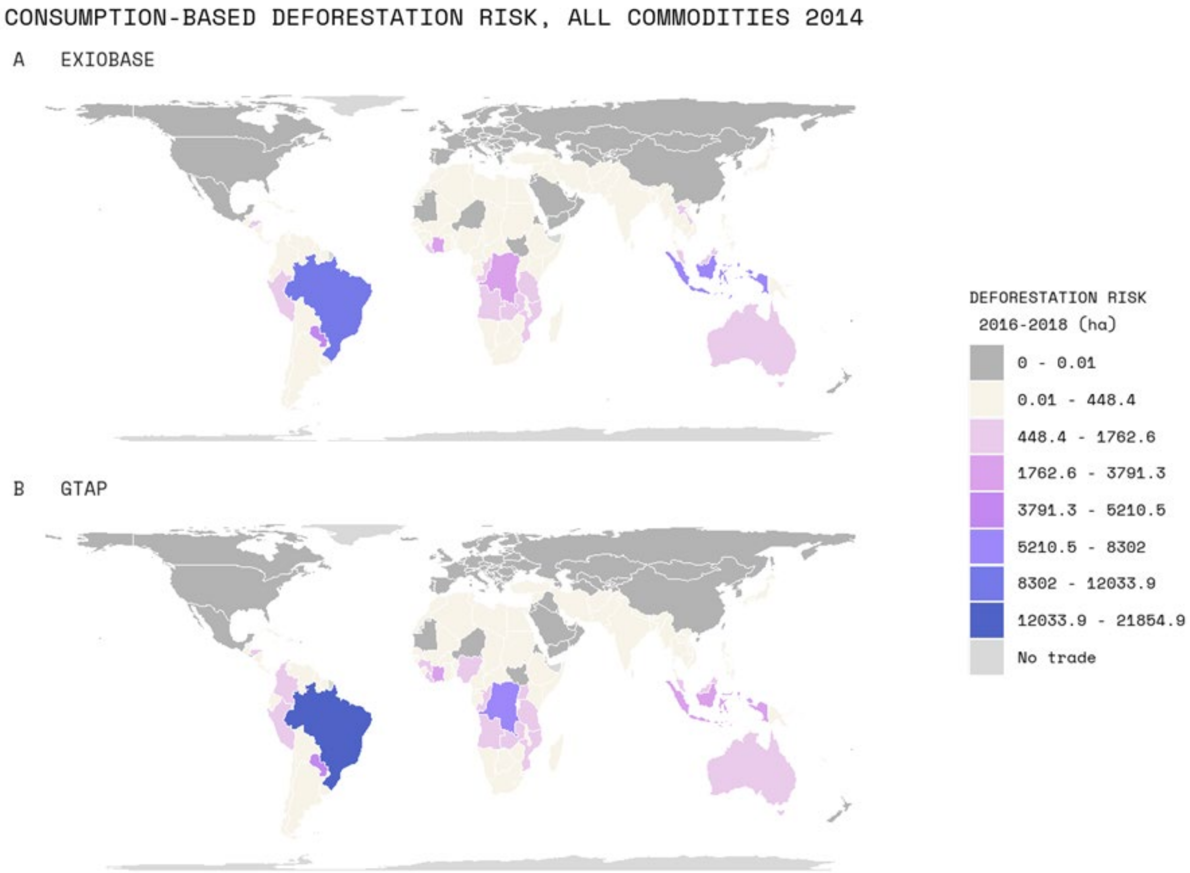

Figure 2. National-level deforestation risk associated with all commodities for 2014, using two different MRIOs: EXIOBASE (A) and GTAP (B).

