REVIEW

Which forest-risk commodities imported to the UK have the highest overseas impacts? A rapid evidence synthesis [version 1; peer review: 2 approved with reservations]

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Abstract

Background: Commodity-driven deforestation is a major driver of forest loss worldwide, and globalisation has increased the disconnect between producer and consumer countries. Recent due-diligence legislation aiming to improve supply chain sustainability covers major forest-risk commodities. However, the evidence base for specific commodities included within policy needs assessing to ensure effective reduction of embedded deforestation.

Methods: We conducted a rapid evidence synthesis in October 2020 using three databases; Google Scholar, Web of Science, and Scopus, to assess the literature and identify commodities with the highest deforestation risk linked to UK imports. Inclusion criteria include publication in the past 10 years and studies that didn't link commodity consumption to impacts or to the UK were excluded. The development of a review protocol was used to minimise bias and critical appraisal of underlying data and methods in studies was conducted in order to assess the uncertainties around results.

Results: From a total of 318 results, 17 studies were included in the final synthesis. These studies used various methodologies and input data, yet there is broad alignment on commodities, confirming that those included in due diligence legislation have a high deforestation risk. Soy, palm oil, and beef were identified as critical, with their production being concentrated in just a few global locations. However, there are also emerging commodities that have a high deforestation risk but are not included in legislation, such as sugar and coffee. These commodities are much less extensively studied in the literature and may warrant further research and consideration.

Conclusion: Policy recommendations in the selected studies suggests further strengthening of the UK due diligence legislation is needed. In particular, the provision of incentives for uptake of policies and wider stakeholder engagement, as well as continual review of commodities included to ensure a reduction in the UK's overseas deforestation footprint.

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Keywords

trade, forest-risk commodities, deforestation, evidence synthesis

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1. Introduction

Global deforestation is largely driven by land use change for agricultural commodity production (Curtis *et al.*, 2018). Combined with shifting agriculture and forestry (timber production), these drivers are estimated to be responsible for 77% of forest loss worldwide. The majority of new land for agriculture historically comes from conversion of intact, tropical forests and an estimated 129 million hectares of forest was lost worldwide between 1990–2015 (FAO, 2015). Although the rate of global forest loss has slowed and tree cover has increased in recent decades, changes are unevenly distributed with large losses still occurring in tropical regions (Song *et al.*, 2018). Expanding agricultural frontiers are the primary driver of tropical deforestation (Curtis *et al.*, 2018; Gibbs *et al.*, 2010) with over 64 million hectares of primary tropical forest estimated to have been lost between 2002–2020 (GFW, 2021). Tropical deforestation is also one of the largest sources of anthropogenic greenhouse gas emissions (Smith *et al.*, 2014) and is a major driver of biodiversity loss, with agriculture threatening a large majority of species identified as at risk of extinction (Benton *et al.*, 2021; IUCN, 2021). Furthermore, it is likely to substantially impair ecosystem function and services, with direct consequences for people's livelihoods and hindering our ability to achieve multiple sustainable development goals (IPBES, 2019).

Tropical deforestation is increasingly driven by international demand for agricultural commodities (Defries *et al.*, 2010; Henders *et al.*, 2015). The impacts of production which are embodied in exports have increased rapidly as trade becomes more globalised (Henders *et al.*, 2015), with assessment of impacts being increasingly difficult due to geographic separation of consumption and production locations (Meyfroidt *et al.*, 2013). Furthermore, as global populations increase (UN, 2019) and climate change results in a reduction of global yields for major crops (Zhao *et al.*, 2017), it is likely that cropland will continue to expand to meet an increasing demand for food (Delzeit *et al.*, 2017). A shift in demand for products that are more land intensive to produce, such as meat and dairy, are also likely to occur alongside increasing demand (Godfray *et al.*, 2010), and reducing this demand will be key for meeting sustainable diets (Willett *et al.*, 2019).

Despite shifting global demands, only a small handful of commodities are responsible for a large proportion of tropical deforestation and associated emissions (Henders *et al.*, 2015). The production of four commodities; beef, soybeans, palm oil, and wood products contribute to around 40% of total tropical deforestation. These 'forest-risk' commodities are defined as "*globally traded goods and raw materials that originate from tropical forest ecosystems, either directly from forest areas, or from areas previously under forest cover whose extraction or production contributes significantly to global tropical deforestation and degradation*" (Rautner *et al.*, 2013). Globalisation has resulted in a growing proportion of impacts being embodied in exports, with between 29–39% of deforestation-related emissions being driven by international trade (Pendrill *et al.*, 2019a).

The increasing role that global consumers play in driving tropical deforestation has led to many countries recognising the need for demand-side policies to improve supply chain sustainability. Arguably, however, it was the private sector who made the first widespread commitments to addressing the deforestation activity embodied in supply chains, with the Consumer Goods Forum (comprised mainly of a group of large, international consumer goods and retail companies) making a commitment in 2010 (CGF, 2017). Corporate commitments were bolstered within the UN Declaration on Forests, signed in 2014 as a non-legally binding political declaration from governments, companies, and civil society to cut natural forest loss by half by 2020, and altogether by 2030 (UN, 2014). Several European countries, including the UK, quickly sought to strengthen commitments via the Amsterdam Declaration towards eliminating deforestation from agricultural commodity chains (ADP, 2018).

However, despite these corporate commitments, underpinned by government support (including the establishment of roundtables focused on monitoring specific deforestation risk commodities e.g., soy and palm oil in the UK; Efeca, 2020a; Efeca, 2020b) the rate of global commodity-driven deforestation has shown little sign of decline (Curtis *et al.*, 2018). In response, the UK Government, in 2019 established the Global Resource Initiative (GRI), which made a series of recommendations designed to tackle UK-linked and global commodity-driven deforestation (GRI, 2020). In the run up to hosting the 26th UN Climate change Conference of the Parties in 2021 (COP26), the UK government has also emphasised the importance of addressing deforestation and associated emissions driven by global agricultural commodity trade (Sharma, 2021).

The UK is one of the world's major economies, and whilst there are individual countries with a larger volume of imports, it is known to be importing significant quantities of commodities produced by commercial agriculture, which – as above - is linked to deforestation. The introduction of regulatory proposals in the form of due diligence legislation – a response to GRI recommendations (GRI, 2020; Goldsmith & Callanan, 2020) – acknowledges the role of the UK in the global deforestation problem and aims at helping to improve the sustainability of forest risk commodities. However, the consultation around the introduction of this legislation (DEFRA, 2020) has largely focused on relatively few commodities, including beef and leather, cocoa, palm oil, rubber, and soy. Therefore, it is important to assess the evidence base for the identification of these commodities and an ongoing assessment of all forest risk commodities (i.e., not just those which garner most attention) is likely to be necessary, as addressing demand for these products will be critical for succeeding in slowing the rate of global deforestation.

This study conducts a rapid systematic literature review across studies which quantify the impact of agricultural commodities traded by the UK. This is to identify the commodities which pose the greatest risk to forests and associated

relevant environmental impacts such as carbon emissions and biodiversity, and to examine the evidence base for the key commodities that should be considered in the UK's risk assessment and policy responses. A systematic review is defined as "a review in which there is a comprehensive search for relevant studies on a specific topic, and those identified are then appraised and synthesised according to a predetermined and explicit method" (Klassen *et al.*, 1998). Systematic reviews have the advantage of minimising bias by ensuring careful *a priori* planning, including the development of a review protocol which establishes the pre-specification of criteria of studies to be included or excluded, methods to be followed and how outcomes will be synthesised (Cook *et al.*, 1997). A review of this type is therefore used here to critically appraise existing identified forest risk commodities. This study also examines the evidence base, methods, and data behind the studies identified, to further investigate remaining uncertainties around quantification of trade-driven deforestation impacts. Due to time limitations, this systematic review was conducted as a rapid evidence synthesis, therefore at times deviates from standard review practise.

2. Methods

The systematic review process is typically split into eight stages. Firstly, an initial research question was defined on the subject of 'What are the high-risk commodities based on sustainability assessment impacts?'. This was further refined to specifically examine agricultural commodities, with a focus on studies examining tropical deforestation and associated impacts, given the current relevance of this lens to UK policy.

