Assessing tropical deforestation and biodiversity risk in Belgium's agricultural commodity supply chains

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Executive summary

SEI York and Trase were commissioned by Belgium's Federal Public Service for Heath, Food Chain Safety and Environment (FPS Public Health) to assess Belgium's association with tropical and subtropical deforestation, plus potential biodiversity-linked risks, 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. The trade methods employed are almost identical to those developed for a comparable assessment of commodity deforestation risk for Germany. This report aims to complement previous assessments by Belgium on its overseas deforestation and biodiversity risk, including that conducted as part of its 'Beyond Food' strategy. Belgium has recently joined the Amsterdam Declarations Partnership and this assessment comes at a time when the EU is proposing the introduction of regulation on deforestation-free products. Belgium recognises the need to develop measures to monitor exposure to overseas environmental risk mediated by trade in order to respond effectively.

Perceptions of Belgium's exposure to deforestation and biodiversity 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 Belgium's economy, including both upstream and downstream activities. In this study, three perspectives are used which draw on different datasets and research techniques to provide useful insights into Belgium's deforestation risk exposure:

A direct trade perspective which attributes responsibility based on considerations limited to direct supply into Belgium; A re-export-adjusted perspective which captures and accounts for the indirect trade pathways, to, via and from Belgium, that are likely to be more representative of the total risk exposure of Belgium'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 Belgium.

Key findings

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

Between 2016-2018 – the three most recent years with available data – Belgium's direct imports from commodity-producing countries are linked to 27,900 hectares (ha) of tropical deforestation. However, the deforestation risk associated with Belgium's total estimated consumption, including imports via other countries which may turn commodities into/embed commodities in processed goods, is nearly twice as large, at 47,000 ha of deforestation over the same period.

Overall, the deforestation risk from directly imported commodities is comparable in later years of the timeseries as to the start of the timeseries, although deforestation risk peaks in 2012 (at 17,500 ha), with 2018 risk a 46% decrease from this year. Deforestation risk from re-export and consumption-based perspectives are also relatively stable over time.

Deforestation risk is concentrated in a few commodities and countries

In the most recent three years of data (2016-2018), 89% of Belgium's directly imported deforestation risk is linked to just six key commodities (in decreasing order of importance): coffee (33%), cocoa (26%), tobacco (16%), soy (5%), cattle (5%), and palm oil (4%).

In the most recent three years of data (2016-2018), more than 80% of the directly imported deforestation risk is from seven countries (in decreasing order of importance): Colombia (18.5%), Peru (14.9%), Côte d'Ivoire (13.2%), Brazil (13%), Tanzania (10.5%), Honduras (7.3%), and Indonesia (4.1%).

The impact of adjusting for re-exports varies between commodities

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

When compared to Belgium's direct import deforestation risk, adjusting for re-exports lowers Belgium's deforestation risk exposure overall by 28% (2016-2018), but this result varies depending on the commodity. It substantially reduces risk associated with tobacco (412ha, down 90%), increases risk for soy (3,374ha, up 136%), increases the risk for palm (5,246ha, up 367%), decreases the risk from cattle (689ha, down 48%), and roughly halves the risk from cocoa and coffee. This is consistent with Belgium acting as an important trade and processing hub of tobacco, cocoa and coffee products.

Note that re-export (and consumption) analyses are likely to slightly underestimate impacts because not all trade could be assigned to 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 is of unknown origin.

The total consumption perspective highlights similar important commodities, but ranked differently

Palm oil products are the most important source of deforestation risk from a total consumption perspective (32.2% between 2016-2018), followed by cattle products (21.5%), and soy (10.7%). Rice and maize (6.2% and 5.4% respectively) emerge as particularly important from this perspective, pushing cocoa (4.8%) and coffee (4.5%) down to sixth and seventh place. The jump up the ranking of palm oil and cattle products compared to the direct trade perspective is particularly striking. Tobacco products do not feature prominently from a consumption perspective suggesting that Belgium exports deforestation risk linked to tobacco to downstream countries.

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

- The importance of coffee as a source of risk has been increasing markedly, and in 2018 is more important than cocoa, soy and palm oil combined from a direct trade perspective. Increased risk is particularly linked to sourcing from Colombia, Honduras and Peru.

- Across all commodities, Colombia emerges as a deforestation-risk hotspot in the most recent years, and is a greater source of directly imported risk than Brazil or Indonesia in 2018. This is mostly linked to increased deforestation risk from Colombian coffee (and to a smaller extent, bananas).

- Palm oil risk increases across all three supply chain perspectives, but is much higher overall from a consumption-based perspective - this highlights the important role of palm oil as an embedded commodity in products likely flowing into Belgium via indirect supply chain pathways.

- The risk from cattle increases in recent years, mostly linked to Brazil, where deforestation rates associated with cattle production have risen (rather than an increase in consumption of Brazilian beef).

Risk may be more concentrated in specific locations at the subnational level

Trase data shows that more than three quarters (78.3%) of the Brazilian soy deforestation risk directly imported into Belgium between 2016-2018 is from just three municipalities in the Matopiba region: Formosa do Rio Preto, Barreiras and Diamantino. For Indonesia, the top three kabupatens (municipalities; Kubu Raya, Indragiri Hulu and Rokan Hulu) make up 25.9% of total palm oil deforestation risk for Belgium between 2018 and 2020). Compared to direct imports, adjusting for re-exports generally produces a wider distribution of commodity deforestation risk, indicating the importance of accounting for indirect trade pathways when pinpointing potential risk hotspots.

Belgium’s consumption-based deforestation risk is among the smallest in the ADP partnership

At 78,200 ha, Belgium’s risk between 2014 and 2018 is dwarfed by the deforestation associated with China’s consumption (1,209,000 ha), and also by ADP-partner countries such as Germany (242,000 ha) and France (202,000 ha). Belgium has higher risk, however, than Norway (21,400 ha) and Denmark (20,000 ha). Conversely, when taking into account the quantities of commodities being traded (the deforestation risk intensity), China’s consumption has a lower deforestation risk per tonne than any of the ADP countries, including Belgium.

Integration of simple biodiversity metrics

This study extends the trade analysis by linking commodity production to species richness information to generate a metric of potential risk to biodiversity. The metric is relatively simple to apply and is a measure of potential proximity to species, which can serve to highlight areas of high species richness that might be threatened by commodity expansion.

Results suggest that from a direct-trade perspective, biodiversity risk is increasing over time. From re-export and consumption-based perspectives, biodiversity risk is relatively stable over the more recent timeseries available.

The highest risk commodities vary across perspectives, with coffee, rapeseed and cocoa associated with the highest species risk from a direct-trade perspective, but with rice, wheat and soy associated with the greatest risk from a consumption perspective.

The metric does not take into account the many aspects and facets of biodiversity that would be necessary to undertake a comprehensive assessment of impact linked to agri-commodity trade. Refinements are therefore suggested (see main report) for the development of enhanced biodiversity metrics in future.

Recommendations

Based on the results, we conclude that this type of information offers the potential to be used as the basis for ongoing monitoring in the form of an indicator (or indicators) of Belgium’s overseas deforestation risk. We therefore make the following recommendations for potential indicator development:

- Belgium should consider uptaking the methods applied in the form of an initial ‘experimental’ statistic/indicator, with consideration given to which trade ‘perspectives’ should be included.

- Because multiple assumptions can be made when bringing together trade and consumption data, and that these assumptions can have an impact on results, additional work to compare the analysis provided in this report with alternative assumptions and methods would increase confidence and aid understanding of the results.

- Because the data and methods adopted in this study likely underestimate re-export and consumption-linked risk, due to the presence of 'unknown' commodity sources, additional work should be explored to attempt to approximate sources and improve estimates.

- Further work to harmonise direct-trade statistics, via reconciliation of trade records, is warranted to improve results comparability.

- Additional work to develop and integrate metrics is required for a more comprehensive assessment of biodiversity risk, with a complement of metrics likely necessary to understand different facets of exposure to biodiversity impacts. Exploration of steps that might be taken to align deforestation metrics (e.g. with the definitions likely being adopted by EU deforestation regulation) is also warranted.

- Increasing the commodity breadth of the indicator beyond agriculture to include products of e.g. forestry, mining and fisheries would increase the relevance of the indicator and offer a more comprehensive assessment of Belgium's international trade impacts.

In addition to indicator development, we also recommend that consideration is given to how information of the type provided in this study can be made more accessible to potential end-users (e.g. via online visualisation of, and access to, data), and that dialogue should also be continued with stakeholders across Belgium who may have access to additional data and resources that will shed further light on the high risk supply chains identified in this analysis.

Introduction and background

Purpose

SEI York and Trase were commissioned by Belgium's Federal Public Service for Heath, Food Chain Safety and Environment (FPS Public Health) to assess Belgium's tropical and subtropical deforestation risk via its trade and consumption of imported agricultural commodities. Additionally, a similar assessment was requested of the potential biodiversity risks.

This report aims to complement previous assessments by Belgium on its overseas deforestation and biodiversity risk, including that conducted as part of its 'Beyond Food' strategy. Belgium has recently also joined the Amsterdam Declarations Partnership, and this assessment comes as similar assessments are being conducted across Europe and at a time when the EU is proposing the introduction of regulation on deforestation-free products (EC regulation proposal COM 2021/0366, EC 2021). Belgium recognises the need, in order to respond effectively, to develop measures to monitor exposure to overseas environmental risk mediated by trade.

The primary aim of this work is to provide stakeholders in Belgium with a detailed understanding of the 'deforestation risk' that the country is exposed to, via its trade and consumption of a range of commodities associated with tropical and subtropical deforestation, in countries of production. This work is designed to enhance knowledge of Belgium's deforestation-risk exposure and inform the development of a potential monitoring and reporting framework. The analysis combines information on global and regional production-related deforestation with trade and consumption data to provide an overview of the scope and nature of Belgium's exposure to deforestation in supply chain activities. It is intended that this work will identify hotspots of potential commodity deforestation risk which warrant further investigation; the methods employed provide a global overview of key sources of deforestation risk rather than a granular assessment of risk in specific supply chains.

In addition, a simple biodiversity risk metric is also combined with the trade linked assessments to offer a measure of broader biodiversity risk that extends beyond a focus on deforestation. This indicator provides an example of how biodiversity information can be combined within risk assessment of this type, but is not intended to provide a comprehensive assessment of biodiversity risk; such an assessment arguably requires more powerful metrics, used in combination, to reflect the various aspects of biodiversity that might be of concern. We discuss, however, the further development of biodiversity risk information within this report.

The work has involved the implementation of a number of models and datasets. Details of the methods used to derive the data are described in the Methodological Summary below. The trade methods employed are almost identical to those developed by Trase for a comparable assessment of commodity deforestation risk for Germany, commissioned by GIZ and BMZ and with an extensive associated report (West et al. 2022), published here. Therefore, whilst for ease of reference and understanding the Methodological Summary contains an overview of approaches, we refer the reader to the report for Germany for a more extensive discussion of the methods employed, including within the associated Annexes to that report. These methods were guided by prior external consultation with stakeholders to understand priorities for data development and harmonisation. This comparable study for Germany, however, did not include any assessment of biodiversity risk, so details of the implementation of this environmental metric are provided below.

The main study summarises the results for Belgium; it highlights hotspots of tropical and subtropical deforestation risk in supply chains and changing trends in exposure, and identifies potential hotspots of biodiversity risk. Along with a general discussion, we summarise opportunities for progressing this work including options for future integration of biodiversity information into risk assessments and considerations and recommendations for the potential development of this work into a formal indicator set for ongoing monitoring purposes.

Supply chain perspectives

This study has been led by SEI York with input from Global Canopy as part of Trase, a partnership founded by the Stockholm Environment Institute and Global Canopy (www.trase.earth). Trase provides insight on subnational commodity deforestation risks in supply chains, links to commodity traders and volumes of imports into countries. Trase's core data are limited to key deforestation-risk landscapes, and supply chain coverage to the point of first import. However, in this analysis we extend the scope of Trase's core coverage via datasets providing 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, and then provides several alternative, complementary perspectives on deforestation risk.

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

Direct trade

First, it may be based on the direct trade relationships that exist between Belgium and countries where agricultural expansion is linked to deforestation. Here, we attribute responsibility based on considerations limited to direct supply into Belgium, an important perspective given such flows can likely be directly influenced by the government and other supply chain participants.

Indirect trade

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 Belgian economy, and would be subject to different considerations when it comes to policy or private sector responses.

For indirect pathways, two perspectives are provided in our analysis:

Re-exports

This perspective is based on the consideration of the production and trade of primary and directly derived commodities only, capturing and accounting for the re-export of primary and/or derived materials via intermediate countries (such as the Netherlands) or flows into Belgium that are subsequently exported to other countries. This ensures that commodities which flow via these countries are assigned back to their point of origin and potential impact.

Consumption based

This other perspective offers a full 'consumption-based account', which captures all downstream activities and thus reflects the total embedded impact of commodity use from the perspective of the products and services actually consumed within Belgium.

National and subnational-scale analysis

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

Biodiversity risk assessment is also applied across the same three supply chain perspectives.

Methodological Summary

A summary of the supply chain perspectives and scales of analyses adopted in the methods of this study is found in Table 1. More detail on each approach, and on the implementation of deforestation and biodiversity information then follows, but we refer the reader to our equivalent study for Germany (West et al. 2022) for more extensive details.[1]

The inclusion of different trade perspectives in this report means that it can sometimes be difficult for the uninitiated lay-reader to determine how certain supply chain products are (or are not) associated with deforestation within the results. For example, the question of "does the cattle deforestation risk also include the risk associated with animal feed used for cattle rearing?" is a common one. For clarity, the deforestation risk for each commodity is associated with the land used directly for the production of that commodity, with the supply chain perspectives then determining the extent to which these estimates of deforestation risk are encapsulated within the assessment of downstream elements of the supply chain. For example, cattle deforestation risk refers to the land use change linked to the pasture used to produce cattle, not to any additional feedstuffs grown separately for use in the cattle industry. Deforestation associated

1. The extension to biodiversity and addition of some additional commodities - including Trase's latest palm oil data - means that this analysis should be considered an update on the equivalent German analysis, but the methods employed are substantively identical.

with - for example - soy used in cattle feed is captured in the soy deforestation risk part of the assessment. In the case of soy, flows associated with soymeal (used in feed) are included across all perspectives but only linked to livestock industries directly within the consumption-based perspective (where they will be embedded within livestock sectors within the MRIO framework).

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

Name	Description	Considerations linked to application 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.	~160 primary (harvested) crop commodities and selected transformed derivatives (where trade data available), plus cattle products available from FAO/ Pendrill at al. 2022. Timeseries 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: 2018-2020). Cattle (Brazil: 2015-2018; Paraguay: 2015-2019).	Results presented for Trase data with associated subnational deforestation.

Name	Description	Considerations linked to application in this study	
		Commodity coverage	Other notes
Re-export-adjusted: national scale	Bilateral trade (point A to point B), but based around a reconciled trade dataset (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.	~160 primary (harvested) crop commodities and selected transformed derivatives, plus cattle products available from FAO/Pendrill at al. 2022. Timeseries 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 Belgian risk perspective) commodities imported into Belgium 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: 2018-2020).	Subnational re-export-adjusted results for Belgian risk account for (i.e. do not include) commodities imported into Belgium 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).

Name	Description	Considerations linked to application in this study	
		Commodity coverage	Other notes
Consumption-based	These results take the data from the national-scale re-export-adjusted trade data and feed these 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.	~160 primary (harvested) crop commodities and selected transformed derivatives, plus cattle products available from FAO/Pendrill at al. 2022. Timeseries 2014-2018	Data estimate total production necessary – and the points of production – to fulfil Belgian consumption, regardless of form and number of processing steps. Some 'unknown sources' are retained, however, given dependency on re-export-adjusted data.

Direct trade

For direct trade estimates at subnational scale, we utilise Trase data (available from supplychains.trase.earth). 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). Trase combines (via application of 'decision trees' and modelling steps, with the dependence on modelling varying by data availability across different country-commodity contexts) 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. In some cases, links between export and origin cannot be made with confidence and trade is reported as being of unknown origin. The timeseries coverage of data available from Trase varies depending on the commodity (see Table 1). We refer the reader to the Trase website and GIZ report for additional description of how Trase develops supply chain maps.

For national estimates at the global scale, we use agricultural production statistics from the Food and Agriculture Organization (FAO)'s crop and livestock products[2] dataset and direct trade estimates (export quantities) from the FAO's detailed trade matrix dataset. Deforestation intensity (hectares per tonne of product) was obtained for each FAO product using the data from Pendrill et al. (2022) that provides estimates of tropical and subtropical deforestation for the 2005-2018 period. Deforestation intensity is calculated for each combination of producer country, commodity and year, by dividing

2. Note that our coverage of commodities in this analysis does not extend to timber products.

deforestation estimates by associated material production estimates from the FAO. These intensities are then multiplied by the quantities exported to Belgium to estimate the deforestation risk linked to traded production. Whilst, in reality, some (or, in extreme cases, all) of these exports could be comprised of previous imports rather than domestic production in exporting countries, an assumption is implicitly made that all exports are composed of domestically produced commodities.

Many important agricultural commodities are traded in processed forms (e.g. palm oil, soybean cake), rather than (or in addition to) their harvested forms. 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 also calculate their 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 the Germany report and, 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 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.

Whilst efforts have been made to align commodity coverage between the subnational contexts and their national scale equivalents for comparability, it is worth noting that in the case of oil palm fruit (the raw oil palm product), the subnational data from Trase only consider the trade of Indonesian palm oil, and not palm kernels (and derived forms such as kernel oil and kernel cake). In contrast, the national scale data do consider the trade of kernels and derived products thereof. Were these to be included in the subnational analyses, they would likely change the quantities, and distribution, of Belgium's risk associated with Indonesian oil palm production accordingly. The exact nature of these changes are impossible to predict at this time, but given that palm oil accounts for approximately 76% of the usable fruit, and the critical importance of oil palm to global deforestation, it was deemed valuable to proceed with this comparison utilising the best data available.

Re-export analysis

Direct trade analysis may not reflect the actual origin or eventual destination of materials. One reason is that products may be 're-exported', and such re-export activities can make up an important part of the supply chain that 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 which are not produced in the Netherlands. 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. Trade data alone also won't capture or represent domestic production remaining in a country; this requires considering the trade data in conjunction with production data. For these reasons it is useful to construct a framework, considering production and trade, accounting for these re-export activities.

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, in the national scale case, this data source comprises both import and export data for nearly 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)[3]. These reconciled trade data are then combined with information on production and opening and closing commodity stocks and compared to utilisation information, including requirements for use as food, feed and seed, and demand for processing into derived forms. Any negative balances here (i.e. a deficit of available supply to meet export and/or other use requirements) 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. FAO Technical Conversion Factors are used in conjunction with Commodity Trees to make matches between associated primary and derived commodities and to translate quantities of derived commodities into their raw equivalents.

3. Note that given these reconciliation steps, the re-export approach is not simply an extension of the direct trade approach. This should be borne in mind when interpreting results from across the three perspectives offered.

For national re-export activities, we take the approach of first estimating re-exports linked to the trade in primary commodities, 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 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. These results for derived product forms are then joined to those for primary commodities, to link destinations of derived forms back to the point of production of the associated primary commodity.

For Trase-linked re-export activities, a similar approach is adopted. Trase data are taken as 'perfect' for this purpose, i.e. within the reconciliation step the data from Trase are accepted automatically within the global trade system and override any conflicting information reported by other parties. 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 subsequently. For example, raw soybeans leaving Brazil for the Netherlands, being processed there and then subsequently exported as soy cake are not linked back to the original Brazilian-sourced soybean, but rather will simply be considered as cake produced in the Netherlands, and the exports will be associated with this production and any other cake previously imported.

Consumption-based accounting

Environmentally extended consumption-based accounting aims to derive estimates of the impacts associated with consumption activities, accounting for all of the upstream dependencies and activities necessary to meet that 'final 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. An example is soy used in animal feed linked to the production of leather for the Belgian 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 taking place within and between global economies. MRIOs comprise country-level input-output tables in which data are harmonised to ensure a balanced representation of the global economic system. After environmental impacts are assigned to the associated producing sectors, matrix algebra can be used to derive the associated impacts of consumption. A limitation of traditional MRIO methods is often their restricted sectoral and geographic resolution. For the treatment of deforestation-risk, this presents a potential problem as deforestation risk can be associated with a small number of specific commodities and concentrated spatially. A lack of commodity-specificity in traditional MRIOs results in these commodities being modelled alongside the flows of other materials which may not be associated with deforestation risk. Similarly, flows being modelled between multi-country regions can lose crucial spatially-explicit risk information.

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) trade in primary commodities, initial processing and then the trade in derivatives, all in physical units, before inserting the resultant origin-linked supply into appropriate sectors of the MRIO database. This allows the MRIO model to then distribute this supply through to points of final consumption. 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. Results from IOTA are implemented only for the national-scale analysis (i.e. for physical trade and processing derived at national scale from FAO). This approach ensures that commodity-specific production and trade information is linked through to all final consumption activities. However, 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 in general - provide estimates of the overall balance of global risk and responsibility.

Deforestation data

The deforestation data used in this study, which are joined to trade information to estimate deforestation in Belgium's imports or consumption activities, vary depending on the spatial resolution of the analysis. Further details are available in the GIZ/BMZ report (West et al. 2022).

National-scale tropical and subtropical deforestation data are utilised alongside our national-scale trade analysis, with the data sourced from Pendrill et al. (2022). The data are derived from a simple 'land-balance' model. Observed forest loss (from the Global Land Analysis and Discovery (GLAD) lab in the University of Maryland) is first attributed to different land use types. Here, based on FAO statistical records, cropland expansion first takes place into pastures (where there is any gross pasture loss according to FAO), then into forest loss areas. Plantation forest expansion is also accounted for. In essence, forest loss is attributed across expanding cropland, pasture or plantations based on their relative areas of overall increase, capped at total regional forest loss. Cropland-attributed forest loss is further linked to individual crops or crop groups in proportion to their relative expansion in harvested area. Forest loss attributed to pasture is linked to cattle grazing. 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 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 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 and deforestation information derived from spatially explicit data obtained through remote sensing. The indicator estimates how much 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 commodity-specific 'lag' period is also defined, referring to the minimum time period between deforestation activity and the earliest possible harvest of the commodity. Deforestation estimates associated with commodity land use expansion are then linked to Trase's commodity supply chains to estimate the deforestation risk 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.

