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Understanding the international displacement of impacts of consumption

Chloe Hatton and Maddie Harris

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For further information please contact:
JNCC, Quay House, 2 East Station Road, Fletton Quays, Peterborough PE2 8YY.
https://jncc.gov.uk/

Communications@jncc.gov.uk

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Author affiliation:
[1] JNCC, Quay House, 2 East Station Road, Peterborough, PE2 8YY

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Summary

This report was undertaken to consider assumptions relevant to modelling the international displacement of environmental impacts of UK consumption. The Global Environmental Impacts of Consumption (GEIC) indicator (https://www.commodityfootprints.earth/) is available online and presents data showing the environmental impacts associated with consumption of commodities across the world. It can be used, for example, to quantify the global footprint of environmental impacts from consumption of commodities in the UK. This is an important tool for understanding past impacts, but in its present form, it is not useful for weighing up the *in situ* effects of current domestic land use decisions with the potential global scale effects that they may have through displacement. For example, if planting 1 ha of trees within the UK, we currently have good evidence on the carbon, biodiversity and other benefits this will bring *in situ*. However, if this is replacing crop production that is supporting UK consumption, there is currently no established method of identifying whether displacement is taking place, and if so where crops are likely to be grown instead (assuming demand, production intensity and exports remain constant) and what impacts this displaced crop growth may have (e.g. might it be linked to deforestation that 'cancels out' the domestic tree planting?). Understanding the assumptions involved in modelling displacement is the first step in filling this evidence gap and paves the way for potential model development in future.

Recommendations made in this paper have been generated by a series of literature reviews, searches and expert consultation. They conclude that a simple model estimating the most likely location for displacement in the short-term could be developed by initially establishing the region of greatest predicted production growth, before overlaying biocapacity and commodity price at the country-level. This could be combined with information on the environmental impacts within the predicted countries (e.g. aligning with the data sources feeding into GEIC) to fulfil the need outlined above. Results would come with a high level of uncertainty as it is difficult to predict trade patterns and consequences of shifts in demand, but it would be conceptually feasible to identify most likely locations and impacts. Such modelling would rely on assumptions, which would need to be clearly communicated, such as:

i) no change in outcomes due to global production trends,

ii) no change in UK production, consumption, or exports, beyond the change input into the model,

iii) no change because of substitutability (e.g. trends towards a more vegetarian diet, or replacement of one commodity with another).

A model could be produced in an iterative manner, whereby a simple initial model is improved upon with subsequent research attempting to integrate better data, for example related to breaking down each of these assumptions.

Overall, this report concludes that development of a model to better understand the international displacement of impacts of consumption would be conceptually feasible to produce. The next phase of work will focus on analytical scoping work, collating relevant datasets and scoping modelling approaches that could contribute towards model development.

Contents

1. Introduction

This report builds on JNCC's Sustainable Consumption work which has included development of the Global Environmental Impacts of Consumption (GEIC) Indicator (funded by Defra and produced in partnership with the Stockholm Environment Institute at the University of York), which estimates the biodiversity loss, deforestation, water use and several other impacts associated with a country or territory's consumption. A number of related research projects that further increase the usefulness of the indicator are being undertaken by JNCC independently, in a rapidly changing policy and data landscape.

This report develops a framework to improve understanding of the potential international displacement of environmental impacts (e.g. biodiversity, deforestation) associated with consumption of terrestrial crops, in response to UK land use change, in particular changes that take land out of agricultural production. A review of both grey and scientific literature identifies previous approaches and assumptions involved in estimating and quantifying such impacts. These are discussed and recommendations for the most appropriate and evidence-based assumptions then made.

1.1. Displaced impacts of consumption

Human activities are causing significant environmental changes, affecting ecosystems and the climate (Steffen *et al.* 2015). These changes lead to global issues such as climate change, resource depletion, and biodiversity loss, which are interconnected and complex, making them difficult to address (Steffen *et al.* 2015). The global population has more than doubled since 1960 and continues to rise (FAO 2024), putting increasing pressures on natural resources available globally.