The second stage was to develop a review protocol (Molotoks & West, 2021; Appendix A). Development of the systematic review protocol was based on a template following PRISMA-P guidelines where applicable. This pre-specified the questions to be addressed and the specific objectives of the review. These objectives include:

- (a) To clarify what literature and evidence is available around UK consumption activities driving deforestation and associated impacts in producer countries.
- (b) To identify key commodities which have a high deforestation risk.
- (c) To suggest policy interventions which could simultaneously reduce negative impacts of commodity production and trade, whilst promoting sustainable livelihoods of local communities.

A comprehensive search strategy was developed as part of the review protocol which included text word searching in key fields including the title and abstract of selected terms and use of search filters across three databases: Google Scholar, Web of Science, and Scopus. These databases were chosen due to being widely used and their relevance to the topic. Furthermore, the inclusion of Google Scholar allowed for grey literature to also be included in results. Search terms were as follows:

"deforestation risk commodities" OR "deforestation risk commodity" OR "forest risk commodities" OR "forest risk commodity" OR "commodity driven deforestation"

AND "United Kingdom" OR "British" OR "UK"

AND "supply chain".

Exclusion criteria included restrictions on language and publication period, therefore filters used included studies written in the English language and those published in the past 20 years. This returned 318 results and was conducted in October 2020, hence any studies published after this period are not included in the review. Results from all databases were checked for duplicates and due to the high number of duplicates from Google Scholar, which were identified manually through use of the reference managing software Mendeley (Version 1.19.8), only the first 150 results were included, resulting in a total of 232 results. Reference-checking the final systematically reviewed papers was also completed in order to reduce the risk of missing information, which was carried out by manually screening the reference lists. Relevant grey literature was included in the search through use of Google Scholar, as well as incorporation of grey literature already known to the authors that met the review protocol criteria.

The fourth stage was to assess the eligibility of the studies identified from the search strategy using the predefined inclusion and exclusion criteria from the review protocol (Molotoks & West, 2021; Appendix A). For example, studies which didn't link commodity consumption to impacts, or that weren't applied or lacked the ability to be applied to the UK were excluded. Identification of relevant studies, including both peer reviewed articles and grey literature occurred in two separate sifts; the first extracted studies based on their title and abstract. A second sift then extracted studies based on the full text. Studies were then examined manually for duplicates which were removed, leaving the remaining selected studies.

Once the final studies had been selected, data was then extracted, checked, and verified against Population, Intervention, Comparison, Outcome, Study design (PICOS) criteria and summary information extracted into a table (Stage 5). The PICOS format is a widely recognised strategy for framing a research question and facilitating the identification of relevant information, setting specific criteria for inclusion within the final selection of studies (Sackett *et al.*, 1997). For example, the 'population' criteria related to the target group assessed within the analysis in this case this was the UK, hence studies not specifically examining UK consumption or containing data which could be linked or applied to the UK were excluded. One of the PICOS criteria (comparison) was not applicable to this evidence synthesis as no comparisons between different groups were planned in the review protocol (Molotoks & West, 2021; Appendix A).

Information manually extracted from the literature into a spreadsheet using Microsoft Excel 2016 software included the

terminology of footprint indicators used, methodology, data inputs, study area, commodities assessed, the time period of the study, and any policy recommendations made. The final selected studies were also grouped according to the region they cover and the commodity they examine. This data on country and commodity context was also extracted from studies from the first screening to demonstrate which commodities, though not specifically linked to UK trade, had been studied most extensively (see results [section 3.1](#)). The final stage before synthesising (Stage 7) and disseminating results (Stage 8) was to assess the quality and validity of the included studies (Stage 6). Literature was assessed using quality assessment questions regarding their evidence base using the pre-defined method from the review protocol to reduce bias and assess certainty in the results for addressing the objective of this study. These included answering three questions as to whether there is (a) evidence of causation, (b) outcome measures, and (c) selective reporting (Molotoks & West, 2021; Appendix A). Due to the rapid nature of the review, only one reviewer conducted the search strategy, data extraction, and quality assessment. This is recognised as a limitation of rapid evidence synthesis and the pre-development of the review protocol was designed to eliminate potential bias of this methodology. No effect measures were used, and no meta-analysis was performed due to the timeframe constraints.

For the synthesis, a narrative of final selected studies was conducted around data inputs used, methodologies and use of trade models, time frames of studies and any themes of policy recommendations made (see results [section 3.2](#)). An overview of the countries and commodities covered is also presented. Furthermore, quantitative results are presented from one study identified as employing the most robust methodologies (see results [section 3.3](#)), to demonstrate the type of data available and indicate which commodities associated with UK trade have the highest overseas footprints, independent of whether they are covered in any detail in other studies that were selected via this rapid evidence review.

3. Results

Of the 318 results returned, 17 studies were included in the final selection process after removal of duplicates, irrelevant, and inaccessible studies ([Figure 1](#)). Duplicates were firstly removed from within each individual database used. Following this, the first sift extracted studies based on their title and abstract ($n=152$ including duplicates between different databases). A second sift then extracted studies based on the full text ($n=26$). Studies were then examined for duplicates between different databases and nine were removed, leaving 17 remaining studies. See [Figure 1](#) for a flow chart summarising the full search and selection process. The risk of bias due to missing results is recognised.

Results presented include a summary of countries and commodities studied from the first screening ([Section 3.1](#)), a narrative synthesis of the final selected studies ([Section 3.2](#)) and presentation of UK specific results from the study using the most robust methodologies ([Section 3.3](#)). For a full list of

Figure 1. Flow diagram of study selection and screening process.

characteristics of each included study, please see Molotoks & West, 2021; Appendix B.

3.1 Synthesis of papers from initial screening

The most common commodity and study area examined exclusively by studies was Brazilian soy, followed by Brazilian beef, and Indonesian palm oil ([Figure 2](#)). Cocoa was the most commonly studied commodity in Africa, whereas palm oil was the most frequent in Asia and soy in South America. Commodities covered in studies looking at more than one geographical context included soy, palm oil, and rubber.

3.2 Synthesis of selected papers from second screening

In the studies selected after the second screening, a more detailed assessment of commodities covered was conducted. The most common commodity and study area examined exclusively was also Brazilian soy ([Figure 3](#)). Other Latin American countries commonly presented in results included Argentina, Bolivia, Colombia, and Paraguay. Indonesia, Malaysia, and Papua New Guinea were also frequently

Figure 2. Country-commodity contexts taken from studies which passed the initial screening in the first sift (n= 152) excluding: duplicates between databases, studies which don't mention specific contexts, and 33 studies which conducted analyses across various countries and multiple commodities at once.

mentioned. After soy, beef, palm oil, and timber were the most common commodities studied exclusively (Figure 3). Other tropical deforestation risk commodities include pulp and paper, leather, rubber, cocoa and coffee.

Land use data. There were over ten different types of footprint indicators used by the 17 selected studies, including deforestation, ecological, biodiversity, carbon, emissions, and harvest

footprints (Molotoks & West, 2021; Appendix B). These were identified by searching for the term 'footprint' in each of the selected studies. 'Land footprint', 'land use footprint' and 'consumption footprint' were the most commonly used terminologies. However, in addition to the different indicators representing different aspects of environmental impacts, precise methodology definitions varied between studies and the underlying data between studies also differed. Therefore,

Figure 3. Forest-risk commodities included in final studies. Leather was incorporated with beef in two of the studies, therefore is counted twice. Likewise, pulp and paper were incorporated in the same category as timber in two studies. PNG = Papua New Guinea.

similar terminology could represent very different types of environmental impacts. For example, in the global studies synthesised, Hansen *et al.* (2013) is the most commonly used spatial dataset for representing forest loss, either solely (Pendrill *et al.*, 2019a; Pendrill *et al.*, 2019b) or in combination with national datasets for certain contexts (Persson *et al.*, 2014; Henders *et al.*, 2015). Specific commodity country contexts, however, often use nationally specific remote sensing datasets exclusively for their land cover inputs (zu Ermgassen *et al.*, 2020; Escobar *et al.*, 2020; Godar *et al.*, 2016; Green *et al.*, 2019; Trase, 2018; Walker *et al.*, 2013).