Biodiversity data

Within this analysis, we have included an indicator which acts as a simple measure of biodiversity risk. The metric integrates species richness information with spatially explicit estimates of crop production to estimate the degree of overlap between crop production and species ranges. It is worth noting that this measure is deliberately simple and - whilst also currently included in similar work to monitor the UK's overseas impacts (Croft et al. 2021) - is certainly not representative of the breadth of biodiversity information that is either available or necessary to fully understand the biodiversity impacts of trade and consumption. Instead, it is included to illustrate the potential of linking trade models to biodiversity information and as a first cut in exploring how biodiversity-based risk assessment might differ from deforestation risk assessments. Options for including biodiversity more thoroughly in future assessments is included in the Discussion.

The included biodiversity risk metric is termed 'species hectares' as short-hand for a 'species-weighted extent of crop production' measure. In order to compile this metric, species distribution data from the IUCN Red List and Birdlife International are used in both national- and subnational-scale analyses. The global mapped ranges (in the form of geospatial polygons) of 11,145 bird species, 10,148 reptiles, 6,707 amphibians and 5,537 terrestrial mammals are utilised to produce species richness layers containing a count of all species present (i.e. summed across all taxonomic groups). The spatial data contains information on origin, presence and seasonality, so to produce the species richness layers, each taxonomic group is filtered according to a number of criteria. First, a filter for extant species is applied to remove species which are listed as extinct or extinct in the wild. Then, whilst all parts of seasonal ranges are used, for origin, only species that are either native to the area or originate from reintroductions or assisted colonisation are included. Once these filters are applied, species richness layers are created in Google Earth Engine at different spatial resolutions depending on the scale of analysis.

For national scale analyses[4], outputs from the Spatial Production Allocation Model (MAPSPAM; (IFPRI & IIASA 2016, IFPRI 2019) are used as estimates of the distribution of 42 global crops (inclusive of 9 aggregate crop groups) for the reference years 2005 and 2010. Note, this indicator is only applied to crop commodities and therefore - unlike the deforestation metric - does not cover cattle. Physical area, measured in hectares, is used, representing the actual area where a crop is grown. This is opposed to 'harvested' area, and therefore activities such as double-cropping or multiple harvests of a crop on the same plot are not accounted for in this analysis. Use of physical area means impacts associated with different production systems or different land use intensities are also not considered. To align with the resolution of this crop data, for national scale analyses, our species richness layers are generated at a five minute resolution, which is approximately 10km at the equator. Then, for each crop, the area of cropland is multiplied by the combined species richness layer for each pixel, i.e. the number of species range polygons that overlap with areas of crop production. Summing these pixel values for each country then allows for an estimate of how many 'species hectares' are associated with the production of each specific crop for each (2005 or 2010) reference year.

4. Additional detail on the methods and sources used to generate the indicator at national scale can be found in Croft et al. (2021).

If the indicator data concord to a single commodity within the FAO classification, that impact is assigned directly to the production of that commodity. If the indicator data concord to multiple commodities, the impact is distributed across the production of those commodities in proportion to the relative land area used in their production. If no land area data are available from FAO for a given country/commodity/year, then an estimate is derived based on global average yields, and this is then used to apportion the share of the indicator data to the crop.

For subnational contexts, species hectares were calculated for the years that we have production and trade data from Trase. Data on crop extents for Indonesia for palm oil are based on data from the Nusantara Atlas and that for Brazil, Argentina and Paraguay for soy uses data from the Global Land Analysis and Discovery (GLAD) laboratory from the University of Maryland (Song et al., 2021). For both of these commodities, data representing cropland extent are available at 30m resolution, which are reduced to 1km resolution for computational reasons. A combined species richness layer is then created at this resolution and the equivalent steps as for the national level analysis are undertaken to calculate the species hectares metric.

Once total impacts have been assigned to the production of corresponding crops, they are converted to intensities in both national and subnational assessments by dividing through by associated annual crop production masses[5]. Mass flows from trade records are then multiplied by the corresponding intensities to estimate the species richness weighted hectares embedded within those flows.

5. For the national-scale dataset, for those years without a directly matching MAPSPAM crop model reference year, the closest available year was used. Data are still converted to annualised intensities, however, by dividing through by associated annual FAOSTAT provided crop production masses.

Methodological assumptions and considerations

There are some methodological assumptions and limitations of the analysis conducted which should be borne in mind when interpreting results. Please refer to Annexes of the German report for additional details, but a summary of key aspects is provided below:

- **Different methods are employed to calculate deforestation and biodiversity 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.

- **The exact methodological details used to provide subnational deforestation data and supply chain maps from Trase 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 and relative confidence in results varies considerably.

- **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, however for the ‘downstream’ supply chain perspectives 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. In sum, 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 Belgium'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 and biodiversity risk associated with Belgium's supply chains from three complementary perspectives and across two scales of analysis – national and subnational. These perspectives are:

· direct trade (derived from Trase's subnational supply chain mapping data, or from national production and trade statistics derived from FAO);

· re-export-adjusted (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;

· consumption-based (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 summarise the overall connection between tropical and subtropical deforestation risk and Belgium's supply chains, employing only national-scale analysis in this overview. Then, for specific commodities of interest, we provide additional detail along with subnational analysis derived from Trase where data are available. An analysis of the global biodiversity risk associated with the trade and consumption of agricultural products (note, this excludes cattle) linked to Belgium is then provided and - again - where Trase data are available we provide details on subnational risk hotspots.

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

Our analysis (Figure 1) indicates no clear trend in overall commodity deforestation risk exposure for Belgium. For the direct trade perspective (Figure 1a), which includes a longer timeseries, overall deforestation risk is 9,470 ha in 2018 compared to 8,220 ha in 2005, but the risk is as high as 17,500 ha in 2012. For the re-export adjusted trade perspective (Figure 1b), the deforestation risk is highest in 2014 (the start of the shorter timeseries available for re-export and consumption-based analyses) from which point it has dropped but remained relatively stable at around 6,000 hectares. From the consumption-based perspective (Figure 1c), overall risk remains relatively stable at close to 15,000 ha between 2014 and 2018.

Figure 1 also provides the commodity-contributions to overall commodity deforestation risk for Belgium. For selected commodities, more detailed information on trends is supplied in commodity-specific sections below.

The results reveal that oil palm products are associated with a relatively small amount of deforestation risk from a direct-trade perspective, but a significant proportion of the overall risk from re-export and consumption-based perspectives. Indeed, oil palm from a consumption perspective is the largest source of risk overall with 5,390 ha in 2018. These differences between perspectives suggest palm oil deforestation risk is highest for Belgium via indirect trade routes (i.e. a significant proportion of risk is not accounted for when only assigning back to direct-trade partners), and that risk is also highly embedded in Belgium's consumption activities. It should also be noted that a non-trivial proportion of re-export adjusted and consumption-based trade is currently associated with 'unknown' risk (see commodity-specific figure captions below for more detail on 'unknown' components of risk, and Discussion for further elaboration); this is particularly true for the palm oil supply chain.

Cattle deforestation risk is the second largest source of risk from a consumption perspective in 2018[6], with 3,470 ha. In contrast to oil palm products, however, cattle deforestation risk is not particularly prominent from a re-export adjusted perspective. This suggests that cattle deforestation risk is not associated strongly with direct imports or imports of directly-derived (e.g. fresh beef) products that might flow through other countries, but is instead associated with materials which are - for example - present within processed foods or other upstream components of Belgium's supply chain.

Tobacco is a key commodity from a direct-trade perspective, with 1,170 ha of deforestation risk in 2018, but is associated with much lower risk from re-export (262 ha) and consumption-based (116 ha) perspectives. This suggests that whilst Belgium is a key importer of tobacco, this tobacco, and products derived from it, are subsequently exported and consumed elsewhere.

Soybean is a key contributor to overall deforestation risk. It is a particular contributor to the risk profile from re-export and consumption-based perspectives (see soy-specific section below for more details).

Cocoa appears prominently in the risk profile, but whilst risk has historically been increasing it has fallen again in recent years (see cocoa-specific section below for more details). Belgium's risk is highest from a direct-trade perspective, suggesting that Belgium is acting as an important processor and exporter of cocoa-linked products.

Coffee also appears to be a prominent source of risk, particularly from direct and, though to a lesser extent, re-export adjusted perspectives. This is again suggestive of Belgium's role as an initial importer of raw/less processed materials, which are subsequently exported in more refined forms. Risk also appears to be increasing over the timeseries; in 2005, from a direct-trade perspective, coffee is associated with 690 hectares of deforestation compared to 3,750 ha in 2018 - a 443% increase overall.

6. Note that tobacco is not included within results from re-export adjusted or consumption-based perspectives given its absence in FAO commodity tree information (see Methodological Summary).

Other commodities that appear as relatively important include oranges, which also appear more prominently in the direct-trade perspective (with 611 ha in 2005 falling to 112 ha in 2018) than in the re-export or consumption-based profiles. Rapeseed deforestation risk also appears prominent for a period, although this is associated with production in Australia and therefore may not be directly associated with deforestation activities (see Annex 1 and Figure A1 for additional information). Maize and rice also appear as important commodities from a consumption-based perspective.

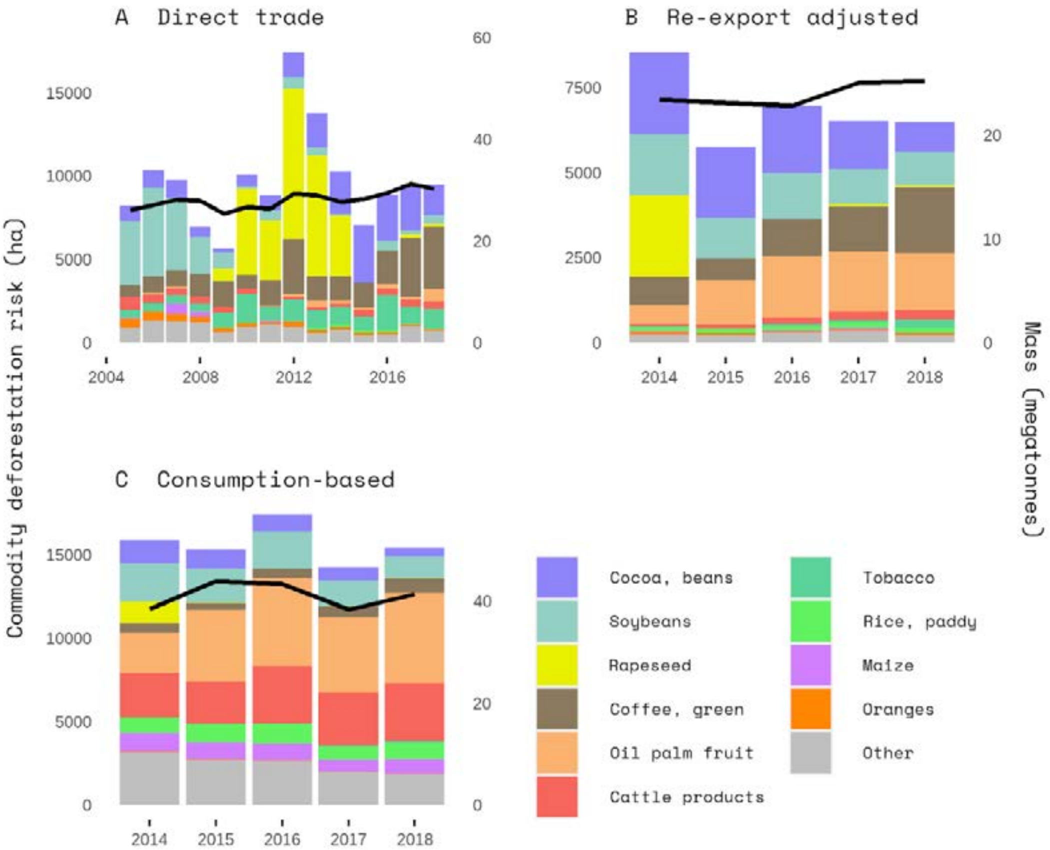

Figure 1: Commodity deforestation risk over time by primary (harvested) commodity, from three supply chain perspectives: direct trade (A), re-export-adjusted trade (B) and a consumption-based approach (C). Results are shown for the top ten commodities across the three perspectives in terms of deforestation risk[7], with all other commodities 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 38.3% of the traded volume in (B) and 25.6% in (C) were of unknown origin and therefore could not be linked to deforestation risk.

7. For this, and all equivalent figures in the report, this is the top commodities (or countries) in terms of total deforestation risk when totals are summed across all three perspectives.

Figure 2 provides the same commodity deforestation risk profile for Belgium but now broken down into source countries. This illustrates quite different contributions of source countries to Belgium's overall deforestation risk across the three supply chain perspectives. For example, Indonesian deforestation is a significant contributor to the re-export adjusted and consumption-based profiles, but not the direct-trade profile. This is explained by the fact that much of the palm oil material entering Belgium will be traded via other countries before reaching Belgium, and - furthermore - will often be embedded in more highly processed materials not captured by the direct-trade flows. In contrast, the commodity deforestation risk associated with Cote d'Ivoire makes a large contribution overall in Belgium's direct-trade and re-export adjusted profiles, but a much smaller contribution from a consumption-based perspective; this is likely a result of Belgium's role as a net exporter of processed chocolate-based products with the deforestation risk then embedded in the supply chains of other countries downstream. The increasing role of deforestation linked to Colombia is apparent across all three perspectives.

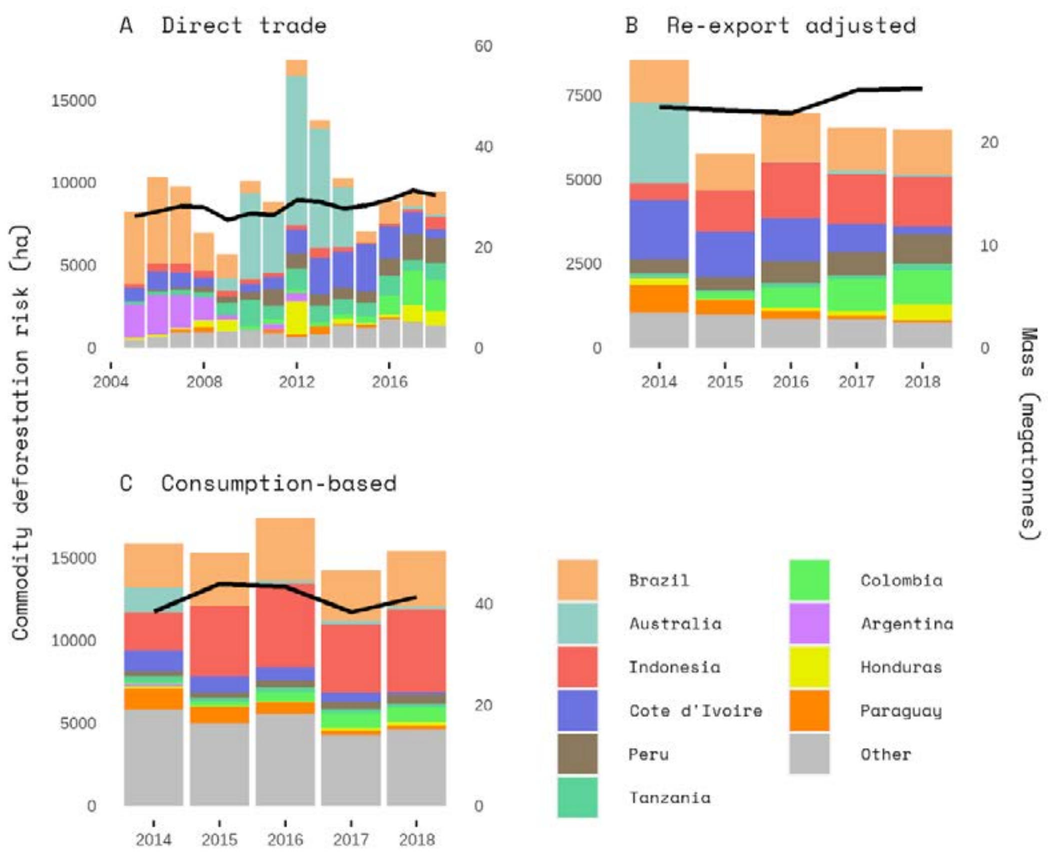

Figure 2: Commodity deforestation risk over time by country of production, summed across all commodities from three supply chain perspectives: direct trade (A), re-export-adjusted trade (B) and a consumption-based approach (C). Results are shown for the top ten countries across the three perspectives 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 36.2% of the traded volume in (B) and 23.6% in (C) were of unknown origin and therefore could not be linked to deforestation risk.

The deforestation associated with Belgium’s overall consumption[8] between 2014 and 2018 (78,200 ha) ranks as the third-smallest (seventh of nine) of the signatory countries to the Amsterdam Declarations Partnership (ADP), with Germany (241,900 ha), France (201,700 ha) and Italy (168,400 ha) in first, second and third place, respectively (Figure 3, Panel A). However, this risk is dwarfed by the deforestation associated with China’s consumption (1,209,000 ha; China is included alongside ADP countries as a comparator given its important role in global deforestation-risk supply chains). Belgium also ranks third-smallest in terms of its deforestation risk compared to other ADP countries from both a direct trade perspective and from a re-export adjusted perspective, ranking below France and the United Kingdom, but above Denmark and Norway, in both perspectives.

Taking into account the quantities of commodities being traded (i.e. considering hectares of deforestation risk per tonne traded, or deforestation risk intensity) reveals that, in contrast to some other countries, Belgium has a relatively consistent risk intensity across all three perspectives (but slightly higher for the consumption perspective), which sits somewhat in the middle of other ADP countries (Figure 3, Panel B). For example, the risk intensity for Belgium is lower than that of the Netherlands for all perspectives, but slightly higher than that of Denmark. Whilst China has the highest risk intensity overall from a direct trade perspective, in the re-export and consumption-based analyses the deforestation risk per tonne was lower for China than for each of the ADP signatory countries, including Belgium.

8. Comparable figures for individual commodities are available as Figures A10-14 in Annex 1.

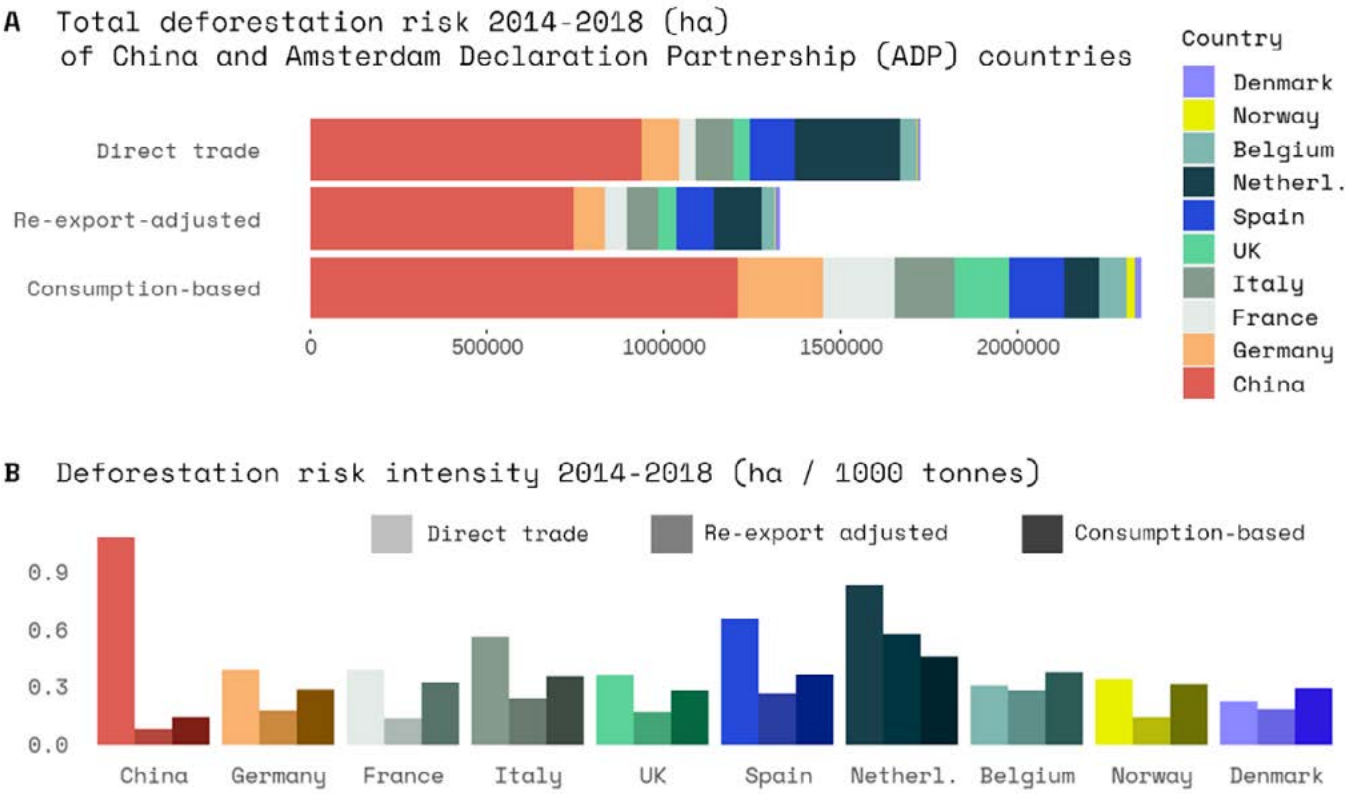

Figure 3: Total commodity deforestation risk (A) and intensity (B) associated with Belgium's agricultural supply chains, along with those of the other ADP signatory countries and China, for the period 2014-2018. Results are shown for all three perspectives (direct trade, re-export-adjusted trade, and consumption-based). Countries are arranged in descending order according to their overall consumption-based commodity deforestation risk.