Globalisation, driven by increased international trade and technological advancements, has boosted food availability and economic development but also increased environmental risks through intensified resource use and ecological degradation (Sandström 2018). The displacement of environmental impacts due to international trade is often overlooked due to a natural focus on immediate and local stimuli, and difficulty in tracking material flows through multiple borders (Sandström 2018; Kastner *et al.* 2014).

Consumption in one place can be driving environmental change such as deforestation, habitat destruction and biodiversity loss elsewhere. For example, in 2022, UK consumption of agricultural crops, cattle and timber commodities was associated with 35,200 ha deforestation across the rest of the world (GEIC Indicator 2024). Approximately 80% of the global population lives in countries that import more agricultural products than they export (Porkka *et al.* 2013) and displacement of environmental impacts is a growing challenge. Between 1995 and 2011, Wood *et al.* (2018) calculated the net impact displaced through trade rose from 23% to 32% for material use, 23% to 26% for water use, 20% to 29% for energy use, 20% to 26% for land use, and 19% to 24% for greenhouse gas emissions. Weinzettel *et al.* (2013) found affluence to be an important factor in understanding the degree to which this displacement occurs, with net displacement of land use from high-income to low-income countries amounting to 6% of the global land demand. The UK's total Ecological Footprint (covering land used both within the UK and across the world to support UK consumption) was 3.8 global hectares (gha) per person in 2024 (Global Footprint Network n.d.). With an average biocapacity of the world being 1.6 gha per person, the average footprint of an individual in the UK is almost 2.5 times our 'fair share.' This exemplifies why it is relevant, and indeed vital, to consider the global picture in understanding the environmental impacts of consumption in the UK and how it may change with competing priorities for domestic land use.

In the literature, *leakage, slippage*, or *spillover* have also been used as terms to describe how economic or ecological outcomes can be displaced from a target jurisdiction to non-target jurisdictions in response to environmentally protective policy (Lewison *et al.* 2019; Meyfroidt *et al.* 2013). Sandström (2018) also describes the "distal socio-economic and environmental interactions, feedback and outcomes between land systems", including displacement of environment impacts, as *telecoupling.*

It should be highlighted that using resources from another country is not a problem. International trade can contribute to optimised natural resources use when production takes place in an area with comparative advantage (Sandström 2018; Kastner *et al*. 2021); supplying more people with their required calorie intake and improving diets. When managed well, it can also have positive contributions to livelihoods in the producer country. However, there is evidence that, currently, OECD countries are transferring environmental pressures to non-OECD countries (Wood *et al*. 2018).

This displacement of impacts from one area, country or region to another, will change over time. For example, new policy, regulation and/or adoption of agricultural best practice which focuses on reducing environmental degradation is likely to reduce outputs from production activities. Unless demand for the commodity also decreases, this will increase reliance on production and trade with other jurisdiction(s), and demand will be met by either intensification or expansion of commodity production. Although in some cases displacement can lead to positive outcomes – for example a policy in one jurisdiction calls for higher standards and improves the conservation outcomes in others – there are many more documented examples of its negative impacts (Lewison *et al.* 2019). This can result in a "zero-sum conservation game" (Hornborg 2009), illustrated by Lewison *et al.* (2019) in Figure 1.

Another example could be where land is taken out of agricultural production due to high competition for land use and instead used for building renewable energy facilities or new homes; similarly offsetting production of crops to another jurisdiction. Similarly, diet shifts, market prices, fluctuations in productivity, or a range of other factors may lead to impacts being displaced overseas. This principle of displaced global impacts is to be explored within this report.