One study uses a combination of spatial and statistical data to estimate relative deforestation risks of each country, using Hansen data on extent of tree loss from the Global Forest Watch data portal in combination with data from the Food and Agricultural Organisation (FAO) on deforestation rates (WWF, 2020). This approach prevents larger countries scoring a higher risk solely based on total land area, as the second dataset accounts for countries losing a large proportion of their small remaining forest cover. Several studies used a combination of different sources of remote sensing spatial data alongside a synthesis of national and international statistical data (Henders *et al.*, 2015; Persson *et al.*, 2014). For studies which did not use spatially explicit methods, data from the Food and Agricultural Organisation Corporate Statistical Database (FAOSTAT) was often used to provide national agricultural land use and production statistics (Niu *et al.*, 2020; Rautner *et al.*, 2013; Sandström *et al.*, 2018). Use of national statistics for the consumption of commodities already defined as ‘forest-risk’ were also

sometimes used as a proxy for deforestation impacts (Rautner *et al.*, 2013; Walker *et al.*, 2013; Zhang *et al.*, 2020).

Trade data and methodologies. A variety of trade databases were also used to connect production to imports or consumption activities. For example, the Eora Multiregional Input-Output (MRIO) database (Niu *et al.*, 2020; Zhang *et al.*, 2020), the UN Comtrade database (Rautner *et al.*, 2013; WWF, 2020), and the Global Trade Analysis Project (GTAP) MRIO database (Green *et al.*, 2019). Trade models based on FAOSTAT data were also commonly used (Henders *et al.*, 2015; Persson *et al.*, 2014; Pendrill *et al.*, 2019a; Pendrill *et al.*, 2019b; Sandström *et al.*, 2018; Trase, 2018). Two studies used a combination of two databases: UN Comtrade and (a) FAOSTAT data (Godar *et al.*, 2016), or (b) national statistics on trade of specific commodities (Walker *et al.*, 2013). Furthermore, one study also compares two databases separately, FAOSTAT and EXIOBASE to provide an inter-comparison (Pendrill *et al.*, 2019a).

At the time of review, there was only one study which conducted a global analysis on a large number of specific commodities which linked embodied deforestation results to UK trade (Pendrill *et al.*, 2019b). Other studies focussed on emissions associated with land use change (Niu *et al.*, 2020; Pendrill *et al.*, 2019a) or only examined a small handful of forest risk commodities (Godar *et al.*, 2016; Henders *et al.*, 2015; Persson *et al.*, 2014; Rautner *et al.*, 2013; WWF, 2020). Sandström *et al.* (2018) only focuses on certain sectors, with all other studies focusing on a single commodity. Pendrill *et al.* (2019b)

is a recent study that uses a combined approach of utilising modelling based on FAOSTAT data in combination with the latest remote sensing data. Given its global coverage and specific deforestation focus that comprehensively covers all crop production, we present UK specific results from this particular study in [section 3.3](#).

Timeframes. Global studies are often reliant on data which does not reflect present circumstances due to difficulties in accessing up to date data. This is particularly the case for global land use data, with [Hansen et al. \(2013\)](#) being the most commonly used data on forest loss ([Henders et al., 2015](#); [Persson et al., 2014](#); [Pendrell et al., 2019b](#); [WWF, 2020](#)) providing annual statistics from 2001–2019. National land use datasets are also often updated annually e.g., the National Institute for Space Research (INPE) and the Image Processing and Geographic Information System (GIS) Laboratory (LAPIG) for which [Godar et al. \(2016\)](#) uses data from 2015. However, even recent studies base analyses on data which are over a decade old e.g., 2002–2011 ([Sandström et al., 2018](#)). For trade data, the majority of studies use FAOSTAT which also provides frequent, often annual, updates on trade statistics. Other sources such as the UN Comtrade database are also frequently updated with studies using various time periods, for example 2011–2018 ([WWF, 2020](#)) or 2011 ([Rautner et al., 2013](#); [Walker et al., 2013](#)), or used to check consistency of other datasets ([Escobar et al., 2020](#)). Studies using MRIO trade models also vary in terms of the time stamp of trade data used, using data from ten years ([Green et al., 2019](#)), five years ([Pendrell et al., 2019a](#); [Zhang et al., 2020](#)) or four years ([Niu et al., 2020](#)) prior to their publication.

Policy recommendations. Despite differences in the underpinning data, methodology and time frame of studies, consistent themes emerge from the reviewed studies around the need for international cooperation for addressing the challenges of promoting sustainable supply chains. It is important to holistically consider the trade-offs between food production and environmental sustainability ([Niu et al., 2020](#)) and align monitoring between countries ([Efeca, 2019](#)). Monitoring indirect suppliers is also critical for progress towards promoting sustainable supply chains ([zu Ermgassen et al., 2020](#); [Trase, 2018](#); [Walker et al., 2013](#)) and applying extensions to cover more stages along the supply chains such as re-exports ([Escobar et al., 2020](#)) is also recommended. Broader policy agendas are also recognised as necessary for identifying synergies with policies beyond supply chains e.g., food security, conservation, national economic development and local/traditional knowledge ([Godar et al., 2016](#)).

Policy recommendations from studies acknowledge the need for a combination of demand and supply side measures ([Henders et al., 2015](#)) and extending supply chain governance beyond biomes of production ([zu Ermgassen et al., 2020](#)). A focus on export markets alone will not adequately address deforestation associated with commodities ([zu Ermgassen et al., 2020](#)) and bilateral agreements between tropical forest countries are essential for avoiding leakage ([Rautner et al., 2013](#)),

for example, to countries without REDD+ policies ([Green et al., 2019](#); [Henders et al., 2015](#)). Differentiation between emissions from consumption and production related activities could also avoid leakage ([Loeff et al., 2018](#)). Emissions are often concentrated in comparatively few trade flows, which suggests effective efforts to reduce deforestation in supply chains should target specific trade relationships and commodities e.g., through use of carbon taxes on food products ([Pendrell et al., 2019a](#)). This means increased transparency is also necessary ([Trase, 2018](#)). Incentives for facilitating uptake and use of transparency information are needed ([Godar et al., 2016](#)), with transparency and corporate disclosure also needing to be incentivised, for example through differential import tariffs and guarantees ([Rautner et al., 2013](#)).

One study gives specific recommendations for UK policy, encouraging mandatory due diligence obligations and legally binding targets for reducing environmental footprints ([WWF, 2020](#)), for example, by moving from zero net to zero-absolute deforestation or by introducing annual targets for reducing deforestation ([Trase, 2018](#)). Many studies also encourage wider stakeholder engagement ([WWF, 2020](#)) and collective action through the establishment of multi-stakeholder partnerships ([Green et al., 2019](#); [Walker et al., 2013](#)). Other suggestions include implementation of biome or landscape level mechanisms ([Escobar et al., 2020](#); [Green et al., 2019](#)), independent auditing systems ([Walker et al., 2013](#)) and improved certification schemes ([Rautner et al., 2013](#)). Broader implementation strategies, such as enforcement of public and private sector initiatives and commitments ([Rautner et al., 2013](#)), to avoid undue burdens on producers ([Trase, 2018](#)) are also recommended. Consumer policy is only mentioned by a few studies with the recommendation of changing consumption patterns ([Niu et al., 2020](#)) to reduce consumption of animal products ([WWF, 2020](#)), in particular, beef ([Sandström et al., 2018](#)).

3.3 Deforestation risk commodities

Data was extracted from the publicly available [Pendrell et al., 2020](#) dataset which is based on the [Pendrell et al. \(2019b\)](#) study. According to this study, the highest risk commodities in terms of deforestation risk for the UK are palm oil, beef, wood products, soy, cocoa, and coffee ([Table 1](#)), collectively contributing to over 89% of the UK's overseas deforestation risk ([Pendrell et al., 2020](#)). It is also worth noting that there are other less well-recognised commodities such as sugar and spices represented in the top ten commodities imported by the UK with the highest deforestation risk by this data ([Table 1](#)).