Commodity-specific deforestation results

Soybean

National scale results

Belgium imports of soy products, or soy production linked to Belgium consumption depending on the supply chain perspective chosen, are associated with 1,430 - 5,030 hectares of deforestation for the period 2016-2018. Soy deforestation risk is significantly higher from a consumption-based perspective (5,030 ha) than from a direct trade (1,430 ha) or re-export-adjusted perspective (3,370 ha). The majority of this risk comes from Brazil in the most recent years (direct trade; DT: 97%, re-export adjusted; RE: 90%, consumption based; CB: 79%), although for re-export and consumption perspectives, Paraguay is an additional important source in the 2016-2018 period (DT: 0%, RE: 9%, CB: 15%) (Figure 4).

Timeseries data reveal a generally decreasing trend in soy deforestation risk from all three perspectives, with direct trade risk in 2018 down 85% from 2005 (Figure 4). The importance of Paraguay in particular has declined in recent years; in the consumption-based profile it accounts for 36% of Belgium's total soy deforestation risk in 2014, down to 10% in 2018. From a consumption-based perspective, this decline in deforestation over the 2014 - 2018 period is explained by a drop in deforestation intensity of soy produced in Paraguay (-82%), as the quantity sourced has decreased only moderately (-14%). From a direct trade perspective, the quantity of soy sourced from Brazil, as well as the associated deforestation and deforestation intensity, have all declined from their peaks in the 2000s. However, trade volume increases notably from 2015 - 2018. Argentina is also an important historical source of risk (captured in the earlier years of the direct-trade timeseries), but risk is not present to a notable extent in recent years across any perspective. Relatively low deforestation intensities since 2010 (rather than a lack of trade) have seen Argentina's contribution to Belgium's total soy deforestation risk diminish in recent years.

Figure 4: 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 10.3% of the traded volume in (B) and 8.8% in (C) were of unknown origin and therefore could not be linked to deforestation risk.

Soy deforestation risk at the subnational level

For Brazil, data for the three most recent available years (2016-2018) reveal that soy deforestation linked to Belgium's imports is concentrated in the Matopiba and Mato Grosso regions, from both a direct trade and re-export-adjusted perspective (Figure 5). The three municipalities with the greatest deforestation risk from a direct trade perspective (Formosa do Rio Preto - 26 ha, Barreiras - 21ha, and Diamantino - 13.5 ha) collectively account for 78.3% of the total soy deforestation risk imported to Belgium from Brazil. After re-export adjustment, the top three (now Formoso do Rio Preto - 125 ha, Niquelandia - 51 ha and Rosario Oeste - 31 ha) collectively account for 78.6% of Belgium's total deforestation risk from Brazilian soy. In general, however, the re-export-adjusted results show a more distributed pattern of risk, with overall risk also being higher than from a direct-trade perspective.

Time-series information from the direct-trade perspective (Annex 1; Figure A2) reveals that deforestation risk has fallen dramatically from historic highs. In 2006, Brazil soy deforestation linked to Belgium via direct trade was associated with 2,910 ha compared to 112 ha in 2018. In the direct trade perspective, the downward trend in deforestation can be explained by a decrease in both deforestation intensity and the quantity of soy sourced directly from Brazil. Historically, key state-level sources of risk have included Mato Grosso, especially when deforestation risk is high early in the timeseries; from 2006 to 2009, Mato Grosso is responsible for 51% of Belgium's directly imported risk, with Maranhao (17%) and Bahia (16%) also important. More recently, directly imported risk is much lower, but Mato Grosso and Bahia remain key sources of deforestation risk, accounting for 42% and 43%, respectively, of Belgium's imported risk from 2016 to 2018. From a re-export adjusted perspective, risk is fairly stable over the available timeseries, with 181ha in 2014 falling slightly to 152ha in 2018. In 2014 and 2015, Tocantins is an important source (41%) of indirectly imported risk, but in the most recent three years (2016-2018), Bahia (32%) and Mato Grosso (27%) are most important. See Annex 1 for state-level figures, and for the traders associated with Belgium's direct-trade soy deforestation risk from Brazil.

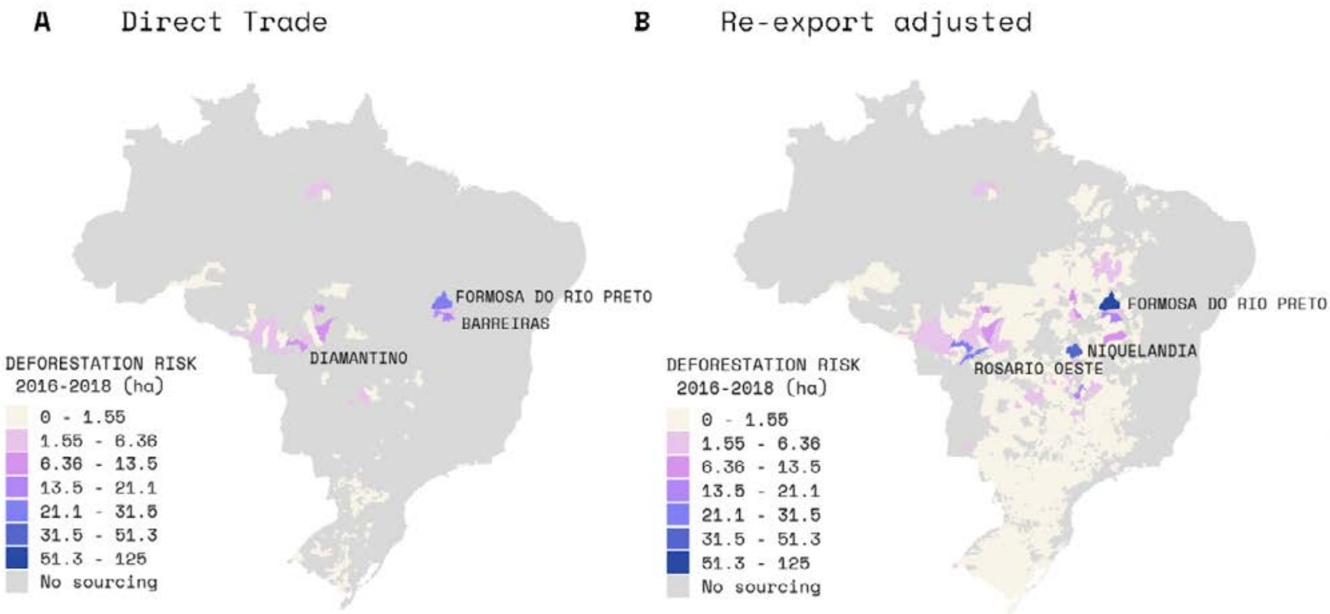

Figure 5: Subnational patterns of soy deforestation risk in Brazil associated with Belgium's imports, summed over the period 2016-2018 (the most recent three years with Trase data). Results are shown from a direct trade (A) and re-export-adjusted (B) perspective.

Very little direct-trade occurs between Paraguay and Belgium according to Trase data, with just 1,727 tonnes in 2019 (associated with <2 ha of deforestation risk) and none in previous years in the timeseries. However, from a re-export adjusted perspective, Figure 6 reveals that 47.7ha of soy deforestation risk are linked to Belgium between 2016 and 2018, which is mainly concentrated in San Pedro (25ha), Caaguazu (7.8ha) and Amambay (5.3ha); 80.9% of the total soy risk is from these three departments. Time-series information for the most recent five years from the re-export adjusted trade perspective (Annex 1, Figure A3) reveals a decreasing trend. In 2014, Paraguay soy deforestation linked to Belgium via re-export adjusted trade is associated with 114 ha compared to 15.4 ha in 2018.

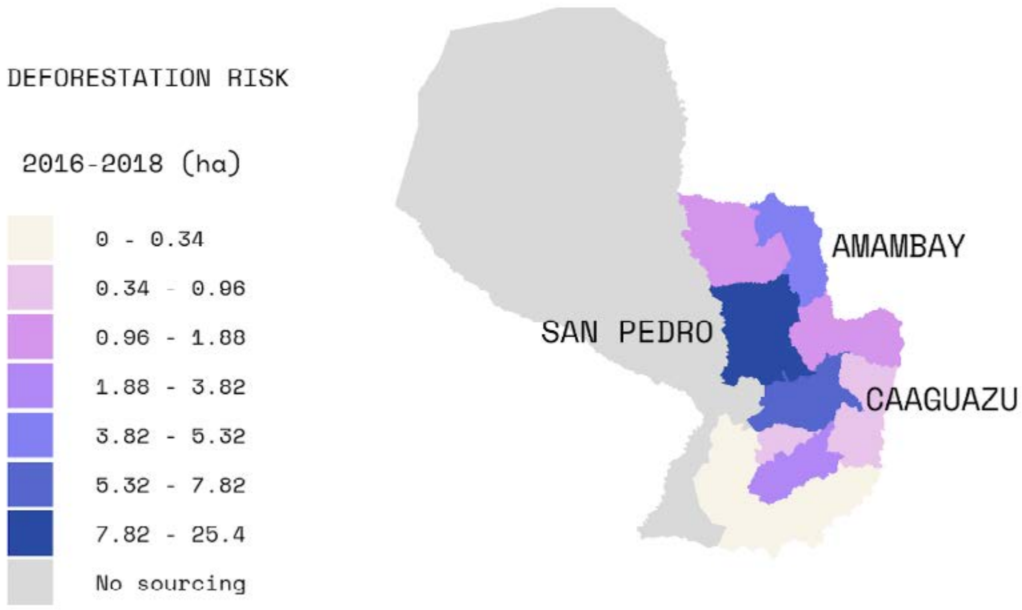

Figure 6: Subnational patterns of soy deforestation risk in Paraguay associated with Belgium's imports, summed over the period 2016-2018. Results are shown from a re-export-adjusted perspective.

Given technical uncertainties in the Argentinian soy data, results are provided here at province rather than department level (Figure 7). From 2016 to 2018, deforestation linked to soy directly imported into Belgium from Argentina (66.5 ha in total) is concentrated in Santiago Del Estero (42 ha), Chaco (14 ha), and Salta (4 ha); 90% of the total soy risk is from these three provinces. The same three provinces are also most important from a re-export perspective (91.9% of risk combined; Santiago Del Estero: 32 ha, Chaco: 15 ha, and Salta: 3 ha) which demonstrates a similar (slightly lower) soy deforestation risk overall at 54.9 ha. Time-series information for the most recent three years from the re-export adjusted trade perspective (Annex 1, Figure A4) reveals a decreasing trend, with the significant drop between 2016 and 2017 mainly due to a large fall in risk from Santiago Del Estero. Annex 1, Figure A7 reveals the traders associated with Belgium's direct-trade soy deforestation risk from Argentina.

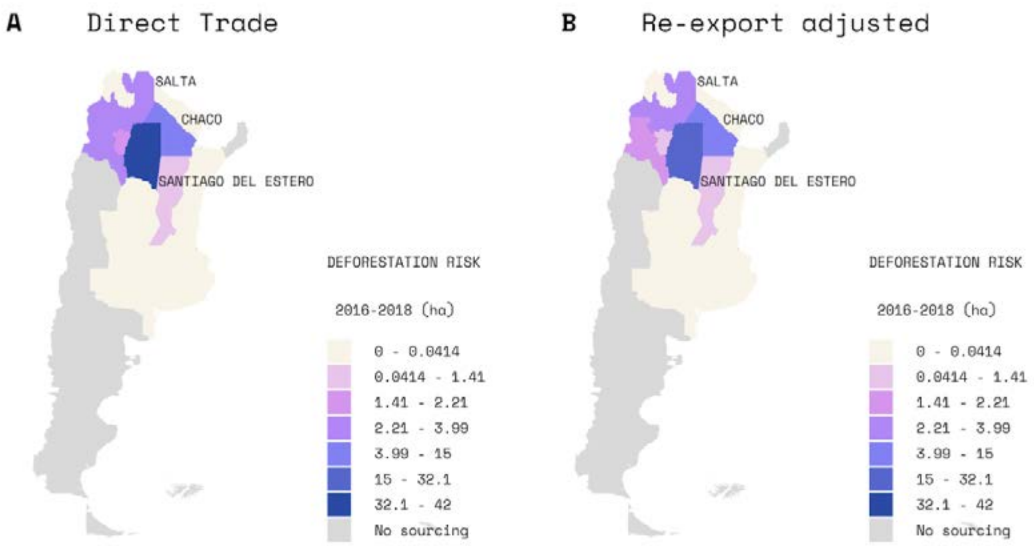

Figure 7: Subnational patterns of soy deforestation risk in Argentina associated with Belgium's imports, summed over the period 2016-2018 (the most recent three years with Trase data). Results are shown from a direct trade (A) and re-export-adjusted (B) perspective.

Palm oil

National scale results

Belgium's imports of palm oil products, or production linked to Belgian consumption depending on the supply chain perspective chosen, are associated with 1.12k - 15.2k hectares of deforestation for the period 2016-2018. Palm oil deforestation risk is significantly higher from a consumption-based perspective (15.2k ha) than from a re-export adjusted perspective (5.25k ha), which is higher again than that from a direct trade perspective (1.12k ha). The majority of this risk comes from Indonesia in the most recent years (DT: 61%, RE: 83%, CB: 87% across perspectives between 2016 and 2018), although Malaysia, Colombia and Papua New Guinea are also important sources (Figure 8).

The timeseries data reveal a generally increasing trend in palm deforestation risk from all three perspectives, with direct trade risk at 712 ha in 2018 at its highest level since 2005 (Figure 8). The re-export adjusted timeseries also indicates an increase overall (although deforestation risk peaks at 1,810 ha in 2016). Deforestation risk from the consumption-based perspective peaks at 5,390 ha in 2018. These increases are linked to an increasing risk from Indonesia, and additionally (whilst with smaller contribution) in Colombia. From a consumption based perspective, the increase in Indonesian deforestation risk from 2014 - 2018 is driven by both increases in deforestation intensity and the quantity of palm oil sourced from Indonesia. The increase in Colombian deforestation risk from 2014 - 2018 is mostly driven by a significant increase in deforestation intensity of palm oil sourced from Colombia.

Figure 8: 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). 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 38.9% of the traded volume in (B) and 16.1% in (C) were of unknown origin and therefore could not be linked to deforestation risk.

Palm oil deforestation risk at the subnational level

For the three most recent years with available Trase data (2018-2020), Belgium's direct imports of palm oil from Indonesia are linked to relatively small amounts of deforestation (245ha in total), concentrated in central Sumatra and West Kalimantan (Figure 9). The kabupaten contributing the largest amount of risk to Belgium is Kubu Raya (23ha), closely followed by Indragiri Hulu (22ha) and Rokan Hulu (19ha). The top three kabupaten account for 25.9% of Belgium's directly imported risk, indicating that this risk is quite broadly distributed. Adjusting Trase's trade records to account for re-exports reveals that indirect trade pathways expose Belgium to greater amounts of Indonesian palm oil deforestation: 503ha over the same three-year period. The three largest contributing kabupatens are Ketapang (61.6ha), Indragiri Hulu (29.2ha) and Berau (26.8ha), together making up 23.4% of Belgium's deforestation risk exposure.

After adjusting for re-exports, the distribution of deforestation risk is broadly similar to that from direct trade, although there is greater risk from East Kalimantan (where Berau is located).

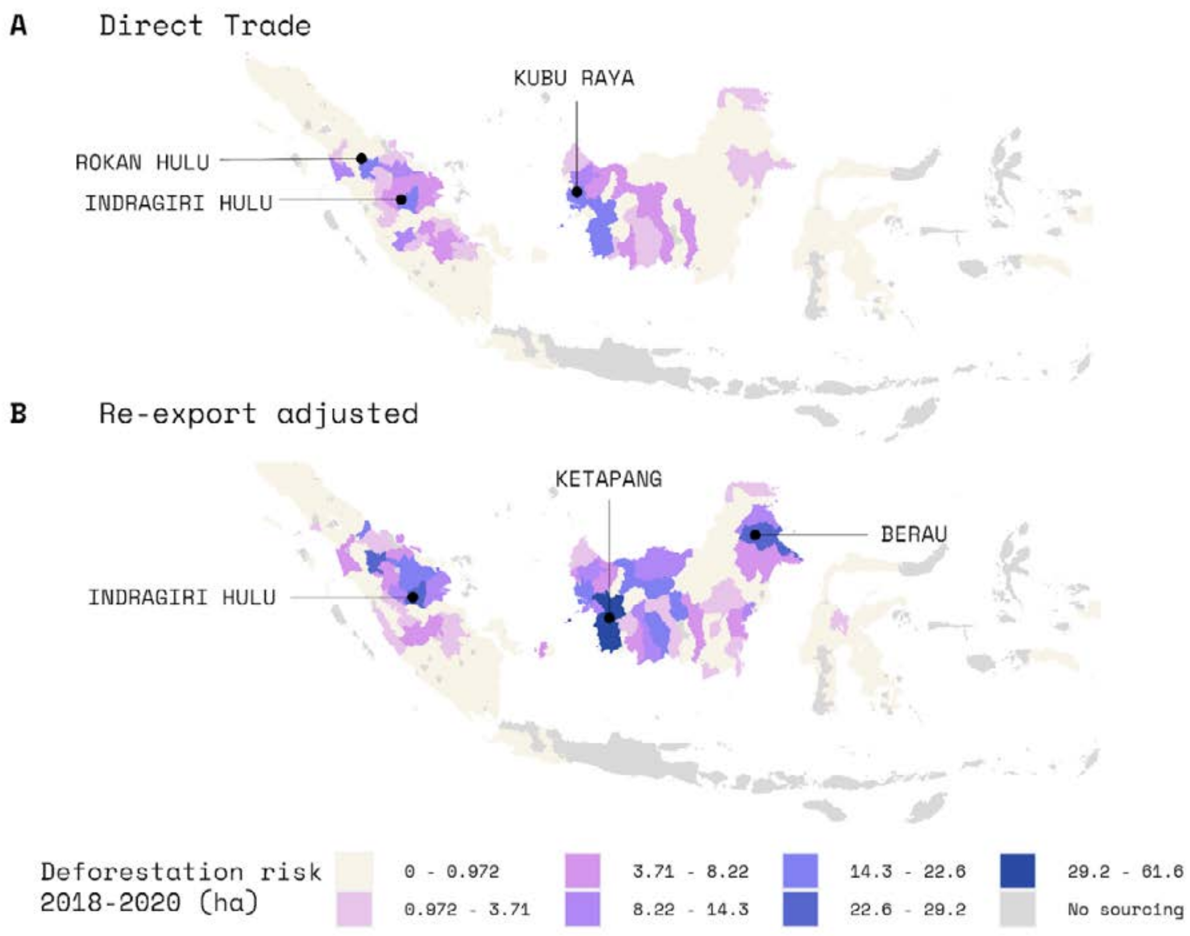

Figure 9: Palm oil deforestation risk associated with Belgium's imports from Indonesia in 2018-2020. Results are shown from a direct trade (A) and re-export-adjusted trade perspective (B). The three kabupaten with the greatest deforestation risk for Belgian imports are labelled in each case.

Cattle

National scale results

Belgium's imports of cattle products, or production linked to Belgian consumption depending on the supply chain perspective chosen, are associated with 689 to 10.1k hectares of deforestation for the period 2016-2018. Cattle deforestation risk is significantly higher from a consumption-based perspective (10.1k ha) than from a direct trade perspective (1.32k ha), but estimates for re-export adjusted trade are lower again (689 ha). From the direct and re-export adjusted trade perspectives, almost all risk originates from Brazil (97% and 92% respectively, for the period 2016-2018). However, from a consumption-based perspective Brazil represents less than half (39% 2016-2018) of the risk, with countries such as Angola, Mozambique, Paraguay and Australia making the main contributions to the remainder (Figure 10).

The timeseries data for direct-trade indicates that deforestation risk from this perspective has decreased from historic highs (2018 risk is 35% lower than in 2005), however all three perspectives reveal an increasing trend in cattle deforestation risk in recent years (Figure 10). These increases are particularly driven by an increasing risk from Brazil, explained by an increase in deforestation intensity over the period 2014 - 2018.