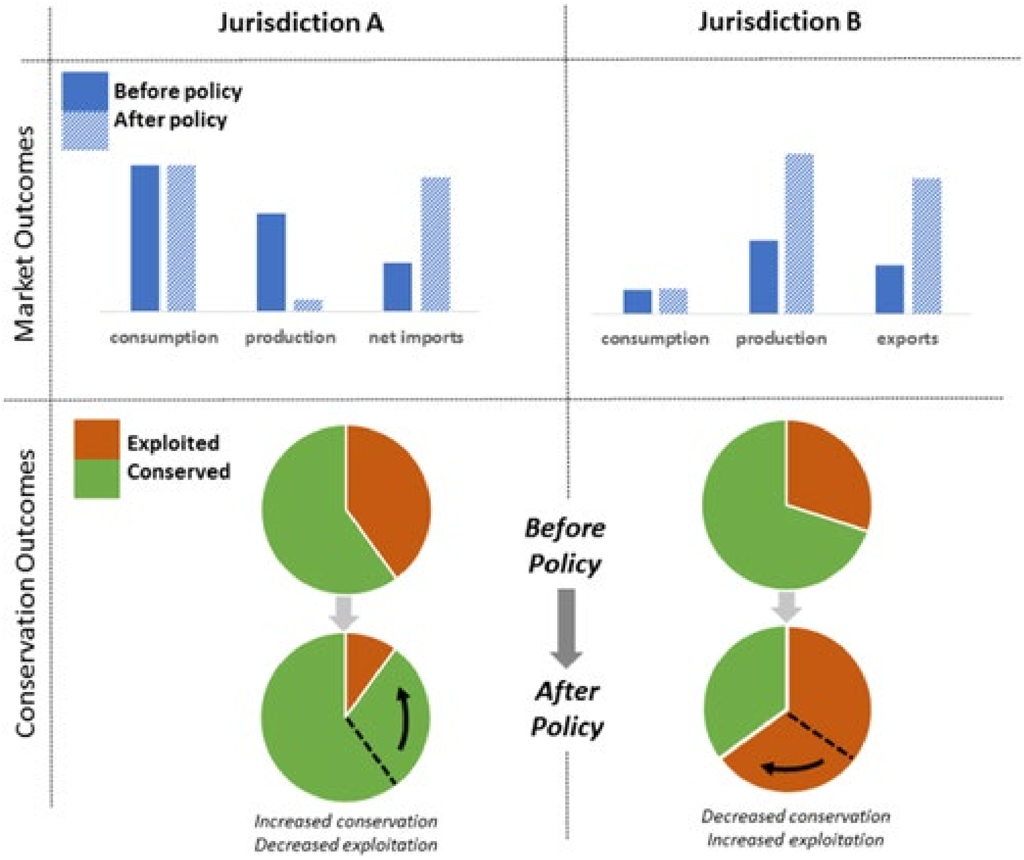

Figure 1. Illustrating the principle of displacement (Lewison *et al.* 2019). "Diagrammatic representation of a negative displacement of environmental impacts. Here we illustrate a common scenario in which a policy designed to protect natural resources in one jurisdiction (A) improves local conservation outcomes but leads to reduced conservation outcomes in another jurisdiction (B) which, in many cases, can lead to a poorer conservation outcome overall. When production or extraction activities are curtailed in A due to environmental and conservation policies, consumption demands in A are met by increased imports from B. This results in a larger, negative environmental footprint or impact in B, which may occur when there is weak governance of resource use in B." This figure is reproduced here under Creative Commons licencing and subject to the publisher's Terms of Use.

1.2. Aims and scope of this report

The purpose of this report is to scope out whether it may be possible, and what assumptions would be required, to develop a method or model that quantifies the potential globally displaced impacts of land use change on biodiversity and other environmental impacts, in line with those assessed by the GEIC indicator. For example, with assumptions dictating fixed value or no change for certain factors, could a model be used to understand impacts in the following scenario: *If 100 hectares of agricultural land in the UK that is currently supplying UK consumption is converted into another land use type (e.g. woodland, renewable energy production or housing), our domestic production of x-crop type will decrease by 100 hectares' output. Therefore (assuming consistent yields and exports), the UK will need to import more of x-crop type to meet demand, increasing the environmental impacts of production in another country. These impacts may be greater or less than the impacts of farming in the UK.*

This report covers:

- A time-limited literature review, identifying whether others have previously tried to answer this question and whether methods are already available.
- A discussion piece, identifying possible assumptions that could be made to estimate where crops are likely to be displaced to.
- A list of recommendations for the most appropriate set of assumptions to take forward and a proposed method combining these assumptions with data available from the GEIC indicator or other sources to link this to environmental impacts.