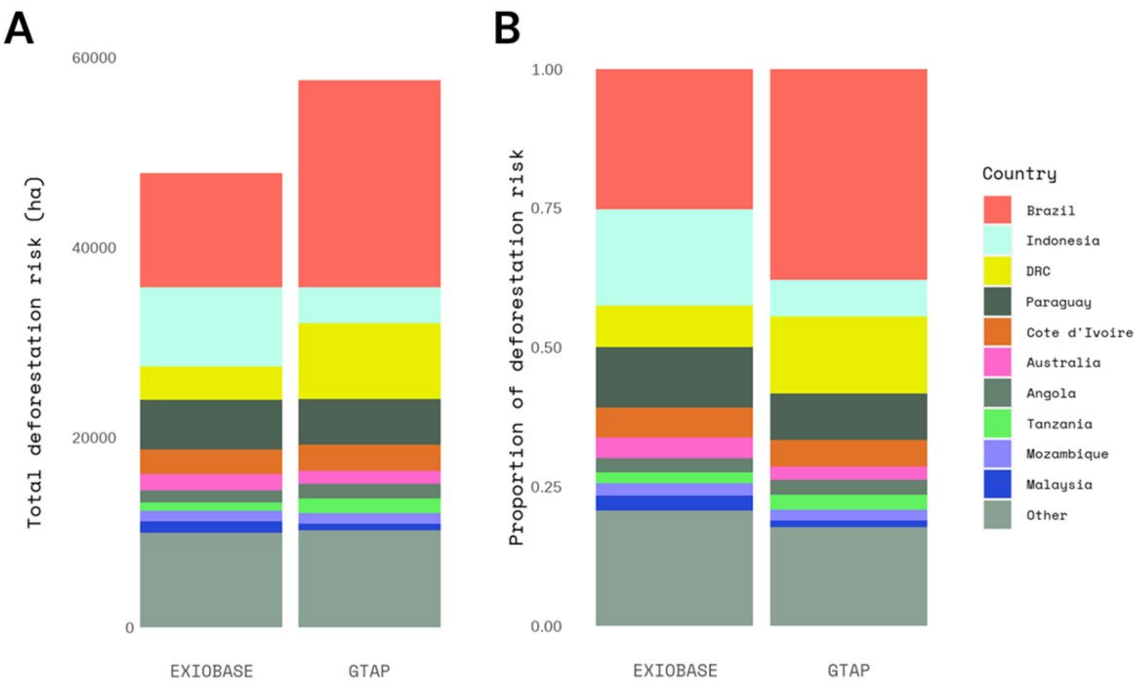

Figure 3. Deforestation associated with German consumption (all commodities, 2014), by country. Results are shown as absolute values (A) and proportions of total risk (B), for both EXIOBASE and GTAP MRIO models.

Commodity-specific results

Below, results are presented for the five main deforestation-risk commodities discussed in the report, plus maize and cassava, which are both important from a consumption-based perspective and show marked differences between EXIOBASE and GTAP.

Soy

The majority of soy deforestation risk originated from Brazil and Paraguay in both EXIOBASE and GTAP, with the overall risk 29% higher with GTAP (16,000 ha, compared to 12,500 ha) (Figure 4). This is due to a greater amount of risk from Brazilian soy, which more than compensates for a slight decrease in the risk from Paraguay. Other countries including Zambia and Argentina make up a very small proportion of the risk with both MRIOs.

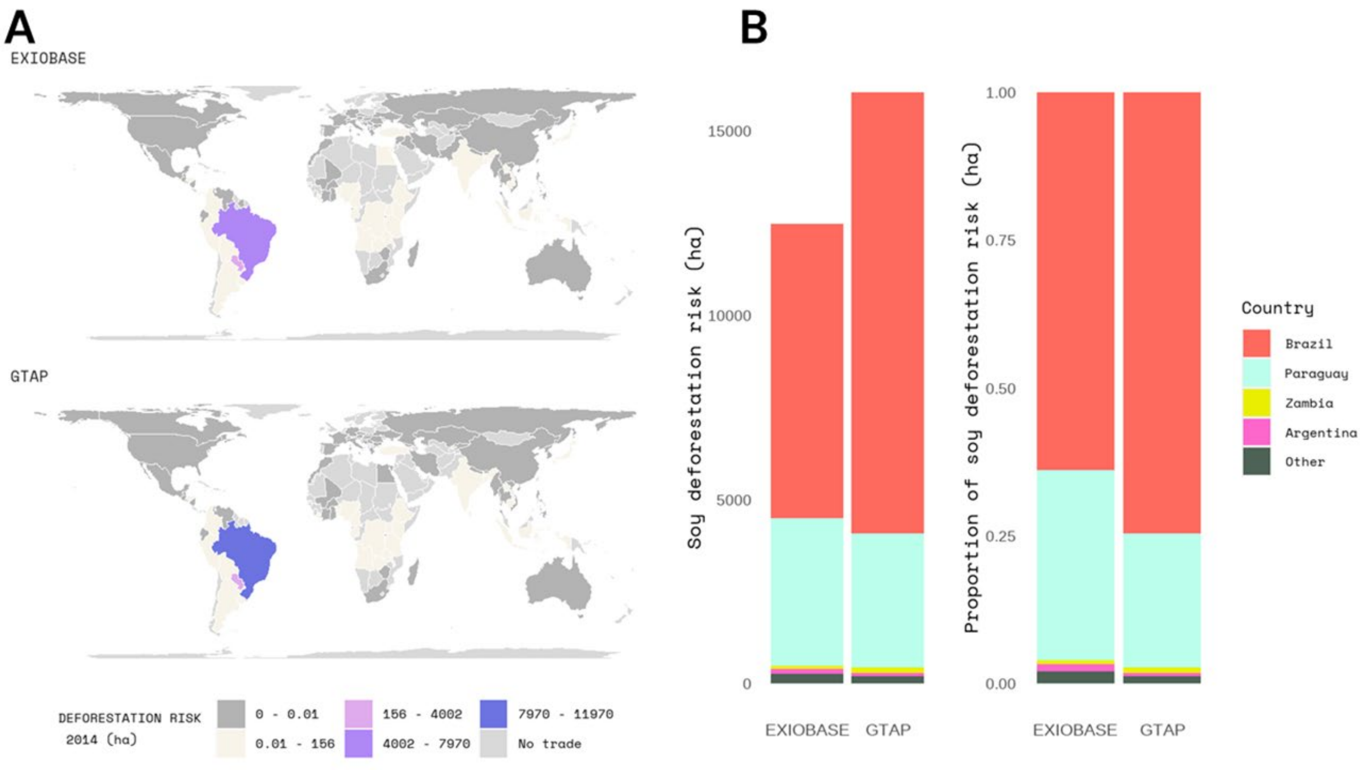

Figure 4. Map (A) and bar charts (B) showing the soy deforestation risk associated with German consumption in 2014, by country. Results are presented for both EXIOBASE (used in the main report) and GTAP models.