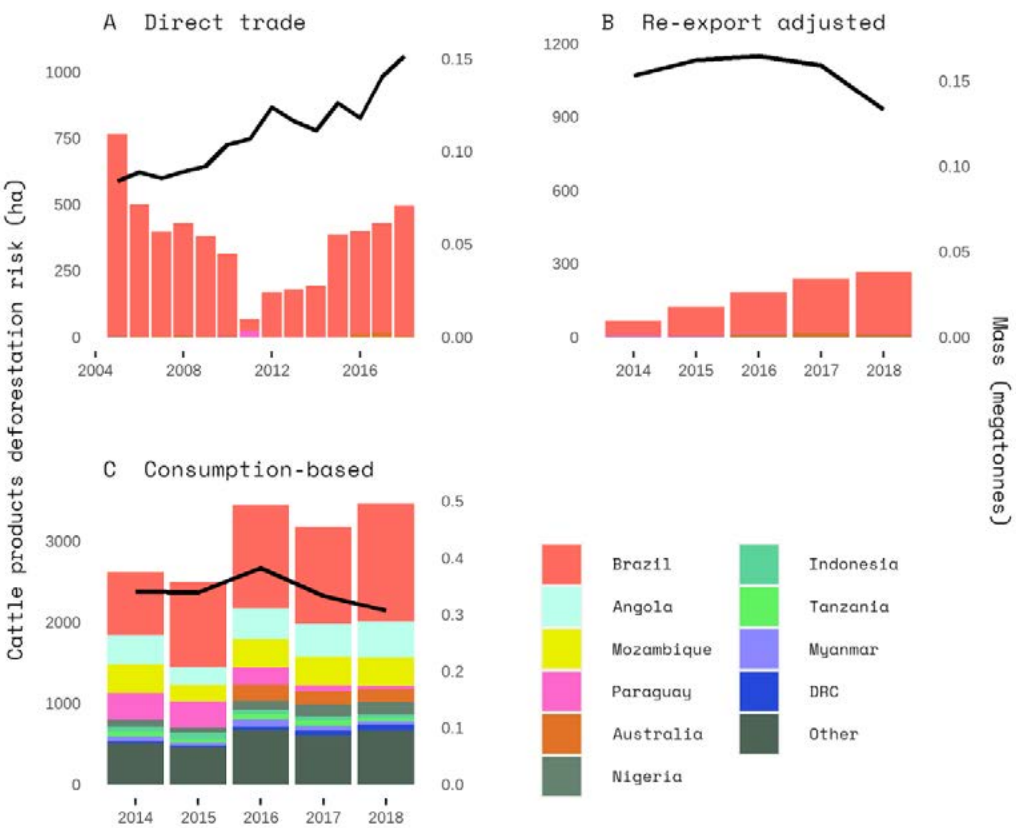

Figure 10: Cattle product deforestation risk over time by source country, from three supply chain perspectives: direct trade (A), re-export-adjusted trade (B) and a consumption-based approach (C). Results are shown for the top ten countries across the three perspectives in terms of deforestation risk, 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 2.2% of the traded volume in (B) and 7.9% in (C) were of unknown origin and therefore could not be linked to deforestation risk.

Cattle deforestation risk at the subnational level

There is minimal direct beef trade between Paraguay and Belgium (17 tonnes only in 2019), therefore results are only included for Brazil[9]. For Brazil, data for the three most recent available years (2015-2017) reveal that the three municipalities with the greatest deforestation risk from a direct trade perspective (Alto Araguaia - 26.7 ha, Tupiratins - 21.0 ha, Sao Felix Do Araguaia - 13.7 ha) account for 18.7% of the total cattle deforestation risk imported to Belgium from Brazil (Figure 11). In contrast to soy, the distribution of cattle deforestation risk linked to Belgium from Brazil is more geographically distributed.

9. Re-export adjusted Trase data are also not currently available for cattle products.

At the state level, the greatest source of risk from 2015-2017 is Mato Grosso (31.2% of the cattle deforestation risk directly imported by Belgium), followed by Mato Grosso do Sul (15.3%) and Goias (11.6%). Over the three year period, deforestation risk declines by 30%, from 192ha to 134 ha, although the relative contribution of different states remains fairly constant (Annex 1, Figure A5). Annex 1, Figure A8 reveals the traders associated with Belgium's direct-trade cattle deforestation risk from Brazil.

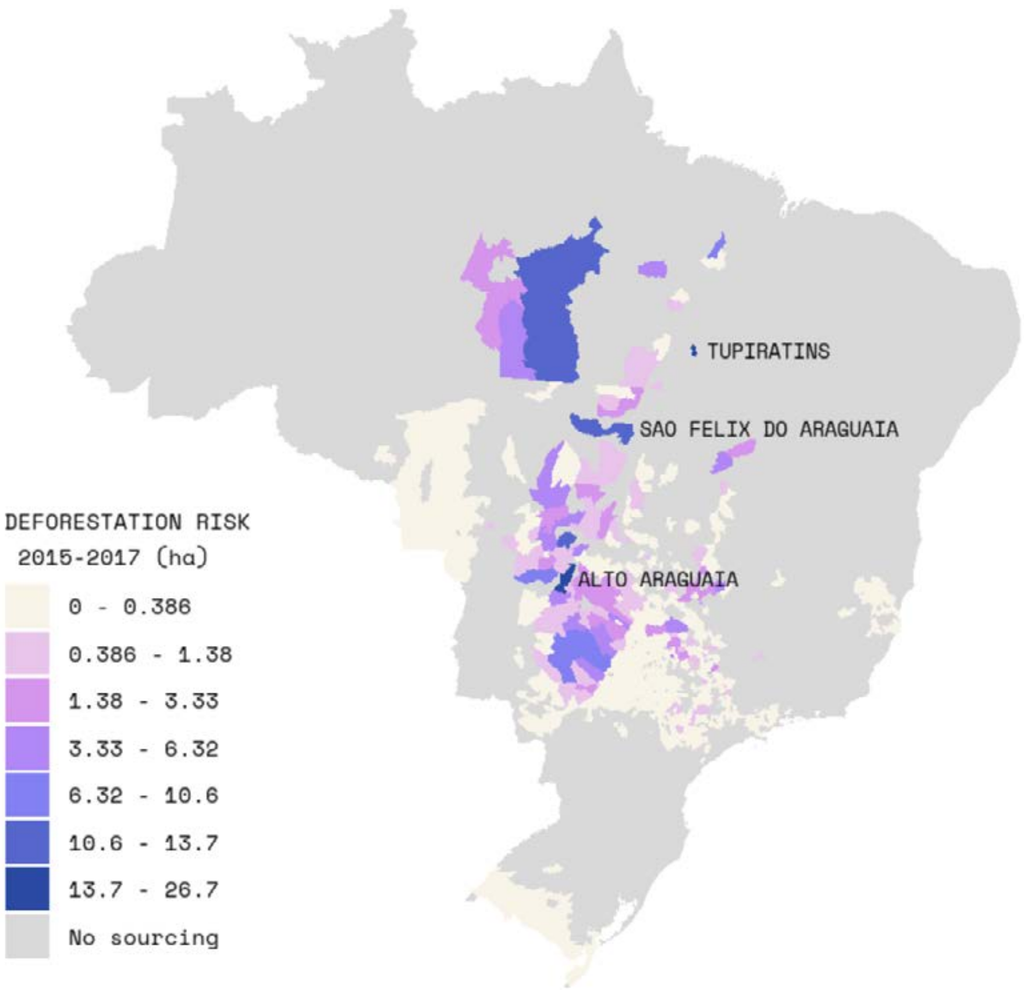

Figure 11: Municipality-level cattle deforestation risk from direct Brazilian exports to Belgium (2015-2017).

Cocoa

Belgium's imports of cocoa products, or production linked to Belgian consumption depending on the supply chain perspective chosen, is associated with 2.27k - 7.30k hectares of deforestation for the period 2016-2018 (Figure 12). Cocoa deforestation risk is significantly higher from a direct-trade perspective (7.30k ha) than from a re-export adjusted trade perspective (4.28k ha), with estimates for the consumption-based perspective lower again (2.27k ha), since Belgium is a major exporter of cocoa-derived products.

Across all three perspectives, risk is distributed across several countries, including Cote d'Ivoire, Peru, Ecuador, Liberia and others. Historically, Cote d'Ivoire is the largest single source of risk, for example contributing more than 50% (CB: 58%, RE: 61%: DT: 72%) of the total risk at the start of each timeseries, but in recent years cocoa deforestation risk from Peru increases in importance and is the largest single source of risk from all three perspectives in 2018 (with CB: 164 ha and 34%, RE: 343 ha and 39%, DT: 701 ha and 40%).

The timeseries data for direct-trade indicates that deforestation risk from this perspective increases overall (2018 risk is 90% higher than in 2005), however all three perspectives reveal a decreasing trend in cocoa deforestation risk in the most recent years, particularly due to decreases in risk associated with Cote d'Ivoire and Liberia. From a consumption-based perspective, these decreases are driven by decreases in deforestation intensity and small decreases in the quantity of cocoa sourced from both nations.

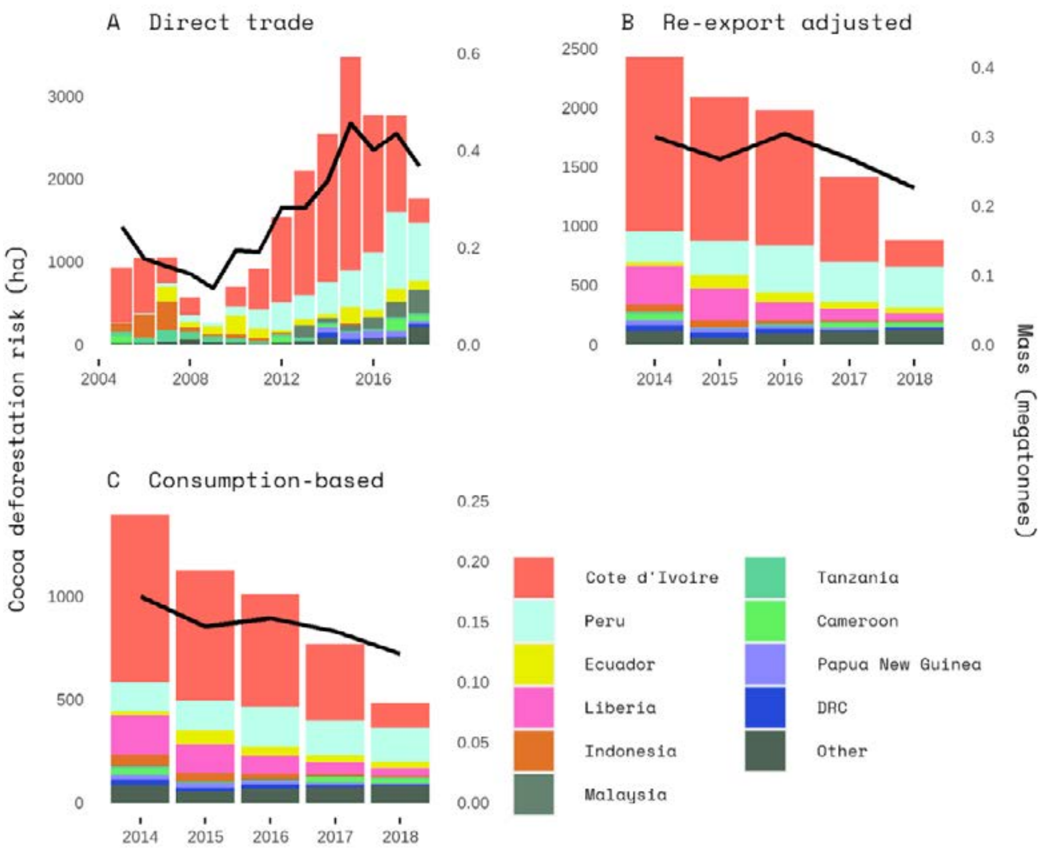

Figure 12: Cocoa deforestation risk over time by source country, from three supply chain perspectives: direct trade (A), re-export-adjusted trade (B) and a consumption-based approach (C). Results are shown for the top five countries across the three perspectives in terms of deforestation risk, with all 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 24.7% of the traded volume in (B) and 23.1% in (C) were of unknown origin and therefore could not be linked to deforestation risk.

Coffee

Belgium's imports of coffee products, or production linked to Belgian consumption depending on the supply chain perspective chosen, is associated with 2.1k - 9.31k hectares of deforestation for the period 2016-2018 (Figure 13). Coffee deforestation risk is significantly higher from a direct-trade perspective (9.31k ha) than from a re-export adjusted trade perspective (4.35k ha), with estimates for the consumption-based perspective lower again (2.10k ha).

Across all three perspectives, risk is distributed across several countries, but is particularly concentrated in Colombia, Peru, and Honduras. Historically, Honduras and Peru are the largest single sources of risk, but in recent years coffee deforestation risk from Colombia increases in importance and is the largest single source of risk from all three perspectives in 2018 (with CB: 351 ha and 40%, RE: 795 ha and 41%, DT: 1560 ha and 42%). The timeseries data for all three perspectives reveal an increasing trend in coffee deforestation risk driven by increases across the three major sources of risk. The consumption-based perspective indicates that whilst the sourced quantity of coffee from Colombia drops slightly over 2014 - 2018, there is a large increase in deforestation intensity, which drove the increase in deforestation risk. The sourcing volume from Honduras from 2017 - 2018 increases significantly, driving increased deforestation risk. Deforestation risk from Peru is driven by an increase in intensity over 2015-2018, whilst volumes remained similar.

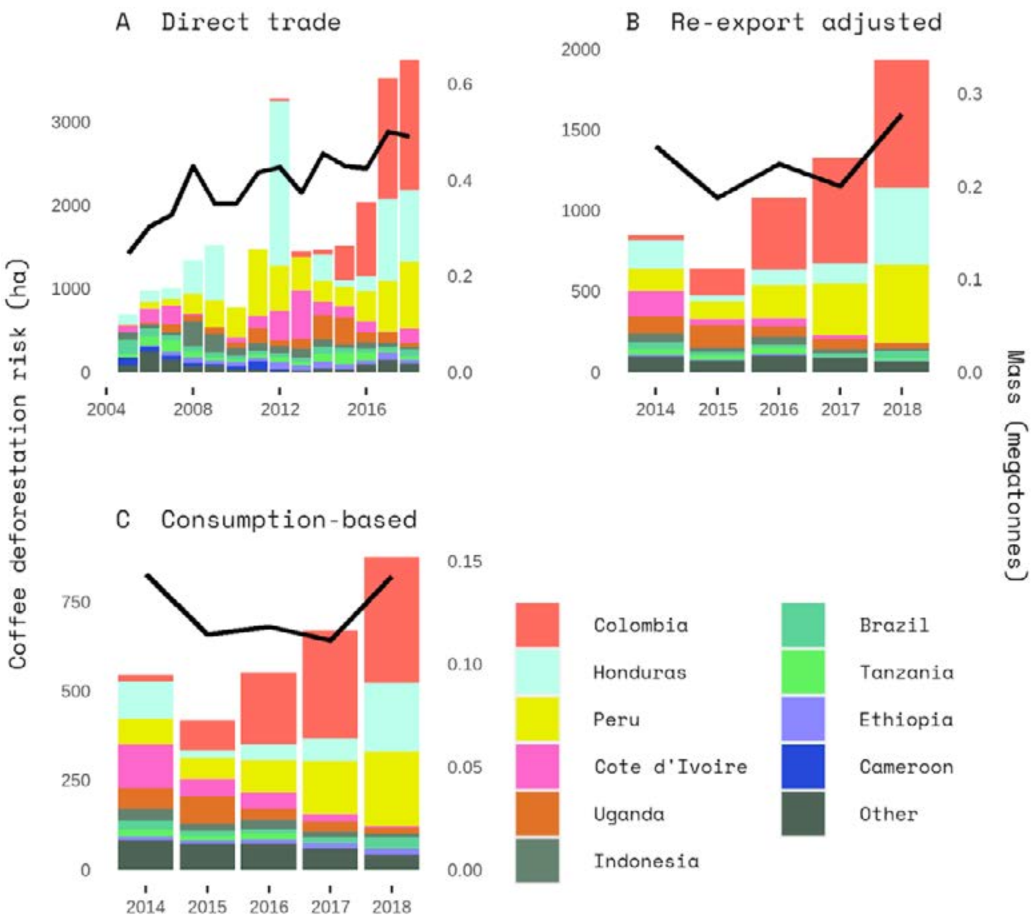

Figure 13: Coffee deforestation risk over time by source country, from three supply chain perspectives: direct trade (A), re-export-adjusted trade (B) and a consumption-based approach (C). Results are shown for the top five countries across the three perspectives in terms of deforestation risk, with 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 10.5% of the traded volume in (B) and 11.3% in (C) were of unknown origin and therefore could not be linked to deforestation risk.

Biodiversity results

Exposure of Belgium to biodiversity risk is increasing over time from a direct trade perspective (highest in 2017 at 2,240 million species hectares, up 58% from 1,430 million species hectares at the start of the timeseries in 2005; Figure 14). From re-export and consumption-based perspectives, biodiversity risk remains relatively stable over time, noting that the timeseries for these two perspectives is shorter. Risk appears highest from the consumption-based and direct trade perspectives (6,863 and 6,420 million species hectares, respectively, between 2016-2018, the three most recent years with available data), and lower from a re-export adjusted perspective (3,470 million species hectares).

Biodiversity risk is spread amongst several commodities, with the most important commodities varying between perspectives (Figure 14). It is important to note that cattle products are not included within the biodiversity results. For direct trade, coffee, rapeseed and cocoa are associated with the highest number of species-hectares across the timeseries, whilst for re-exports, cocoa ranks highest, followed by rapeseed and soybeans. The risk profile is different from a consumption-based perspective, with rice, wheat and soy associated with the greatest risk. The longer timeseries of the direct trade perspective reveals that the cocoa and rapeseed biodiversity risk increases over time (up 44% and 330%, respectively, from 2005 to 2018). Additionally, in contrast with the trends observed for the deforestation data, there is no noticeable decrease in cocoa risk in recent years.

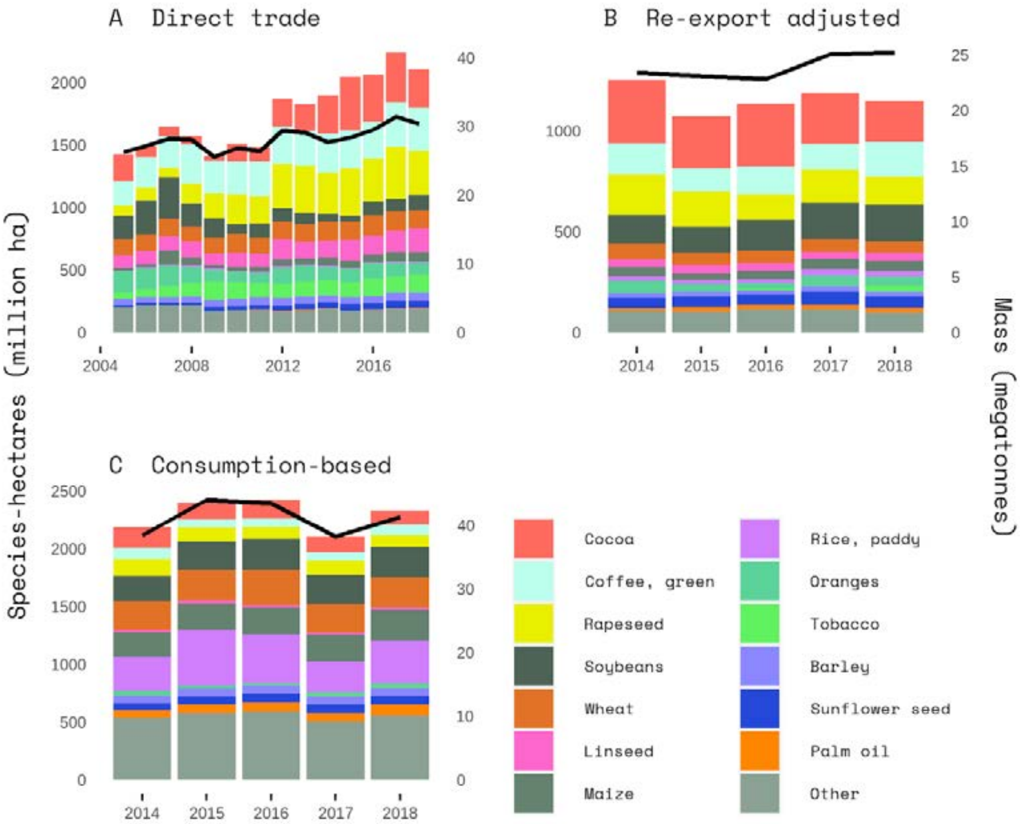

Figure 14: Commodity-linked biodiversity risk over time by primary (harvested) commodity, from three supply chain perspectives: direct trade (A), re-export-adjusted trade (B) and a consumption-based approach (C). Results are shown for the top ten commodities across the three perspectives in terms of biodiversity risk (measured in species-weighted extent of crop production; 'species-hectares'), with all other commodities grouped in the 'other' category. The total trade volume/production linked to consumption (mass of raw material equivalents across all country sources) is also shown by the black line and right-hand axis. Note that 36.2% of the traded volume in (B) and 23.6% in (C) were of unknown origin and therefore could not be linked to biodiversity risk.

This biodiversity risk originates from a broader suite of countries than for deforestation risk, especially from a consumption-based perspective (Figure 15)[10]. From a direct trade perspective, Brazil, France and Cote d'Ivoire are the greatest sources of risk, together accounting for 36% of the total species hectares linked to Belgian imports. After re-export adjustment, Australia replaces France in the top three source countries, which together make up 34% of the total impact. For the consumption-based results, the risk in Brazil is noticeably larger than in other countries, with India and Ukraine in second and third place, respectively. Over time, the direct trade perspective shows an increasing number of species-hectares linked to Belgian imports from Cote d'Ivoire (up 145% between 2005 and 2018), while Australia also appears more significant from 2012 onward. The risk associated with Canada appears lower later in the timeseries. Commodities produced in Belgium account for 0.9% (105 million) of the total species hectares linked to Belgian consumption.

10. It is important to note that the indicator for biodiversity is global, whereas the deforestation indicator covers tropical and subtropical deforestation only.