[Figure 4](#) shows the country commodity contexts with the highest deforestation risk associated with UK trade. The associated carbon emissions (including peat emissions) from UK imports are also shown ([Pendrell et al., 2020](#)). Results illustrate that a high proportion of tropical deforestation associated with UK imports can be attributed to just a few commodities and producer countries. Three contexts alone, Indonesian palm oil, Brazilian beef, and Brazilian soy, are estimated to

Table 1. Top ten UK imported agricultural commodities with the highest deforestation risk in 2017 (data from (Pendrill *et al.*, 2020), based on methods described in Pendrill *et al.* (2019a); Pendrill *et al.* (2019b)).

Commodity	Sum of deforestation risk (hectares (ha)/year)
Palm oil	5390
Beef (inc. buffalo)	2483
Timber (forest plantations)	2140
Soybeans	1871
Cocoa, beans	1261
Coffee, green	1208
Sugar Raw Centrifugal	322
Pepper (piper spp.)	178
Rubber, natural	94
Nutmeg, mace and cardamoms	92

amount to almost half the total UK deforestation footprint (Figure 4). These same contexts are also identified previously as those that have been most exclusively researched (Figure 2 and Figure 3).

For each of the top six commodities (Table 1), the majority of their deforestation risk (over 75%) is concentrated in just three countries (Figure 5 and Figure 6)

It is important to note that other countries also contribute to each commodity's deforestation risk but are not shown in Figure 5 as they constitute a relatively small proportion to overall risk. This is demonstrated in Figure 6 where the total from all other countries shows a relatively small contribution to each commodities deforestation risk. Furthermore, it is also important to note this study only covers commodities associated with tropical deforestation, hence there is a risk of bias.

Figure 4. Deforestation risk (hectares/year, (ha/yr), shown in outer ring) and associated carbon emissions (MtCO2/year) from UK imports of agricultural and forestry commodities in 2017 (data from (Pendrill *et al.*, 2020), based on (Pendrill *et al.*, 2019a; Pendrill *et al.*, 2019b)).

Figure 5. Major countries that the six highest forest-risk commodities (Table 1) are sourced from, by the UK (Pendrill *et al.*, 2020) based on (Pendrill *et al.*, 2019a; Pendrill *et al.*, 2019b), excluding countries within which commodities contribute a small amount to deforestation.

Figure 6. The three countries with the highest deforestation risk (ha/yr) for each of the six top commodities (Pendrill *et al.*, 2020), based on (Pendrill *et al.*, 2019a; Pendrill *et al.*, 2019b)) and all other countries grouped together as 'Other'. PNG = Papua New Guinea, DRC= Democratic Republic of the Congo.

4. Discussion

Appraisal of land cover datasets employed in reviewed studies

The data from [Pendrell *et al.* \(2019b\)](#) presented in [section 3.3](#) illustrates the type of information that ‘state of the art’ methods for attributing global deforestation risk (and associated emissions) to traded commodities provide. Although this is not a definitive source, it is one of the most comprehensive, up to date, analyses linking UK trade to specific commodities and their environmental impacts in terms of deforestation risk. However, as with any assessments that attempt to link the impacts of production to international supply chains, there are a few caveats and limitations. The [Pendrell *et al.* \(2019b\)](#) data only covers tropical and sub-tropical commodities. Furthermore, timber as represented in this dataset only includes timber plantations, a limitation other studies also face ([Zhang *et al.*, 2020](#)), as opposed to extraction from primary forest, hence these are potential data gaps. This gap is partially filled by a more recent study which has been published since this review was conducted ([Hoang & Kanemoto, 2021](#)). This study also uses [Hansen *et al.* \(2013\)](#) as well as differentiating between tropical forests from plantations. However, it does not provide commodity-specific deforestation footprints.

The use of different forest datasets will also result in different outcomes depending on the methodology used. [Pendrell *et al.* \(2019b\)](#), like many studies, uses [Hansen *et al.* \(2013\)](#) which is one of the main sources for tree loss data. The other main source of deforestation data comes from the Global Forest Resources Assessment, which uses statistics from the UN Food and Agricultural Organisation (FAO). A detailed study comparing these methods found estimates of deforestation rates lower using Hansen data due to the different definitions of deforestation applied ([McNicol *et al.* 2018](#)). Hansen data is based on tree cover, defined as over five metres tall, whilst FAO estimates are based on land use classifications and extrapolations of rates of change, which are a net change figure. The way Hansen defines tree cover as all vegetation over five metres in height gives higher estimates of tree cover ([McNicol *et al.*, 2018](#)). However, its sensitivity for capturing smaller canopy disturbances can ultimately lead to an underestimation of deforestation rates driven by small-scale disturbances, particularly on local-regional scales ([Milodowski *et al.*, 2017](#)).

There are therefore likely to be benefits of using nationally specific deforestation datasets as opposed to applying global datasets to national scales. This is particularly important for countries with large areas of forest cover and low levels of deforestation where small disturbances make up a large proportion of forest loss ([Galiatsatos *et al.*, 2020](#)). Many of the studies that focus specifically on one country-commodity context use national datasets as these datasets may provide more granular and ultimately more accurate representations of forest cover. Although the Hansen dataset is 30m resolution, it is rescaled from a coarser 250m resolution which limits its applicability for detecting afforestation or degradation changes

([Milodowski *et al.*, 2017](#)). Differences in definitions between global and national datasets as to what constitutes ‘forest’ can also result in differences, as found when PRODES data showed systematically lower rates of deforestation than Hansen, despite use of the same satellite data and mapping methods ([Milodowski *et al.*, 2017](#)). However, use of national datasets inevitably makes inter-comparisons between different countries or regions more difficult. Using Hansen data on a national scale and suitably calibrating for percent tree cover using national datasets could provide a potential solution to harmonisation. Given that different thresholds will be necessary for providing the closest correspondence to different national forest cover statistics, this could prevent over or under estimation ([Sannier *et al.*, 2015](#); [Galiatsatos *et al.*, 2020](#)). However, there is a need for more inter-comparisons of national and global datasets for assessing accuracy and increasing confidence in the data, with provision of confidence limits for data users being particularly important.

Appraisal of different trade databases/approaches to modelling

FAOSTAT data was used in the majority of studies, which is unsurprising given its position as the most detailed global dataset on agricultural commodity production and trade. However, the methodologies and criteria for data collation within FAOSTAT may vary in quality depending on the national reporting guidelines and capabilities. This is reflected in, for example, the mismatch between export and import reports which, when compiled into footprinting studies, require methodological choices to harmonise which may impact results. Any attempts to correct bilateral trade statistics for the ‘re-export’ of materials (as per [Pendrell *et al.*, 2019b](#)) will also necessitate a modelling-based approach whose assumptions may vary with impact on the distribution of production impacts between production and consumption.

Several studies extend beyond the use of bilateral trade data and use multi-regional input-output approaches (MRIOs) to provide a ‘final consumption’ account. Of these, GTAP ([Green *et al.*, 2019](#)), Eora ([Niu *et al.*, 2020](#); [Zhang *et al.*, 2020](#)) and EXIOBASE ([Pendrell *et al.*, 2019a](#)) MRIOs were used in the studies which were included after the second screening in our review. Choosing to apply an MRIO in combination with ([Green *et al.*, 2019](#); [Niu *et al.*, 2020](#); [Zhang *et al.*, 2020](#)) or as an alternative to ([Pendrell *et al.*, 2019b](#)) FAOSTAT can have a large impact on results. This is driven by a combination of the different perspective (i.e., true consumption vs trade) adopted by the inclusion of an MRIO method, and by differences in the underpinning data and the methods via which they are applied. As an example, a recently published (but currently un-peer reviewed) interim report compiling the UK deforestation footprint ([Croft *et al.*, 2021](#)) used the same deforestation dataset as [Pendrell *et al.* \(2019a\)](#). The combination with a hybridised MRIO approach (similar to that applied in ([Croft *et al.*, 2018](#))), estimated ~20,000ha for UK total deforestation risk ([Croft *et al.*, 2021](#)) compared to ~16,000ha for the [Pendrell *et al.*, 2019a](#) account presented above ([Figure 4](#)). Such a difference reflects the fact that a full consumption

footprint encompasses indirect utilisation of commodities (e.g., in more complex products) which are not included to the same degree when only bilateral trade information is considered.