Palm oil

Consumption-based palm oil deforestation risk is considerably lower (-49.9%) with GTAP than with EXIOBASE (Figure 5). Although GTAP sees slightly higher risk from Papua New Guinea, Brazil and DRC, the risk from Malaysia and Indonesia (the most significant sources of palm oil deforestation) is much lower, with risk from Indonesia more than halved (-59.0%).

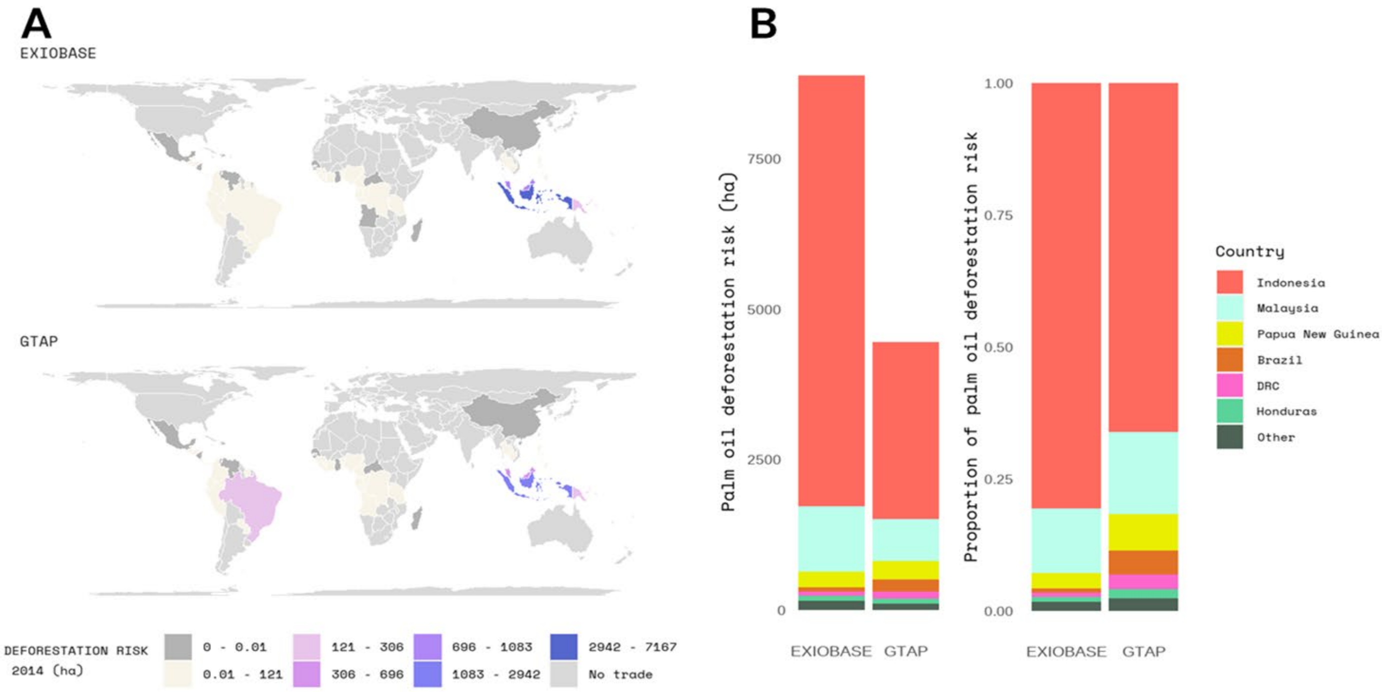

Figure 5. Map (A) and bar charts (B) showing the palm oil deforestation risk associated with German consumption in 2014, by country. Results are presented for both EXIOBASE and GTAP models.

Cattle products

Cattle deforestation risk from a consumption based perspective was approximately the same for both EXIOBASE and GTAP (8470 ha and 8500 ha respectively), although the relative contribution of Brazil was larger with GTAP, making up 41% of the deforestation risk compared with 34% with EXIOBASE (Figure 6).