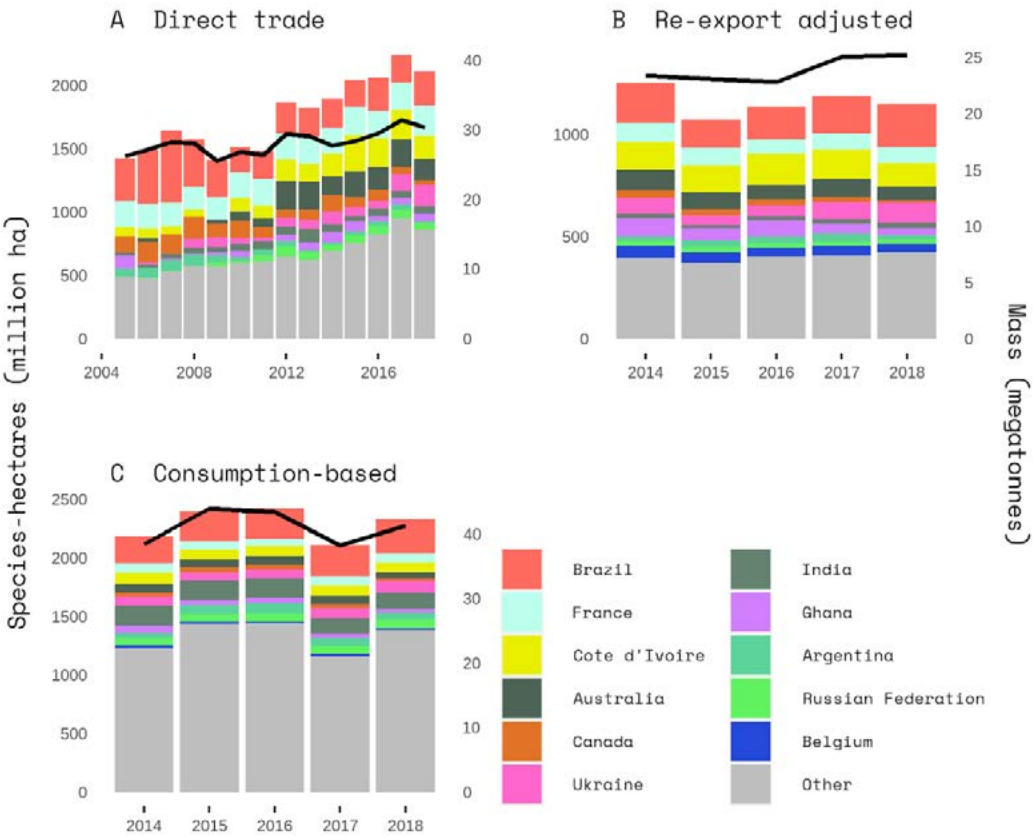

Figure 15: Commodity-linked biodiversity risk over time by country of production, summed across all commodities from three supply chain perspectives: direct trade (A), re-export-adjusted trade (B) and a consumption-based approach (C). Results are shown for the top ten countries across the three perspectives in terms of biodiversity risk (measured in species-weighted extent of crop production; 'species-hectares'), 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) is also shown by the black line and right-hand axis. Note that 36.2% of the traded volume in (B) and 23.6% in (C) were of unknown origin and therefore could not be linked to biodiversity risk.

Turning to the Trase derived subnational data, for Brazilian soy (Figure 16) from a Belgian direct-trade perspective, the top three municipalities (Chapado do Ceu - 11.1m sp ha, Guarapuava - 8.95m sp ha, Diamantino - 6.81m sp ha; summed 2016-2018) account for 26.3% of total risk. From a Belgian re-export adjusted perspective, the top three municipalities (Diamantino - 17.1m sp ha, Chapadao do Ceu - 12.2m sp ha, Guarapuava - 11.3m sp ha) account for 17.5% of risk. In addition to the significant broadening of risk hotspots when re-exports are considered, note that hotspots are present in southern Brazil that are not present in deforestation-only results. Additionally, whilst the Matopiba region of Brazil still features as important, the relative prominence of the Mato Grosso area and parts of central Brazil increases in comparison to the deforestation results.

Turning to the Trase derived subnational data, for Brazilian soy (Figure 16) from a Belgian direct-trade perspective, the top three municipalities (Chapado do Ceu - 11.1m sp ha, Guarapuava - 8.95m sp ha, Diamantino - 6.81m sp ha; summed 2016-2018) account for 26.3% of total risk. From a Belgian re-export adjusted perspective, the top three municipalities (Diamantino - 17.1m sp ha, Chapadao do Ceu - 12.2m sp ha, Guarapuava - 11.3m sp ha) account for 17.5% of risk. In addition to the significant broadening of risk hotspots when re-exports are considered, note that hotspots are present in southern Brazil that are not present in deforestation-only results[11]. Additionally, whilst the Matopiba region of Brazil still features as important, the relative prominence of the Mato Grosso area and parts of central Brazil increases in comparison to the deforestation results.

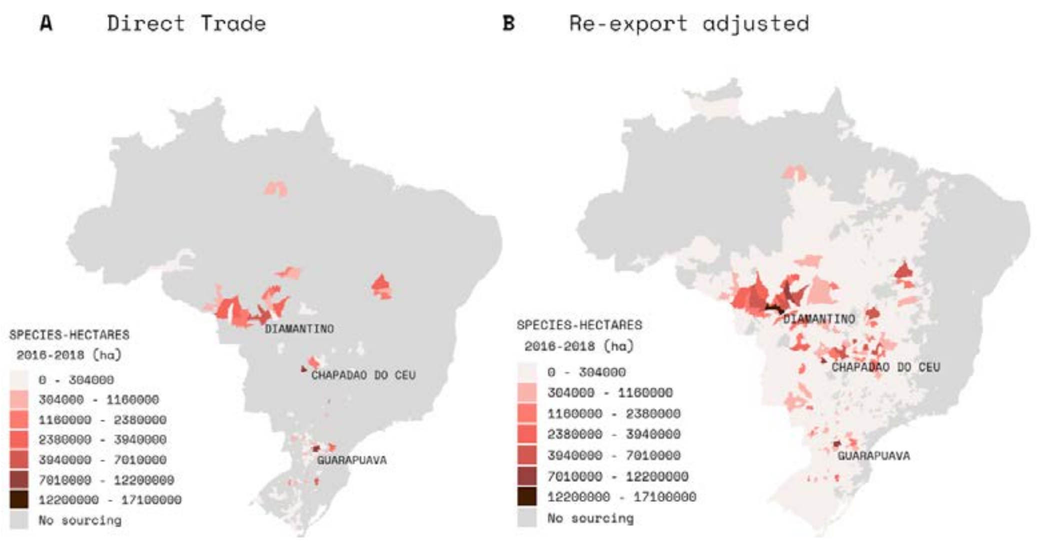

Figure 16: Subnational patterns of soy biodiversity risk in Brazil associated with Belgium's imports, summed over the period 2016-2018 (the most recent three years with Trase data). Results are shown from a direct trade (A) and re-export-adjusted (B) perspective.

For Paraguayan soy (Figure 17) from a Belgian re-export adjusted trade[12] perspective, the top three municipalities (Caaguaza - 959k sp ha, San Pedro - 612k sp ha, Caazapa - 538k sp ha; summed 2016-2018) account for 63% of total risk. Caaguazu is associated with the highest risk whereas for deforestation it is San Pedro. The department of Amambay also appears to be relatively less important from a biodiversity risk perspective, and Caazapa more important.

11. As for national-scale results, the biodiversity data presented here has broader coverage than Trase deforestation data which is biome-specific.

12. No direct trade flows exist for Paraguayan soy to Belgium.

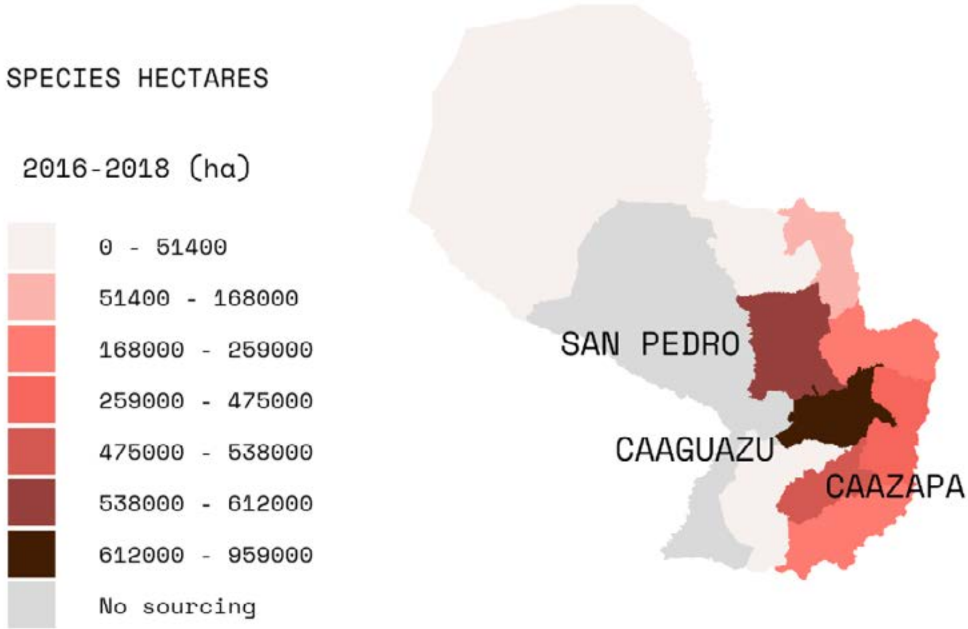

Figure 17: Subnational patterns of soy biodiversity risk in Paraguay associated with Belgium's imports, summed over the period 2016-2018. Results are shown from a re-export-adjusted perspective.

For Argentinian soy (Figure 18) from a Belgian direct-trade perspective, the top three states (Cordoba - 36.8m sp ha, Santiago Del Estero - 18.3m sp ha, Santa Fe - 15.8m sp ha; summed 2016-2018) account for 66.4% of total risk. From a Belgian re-export adjusted perspective the results are similar, with the top three states accounting for 66.7% of the total risk, although the order of the top three changes (Cordoba - 35.8m sp ha, Santa Fe - 16.2m sp ha, Santiago Del Estero - 14.2m sp ha). The distribution of biodiversity risk is more widespread than deforestation risk, given that Trase's deforestation data cover only the Chaco biome.

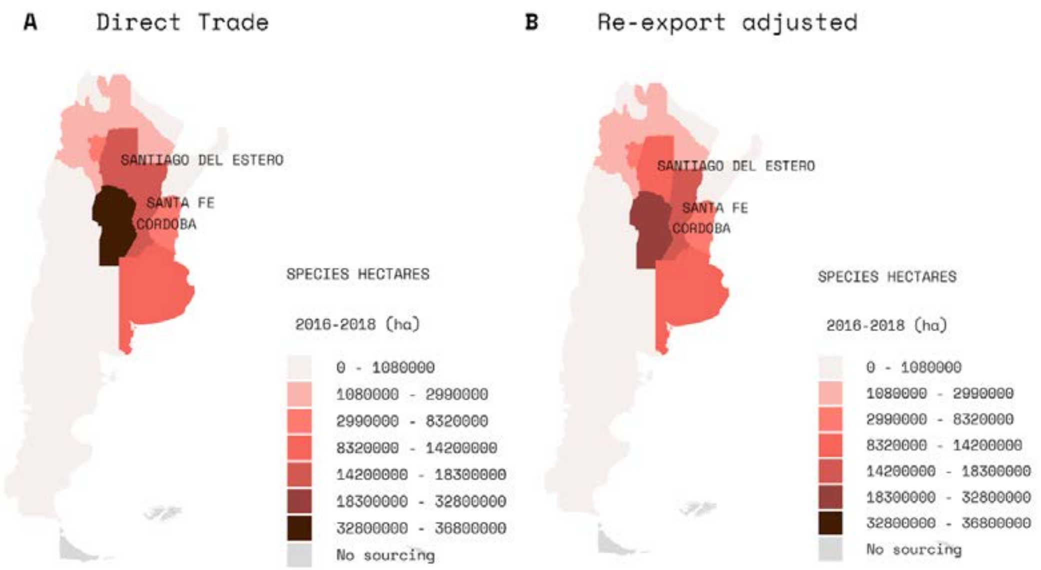

Figure 18: Subnational patterns of soy biodiversity risk in Argentina associated with Belgium's imports, summed over the period 2016-2018 (the most recent three years with Trase data). Results are shown from a direct trade (A) and re-export-adjusted (B) perspective.

For Indonesian palm oil (Figure 19) from a Belgian direct trade perspective, the top three kabupaten for biodiversity risk were in central Sumatra (Musi Banyuasin - 1.85m sp ha, Kampar - 1.72m sp ha, Indragiri Hulu - 1.57m sp ha). Together, these three kabupaten account for 19.5% of the total risk for the years 2018-2020. As with deforestation risk, biodiversity risk is higher after adjusting for re-exports, revealing the importance of indirect trade as a source of risk. From a re-export adjusted trade perspective, the top three kabupaten (Musi Banyuasin - 8.29m sp ha, Banyuasin - 4.88m sp ha, Kampar - 4.82m sp ha; years 2018-2020) account for 26.8% of total risk. For either perspective, these top kabupaten are all within Sumatra, showing that the risk hotspots for biodiversity are different to those for deforestation (where there was more risk from palm oil sourced from Kalimantan). However, at the broader scale, in common with the results for palm oil deforestation risk, biodiversity risk also appears to be widespread across both Sumatra and Kalimantan.

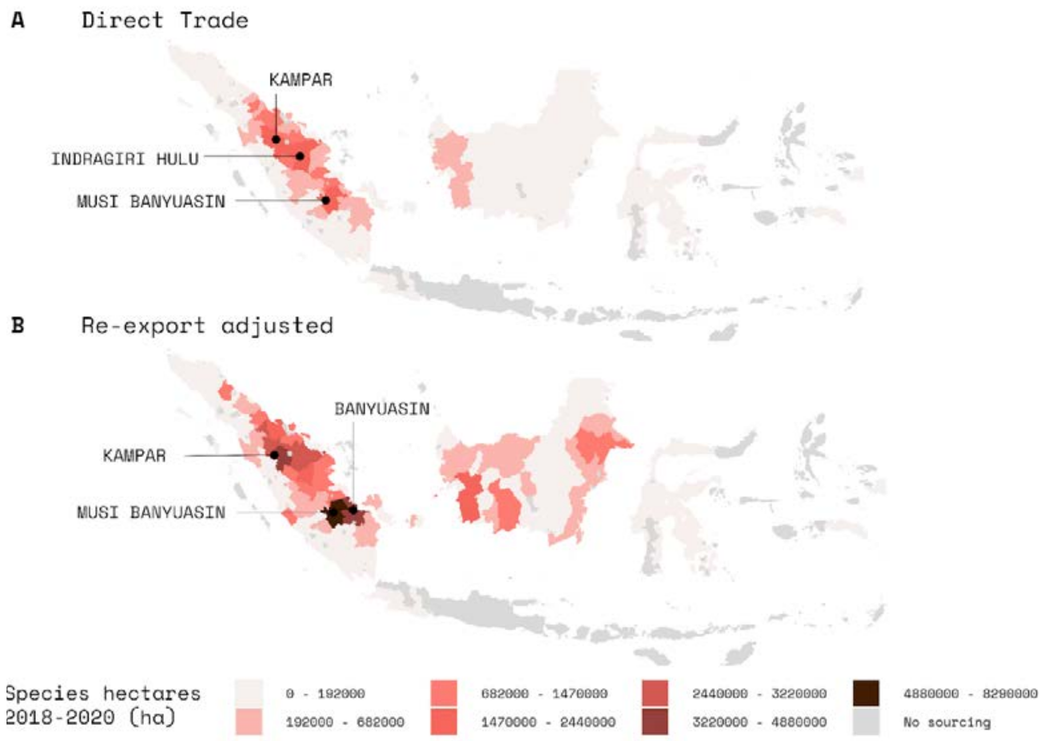

Figure 19: Palm oil biodiversity risk associated with Belgium's imports from Indonesia for the years 2018-2020. Results are shown from a direct trade (A) and re-export adjusted trade (B) perspective.

Discussion

Summary of Belgium's deforestation and biodiversity risk in agricultural supply chains

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

Overall, our results suggest that Belgium's contribution to tropical and subtropical deforestation linked to agricultural commodities remains relatively stable over the periods analysed. This is in contrast with, for example, the equivalent analysis conducted with near-identical methods for Germany, which indicates a generally decreasing trend across all three perspectives. These results suggest that work is required from a Belgian perspective to reduce deforestation risk for direct, indirect and embedded supply chain pathways. Belgium's consumption-based risk results are also significantly higher than its direct or re-export-adjusted risk, illustrating that much of Belgium's link to deforestation is through more complex supply chain pathways. A component of the risk from this consumption-based perspective will be associated with commodities which are directly consumed far upstream in Belgium's supply chain and may not be physically present in the materials ultimately consumed in Belgium, i.e. embedded consumption. The degree to which Belgium 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.

Common across the results and perspectives is the relative importance of particular commodities and source regions. For example, critical soy-producing countries with substantial rates of deforestation are Brazil and Paraguay; for palm oil, Indonesia dominates (although Malaysia and Colombia are also important); and for cattle, Brazil is the key hotspot of concern (with countries such as Angola, Mozambique, Paraguay and Australia emerging in the consumption-based perspective). For cocoa and coffee, the distribution of risk is broader; Côte d'Ivoire, Peru, Ecuador and others are of importance for cocoa, and for coffee Colombia, Peru and Honduras stand out. It is worth noting that, whilst the deforestation risk associated with Belgium overall is significantly lower than that of Germany, these results indicate that the key sources of deforestation across commodities are broadly shared with the German economy (see West et al. (2022) for further details on the German results).

Our analysis shows that Belgium has a significant link to international deforestation, but compared to several other Amsterdam Declaration Countries its risk is lower. Given the potential overlap in the most significant sourcing regions and commodities across the ADP partnership (as indicated in comparison with Germany's data, above), multinational partnerships are likely to play an important role in leveraging influence towards deforestation-free supply chains in Belgium, as will be the EU's incoming proposed regulation on deforestation-free products. 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 complete alignment with the deforestation metrics used in this study, which also only focus on tropical and subtropical regions (whereas the EU regulation will cover all sources). 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.

Whilst there is an absence of an overall increasing or decreasing commodity deforestation risk trend for Belgium, this appears to be as a result of a combination of positive and negative trends at the commodity level balancing out Belgium's overall risk. For example:

- Soy deforestation appears to show a decreasing trend across all three perspectives analysed, which is particularly linked to a decreasing deforestation risk in Paraguay in recent years.

- In contrast, Belgium's deforestation risk associated with palm oil products appears to be increasing across all three perspectives, linked particularly to Indonesian production.

- While overall risk has been reducing for cattle products over the full timeseries from a direct-trade perspective, the most recent years of the timeseries from all three supply chain perspectives suggest that deforestation linked to this commodity is increasing, particularly in those supplies from Brazilian production systems.

- For cocoa, we observe that risk is increasing over the full timeseries from a direct-trade perspective but is decreasing more recently across all three supply chain perspectives, with decreases particularly for Cote d'Ivoire and Liberia.

- For coffee, we see an increasing deforestation-risk trend from all three perspectives, particularly driven by increases in deforestation risk in Colombia, Honduras and Peru which are also the main contributors to coffee deforestation risk overall.

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. These include rapeseed that appears as an important commodity for selected years in all supply chain perspectives (see Annex 1 for an important limitation of the method that may explain this result). Commodities such as tobacco, rice, maize, and oranges also appear (with varying contributions across perspectives) in the top deforestation risk commodities, albeit with a substantially lower risk than the more commonly considered commodities (i.e. soy, palm oil, beef, cocoa, coffee). Given the fact that these commodities appear particularly important within the consumption-based results, the nature of the linkage to the Belgian 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 Belgian 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.

Direct comparison with alternative studies is difficult given differences in the methodologies adopted, but contrasting our results to those of others based on similar data (Annex 2) reveals that there are qualitative similarities in terms of the key commodities identified and their relative importance to the Belgian risk profile. This study - whilst still only constituting a relatively simple assessment of biodiversity risk - also offers a more comprehensive assessment of the discrete nature of Belgium's association with trade-linked biodiversity risks than that conducted by The Rock Group (The Rock Group 2021). In particular, this study helps to identify the source regions for key commodities of concern (something that The Rock Group could not do via its use of direct-trade data alone) and has provided a quantified assessment of biodiversity risk (rather than only a qualitative assessment as per The Rock Group). See Annex 2 for additional details.

Analysis at sub-national level, where Trase data availability allows, illustrates the important role of re-exports in providing a link between Belgium and regions of deforestation (or biodiversity risk). For Paraguayan soy where Trase provides subnational data there are no significant trade activities directly to Belgium. Our re-export adjusted analysis, however, reveals a deforestation risk for Belgium linked to Paraguayan soy. For palm oil, re-export adjusted results indicate a more significant risk associated with Indonesia. Results for both direct trade and re-export adjusted trade at subnational level are available for Brazil soy, which reveals a slight 'broadening' in the geographic spread of risk, which also increases overall when re-exports are accounted for. Equivalent results for Argentina (state level) indicate rather similar patterns of risk from both direct and re-export adjusted perspectives.

Whilst constituting just a simple exploration of the proximity of biodiversity (species richness) to commodity production linked to Belgian trade, our species risk measure indicates that the perception of hotspots of risk may be modified when biodiversity, rather than (tropical and subtropical) deforestation, is considered. Firstly, the biodiversity results indicate a potentially increasing risk over time from the direct-trade perspective (in comparison to no clear upward trend for deforestation). The mass of materials consumed from a direct trade perspective has been increasing and, since the 'species hectare' measure is proportional to the number of hectares under production (which are then weighted by species presence), this trend is likely predominantly explained by this phenomenon. The broader coverage (global rather than biome-specific) of the biodiversity metric means that biodiversity risk can also manifest itself in regions not covered by the deforestation accounts. That said, there are some key commonalities in important commodities and locations of concern. Additional work to improve upon the simple biodiversity metric integrated here, and to explore the additionality of biodiversity metrics alongside deforestation data, is required to fully understand differences in areas of potential concern (see 'Biodiversity options).

Biodiversity metric options

Biodiversity refers to the variety of life - commonly measured at the genetic, species or ecosystem level - and environmental scientists consider its variation, quantity and distribution when identifying areas of particular value or concern (Molotoks et al. 2020). No single metric captures all of the components of biodiversity that we might want to include in an indicator. Many biodiversity indicators are based on habitat loss or vertebrate species richness (Hillebrand et al. 2018), thereby neglecting other aspects, such as species abundance, functional diversity, or genetic diversity (Molotoks et al. 2020).