All MRIOs have their own strengths and weaknesses, which can dictate their choice in different applications. However, deforestation footprints and associated emissions will vary according to the MRIO used due to differences in geographic and temporal resolution, time lags, country and sectoral representation, and methods used to harmonise the statistics they contain (Giljum *et al.*, 2019). There are limited comparisons between MRIOs to understand how differences affects results, therefore methodological development and alignment between global MRIOs is an important research priority. There is also a need for more detailed data on specific locations of risk, especially for countries with high deforestation rates (Pendrill *et al.*, 2019a), as international supply chain assessment will lack specific supply chain detail. There are approaches which attempt to give this detail; for example, the Transparency for Sustainable Economies (Trase) initiative (<http://www.trase.earth>). This approach is used in several of the studies in this review (zu Ermgassen *et al.*, 2020; Escobar *et al.*, 2020; Trase, 2018) and uses publicly available data to link imports of consumer countries to subnational places of production. More detailed, sub-national assessments are not possible internationally at this time, however, and efforts to improve data availability and target other interventions for risk-mitigation first requires an understanding of the likely hotspots (Figure 5, Figure 6).

Context of results in UK policy

The hotspots i.e., the main deforestation risk commodities analysed within papers comprising this synthesis, and the results presented from Pendrill *et al.*, 2019a are a good match with current UK policy-linked dialogue. The commodities mentioned in the UK's due diligence consultation (DEFRA, 2020), for example, include beef and leather, cocoa, palm oil, rubber, and soy. The main commodities illustrated here that have the highest deforestation risk yet are not included in the DEFRA consultation list are wood products and coffee (Table 1). Timber and pulp and paper are mentioned briefly in introductory materials, despite not appearing in the list of included commodities for questions set within the due diligence consultation, but it is worth noting there are already due diligence requirements on timber imports (OPSS, 2014). However, these highest risk commodities are not considered equally across the reviewed literature, with coffee and cocoa having significantly less dedicated studies, for example (Figure 2 and Figure 3). Whilst not mentioned in the UK due diligence consultation, certain spices such as nutmeg, pepper, and sugar are also listed as being in the top ten forest risk commodities imported by the UK (Table 1) with major producer countries being Indonesia, Vietnam, and Belize respectively (Pendrill *et al.*, 2020). This is despite having a higher estimated deforestation risk than some commodities included in the consultation, for example rubber. No studies in our rapid

review specifically covered these emerging commodities as deforestation risk commodities linked to the UK (Figure 2 and Figure 3). There is therefore a potential gap related to the inclusion of less well-known commodities, shown in recent research to have a deforestation risk associated with UK imports, in terms of their scientific and policy coverage.

This point about the balance of coverage in the literature and policy documentation and identified forest-risk commodities within emerging recent analysis is an important consideration. There may be commodities which are less extensively studied for reasons of data availability or scientific capacity which have a relatively high deforestation footprint. Furthermore, the inclusion of certain commodities but not others in policy materials could bias efforts towards certain areas at the expense of others. Brazilian soy for example was the most commonly studied commodity in our review (Figure 2), likely in part due to data availability and a recognised historical link between its production and impacts on critical biomes such as the Amazon rainforest (Fearnside, 2001). There is no doubt that Brazilian soy is a critical deforestation-risk commodity, and the presence of lesser-studied commodities in deforestation footprints should not distract from attention on this and the landscapes where it is a threat. However, additional attention on other commodities that are less commonly studied is warranted, particularly to avoid these being associated with deforestation frontiers in future (Table 1).

It is particularly important to keep commodities listed as being a deforestation risk in legislation under review as, should reducing deforestation associated with one commodity be successful, there is a risk of deforestation being displaced to others via leakage effects (Meyfroidt *et al.*, 2013). Quite a few of the studies mention the issue of leakage and the importance of avoiding impacts of commodity production simply moving to a different area, which is only likely to be minimized by wider adoption and enforcement of zero-deforestation commitments (Garrett *et al.*, 2019). The impacts of climate change may also contribute to changing crop yields and shifting areas of cultivation in future. Although negative impacts of climate change on major crops are well recognised (Zhao *et al.*, 2017), particularly in high and low latitudes, uncertainty remains for the impact of climate change on crop yields in mid-latitude regions (Rosenzweig *et al.*, 2014). Climate change impacts are likely to be most severe in the tropics where the majority of global commodity-driven deforestation is also concentrated (Curtis *et al.*, 2018). Uncertainties in future projections are also more severe for certain agricultural commodities such as soy, which have more concentrated production areas, increasing sensitivity to regional differences in model projections. Furthermore, depending on the model and scenario used, impacts of future cropland expansion can vary considerably (Molotoks *et al.*, 2020). Predicting future hotspots of commodity-driven deforestation is therefore difficult and subject to variations in model structures and assumptions, underpinning a necessity for policy, which can respond to 'early warning', signs of deforestation occurring in new areas should these emerge in response to changing climate.

Overview of policy recommendations

Recommendations for policy drawn from the synthesised literature include a need for international collaboration between producer and consumer countries, multi-stakeholder engagement, and increased transparency of supply chains to address deforestation footprints. For the country-commodity contexts with the highest deforestation risks, Brazilian soy and beef, and Indonesian palm oil (Figure 6), forest and commodity-based exports are often particularly important for economic development. Hence there is a strong trade-off between development and environmental sustainability which makes working closely with these countries to support forest-risk commodity producers particularly important (Bager *et al.*, 2021). There is also often a trade-off between political feasibility and impact on reducing deforestation footprints. Policy options which are more feasible to implement tend to have a weaker theory of change and, in light of voluntary commitments being relatively ineffective (Garrett *et al.*, 2019), multiple policy levers are likely to be required.

Voluntary certification programmes have been the focus of previous initiatives to reduce deforestation, however, these schemes only cover a small share of the global market (Garrett *et al.*, 2019). They also place the burden for proving compliance on producers and changing policies or inconsistent enforcement can affect the ability of companies to implement commitments. Adoption of zero-deforestation certifications is very low for soy (Garrett *et al.*, 2019) and certified production only covers a small proportion of conventional production of major forest-risk commodities (van der Ven *et al.*, 2018). Furthermore, there has been a lack of success in halting land use change patterns through certification schemes, partly due to lack of uptake, but also due to regulatory loopholes and lack of enforcement (van der Ven *et al.*, 2018). There is also a major gap in commitments around beef production, with indirect suppliers not considered, hence there has been very little impact on reducing deforestation in this sector (Alix-Garcia & Gibbs, 2017)

Other supply-side commitments have been more successful. For example, the soy moratorium has been evaluated by recent reports to confirm their effectiveness due to a combination of multi-stakeholder action enforced through strict accountability (Gibbs *et al.*, 2015). However, studies included in this rapid review have stressed that a combined approach of both demand and supply side policies will be essential for effective reduction in commodity-driven deforestation. Policies to prevent deforestation therefore also need measures that target consumers, hence demand-side measures which target lifestyle changes can also encourage deforestation-free production along supply chains (Henders *et al.*, 2018). Reducing meat consumption, in particular beef, can effectively reduce deforestation and associated emissions (Sandström *et al.*, 2018). By reducing demand for beef, it is possible to reduce emissions related to feed production, particularly soy, which is often embedded within animal products consumed in the EU. As per the recommendations of the UK's Global Resource

Initiative, policy makers should therefore carefully consider the potential to introduce demand-linked measures (such as the promotion of lifestyle changes) in addition to the measures focusing on supply chain actors placing forest-risk commodities on the market (GRI, 2020).

Provision of economic incentives is one option for shifting the demand for forest-risk commodity consumption, however carbon taxation of food for example has shown to be relatively ineffective at affecting consumption (Bager *et al.*, 2021). This approach is more likely to be effective if levied on supply-chain actors where economic incentives are stronger for shifting consumption patterns. However, for this to be effective in reducing deforestation risk, emissions should be differentiated relative to contributions to deforestation. Economic incentives are also mentioned in studies included in this review as likely being necessary to promote increased supply chain transparency (Godar *et al.*, 2016; Trase, 2018). Furthermore, there have recently been calls from 22 major companies, supported by the Sustainable Trade Initiative UK, for provision of additional measures, including reporting guidelines, sector specific requirements, and incentive-based approaches alongside due diligence legislation (IDH, 2020). This suggests that, despite mandatory due diligence for supply chain actors being effective in reducing imported deforestation and relatively implementable (Bager *et al.*, 2021), the UK due diligence does not go far enough. Therefore, strengthening this legislation and applying other measures are likely to be required to overcome feasibility barriers that due diligence alone faces, such as jurisdictional approaches and wider stakeholder engagement (von Essen & Lambin, 2021).