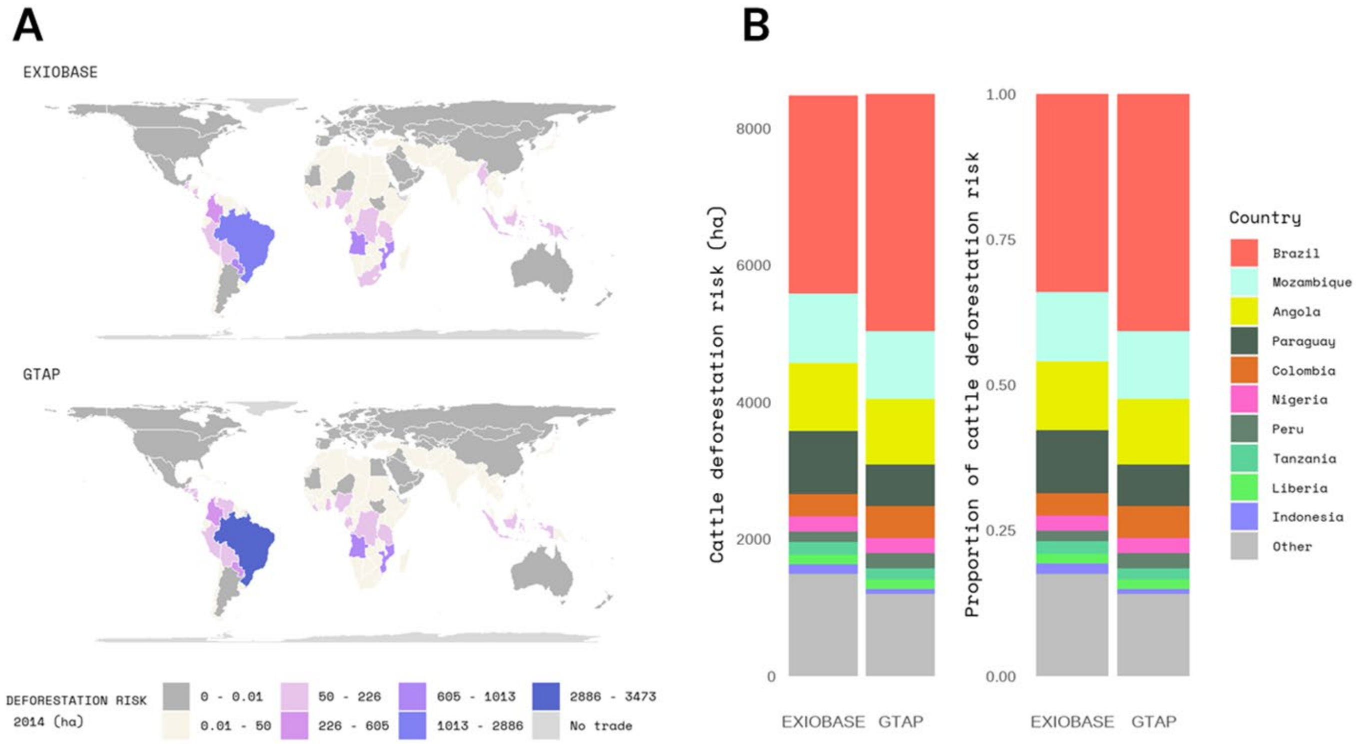

Figure 6. Map (A) and bar charts (B) showing the cattle deforestation risk associated with German consumption in 2014, by country. Results are presented for both EXIOBASE and GTAP models.

Coffee

Coffee deforestation risk was higher with GTAP (2,280 ha, compared with 1,190 ha with EXIOBASE) (Figure 7). The relative contributions of the top ten countries was almost identical with both models however, with Honduras, Peru and Uganda the most significant sources of risk in 2014.