The biodiversity metric included here is quick and easy to apply, using well-established and widely available data on vertebrate ranges (IUCN Red List and Birdlife International). It is a measure of potential proximity to species, which can serve to highlight areas of high species richness that might be threatened by commodity expansion. However, the method does not take account of species occupancy within their range (so the whole range is treated equally), and it does not, in this form, account for the rarity of species or historical habitat loss of individual species. That said, the simplicity of the measure makes it easy to understand and compile, which means that it is suitable for rapid risk assessments, and can be relatively simply communicated to a non-specialist audience. It can also be easily tailored to look at, for example, endangered species or endemic species.

A biodiversity metric can only ever approximate the true biodiversity value, but using multiple metrics provides the best chance that real world ecological changes are captured within the footprint in a timely manner (Brown et al. 2022; Marquardt et al. 2019; Verones et al. 2020). Ideally, an assessment should consider the broader aspects of biodiversity - such as abundance, or considerations of species' functional roles - that might be of concern and aim to develop and apply metrics which meet measurement objectives. In this case, this might include more knowledge of how the intensity of land use affects species. In looking at other metrics, however, we must also be mindful of trade-offs; more comprehensive indicators that incorporate a fuller understanding of biodiversity and ecosystem impacts may have poorer geographic coverage, or may not be kept as up-to-date as simpler ones. What is more, the additional complexity that a multidimensional characterisation of biodiversity entails must be weighed against the usability of such an assessment (Molotoks et al. 2020).

In any toolkit developed for policy makers it is vital, given the confusing landscape of biodiversity metrics and their overlap and similarities, that users can understand what it is that each metric offers, and its limitations, in order to interpret the information and act on it appropriately. There is an important scope of work to assess the complementarity between metrics and what a minimum 'set' might be for policy making (Brown et al. 2022).

The potential for future development of biodiversity measures linked to trade includes that:

1. There are several opportunities to make stepwise improvements to the existing 'species-weighted extent of crop production' (species hectares) indicator:

a. Chief amongst these is to refine the species range data to consider 'Area of Habitat'. This has the effect of cutting out, for each species individually, the habitat and elevation types that are unsuitable for it (Brooks et al. 2019). In doing so, the representation of species richness is vastly improved, as is our understanding of the remaining habitat for each species and, therefore, how critical each parcel of land is for biodiversity conservation; an area that hosts habitat of species that do not occur elsewhere will received greater weight than an area with the same number of species, but which are more widely distributed.

b. Second, biodiversity is highly spatially heterogeneous; within relatively small areas, the biodiversity value can be dramatically different. Spatial information on where crops are grown are the lynchpin of our ability to connect commodity production, and in turn trade, to its impacts upon species. Their spatial specificity is, therefore, of particular importance for biodiversity (Green et al. 2019). Advances in remote sensing and land use mapping could provide better spatial and temporal specificity for monitoring land use, as well as more timely processing of data to identify emerging frontiers.

c. Lastly, work is ongoing to try to set the ongoing impacts of commodity loss against the historical context of species' habitat losses (Duran et al. 2020). For example, if two species have 100 ha of their habitat remaining, but one only ever had 100 ha (even prior to large scale land use change by humans) whilst the other had lost 900 ha, then we would be most concerned about the species that had experienced a 90% decline in its extent of original habitat. This metric also uses species range data, refined by habitat preferences, but goes further by identifying the areas that host the species that are most threatened by habitat loss and thereby allows us to understand impacts in the light of local and global extinction risks.

2. Habitat loss is a major driver of species' declines, particularly those driven by commodity crop systems. However, it is not just the direct impact on the parcel of land where habitat is lost that is important; impacts can occur indirectly, for example, via pollution from agrichemicals or effluent, or through the fragmentation of larger tracts of habitat and the greater human disturbance experienced at the edges of farmland and infrastructure such as roads. Understanding how landscape-level impacts on biodiversity accumulate is important for our understanding of how jurisdictional policies on agricultural development will impact upon biodiversity at the landscape level.

3. As biodiversity footprint assessments become more common at both national and subnational levels, and with the recognition that a range of metrics would better represent the different aspects of biodiversity, there is a growing need to understand the complementarity of metrics (Molotoks et al, in press). This is an ongoing focus of research, for example through the Trade Hub and the GRADED[13] projects, both of which are in the process of applying biodiversity metrics to global trade models. The projects share the objective of understanding the biodiversity impacts associated with trade, and of understanding the additionality to risk assessment of the application of more complex biodiversity measures compared to their simpler analogues.

13. GRADED is a new project sponsored by Germany's BMZ/GIZ, led by Thomas Kastner at the Senckenberg Biodiversity and Climate Research Centre with support from SEI York and Chalmers University of Technology.

Advances and limitations

The analysis conducted here combines several state-of-the-art approaches to assessing an economy's deforestation-risk exposure, first developed for an equivalent project for GIZ/BMZ (West et al. 2022), but also building on work developed for the UK's indicator of overseas impact (Croft et al., 2021). In particular, we have provided a dataset which contains a detailed account of the trade and consumption of tropical and subtropical deforestation risk commodities.

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

– **Comparability across scales:** Deforestation metrics are compiled using approaches which vary depending on the scale of the analysis. Subnational data from Trase are 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.

– **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, 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 combining both export and import records to create a reconciled data set in order to deal with data mismatches. Reconciled direct trade statistics would be possible to compute, but this has not been conducted for this report.

– **Results do not provide traceability, nor measures of deforestation impact:** All of the results presented here are based on techniques that require models or analytical assumptions. These are described in the Methodological Summary (and in more detail in the equivalent GIZ/BMZ report; West et al. 2022) but include, for example, the fact that assumptions need to be made about the mix of sources in a country's outgoing 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 mean that deforestation risk may be underestimated in some cases. The contribution of 'unknown origin' trade to results can be found in figure captions in the Results. In sum, the data do not provide a traceability assessment and/or an assessment of the impact of the Belgian supply chain, but rather risk assessment based on tried-and-tested techniques for linking production-to-consumption systems for international economies.

Recommendations for indicator development

The aim of this study was to provide stakeholders in Belgium with a comprehensive understanding of the deforestation and biodiversity risk that the country is exposed to via its trade and consumption. It also provides a timeseries-based analysis of how Belgium's tropical and subtropical deforestation risk may have changed over time. In addition to defining hotspots of risk that might be prioritised for further analysis, this type of information offers the potential to be used as the basis for ongoing monitoring in the form of an indicator (or indicators) of Belgium's overseas deforestation risk.

The development of formal 'indicators' for monitoring environmental risk exposure requires considerations beyond the simple question of whether or not data are available. Indicators - especially if adopted into national statistical frameworks - must fulfil certain criteria; they must be relevant (meeting the users' basic needs), accurate and reliable, timely and available for release in a punctual manner, accessible and clear (with sufficient supporting information), coherent and comparable (including over time and with other data sources), complete (in terms of providing full answers to users' needs) and cost-effective (United Nations, 2019). Annex 3 offers an exploration of whether the methods developed here meet these criteria.

In cases where criteria are currently only partially met (or where fit to the criteria could be improved), recommendations are provided below on what steps might be taken to improve the alignment of the methods and data presented in this report for the purposes of indicator development. Note, this assessment is concerned primarily with the potential to use the national scale data for indicator development, given the current geographic coverage limitations associated with subnational datasets. It is worth noting that methodologically similar methods have been uptaken by the UK government in the form of an official - albeit experimental - indicator for monitoring progress against its 25 Year Environmental Plan (Croft et al. 2021). That indicator has also been recommended by the UK government for inclusion in the Convention on Biological Diversity (CBD) monitoring framework (Defra 2022).

We make the following recommendations for potential indicator development:

– **Initial uptake as an 'experimental' dataset:** The methodological framework applied here has also (in simpler form) been uptaken in the UK as a formal experimental indicator. Whilst the UK indicator is subject to - for example - commodity coverage limitations (its primary focus, as for this study, is agricultural commodities), this uptake is evidence that it can provide a useful dataset for national statistical purposes. We would recommend that consideration is given to whether similar uptake is possible in Belgium - even on an experimental basis - based on methods similar to those provided in this study. Here, consideration would be needed as to whether all three perspectives are relevant to the indicator (only a consumption-based perspective is adopted in the UK) and what 'version' of IOTA is required for the dataset.

– **Undertake sensitivity analysis and model intercomparison:** Multiple assumptions can be made when bringing together production, trade and consumption data, and the IOTA framework can utilise different MRIO datasets (there are several available globally). Adoption of different assumptions and datasets would likely lead to alternative conclusions about the magnitude and distribution of environmental risks to which Belgium is exposed. Additional work to compare the impacts of alternative assumptions and data on results would help increase the comparability of this data with other studies (e.g. those using alternative MRIOs) and would increase confidence in and/or understanding of results (e.g. by allowing insight into conclusions that remain fixed across model implementations, or assessing a distribution of results under different implementations).

– **Take additional steps to address flows of 'unknown' origin:** The current data contain trade flows that cannot be resolved back to the country source of commodity production, due to mismatches in trade records and the use of opening and closing stocks in FAO data. Theoretically, with additional work, it would be possible to unpack at least some such unknown flows to provide approximations of their source. This would introduce additional assumptions into the modelling framework, but would offer a more complete assessment of overall environmental risk.

– **If direct-trade data are required, take steps to harmonise:** In this analysis, direct trade records are based simply on export-reports obtained from FAO. This ensures that direct-trade estimates relate directly back to the original trade statistics. However, since re-export and consumption-based approaches depend on modelling anyway, we lose a direct link to the inputted trade data and an integrated trade reconciliation step provides improved results without a significant additional 'cost' of raw data dilution. However, the reconciliation step means there is a discrepancy between direct trade methods and the methods applied to the other perspectives. In future, it would be also possible to undertake trade-reconciliation steps for direct-trade results also, and we would recommend this step be explored (with potential also to conduct intercomparison of results, e.g. between export-, import- and reconciled-based assessments) if direct trade data are deemed useful as part of an indicator set.

– **Develop more 'refined' risk metrics:** The biodiversity metric applied here is simple and consequently not representative of all potential threats that might be imposed on biodiversity (see 'Biodiversity options' above). Within the GCRF Trade Hub project (to which members of this project-team are linked), additional analysis is underway to explore the integration of alternative and more powerful metrics into the IOTA framework. It is recommended that this process is followed so that these alternative metrics can be applied when ready, although there is also merit in applying simpler metrics in terms of indicator accessibility and timeliness. An additional recommendation would be to seek for the deforestation metric to align more closely with the FAO Forest Resource Assessment definition of forests; to date appropriate data have not been available to make such an alignment, but discussions should take place to seek to do so as and when data emerges. This is likely important to ensure the coherence of a potential indicator with incoming EU deforestation regulation. Additionally, other potential risks that are not currently included, such as those linked to water, soil erosion, emissions and social impacts, could be explored to broaden the scope of the indicator in future to increase potential relevance.

– **Broaden scope of commodity coverage:** At the current time, crop commodities, plus cattle (for deforestation), are included in this dataset. Broadening the scope of commodities to include products of forestry, mining and fisheries[15] - and potentially others - would increase the relevance of the indicator and offer a more comprehensive assessment of Belgium's international trade impacts.

Alongside indicator development itself, consideration is warranted as to how the

15. Forest products are already included in the UK indicator set but have not been applied to date within the more complex methods applied here. Inclusion of minerals and fisheries data within the IOTA framework is under investigation by the project team.

underpinning data can be made accessible to end-users. The development of the UK indicator was complemented with the development of an online dashboard (www.commodityfootprints.earth) that has been used by the UK government and by other stakeholders across, and beyond, the UK (the dashboard is not UK-centric and provides global data). Such online resources are a useful mechanism for providing users with powerful information without (or as a complement to) a dependence on large data-files that can require a relatively advanced level of data literacy to be useful.

Additionally, we also believe that the full integration of subnational information (e.g. from Trase) into the IOTA framework would enhance the power of the data provided by allowing a 'downscaling' of global data to subnational level where data availability allows. This is a longer-term research endeavour of the project team, and therefore we do not make a recommendation that this would be required for indicator development at the current time.

A final recommendation, beyond indicator development, relates to the use of this report by FPS Public Health. As specified, the data present a hotspotting and trend analysis of Belgium's overseas deforestation and biodiversity risk, but stakeholders across Belgium may have access to other resources that will almost certainly shed further light on the high risk supply chains identified in this analysis. Whilst this study provides a tool to prioritise areas of potential investigation, discussion should be sought along the supply chain (including in regions of production) to deepen understanding of where deforestation might be linked to Belgium via trade and consumption and - importantly - what steps are underway and/or could be supported to mitigate this risk and improve sustainability across production landscapes.

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Annex 1 – Additional Results

Rapeseed-linked deforestation

The results presented in Figure 1 indicate a substantial deforestation risk associated with rapeseed, which appears to be a major contributor to Belgium's overall deforestation risk profile from the direct trade perspective between the years 2009 and 2014. However, Figure A1 reveals that the primary source of this deforestation risk is Australia. Because of this, 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.

Figure A1: Rapeseed 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 three 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 19.6%

of the traded volume in (B) and 16.5% in (C) were of unknown origin and therefore could not be linked to deforestation risk.

Additional sub-national timeseries

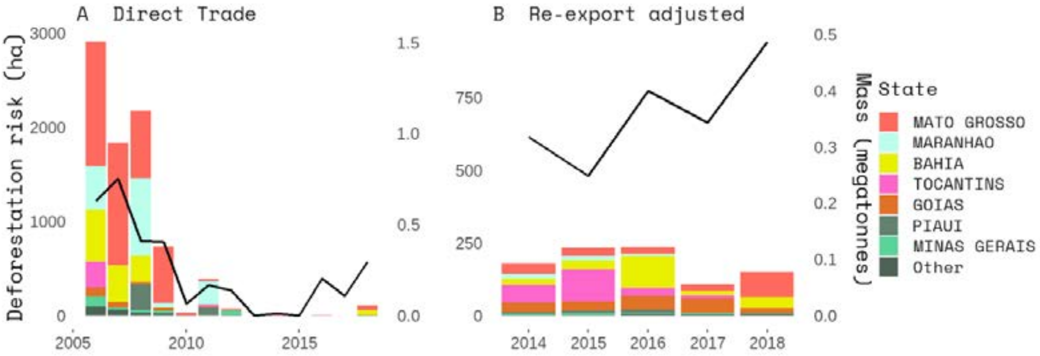

Figure A2: Belgian imports of Brazilian soy by source state over time, for direct trade (A) and re-export adjusted trade (B). Black lines indicate the traded quantity, in megatonnes, regardless of any link to deforestation.

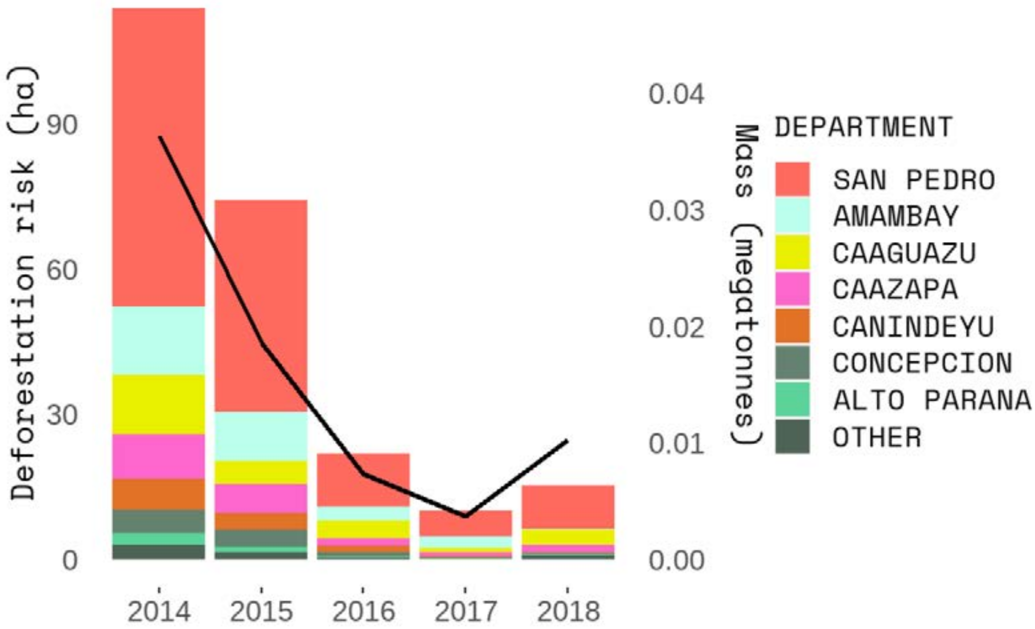

Figure A3: Belgian imports of Paraguayan soy by source department over time for re-export adjusted trade only. The black line indicates the traded quantity, in megatonnes, regardless of any link to deforestation.

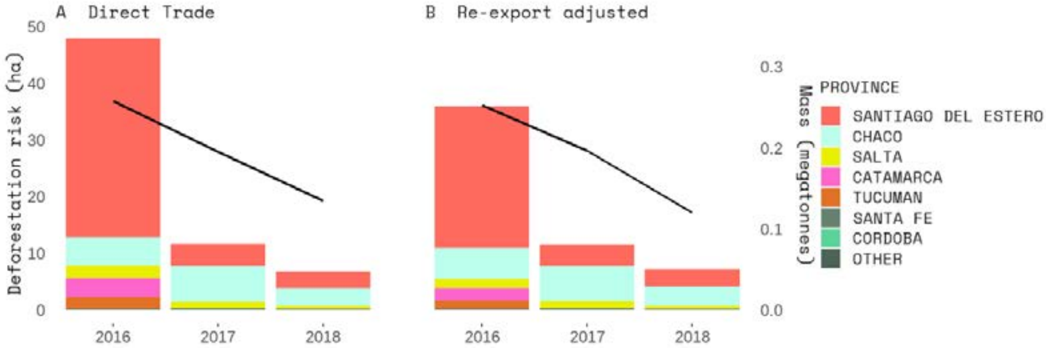

Figure A4: Belgian imports of Argentinian soy by source province over time, for direct trade (A) and re-export adjusted trade (B). Black lines indicate the traded quantity, in megatonnes, regardless of any link to deforestation.

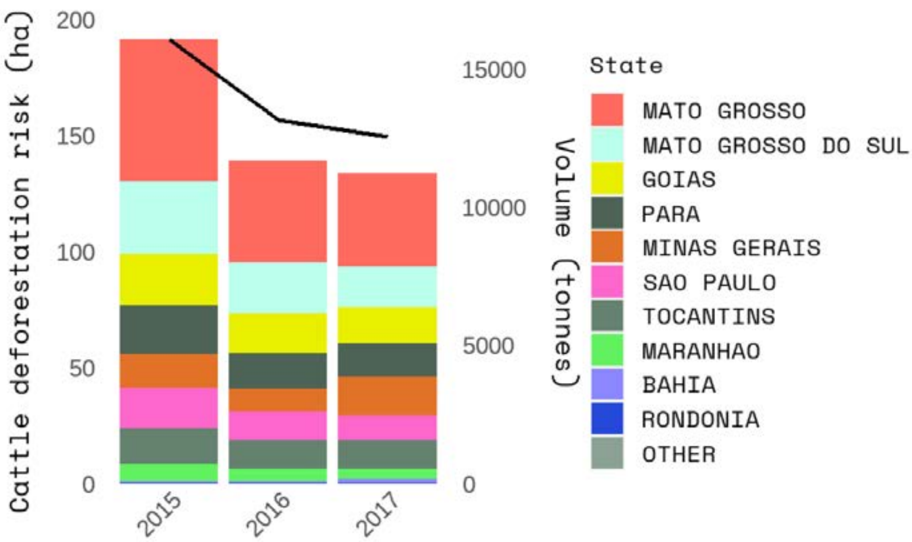

Figure A5: Belgian imports of Brazilian cattle products by source state over time, for direct trade only. The black line indicates the traded quantity, in tonnes, regardless of any link to deforestation.

Direct-trade commodity risk time series, by trader

Identification of traders does not imply that such stakeholders are directly implicated in deforestation activities; additional assessment would be needed to establish causal links. However, according to Trase data, the traders indicated in the figures below are exposed to the deforestation risk associated with direct-imports into Belgium.