5. Conclusion

There is a good evidence base for the inclusion of the forest risk commodities that are explicitly covered in the UK due diligence legislation. The commodities with the highest deforestation risk, particularly soy, palm oil and beef, are well recognised in the literature, with a large coverage by studies included in this review. However, there is not equal coverage of all deforestation risk commodities, with coffee and cocoa being particularly less extensively studied in studies relevant to our rapid review. There are also gaps in the literature on less well-known commodities such as sugar and other spices, which represent a relatively large deforestation risk embodied within UK imports. These commodities are also not recognised explicitly in the UK due diligence consultation. It is therefore recommended that the scope of commodities listed in UK policy communications are both broadened and kept under continuous review both within the ongoing development of due diligence policy, but also within the portfolio of additional measures that will likely be needed to address the UK's deforestation footprint and deforestation in critical landscapes more generally.

Furthermore, importantly, more work needs to be done to understand the uncertainties and differences between results from

global studies to inform national policies, and to improve coordination between economic sectors that may be driving deforestation. Expanding research to cover commodities that are less extensively studied is also important to prevent bias, avoid leakage, and to prevent emergent deforestation frontiers. Although global studies are important for identifying hotspots of deforestation risk and guiding designation of priority areas, they are also limited in terms of their granularity and ability to inform policy effectively. Hence, integration of sub-national data, particularly for trade flows, which account for large proportions of deforestation risk, is necessary for a more in-depth understanding of where impacts are occurring, which commodities are driving deforestation and what policies are needed to address them.

Data availability

Underlying data

Zenodo. Which forest-risk commodities imported to the UK have the highest overseas impacts? A rapid evidence synthesis

systematic review. DOI [10.5281/zenodo.5227100](https://doi.org/10.5281/zenodo.5227100)

This project contains the following underlying data:

- Appendix A: Original review protocol
- Appendix B: Data extraction table.

Data are available under the terms of the [Creative Commons Attribution 4.0 International license](https://creativecommons.org/licenses/by/4.0/) (CC-BY 4.0).

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Zhao C, Liu B, Piao S, *et al.*: **Temperature increase reduces global yields of major crops in four independent estimates.** *Proc Natl Acad Sci U S A.* National Academy of Sciences, 2017; **114**(35): 9326–9331.

[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)

zu Ermgassen zu EKHJ, Godar J, Lathuillière MJ: **The origin, supply chain, and deforestation footprint of Brazil's beef exports.** 2020.

[Reference Source](#)

Open Peer Review

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Joss Lyons-White

ETH Zurich, Zürich, Switzerland

This manuscript presents a rapid systematic literature review (rapid evidence synthesis) to identify the tropical deforestation footprint of agricultural and forestry commodities imported by the UK. The manuscript thereby seeks to identify commodities that should be targeted by UK "due diligence" legislation. This legislation will require companies to ensure that commodities associated with deforestation are not imported to the UK through their supply chains. The authors followed PRISMA-P guidelines and implemented a logical protocol to conduct the review and develop their findings. They identified 318 potentially relevant studies, of which 17 met the inclusion/exclusion criteria and were reviewed. A narrative synthesis of findings is provided. The authors present differences between studies including the use of different trade and land-use data, timeframes, and methodologies. They examine the dataset from one pertinent study in detail. Palm oil, beef, wood products, soy, cocoa, and coffee are identified as major forest-risk commodities imported to the UK. The authors also identify some other commodities less frequently associated with deforestation, such as sugar, pepper, and nutmeg. The authors conclude that the major forest-risk commodities broadly overlap with those targeted by UK due diligence legislation. However, they argue that care must be taken to ensure that neglected commodities (such as sugar and spices) are not overlooked; target commodities are reviewed frequently; and additional policy instruments and multilateral engagements are pursued to strengthen the legislation's impact.

Overall assessment:

Overall, I found the methods presented to be robust, providing a sound basis for the development of the authors' findings and conclusions, which have high policy relevance. However, the manuscript has some shortcomings which should be addressed before a final version is published. My overarching comments are as follows, with specific comments on each manuscript section provided below.

Key comments:

- The writing is often confusing and difficult to follow. I provide some specific examples below, but the authors should consider reviewing the manuscript to check it for clarity, and

avoid long and confusing/misleading sentences.

- The text in the Methods section describing the exclusion of duplicates from the Google Scholar search is confusing and begs questions about the methods. The related numbers in Figure 1 are also difficult to add up. Why did the authors decide only to look at the first 150 Google Scholar search results rather than follow their protocol (which specified to review the first 20 pages of results) and exclude duplicates systematically? This begs the (admittedly minor) question of why the protocol specified 20 pages of results to be examined for each database, which could have had different numbers of results per page. The authors should consider revising the text about Google Scholar duplicates to clarify precisely what they did and justify the deviation from their protocol. The authors should also consider amending Figure 1 to show how many duplicates found through Google Scholar were excluded from the initial 318 papers identified (presumably 86?).
- The authors describe the research as being time-limited, which meant it was necessary to conduct a rapid evidence synthesis rather than a full systematic review. However, they do not say why the research was time-limited. This is important because the authors note that the time constraints meant their methods had to deviate from standard review practice, which could have undermined the rigour of the study. Appendix A indicates that findings were developed for the UK DEFRA; perhaps the time constraint came from the need to develop policy-relevant findings in a timely manner? But because this is not stated, it is unclear why the rapid evidence synthesis approach was used and what its limitations for the study's findings might have been/how these were managed. The authors should consider expanding on: 1) why the use of the rapid evidence synthesis was justified; and 2) what the implications might have been for their findings.
- The search strings were highly specific and can be expected to have tightly constrained the studies found. For example, any studies on “commodities” and “deforestation” that did not refer specifically to “risk” would have been excluded, as would have any studies referring to “value chains” rather than “supply chains”. This may have kept the scope of the research tight and facilitated the rapid approach, but it is possible that important studies may have been excluded. The authors acknowledge as much in the Results (“The risk of bias due to missing results is recognised”). However, they don’t elaborate on what the effects of this bias might have been, or what implications it might have for the interpretation of their findings. The authors could consider commenting further in the Discussion on how these aspects of their approach might have limited their findings.
- Further to the previous point, Figure 1 also says 14 studies were “not available”. How was “not available” defined? What steps did the authors take to try to include these studies? The omission of these studies contributes to the risk that important studies may have been excluded.
- The third research objective (“To suggest policy interventions which could simultaneously reduce negative impacts of commodity production and trade, whilst promoting sustainable livelihoods of local communities”) is only partially addressed, as impacts on the sustainable livelihoods of local communities are not reported. In the Discussion, mention is made of the trade-off between economic development and environmental sustainability, but this is a different issue. The livelihoods of local communities are an important consideration, especially as equity is a major challenge in existing zero-deforestation supply chain policies (see Grabs *et al.*, 2021, *Global Environmental Change*).¹ This left me wondering why the narrative synthesis presented in the Results (and Discussion) was not constructed around

the research objectives. Could the authors perhaps comment on how the potential impacts of UK due diligence legislation on local communities' livelihoods in producing countries should be examined in future research?

Specific comments on manuscript sections, figures, and appendices

1. Abstract

- First sentence: “globalisation has increased the disconnect between producer and consumer countries”: this is incorrect. Globalisation has increased the connections between producer and consumer countries (hence “telecoupling”). Increased connections due to globalisation are the explicit subject of the global value chain research literature (e.g., Gereffi *et al.*, 2005).
- “Inclusion criteria include publication in the past 10 years and studies that didn’t link commodity consumption to impacts or to the UK were excluded”: this sentence is confusing. At first, it reads like there were two inclusion criteria (publication in the last 10 years and studies that did not link commodity consumption to impacts or to the UK), but then the latter ends up being described as an exclusion criterion. The authors should consider dividing the sentence into two or framing both criteria as inclusion criteria (e.g., inclusion criteria were studies published in the last 10 years and studies that linked commodity consumption to impacts or to the UK).
- Sugar and coffee are not “emerging commodities”, they have been traded globally for years, although they might be considered emerging deforestation-risk commodities.
- Final sentence is missing a verb (the provision of incentives and review of commodities **is needed** to ensure a reduction in the UK’s overseas deforestation footprint).