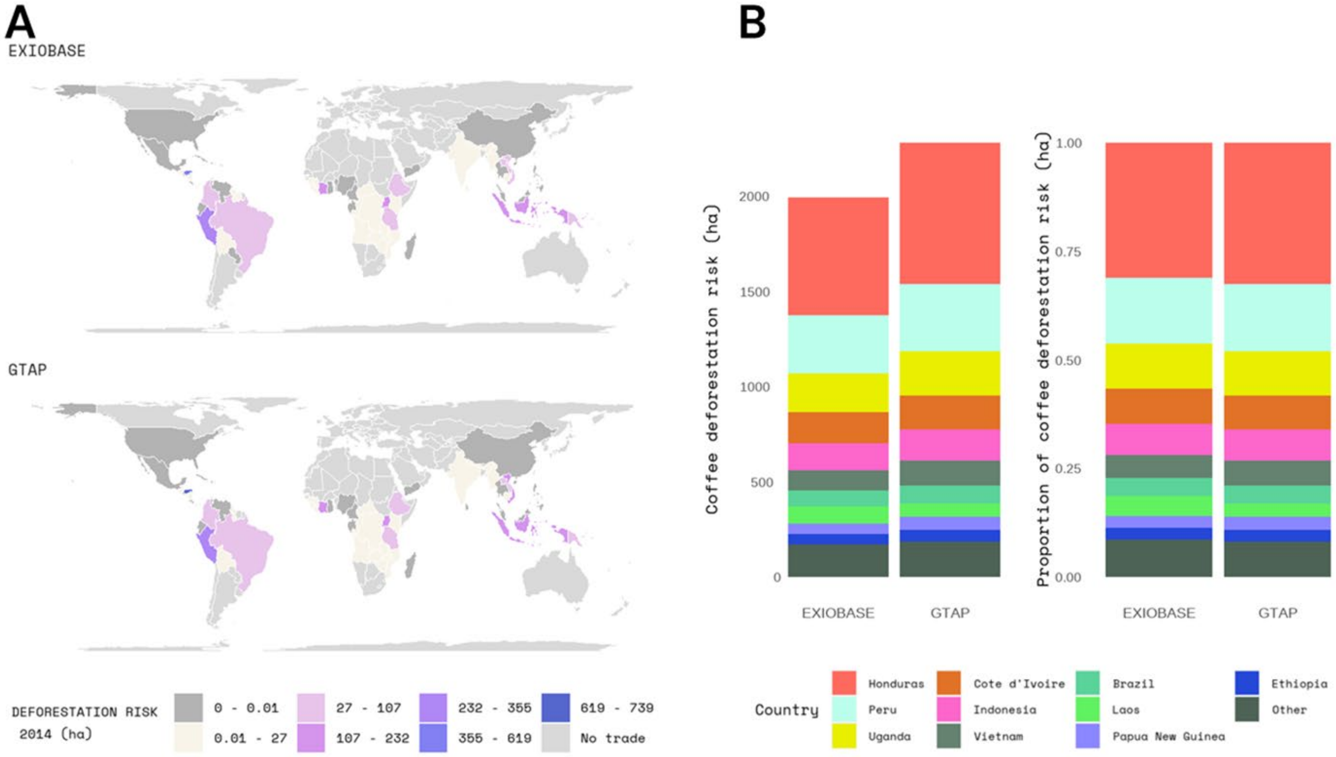

Figure 7. Map (A) and bar charts (B) showing the coffee deforestation risk associated with German consumption in 2014, by country. Results are presented for both EXIOBASE and GTAP models.

Cocoa

As with coffee, cocoa deforestation risk was slightly higher with the GTAP MRIO (3,460 ha vs 3,070 ha with EXIOBASE), but the relative contributions of the top ten countries were similar with both MRIOs (Figure 8). One exception is Brazil, which, at 216 ha, had a much higher risk and relative importance in GTAP, compared to just 33ha in EXIOBASE. However, compared to African countries like Cote d'Ivoire, Liberia and Congo, it was still relatively unimportant overall.