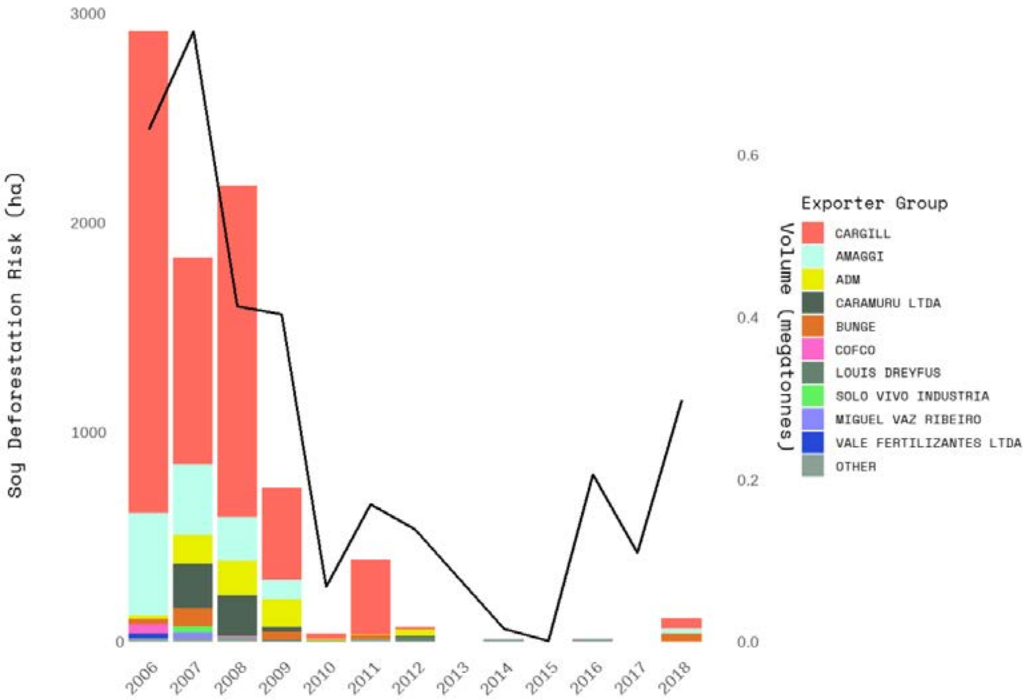

Figure A6: Direct trade soy deforestation risk in Brazil over time by exporter group. The total trade volume/production sourced in Brazil linked to Belgian soybean imports (mass of raw soybean equivalents, regardless of their association – or not – with deforestation) is also shown by the black line and right-hand axis. Trader name abbreviations as follows: Caramuru Ltda (Caramuru Administração e Participações Ltda), Solo Vivo Indústria (Solo Vivo Indústria e Comércio de Fertilizantes), Vale Fertilizantes Ltda (Vale Fertilizantes Ltda - ME)

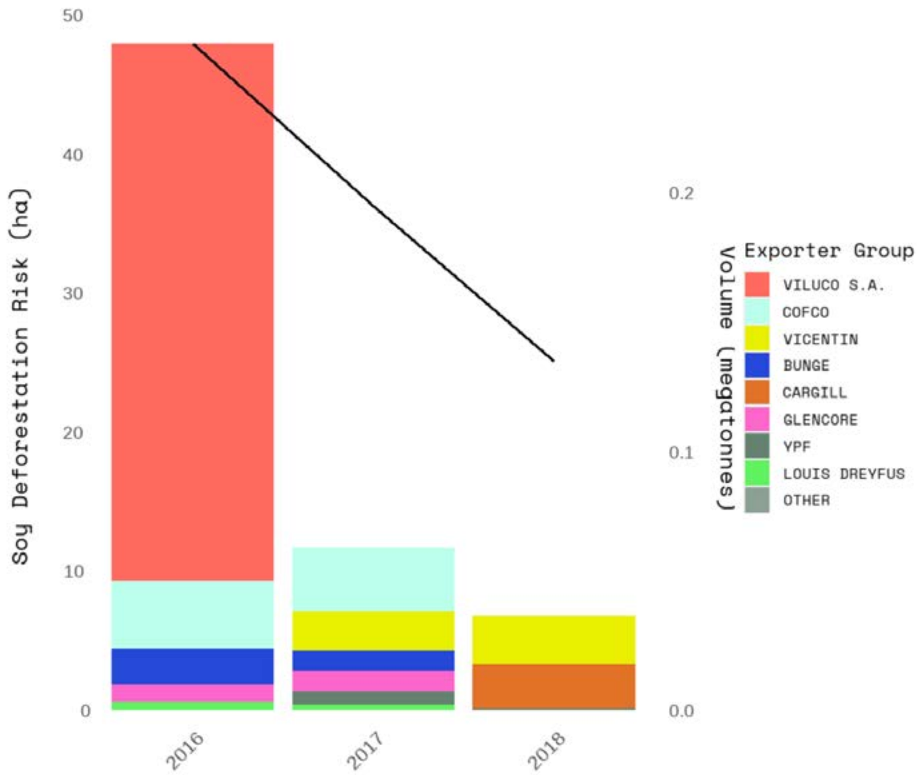

Figure A7: Direct trade soy deforestation risk in Argentina over time by exporter group. The total trade volume/production sourced in Argentina linked to Belgian soybean imports (mass of raw soybean equivalents, regardless of their association – or not – with deforestation) is also shown by the black line and right-hand axis.

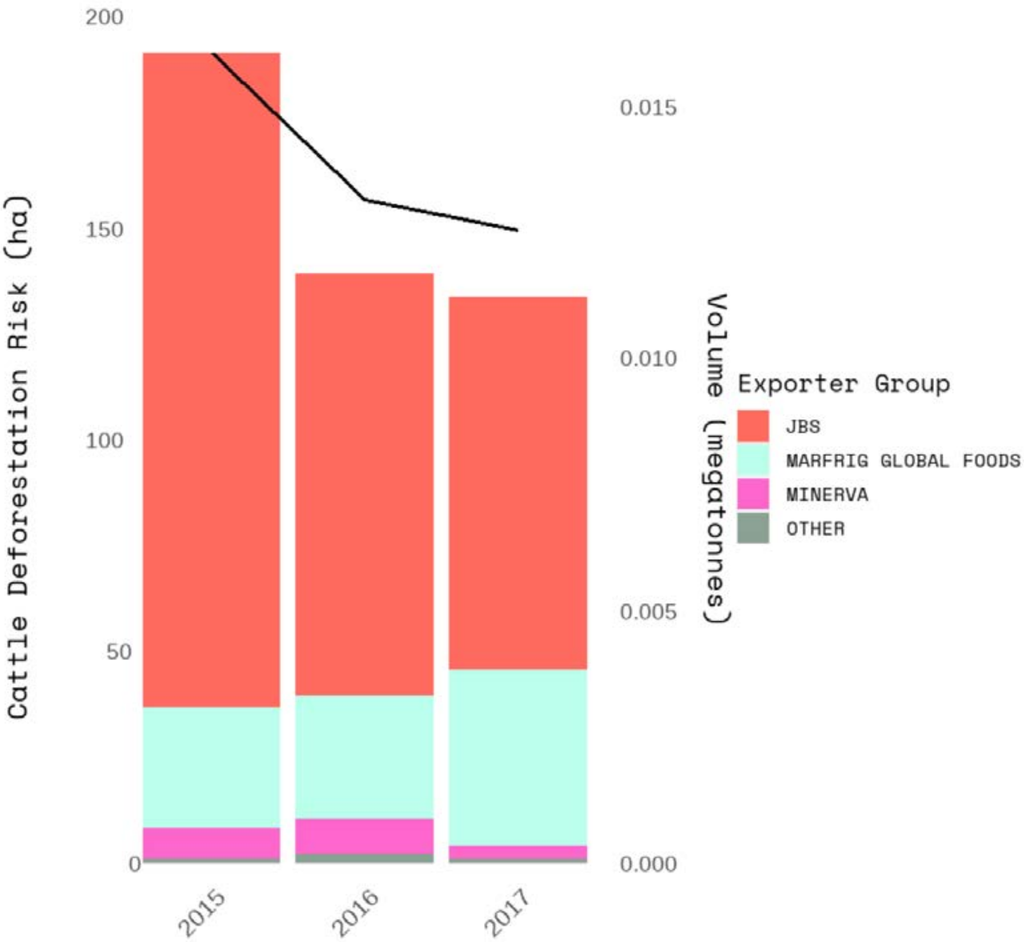

Figure A8: Direct trade cattle deforestation risk in Brazil over time by exporter group. The total trade volume/production sourced in Brazil linked to Belgian beef imports (mass of raw beef equivalents, regardless of their association – or not – with deforestation) is also shown by the black line and right-hand axis.

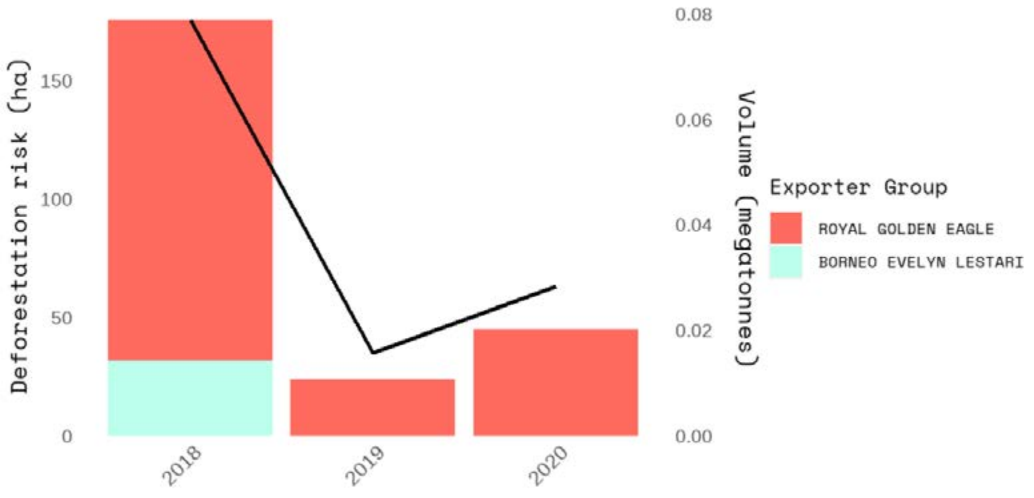

Figure A9: Palm oil deforestation risk between 2018-2020 by exporter group for direct trade from Indonesia to Belgium. The total trade volume sourced in Indonesia linked to Belgian palm oil imports (mass of palm oil equivalents, regardless of their association – or not – with deforestation) is also shown by the black line and right-hand axis.

Commodity specific comparisons between Belgium, other ADP countries and China

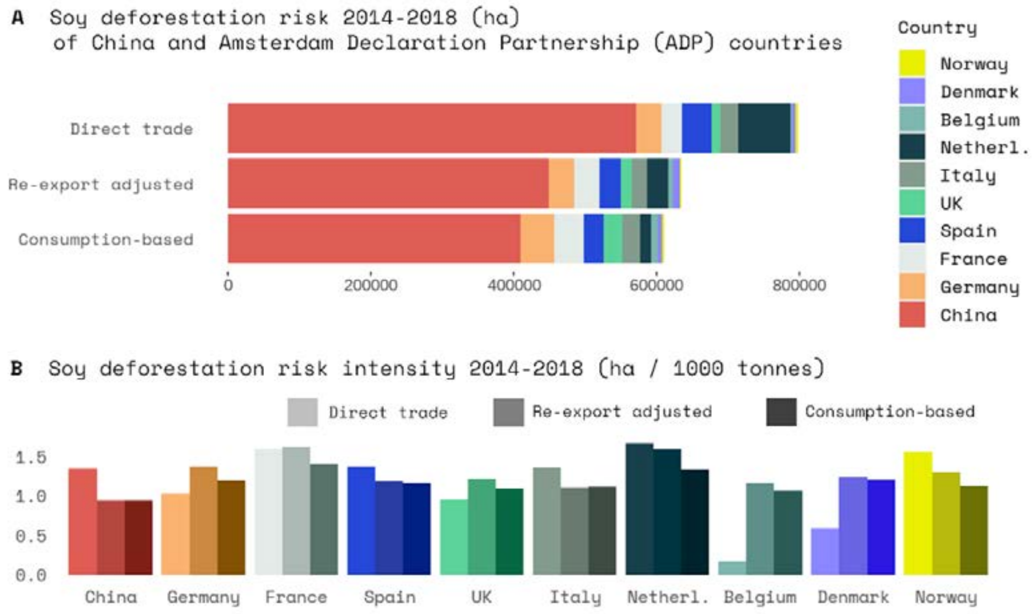

Figure A10: Total soy deforestation risk (A) and intensity (B) associated with Belgium's agricultural supply chains, the other ADP signatory countries, and China for the period 2014-2018. Results are shown for all three perspectives (direct trade, re-export-adjusted trade, and consumption-based). Countries are arranged in descending order according to their overall consumption-based commodity deforestation risk.

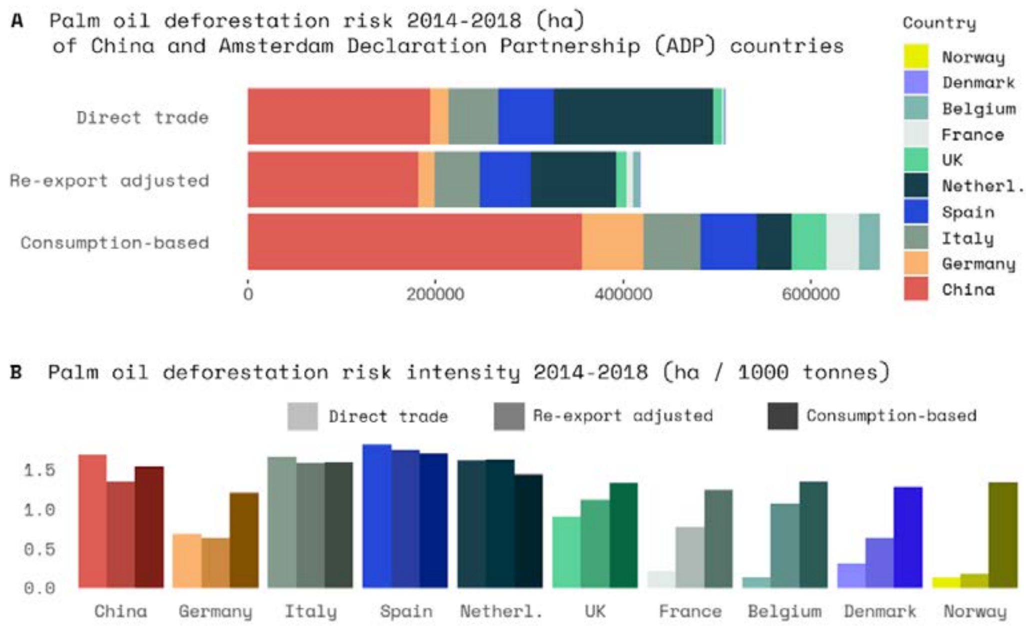

Figure A11: Total palm oil deforestation risk (A) and intensity (B) associated with Belgium's agricultural supply chains, the other ADP signatory countries, and China for the period 2014-2018. Results are shown for all three perspectives (direct trade, re-export-adjusted trade, and consumption-based). Countries are arranged in descending order according to their overall consumption-based commodity deforestation risk.

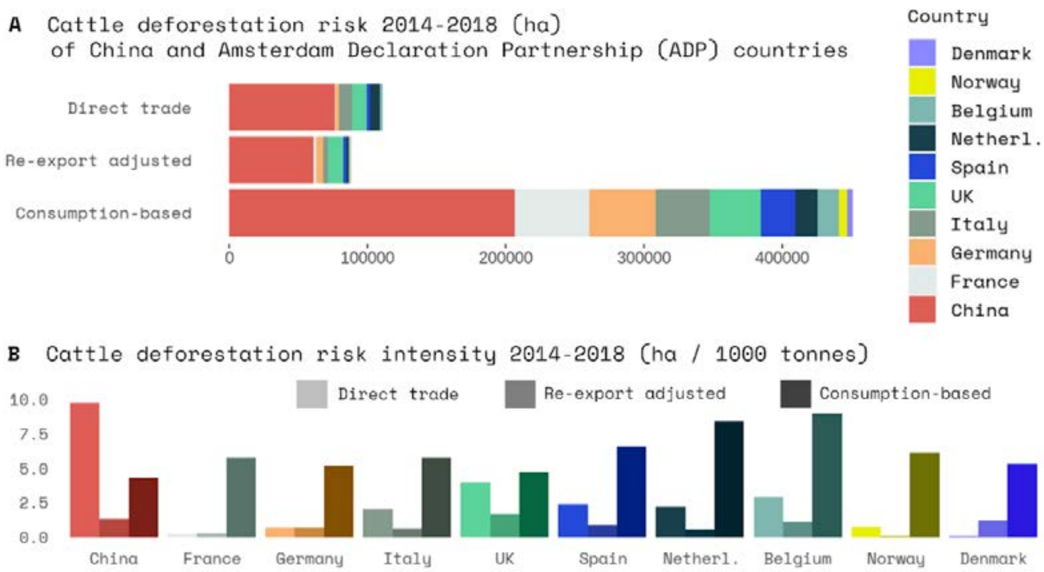

Figure A12: Total cattle products deforestation risk (A) and intensity (B) associated with Belgium's agricultural supply chains, the other ADP signatory countries, and China for the period 2014-2018. Results are shown for all three perspectives (direct trade, re-export-adjusted trade, and consumption-based). Countries are arranged in descending order according to their overall consumption-based commodity deforestation risk.

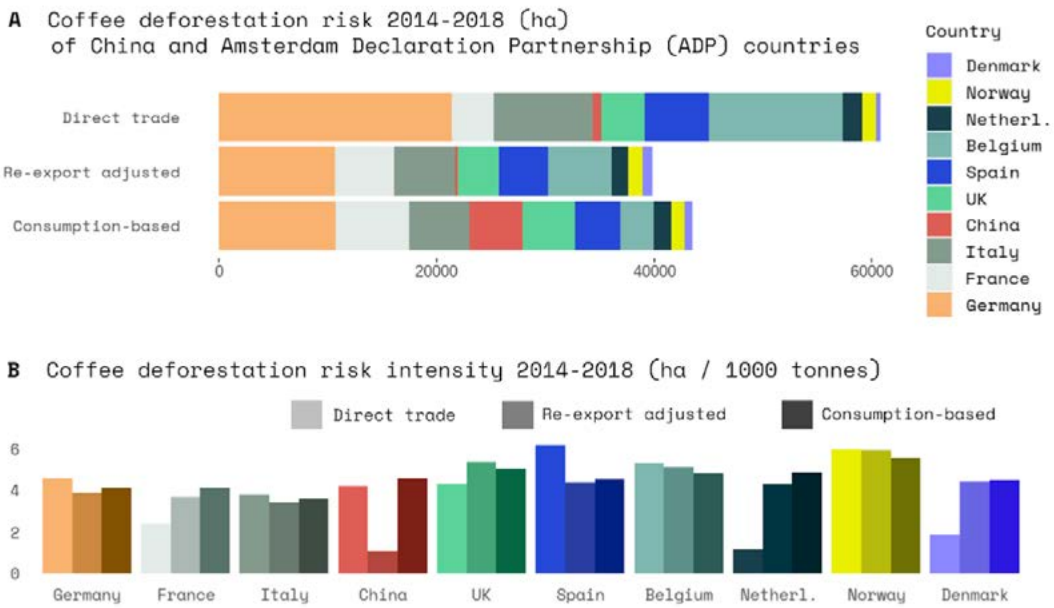

Figure A13: Total coffee deforestation risk (A) and intensity (B) associated with Belgium's agricultural supply chains, the other ADP signatory countries, and China for the period 2014-2018. Results are shown for all three perspectives (direct trade, re-export-adjusted trade, and consumption-based). Countries are arranged in descending order according to their overall consumption-based commodity deforestation risk.

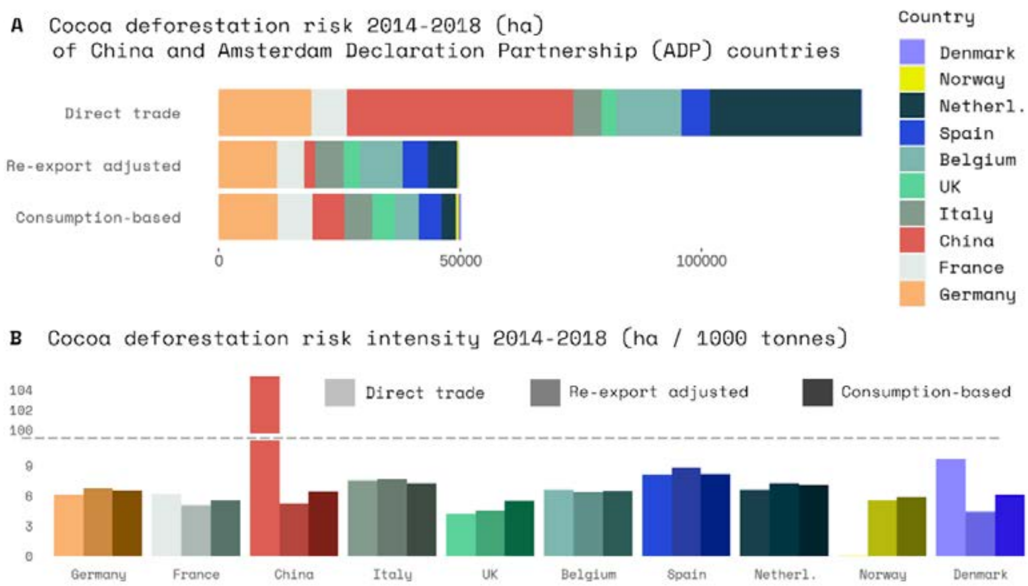

Figure A14: Total cocoa deforestation risk (A) and intensity (B) associated with Belgium's agricultural supply chains, the other ADP signatory countries, and China for the period 2014-2018. Results are shown for all three perspectives (direct trade, re-export-adjusted trade, and consumption-based). Countries are arranged in descending order according to their overall consumption-based commodity deforestation risk.

Annex 2 – Comparisons with other studies

Comparisons with previous studies adopting similar methodological approaches

A number of previous studies have quantified estimates of Belgium's commodity deforestation risk. Table A2.1 presents these to allow basic comparison with our own results. Direct comparison is challenging given methodological differences and the existence of data gaps (e.g. 'unknown sources' within our results for re-export and consumption-based perspectives).

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 at time of writing 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[16]. Comparing results for the year 2017, we observe that while this analysis indicates 14.2k ha of overall commodity deforestation risk, the data from the UK indicator work indicate Belgium is linked to 15.5k ha of deforestation risk. For palm oil, this study indicates 4.48k ha of commodity deforestation risk for Belgium in 2017, in comparison to 2.93k ha from the UK indicator work. For cattle, the results are 3.18k ha and 2.80k ha respectively. For soybeans, 1.52k ha and 1.02k ha. For coffee, 669 ha and 1.68k ha. For cocoa, 770 ha and 484 ha.

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 6.49k ha for the total 2018 deforestation risk for Belgium, compares to the trade-linked estimate in Pendrill et al. (2022) of 7.53k ha. For palm oil, this study indicates 1.68k ha of deforestation risk for Belgium in 2018, in comparison to 3.12k ha from the Pendrill et al. (2022) trade-linked estimates. For cattle the results are 268 ha and 554 ha respectively. For soybeans, 975 ha and 1.13k ha. For coffee, 1.94k ha and 620 ha. For cocoa, 883 ha and 1.03k 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.