2. Introduction

- Paragraph 2: Why is assessment of impacts becoming *increasingly* difficult, rather than just being difficult by virtue of the telecoupled nature of production and consumption? Arguably, it is becoming easier to assess impacts with the emergence of tools for supply chain traceability and forest monitoring such as Trase, Global Forest Watch, etc.
- Paragraph 4: “Arguably, however, it was the private sector who made the first widespread commitments to addressing the deforestation activity embodied in supply chains, with the Consumer Goods Forum (comprised mainly of a group of large, international consumer goods and retail companies) making a commitment in 2010”. This sentence is slightly misleading, as it implies that the private sector unilaterally took the lead on adopting zero-deforestation commitments. In fact, the adoption of ZDCs was driven by NGOs, and governments played an important role. WWF proposed the first global target for zero net deforestation by 2020 at the 9th CBD COP in 2008. This target referred to companies' supply chains and was signed by 67 governments. Parties to the CBD (i.e., governments) also agreed in 2010 to set a target of halving the rate of forest loss by 2020. The authors should consider tweaking this sentence to avoid the misleading implication that the private sector unilaterally took the lead on addressing deforestation in supply chains, when in fact, other organisations played key roles and companies hold considerable responsibility for having driven deforestation in the same period.

- The year given for the Amsterdam Declaration reference citation (2018) is misleading, the Declaration was signed in 2015.
- “The rate of global commodity-driven deforestation has shown little sign of decline (Curtis *et al.* 2018)”: the cited reference is based on data that are now seven years old (2015), so it is not fully supportive of the statement. The authors should consider citing more recent datasets, e.g., WRI Global Forest Review, which is based on peer-reviewed data (Hansen *et al.* and Curtis *et al.*) with coverage up to 2021: <https://research.wri.org/gfr/global-forest-review>

3. Methods

- PRSIMA-P guidelines: needs a reference citation and definition of acronym.
- “Exclusion criteria included restrictions on language and publication period, therefore filters used included studies written in the English language and those published in the past 20 years.” This sentence is confusing because – like in the Abstract – it claims to be about exclusion criteria but describes inclusion criteria (i.e., written in the English language and published in the past 20 years). This sentence also contradicts the Abstract, which says “Inclusion criteria include publication in the past 10 years”, but here (and in Appendix A) it says 20 years.
- What do the authors mean by “reference checking the final systematically reviewed papers”? Do they mean they checked the papers they reviewed against the lists from the search results?

4. Results

- Section 3.1: “The most common commodity and study area examined exclusively by studies was Brazilian soy, followed by Brazilian beef, and Indonesian palm oil”: this sentence is confusing and the word “exclusively” seems to be problematic. All the commodities and study areas were examined exclusively by studies (they weren’t examined by anything else). The authors should consider rephrasing this sentence for clarity.
- Section 3.2: when the authors say “similar terminology could represent very different types of environmental impacts”, they go on to state that different remote sensing methodologies were used for the global and country-level analyses, but they don’t actually say what the differences in the types of environmental impacts represented might be (until the Discussion). This should be stated here, even briefly, as otherwise the reader is left wondering what the authors are referring to.
- Section 3.2: “National land use datasets are also often updated annually e.g., INPE” – should mention which countries the datasets belong to (Brazil for INPE).
- Section 3.3: “For each of the top six commodities (Table 1), the majority of their deforestation risk (over 75%) is concentrated in just three countries”: this sentence is confusing and I had to re-read it a couple of times, as it seems to suggest that the majority of deforestation risk for the top six commodities is concentrated in three countries. Again, consider rephrasing for clarity.

- Section 3.3: "...it is also important to note this study only covers commodities associated with tropical deforestation, hence there is a risk of bias." But the authors don't say what the bias might be, or how it should influence the interpretation of their findings? If the point is only that the study is focused on the tropics, that's not bias, it's a limitation of the scope.

5. Discussion

- PRODES needs to be introduced/explained and the acronym needs to be defined.
- Section: Appraisal of different trade databases/approaches to modelling:
 - Paragraph 2: should be "difference" not "different"
 - Paragraph 3: "There are limited comparisons between MRIOs to understand how differences affects results", should be "affect" not "affects".
- Section: Context of results in UK policy: "...with coffee and cocoa having significantly less dedicated studies, for example": should be "significantly fewer" (the studies themselves are not less dedicated).
- Nutmeg, pepper, and sugar are not "emerging" or "less well-known" commodities. They have been used in the UK for a long time by many households and would be well-known by most of the general public. "Less-strongly associated with tropical deforestation" would be more accurate.
- "Quite a few of the studies mention the issue of leakage and the importance of avoiding impacts of commodity production simply moving to a different area, which is only likely to be minimized by wider adoption and enforcement of zero-deforestation commitments". This is not entirely accurate. Wider adoption and enforcement of ZDCs is required, but ZDCs on their own are insufficient to stop leakage or address deforestation (as later acknowledged by the authors themselves). The authors should consider also referring to the need for improved public regulation of forest (and other ecosystem) conservation both within and between countries to stop leakage.
- Soy is not the best example of a crop with concentrated production areas and increased sensitivity to regional differences as it can also be grown outside the tropics (e.g., in the US), whereas other commodities investigated here are restricted to the tropics alone (e.g., cocoa, oil palm).
- "... underpinning a necessity for policy, which can respond to 'early warning', signs of deforestation occurring in new areas should these emerge in response to changing climate." The commas in this sentence disrupt the flow.
- The paragraph on voluntary certification schemes and "other supply-side commitments" conflates the discussion of certification (e.g., soy certification [RTRS]) and voluntary ZDC commitments (e.g., G4 and MPF-TAC cattle agreements, the Soy Moratorium). The latter commitments can be quite different to certification, which has achieved more market coverage in some sectors than others (e.g., RSPO certified oil palm accounts for ~20% of the market vs RTRS-certified soy which accounts for <2%). This paragraph would benefit from drawing the distinction between certification and voluntary commitments more precisely. In addition, while it is true that certification schemes have generally achieved modest impacts,

improved referencing would help reflect the literature more accurately. For example, Carlson *et al.* (2018)² found a 33% reduction in deforestation in RSPO-certified oil palm plantations in Indonesia (although most plantations had lost most of their forest before becoming certified).

- The authors state that "... despite mandatory due diligence for supply chain actors being effective in reducing imported deforestation and relatively implementable (Bager *et al.*, 2021), the UK due diligence does not go far enough". Bager *et al.* (2021) did not measure the effectiveness of due diligence legislation so this statement is too strong. It would also be helpful if the authors could explain how they think UK due diligence legislation should "go further" and be "strengthened", since the additional policy instruments they discuss are just that – additions to due diligence legislation – rather than steps to increase the scope or stringency of the legislation itself.

6. Conclusions

- Second paragraph, "...work needs to be done to understand the uncertainties and differences between results from global studies to inform national policies..." Based on the discussion, presumably the authors mean differences between results from global and national studies?

7. Figure 2

- Neither the figure legend nor the figure itself state what the rings represent (regions, countries, and commodities).
- The text in the figure legend is confusing. If the 33 studies which conducted analyses across various countries and multiple commodities at once were excluded – as stated in the legend – then what is the orange part of the figure showing "various regions" and "various countries" supposed to show?
- The distinction between "various" regions and Africa, Asia, and South America is also confusing, because "various" appears to exclude these other regions – when in fact, it seems like the studies on "various" countries/regions actually refer to studies on multiple countries or regions that may have included Africa, Asia, and South America. Perhaps "multiple" would be a better term.

8. Figure 4

- This figure has no data labels and does not give the reader anything more than a rough sense of what proportions of deforestation risk and carbon emissions are associated with different commodities in UK imports. At least for deforestation risk, Table 1 shows the data per commodity (but not by commodity/country), but for emissions, the reader just has to rely on the un-labelled ring segments. The figure is also low resolution. I wonder if a bar chart wouldn't be more useful, or at least a higher-resolution version of the existing figure with data labels for (at least) the most prominent segments.