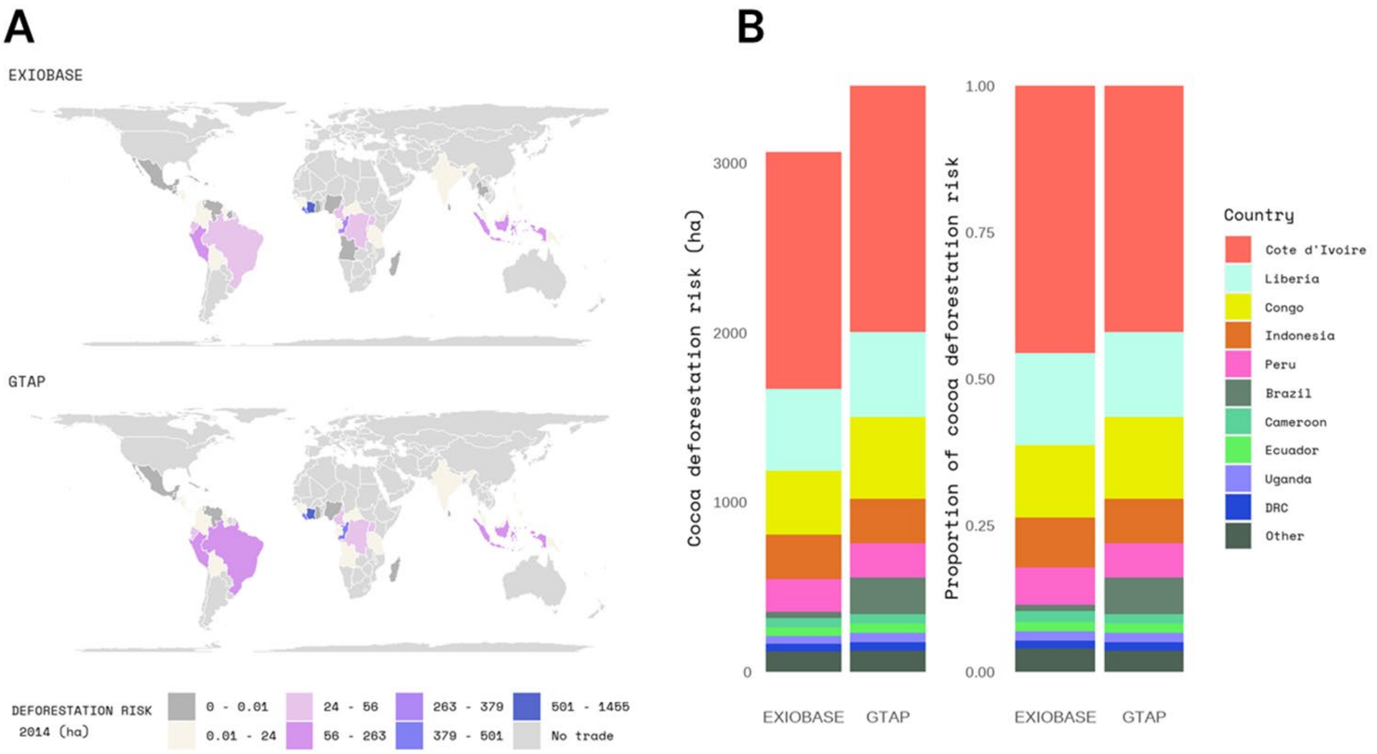

Figure 8. Map (A) and bar charts (B) showing the cocoa deforestation risk associated with German consumption in 2014, by country. Results are presented for both EXIOBASE and GTAP models.

Maize

Maize consumption was associated with significantly higher deforestation risk in GTAP than EXIOBASE - tripling from 2,790 ha to 8,540 ha, with maize becoming a more important source of consumption-based risk than palm oil in this year (2014) (Figure 9). While Germany's risk from maize increases for many countries in GTAP, this is most pronounced for Brazil and DRC, up 490% and 150% respectively in GTAP.

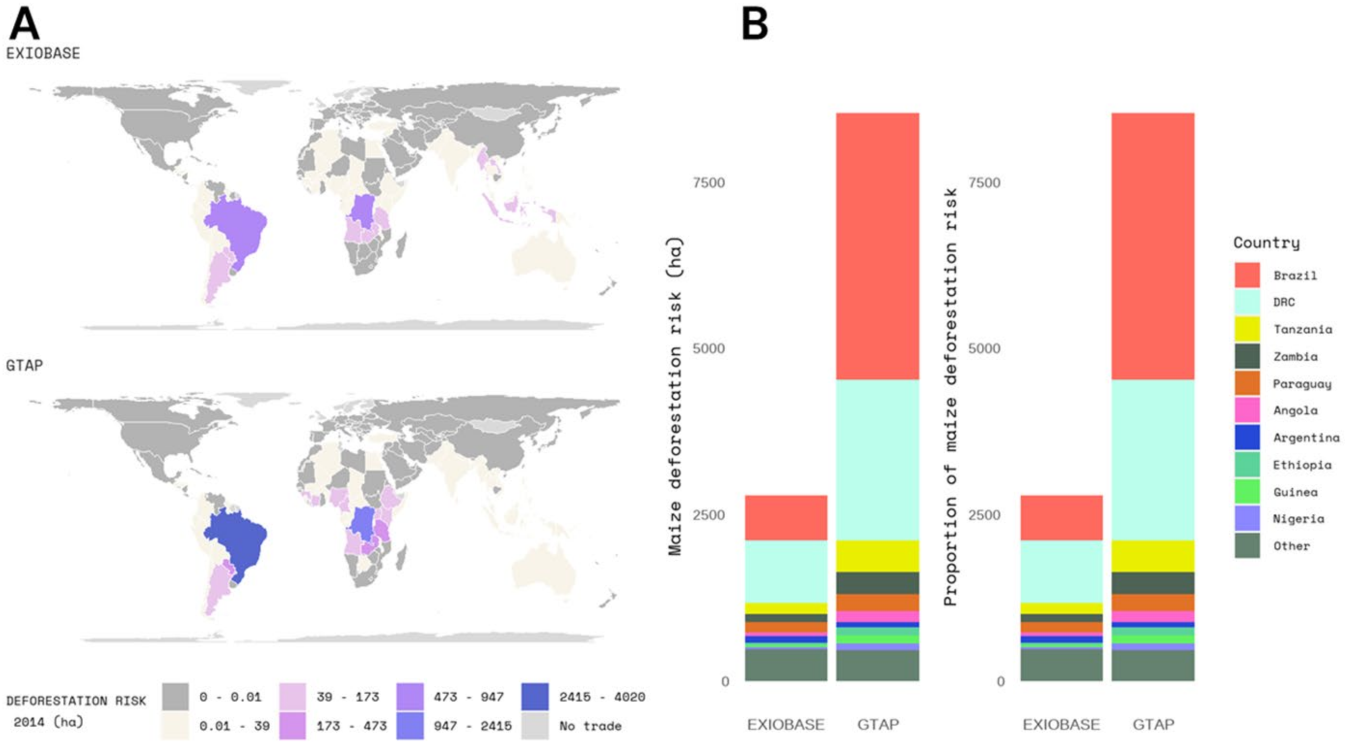

Figure 9. Map (A) and bar charts (B) showing the maize deforestation risk associated with German consumption in 2014, by country. Results are presented for both EXIOBASE and GTAP models.

Cassava

Deforestation risk from cassava was 120% higher when GTAP was used as the MRIO, with a total of 5,260 ha compared to 2,390 ha with EXIOBASE (Figure 10). Despite this large increase, which is mainly associated with DRC, the relative contributions of source countries is similar for both MRIOs. One exception is Brazil, which accounted for only 1% of the risk with EXIOBASE, but 10% with GTAP, making it the second most important country here.