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 Belgium. In our consumption-based analysis, 75% of the total commodity deforestation risk in 2017 comprised products of palm oil, soy, cattle, coffee and cocoa, compared to 58% in the UK indicator results. From a re-export perspective, these commodities comprise 88% of the total risk estimate in our study in 2018, compared to 86% in trade-linked results from Pendrill et al. (2022).

16. 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.

Table A2.1. Other studies that quantify the deforestation risk associated with Belgium's trade or consumption. Table contains detail on the perspective adopted in the study, results and relevant explanatory notes.

Study (and reference)	Perspective adopted	Deforestation risk estimates (ha)	Mass estimates (tonnes)	Notes
Indicator set developed for the UK government, including tropical and subtropical deforestation (Croft et al. 2021, www.commodity-footprints.earth)	Consumption-based	15.5k total in 2017: Oil palm fruit – 2.93k Cattle – 2.80k Soybeans – 1.02k Coffee – 1.68k Cocoa – 484	In 2017: Oil palm fruit – 2.12M Cattle – 398k Soybeans – 1.33M Coffee – 134k Cocoa – 78k	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.
Deforestation risk embodied in production and consumption of agricultural and forestry commodities 2005-2018 (Pendrill et al. 2022)	Re-export-adjusted	9.35k total in 2017 / 7.53k total in 2018: Oil palm fruit (2017/2018) – 3.90k / 3.12k Cattle – 408 / 554 Soybeans – 1.12k / 1.13k Coffee – 755 / 620 Cocoa – 1.70k / 1.03k	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.

Study (and reference)	Perspective adopted	Deforestation risk estimates (ha)	Mass estimates (tonnes)	Notes
Deforestation risk embodied in production and consumption of agricultural and forestry commod-ities 2005-2018 (Pendrill et al. 2022)	Consumption-based	17.8k total in 2017 / 20.2k total in 2018: Oil seeds (2017/2018) – 4.56k / 6.04k Cattle – 4.66k / 6.01k Crops not elsewhere classified – 2.95k / 2.43k Vegetables, fruit, nuts – 2.47k / 2.17k	Not provided	Uses EXIOBASE model, but not in a 'hybrid' format (i.e. not linked to physical trade/ processing steps). Data are aggregated into coarser sectors of production/ consumption.

Comparison to The Rock Group report "Tracking biodiversity impact: report on import trade monitoring"

In 2021, the Belgium's Federal Public Service for Heath, Food Chain Safety and Environment commissioned The Rock Group to undertake a study exploring the relevance of Belgian imports to biodiversity impact and dependency.

This report undertook an assessment of the key imported commodities of potential biodiversity concern, and the volumes and sources of imports of these commodities, along with a qualitative assessment of the biodiversity threats they might be linked to.

It is difficult to directly compare the results of this report to those of The Rock Group but some comparison is useful to understand how results might align. Difficulties in undertaking direct comparison include:

– **The nature of biodiversity assessment conducted:** This study undertakes an assessment of biodiversity risk based on spatially explicit production and biodiversity information, and links biodiversity risk to agricultural land use. In contrast, in The Rock Group report, expert input (mainly from a paper undertaking a life-cycle assessment of potential EU food impacts on biodiversity) is used to define a list of commodities likely to be impacting (or dependent upon) biodiversity. This source paper uses non-spatial (world average) biodiversity characterisation factors, but these also extend beyond land use-linkages (e.g. to include eutrophication, toxicity, global warming effects, among others).

– **The nature of trade assessment conducted:** This study conducts a comprehensive assessment of direct-trade, re-export adjusted trade, and consumption-based risks[17].

17. For selected commodities below, some perspectives are not currently included in our results. See commodity sections for more detail.

In contrast, The Rock Group study undertakes an assessment of only direct-trade linkages, and presents results only for the largest trades (for the period 2016-2020). Whilst then, their trade data are comparable to our 'direct trade' analysis, the Rock Group study does not attempt to directly quantify the risks of these trades on biodiversity (as conducted for this study) but rather provides qualitative information on the types of biodiversity impact that might be expected to be linked to these trades.

Given these methodological differences, below we provide information on each of the commodities identified by The Rock Group Study. We summarise the sources of trade for these commodities that they identify for Belgium (they do not provide country-specific masses in their report, so we simply list these countries in the tables below), and provide equivalents (in mass terms), for the top five sources from direct, re-export and consumption-based perspectives. We then provide the top five regions of biodiversity risk (in 'species-hectares'). For some commodities (dairy, oil & gas, gold & minerals, forestry, fisheries) covered in The Rock Group report, we cannot provide data as these are currently not included in our biodiversity datasets from a production point of view. Additionally, for completeness we include our mass-based results for beef/cattle, but do not have biodiversity data for cattle at the present time.

Cotton

Table A2.2: Key countries of cotton import according to The Rock Group report, plus top five countries (with masses) of origin according to the results of this study. Masses summed across 2016-2018.

Country (Rock Group)	Country and mass (tonnes); direct-trade (this study)	Country and mass (tonnes); re-export adjusted (this study)	Country and mass (tonnes); consumption-based (this study)
Turkey	India (35,200)	Kazakhstan (6,410)	Pakistan (245,800)
Pakistan	Turkey (4,830)	USA (2,450)	USA (184,000)
India	France (2,400)	Spain (2,070)	India (150,000)
China	USA (2,240)	Benin (932)	Uzbekistan (121,600)
France	Pakistan (2,070)	Burkina Faso (663)	China (94,200)

Table A2.3: Top five countries of biodiversity risk associated with cotton (measured in 'species hectares') according to the results of this study. Species hectares summed across 2016-2018.

Country and biodiversity risk (species hectares); direct-trade (this study)	Country and biodiversity risk (species hectares); re-export adjusted (this study)	Country and biodiversity risk (species hectares); consumption-based (this study)
India (8,550,000)	Kazakhstan (1,080,000)	Pakistan (40,700,000)
Indonesia (2,200,000)	Benin (588,000)	India (36,500,000)
Costa Rica (628,000)	USA (323,000)	USA (24,200,000)
Benin (602,000)	Spain (277,000)	Brazil (13,300,000)
Thailand (407,000)	Burkina Faso (251,000)	Uzbekistan (12,900,000)

Coffee

Table A2.4: Key countries of coffee import according to The Rock Group report, plus top five countries (with masses) of origin according to the results of this study. Masses summed across 2016-2018.

Country (Rock Group)	Country and mass (tonnes); direct-trade (this study)	Country and mass (tonnes); re-export adjusted (this study)	Country and mass (tonnes); consumption-based (this study)
Brazil	Brazil (359,000)	Brazil (179,000)	Brazil (101,000)
France	Honduras (230,000)	Viet Nam (101,000)	Viet Nam (54,600)
Netherlands	Colombia (114,000)	Honduras (80,500)	Honduras (34,700)
Viet Nam	Germany (77,000)	Colombia (55,800)	Colombia (25,200)
Honduras	Uganda (76,900)	Peru (42,800)	Uganda (19,500)

Table A2.5: Top five countries of biodiversity risk associated with coffee (measured in 'species hectares') according to the results of this study. Species hectares summed across 2016-2018.

Country and biodiversity risk (species hectares); direct-trade (this study)	Country and biodiversity risk (species hectares); re-export adjusted (this study)	Country and biodiversity risk (species hectares); consumption-based (this study)
Brazil (205,000,000)	Brazil (102,000,000)	Brazil (57,800,000)
Honduras (142,000,000)	Uganda (52,900,000)	Uganda (24,800,000)
Uganda (97,900,000)	Honduras (49,800,000)	Honduras (21,400,000)
Colombia (92,900,000)	Colombia (45,500,000)	Colombia (20,500,000)
Peru (67,400,000)	Peru (38,200,000)	Peru (17,100,000)

Cocoa

Table A2.6: Key countries of cocoa import according to The Rock Group report, plus top five countries (with masses) of origin according to the results of this study. Masses summed across 2016-2018.

Country (Rock Group)	Country and mass (tonnes); direct-trade (this study)	Country and mass (tonnes); re-export adjusted (this study)	Country and mass (tonnes); consumption-based (this study)
Netherlands	Cote d'Ivoire (495,000)	Cote d'Ivoire (337,000)	Cote d'Ivoire (171,000)
Cote d'Ivoire	Netherlands (195,000)	Ghana (104,000)	Ghana (59,200)
Germany	Ghana (97,600)	Nigeria (44,400)	Nigeria (24,800)
France	Cameroon (87,400)	Cameroon (25,100)	Cameroon (15,800)
Ghana	France (69,600)	Peru (18,200)	Ecuador (9,500)

Table A2.7: Top five countries of biodiversity risk associated with cocoa (measured in 'species hectares') according to the results of this study. Species hectares summed across 2016-2018.

Country and biodiversity risk (species hectares); direct-trade (this study)	Country and biodiversity risk (species hectares); re-export adjusted (this study)	Country and biodiversity risk (species hectares); consumption-based (this study)
Cote d'Ivoire (559,000,000)	Cote d'Ivoire (380,000,000)	Cote d'Ivoire (193,000,000)
Ghana (151,000,000)	Ghana (160,000,000)	Ghana (91,400,000)
Cameroon (149,000,000)	Nigeria (81,000,000)	Nigeria (45,200,000)
Nigeria (96,900,000)	Cameroon (42,900,000)	Cameroon (27,000,000)
Ecuador (43,200,000)	Ecuador (22,700,000)	Ecuador (13,800,000)

Palm oil

Table A2.8: Key countries of palm oil import according to The Rock Group report, plus top five countries (with masses) of origin according to the results of this study. Masses summed across 2016-2018, and expressed in tonnes of harvested palm oil fruit.

Country (Rock Group)	Country and mass (tonnes); direct-trade (this study)	Country and mass (tonnes); re-export adjusted (this study)	Country and mass (tonnes); consumption-based (this study)
Netherlands	Netherlands (5,420,000)	Indonesia (1,740,000)	Indonesia (5,220,000)
Malaysia	Papua New Guinea (297,000)	Malaysia (428,000)	Malaysia (2,140,000)
Indonesia	Indonesia (274,000)	Papua New Guinea (208,000)	Thailand (556,000)
Germany	Germany (179,000)	Colombia (92,300)	Papua New Guinea (205,000)
Papua New Guinea	Guatemala (76,400)	Guatemala (91,100)	Colombia (161,000)

Table A2.9: Top five countries of biodiversity risk associated with palm oil (measured in 'species hectares') according to the results of this study. Species hectares summed across 2016-2018.

Country and biodiversity risk (species hectares); direct-trade (this study)	Country and biodiversity risk (species hectares); re-export adjusted (this study)	Country and biodiversity risk (species hectares); consumption-based (this study)
Indonesia (6,370,000)	Indonesia (40,400,000)	Indonesia (121,000,000)
Papua New Guinea (6,280,000)	Malaysia (14,300,000)	Malaysia (71,400,000)
Guatemala (2,610,000)	Papua New Guinea (4,380,000)	Thailand (22,500,000)
Brazil (1,770,000)	Guatemala (3,110,000)	Nigeria (9,800,000)
Malaysia (845,000)	Colombia (3,100,000)	Colombia (5,410,000)

Tea

Table A2.10: Key countries of tea import according to The Rock Group report, plus top five countries (with masses) of origin according to the results of this study. Masses summed across 2016-2018.

Country (Rock Group)	Country and mass (tonnes); direct-trade (this study)	Country and mass (tonnes); re-export adjusted (this study)	Country and mass (tonnes); consumption-based (this study)
China	Poland (6,720)	Sri Lanka (256)	Kenya (9,380)
Netherlands	Sri Lanka (5,540)	India (99)	China (7,610)
Sri Lanka	Turkey (4,850)	Malawi (71)	India (6,920)
Turkey	China (3,250)	China (70)	Vietnam (3,180)
France	United Kingdom (3,220)	Kenya (49)	Argentina (3,090)

Table A2.11: Top five countries of biodiversity risk associated with tea (measured in 'species hectares') according to the results of this study. Species hectares summed across 2016-2018.

Country and biodiversity risk (species hectares); direct-trade (this study)	Country and biodiversity risk (species hectares); re-export adjusted (this study)	Country and biodiversity risk (species hectares); consumption-based (this study)
China (1,560,000)	Sri Lanka (67,800)	China (3,660,000)
Sri Lanka (1,460,000)	China (33,500)	Kenya (3,190,000)
India (900,000)	India (33,500)	India (2,330,000)
Turkey (358,000)	Malawi (17,900)	Vietnam (1,240,000)
Malawi (301,000)	Kenya (16,500)	Myanmar (1,030,000)

Sugarcane

Table A2.12: Key countries of sugarcane import according to The Rock Group report, plus top five countries (with masses) of origin according to the results of this study. The data from this study are linked to sugarcane only. The lack of direct trade data is because there was no direct trade of sugarcane products to Belgium (2016-2018) that can be distinguished from sugar beet products. The Rock Group study infers their list may include linkages to sugar beet. Masses summed across 2016-2018.

Country (Rock Group)	Country and mass (tonnes); direct-trade (this study)	Country and mass (tonnes); re-export adjusted (this study)	Country and mass (tonnes); consumption-based (this study)
France	NA	India (27,000)	Brazil (3,070,000)
Netherlands	NA	Brazil (3,290)	India (1,330,000)
Germany	NA	Colombia (3,030)	Pakistan (648,000)
Colombia	NA	Costa Rica (57.7)	Myanmar (302,000)
Laos	NA	Pakistan (7.67)	Colombia (168,000)

Table A2.13: Top five countries of biodiversity risk associated with sugarcane (measured in 'species hectares') according to the results of this study. The lack of direct trade data is because there was no direct trade of sugarcane products to Belgium (2016-2018) that could be distinguished from sugar beet products. Species hectares summed across 2016-2018.

Country and biodiversity risk (species hectares); direct-trade (this study)	Country and biodiversity risk (species hectares); re-export adjusted (this study)	Country and biodiversity risk (species hectares); consumption-based (this study)
NA	India (188,000)	Brazil (28,100,000)
NA	Brazil (30,100)	India (9,260,000)
NA	Colombia (19,200)	Pakistan (4,380,000)
NA	Costa Rica (492)	Myanmar (3,070,000)
NA	Pakistan (51.7)	Bangladesh (1,190,000)

Bananas

Table A2.14: Key countries of banana import according to The Rock Group report, plus top five countries (with masses) of origin according to the results of this study. Masses summed across 2016-2018.

Country (Rock Group)	Country and mass (tonnes); direct-trade (this study)	Country and mass (tonnes); re-export adjusted (this study)	Country and mass (tonnes); consumption-based (this study)
Colombia	Colombia (1,520,000)	Colombia (177,000)	Colombia (118,000)
Ecuador	Costa Rica (775,000)	Costa Rica (89,600)	Ecuador (114,000)
Costa Rica	Ecuador (561,000)	Ecuador (79,800)	India (105,000)
Cameroon	Cameroon (317,000)	Cameroon (43,900)	Philippines (76,500)
Cote d'Ivoire	Cote d'Ivoire (275,000)	Cote d'Ivoire (31,800)	Costa Rica (72,100)

Table A2.15: Top five countries of biodiversity risk associated with bananas (measured in 'species hectares') according to the results of this study. Species hectares summed across 2016-2018.

Country and biodiversity risk (species hectares); direct-trade (this study)	Country and biodiversity risk (species hectares); re-export adjusted (this study)	Country and biodiversity risk (species hectares); consumption-based (this study)
Colombia (36,500,000)	Colombia (4,240,000)	Tanzania (3,210,000)
Cameroon (14,900,000)	Cameroon (2,060,000)	Brazil (3,070,000)
Costa Rica (11,600,000)	Costa Rica (1,340,000)	Colombia (2,830,000)
Ecuador (7,240,000)	Ecuador (1,030,000)	DRC (1,760,000)
Cote d'Ivoire (3,500,000)	Ghana (412,000)	Cameroon (1,730,000)

Soy

Table A2.16: Key countries of soy import according to The Rock Group report, plus top five countries (with masses) of origin according to the results of this study. Masses summed across 2016-2018, expressed in tonnes of raw soy beans.

Country (Rock Group)	Country and mass (tonnes); direct-trade (this study)	Country and mass (tonnes); re-export adjusted (this study)	Country and mass (tonnes); consumption-based (this study)
Netherlands	Netherlands (3,050,000)	Brazil (1,340,000)	Brazil (1,740,000)
Canada	Brazil (614,000)	USA (778,000)	USA (1,270,000)
Ukraine	Argentina (501,000)	Argentina (586,000)	Argentina (1,230,000)
France	USA (419,000)	Canada (207,000)	Paraguay (185,000)
Australia	Canada (271,000)	India (97,400)	Canada (148,000)

Table A2.17: Top five countries of biodiversity risk associated with soy (measured in 'species hectares') according to the results of this study. Species hectares summed across 2016-2018.

Country and biodiversity risk (species hectares); direct-trade (this study)	Country and biodiversity risk (species hectares); re-export adjusted (this study)	Country and biodiversity risk (species hectares); consumption-based (this study)
Brazil (135,000,000)	Brazil (295,000,000)	Brazil (383,000,000)
Argentina (48,100,000)	USA (79,300,000)	USA (129,000,000)
India (47,200,000)	Argentina (56,300,000)	Argentina (118,000,000)
USA (42,800,000)	India (28,400,000)	Paraguay (43,800,000)
Canada (25,100,000)	Canada (19,200,000)	India (35,400,000)

Annex 3 – Indicator criteria quality assessment

Table A3.1: Indicator quality criteria (aligned with United Nations statistical criteria), with commentary on whether and how the data presented in this study might meet these.

Quality criteria	Comments
Relevance	The data presented in this report provide information on the potential deforestation risk (and a simple measure of biodiversity risk) linked to Belgian supply chains and its consumption. This is of potential relevance in the formulation of policy to tackle the overseas impacts associated with Belgium's trade. It is also of potential relevance to the private sector and civil society in Belgium who may want to align their activities with Belgium's overseas impact priorities. The analysis produced here was also on the request of FPS Public Health. **Criteria assessment:** Passed.
Accuracy and reliability	The trade data are known to suffer from issues of accuracy given that the quality and provision of statistics on which they are based varies depending on their sources. For example, FAO interpolates production and trade statistics in cases where they cannot be provided by national statistics agencies. Likewise, there is no universally accepted MRIO dataset that can be considered fully 'accurate', instead there are several MRIOs available with strengths and weaknesses, but all rely on assumptions in their compilation which mean that they depart from real-world economic transactions. In this study, however, we chose the EXIOBASE MRIO which is well-established as a robust MRIO for the European economy. Overall, the quality and type of trade and consumption data available means that it is currently impossible to provide a fully-accurate representation of Belgium's trade-linked dependencies and impacts. **Criteria assessment:** Partially passed (difficult to improve in current international data context).
Timeliness and punctuality	The data provided in this assessment are the most recent available, with the main constraint being the availability of deforestation-data which is in turn constrained by the availability of third-party statistical data. The 2018 deforestation data utilised here, however, was released in 2022, so we have been able to make 'timely' use of this information in the preparation of the Belgian analysis. Ultimately a lag of ~3-4 years is expected between the release of data and the focal year. **Criteria assessment:** Passed, but subject to data lags.
Accessibility and clarity	The data used in the analysis are from open-source repositories and freely available for non-commercial use. Furthermore, outputs from this work can be made freely available, and are amenable to presentation via e.g. online dashboards. Within this report, and the associated GIZ/BMZ report, we have sought to be as transparent as possible about the methods employed, with relatively detailed explanation of data construction which should allow comprehension by those with basic technical backgrounds. Results are also provided for deforestation in units that will be understood by stakeholders, and the simplicity of the biodiversity metric employed means that it should be relatively easily understood. **Criteria assessment:** Passed, but consideration would be needed as to how to make data accessible outside of project reporting.

Quality criteria	Comments
Coherence and comparability	The data provided for this study are primarily produced from a central methodological framework (IOTA) which aims to adopt consistent methods for linking production, trade and consumption. Therefore, results are largely (or can be made) internally consistent[18]. Unfortunately, there are no universal standards for the application of consumption-based or trade-linked assessments (although standards do exist for related analyses such as Economy Wide Material Flow Analysis). That said, consumption based approaches are increasingly working their way into statistical frameworks. An issue remains that different authors maintain different methods which will influence the comparability of results. However, the IOTA framework has now been utilised by German, UK and Belgian governments in analysis, and IOTA can be applied to all other countries and world regions - meaning that results from one country can be directly compared against those of another. Direct comparison of results from IOTA with results from other studies (which may have relative strengths and weaknesses compared to the analysis here) is challenging given the variety of methods that might be used for a study of this kind. **Criteria assessment:** Partially passed, but coherence depends on adoption of similar methods more broadly.
Completeness and coverage	The data framework utilised offers as complete coverage of global supply chains as is currently possible, and is relatively comprehensive in terms of crop-commodity coverage. However, several commodities are not included in our dataset at the current time, including forest products, livestock products beside cattle, minerals, etc. Additionally, the metric of deforestation utilised only includes tropical and sub-tropical deforestation and other methods of assessing deforestation (e.g. those seeking alignment with FAO Forest Resource Assessment definitions) may offer alternative results. Furthermore, the biodiversity metric employed offers simple and only very partial coverage of the potential biodiversity threats that Belgium's trade might impose on biodiversity. **Criteria assessment:** Partially passed, completeness assessment ultimately depends on the ultimate purpose of the indicator.
Cost-effectiveness	Having developed comparable data frameworks for studies for the UK and Germany, the data provided here are relatively cost-effective to update. The main costs associated with updates relate to any associated documentation and reporting required to supplement the data release. Note that this excludes the costs associated with the provision of the original, third-party, data used in this study on which future updates would also be dependent. **Criteria assessment:** Passed

18. Note there is a current inconsistency in the treatment of direct-trade flows, but see recommendations in the Discussion for more description of how this might be overcome.

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