9. Figure 5

- Legend: delete comma between "sourced from, by the UK".
- Legend: how was "a small amount" defined?

10. Appendix A

- Related to my point in the Methods regarding inclusion and exclusion criteria: “Only past 20 years” and “English language only” are inclusion criteria, not exclusion criteria. Exclusion criteria would be “no studies older than 20 years” and “no studies in languages other than English”.
- Quality assessment: when the authors checked for evidence of causation, what were they looking for? Does this suggest only studies with causal inference were included? This would appear to be an inclusion criterion if so.

References

1. Grabs J, Cammelli F, Levy S, Garrett R: Designing effective and equitable zero-deforestation supply chain policies. *Global Environmental Change*. 2021; **70**. [Publisher Full Text](#)
2. Carlson K, Heilmayr R, Gibbs H, Noojipady P, et al.: Effect of oil palm sustainability certification on deforestation and fire in Indonesia. *Proceedings of the National Academy of Sciences*. 2018; **115** (1): 121-126 [Publisher Full Text](#)

Is the topic of the review discussed comprehensively in the context of the current literature?

Yes

Are all factual statements correct and adequately supported by citations?

Partly

Is the review written in accessible language?

Partly

Are the conclusions drawn appropriate in the context of the current research literature?

Yes

Is the argument information presented in such a way that it can be understood by a non-academic audience?

No

Does the piece present solutions to actual real world challenges?

Yes

Is real-world evidence provided to support any conclusions made?

Yes

Could any solutions being offered be effectively implemented in practice?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: My expertise is on tropical forest conservation in the private sector, including sustainable supply chain policies and zero deforestation commitments. Specifically, my research focuses on the effectiveness and equity of policies to reduce deforestation for agricultural commodities such as palm oil and cocoa. My research primarily (but not exclusively) involves qualitative methods. I am not an expert in systematic reviews, so the Editors may consider recruiting an additional reviewer to evaluate this aspect of the manuscript.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Reviewer Report 23 November 2021

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Eleanor M. Warren-Thomas

Bangor University, Bangor, United Kingdom

Abstract

1st paragraph (background) please reword final sentence, as currently “policy needs” reads as a noun on first reading

2nd paragraph – split second sentence into two sentences, and please check exclusion criteria. Here you write 10 years, but in the body text you write 20 years.

Note on methods – it isn’t clear whether the review included studies that quantified embodied deforestation in trade to the EU, which would have included the UK?

3rd paragraph – 3rd sentence, I’m not sure what ‘global locations’ means. Could you instead use ‘countries’?

4th paragraph – check plural agreement in first sentence between ‘recommendations’ and ‘suggests’. Should “due-diligence” be hyphenated as in paragraph 1, or not as here?

Introduction

2nd paragraph – demand for cropland or agricultural land (as broadly defined) is not only for food, there is also increasing demand for non-food crops/plantations including oil palm for biofuel, rubber for vehicle tyres, cotton, paper, etc.

3rd paragraph – a critique of classifying forest risk commodities is that this concept does not account for indirect land use change – for example through replacement of existing food cropland with industrial cash crops, displacing food crops onto deforestation frontiers. This may be useful to flag early, ready to refer to in the discussion/policy recommendations, as indirect LUC/leakage effects may be key limiters to the efficacy of due diligence around deforestation risk, if focussed on particular crops.

5th paragraph – you could now include any COP outcomes on deforestation that are relevant
Final paragraph – the final sentence could be clarified – it currently sounds like the review wasn't conducted thoroughly because of time constraints, undermining its claim to be a systematic review. Perhaps make it clearer what was done differently and how this can be accounted for when interpreting the findings. What would a person need to do, to fill remaining gaps in the search/review process?

Methods

Appendix A

How were results sorted in each of the three database searches? This matters for understanding the 20-page cutoff of results. Were they ordered by citation number, or relevance (pre-determined by the database)? Was the number of results per page the same for each database, and if not, did you control for this?

Inclusion of known grey literature should be better justified.

What does 'residential' mean? Mentioned twice in Appendix A.

Main text

Please provide a citation for PRISMA-P

3rd paragraph – these keywords presumably mean that any studies assessing EU forest risk commodities, which would have included the UK but would not have named the UK in the title or abstract, are missing from this review? If so, this should be noted as a potential limitation.

4th paragraph – 10 years as in abstract, or 20 years as here? The 'first 150 results' is not clear – is this the first 150 Google Scholar results (in contrast to the first 20 pages as stated in Appendix A?) Please note any potential limitations/bias of manual inclusion of specific grey literature by the authors, or explain why this is not an issue.

5th paragraph – please check placement of commas and semi-colons here, and throughout. Some sentences are a little hard to read.

Results

I suggest Appendix B could be included in the main text, as it is a very useful summary of the main results of the review.

Section 3.1 the meaning of "examined exclusively by studies" is not clear, please rephrase.

Section 3.2 perhaps use a different word instead of "exclusively" as it took me a couple of readings to understand what was meant. "Single-commodity studies" might be clearer.

Land use data remove comma between "carbon" and "emissions". What's the difference between "ecological" and "biodiversity" footprint measures?

If possible, I would encourage the inclusion of a paragraph in this section that outlines the potential limitations, uncertainties and assumptions that each paper/method in the review entails. That would be a very helpful addition for the interpretation of the results, even if it is only brief and directs the reader to specific papers within the review to find out more about specific methodologies. I realise there are three paragraphs in the discussion on this, but I wonder if some of the detail from those paragraphs could be moved to the results, or even presented in a figure e.g. type of models and databases used?

Section 3.3

Paragraph 4 – please check plural vs possessive for ‘commodities’ in some places

Figure 5 legend – what is the threshold for ‘a small amount’ ?

Discussion

Paragraph 5 “different” should be “difference”

Paragraph 6 I think an additional paragraph is needed, or even a subsection, appraising the methods for linking forest cover change to trade volumes. A key limitation of e.g. Pendrill et al, is that the analysis can only attribute deforestation to crop expansion by proportional allocation, not by direct detection/allocation. I think this is a key limitation that is not well understood outside of the field, and which is relevant for policymakers to understand.

Context of results in UK policy –

Paragraph 1 – “fewer studies” not “less”

Paragraph 2 - Here it could be helpful to mention the risk of not capturing indirect LUC/deforestation, and thus not effectively tackling deforestation via a focus on specific commodities and their direct footprints. Doing so is methodologically challenging, and requires further scientific advances, but also could be tackled through policies that take a systems view of land use change to account for potential leakage, or through the adoption of a precautionary approach.

Overview of policy recommendations

Paragraph 3 – the second sentence, citing Gibbs et al 2015, does not read clearly, please rephrase. Please include reference to literature on relative meat consumption in EU/US vs most other countries, and that in many countries protein consumption is below recommended levels – so reducing meat consumption is a demand-side issue that is linked to wider distributional issues around food systems.

Conclusion

If you are mentioning neglected crops, such as spices and pepper from Table 1, it seems odd to omit rubber from the discussion as well. There are some assumptions and limitations in the analysis by Pendrill *et al* around rubber that may make it even more important as a deforestation risk commodity <http://www.focali.se/en/articles/artikelarkiv/new-focali-policy-brief-flawed-numbers-underpin-recommendations-to-exclude-commodities-from-eu-deforestation-legislation> and I am aware of some limitations of the analysis that mean deforestation risk is likely underestimated (at the EU level, at least).

Is the topic of the review discussed comprehensively in the context of the current literature?

Yes

Are all factual statements correct and adequately supported by citations?

Yes

Is the review written in accessible language?

Yes

Are the conclusions drawn appropriate in the context of the current research literature?

Yes

Is the argument information presented in such a way that it can be understood by a non-academic audience?

Yes

Does the piece present solutions to actual real world challenges?

Yes

Is real-world evidence provided to support any conclusions made?

Yes

Could any solutions being offered be effectively implemented in practice?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: I am not an expert in systematic review methods - it would be worth inviting someone to check this aspect of the study. My areas of research are around impacts of tropical commodity crops on deforestation and biodiversity, trade-modelling and spatial analyses.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.