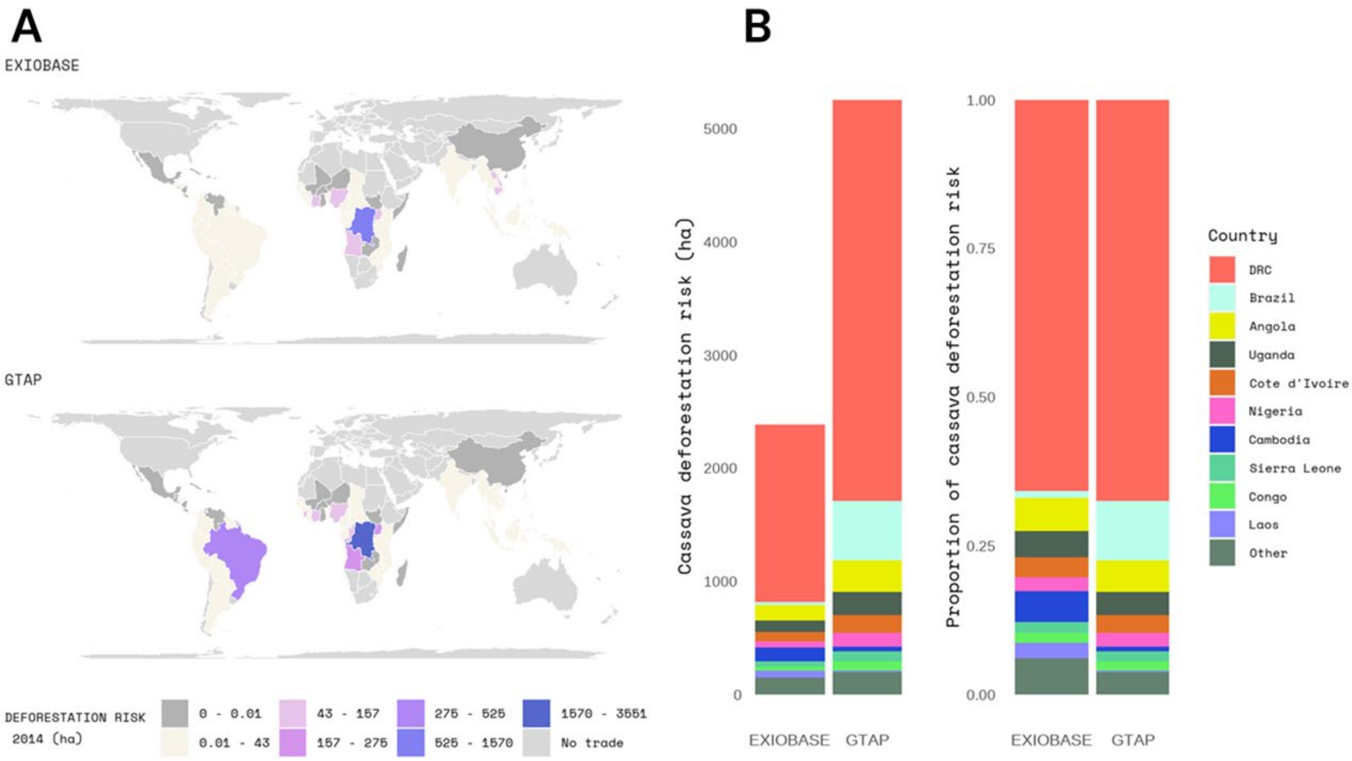

Figure 10. Map (A) and bar charts (B) showing the cassava deforestation risk associated with German consumption in 2014, by country. Results are presented for both EXIOBASE and GTAP models.

Annex 4

Summary of steps required to downscale IOTA with Trase data

The major challenge in incorporating Trase data within global systems models is that a global system requires an inherent level of consistency such that all components fit together and balance. The nature of the Trase data, or more specifically the methods that underpin their generation, is such that each context (i.e. country and commodity pairing) is created in isolation given the requirement to preserve key datasets and retain consistency with e.g. official statistics in order to make the data relatable to the sources from which it is constructed. Trying to incorporate these data into a fully connected global context requires decisions about where, and how, to adjust and rebalance data versus preserving inputs. In many ways these challenges present themselves in the incorporation of Trase data within the re-export adjustment methods used in this study (see Annex 2). However, in that case it is easier to implement (and justify) the preservation of Trase data over other data sources, and within the re-export adjusted Trase data used in the main study we therefore take Trase's trade data as an "absolute truth" and ignore contradictory data within reconciliation and re-export correcting steps used when adjusting for re-export activities.

The MRIOs used for international trade assessments, such as the one conducted in this study, only contain - at best - national-level data. Therefore, whilst the sub-national component of Trase's data can (and has; see Croft et al. 2018) be incorporated into IOTA's MRIO framework, the level of integration, and consistency with broader methods, hinges on a combination of assumptions and amiability of the data. Two key examples are imports and processing.

For some countries/contexts, e.g. Brazil and Paraguay soy, imports into these countries of the focal commodities do not present much of an issue since their magnitude is minimal; it is not problematic to make assumptions about these and how they interact with exports, or even to treat them as insignificant to global trade patterns and effectively ignore such flows all together. In contrast, the case of Argentinian soy supply dynamics is more challenging, since Argentina's soy activities rely heavily on its role as a processor as well as producer, and a not insignificant component of its processing (and subsequent export activities) refer to imported soybean along with its own domestic production. This is complicated further by the fact that much of this imported soybean is illegal and/or unreported, which presents an inconsistency within its reporting and interactions with other countries. Within national scale approaches, this can be countered by use of "opening stocks" and other balance adjustments as necessary (and - indeed - this is how the national-scale assessments are implemented within this study), but at a sub-national scale this is more challenging; how the discrepancies and balancing stages should be assigned at a subnational scale is a non-trivial question if the underlying sub-national data do not reflect this scenario of imports originating from other countries being used alongside domestic production.

In terms of commodity processing (and production of derived commodities) there are constraints and relationships between processing and the production of (often multiple) derived forms; you can only produce so much of a given derived commodity from a finite supply of the primary commodity, and this often applies to co-products produced in fixed ratios, for example. These physical relationships determine what processing is possible. In some Trase contexts (e.g. Paraguayan soy and corn) these constraints are fully and explicitly modelled within the methodology adopted to produce that particular Trase context. This means that these Trase contexts can be readily combined into the global representation of commodity processing and production. However, in other cases (e.g. Brazil soy) the linkages between derived and primary commodity forms are handled in a different manner within the Trase methodology adopted; via commodity equivalence conversion factors. In such cases, this can lead to problematic inconsistencies when attempting to nest subnational results within a broader international trade and processing system. Without having these constraints explicitly factored into the methods used to develop the Trase context (and thus implicitly manifesting themselves within the results), it is very challenging to adapt the subnational results into a broader framework in such a way that simultaneously preserves their integrity and provides alignment.

One solution to these issues is to feed each country through the IOTA framework individually, in the process preserving the Trase data and adapting other data around it (as was done within the Trase-linked re-export adjusted results presented in this study). Indeed, in previous implementations (Croft et al. 2018), the process of hybridising Trase data within the IOTA framework was only carried out for an individual country context (Brazil soy, in that case). However, if a desire is to undertake this hybridisation across multiple countries and then combine the results to provide a more holistic overview of deforestation risk, there arises the likelihood of producing results that are inconsistent upon closer scrutiny (e.g. comparisons between downscaled IOTA results using Trase, and the Trase results themselves would illuminate differences which are not easy to comprehend by potential users). This does not mean that such results would be without merit or value, but it would represent a compromised approach and a significant communication challenge.

At the current time these challenges remain an obstacle to progress work to downscale IOTA to a subnational level using Trase data in a fully consistent and robust manner. However, in future downscaling IOTA with Trase data should become much more viable due to ongoing efforts to address some of the underlying inconsistencies within Trase contexts. Both Brazilian and Argentinian soy are currently being re-worked to tackle the issues mentioned. In the Brazilian context, this means implementing constraints around the processing of higher level commodities and corresponding production of derived forms. As well as removing a challenging inconsistency between data sources, this will also allow for missing sub-national information around processing activities to be inferred and ingested into the global-level model. Similar efforts are being made in the Argentinian context, but with additional focus to address the issue of imports, including those of illegal/unreported nature. This means the sub-nationally linked trade connections will also account for exports originating from unknown origins

These developments to harmonise Trase's commodity contexts will mark a major step forward in being able to combine these contexts into a consistent broader framework, but will not remove all challenges associated with downscaling IOTA, nor the remaining need for certain assumptions. Specifically, an absence of sub-national import data will remain, and will mean that the role of imports (where they are significant, such as in the case of Argentinian soy), will then require appropriate methods and assumptions as to how to address this data gap. Additionally, there is currently a lack of explicit subnational data for processing and utilisation, likely requiring assumptions to downscale national-scale processing data to account for such sub-national activities.

Although work is underway on some Trase contexts which will help facilitate their incorporation into a downscaled IOTA framework, there are other contexts for which this currently remains a desirable rather than planned development. As such, the notion of all Trase data being equally aligned and usable under one consistent approach to downscale IOTA remains, for the foreseeable future, unlikely. More plausible is that for certain commodities, such as soy, it becomes the case that all available contexts could be incorporated in unison. Even then, the ongoing work is labour and time intensive, requiring the collaboration of multiple researchers over periods of months. Beyond that, the full process of incorporating these outputs into a consistent and robust methodological framework will equally require considerable time and effort; the size and complexity of the data necessitating careful and considered integration, and likewise the results needing prudent processing, analysis and dissemination.

Annex 5

List of commodities and equivalence factors (data tables)

resources.trase.earth/data/GIZ_Report-Annex5-Commodities_equivalence_factors_MRIO_sectors.xlsx

Annex 6

Underpinning data (data tables)

resources.trase.earth/data/GIZ_Report-Annex6-Datasets.xlsx

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