The scope of this report does not include:

- Creation of the model to undertake the analyses – although this report aims to be a starting point for development of such a model.
- A review of data sources that could be used to link the predicted displacement to environmental impacts. This is because significant work to identify and review appropriate sources for estimating the environmental impacts of the production of commodities in each country of the world has already been undertaken as part of the work developing the GEIC indicator. Aligning with these data sources avoids duplication of effort and ensures consistency with a recognised Official Statistic. It is therefore assumed that the model would rely on the same data sources linking production with environmental impacts that GEIC does; once the land areas in each country are predicted, similar multiplying factors would be applied. For example, if it is estimated that a change will lead to 1 ha of land required in country x, and the deforestation dataset shows that 50% of production of that crop in country x is associated with deforestation, it would be assumed that this change is associated with 0.5 ha of deforestation. Full details on the data sources underpinning GEIC can be found in the technical documentation (Croft *et al*. 2024).
- Comparison of the displaced negative environmental impacts with potential positive outcomes in the UK, that may be associated with the land use change. This is because many models are available (e.g. INVEST, IMP, NEVO) that allow users to input land use change and predict the environmental consequences within the surrounding area. This report aims to fill the evidence gap associated with internationally displaced impacts, which could be compared against existing domestic tools to gain a holistic understanding of environmental impacts.
- Displacement of environmental impacts associated with sourcing commodities other than agricultural crop commodities, cattle and timber (e.g. stone and precious metals). This is because these commodities have more readily available data on production, price and links to environmental impacts. However, parallel work under the GEIC project is ongoing to expand this selection in future, so it may be possible to use this work to increase coverage of the displacement model as well at a later stage in its development.
- Displacement of carbon emissions, beyond emissions related to deforestation.
- Differing assumptions for different crop types or producer countries. Whilst some crops may have more detailed and finer scale resolution data available in certain producer countries, the report aims to be universal and comparable in its coverage, and so only considers data sources and assumptions that can be made across the board.
- Impacts beyond environmental; although it should be noted that social impacts, such as livelihoods and human rights concerns, can also be displaced.

- Implications of waste (if waste is reduced, consumption and associated impacts will reduce; but for the purposes of this study, waste is assumed to be constant).

1.2.1. Caveats

This report was written over a short period of time and is not intended to be a comprehensive or systematic review of all research and examples in this field. Its focus is on identifying where various studies have utilised assumptions (for example around trade relationships) to quantify impacts of displacement from consumption: it considers how realistic each assumption is and makes recommendations for future work in the UK. A full reference list of sources is provided which can be explored to give more information on the subject.

1.3. Policy context

The global policy context surrounding both production and consumption of agricultural products is pivotal in quantifying the domestic and displaced environmental impacts. A range of policy decisions, both in the jurisdiction of commodity production and of commodity consumption, will have standalone and complex interacting implications.

For example, the following policy areas are likely to have impacts on the relationships between production and consumption jurisdictions:

- Planning and land use priorities
- Agricultural subsidies
- Environmental commitments, standards and regulation
- Food certification and assurance schemes
- International trade agreements, tariff changes and market stability
- Taxation of specific commodities
- Price of crops, land and labour

In addition, societal factors such as dietary choices and shifts may have similar effects.

The framework proposed in this report does not take these factors into account; it assumes that the predicted area of domestic land use change is known, and seeks to understand whether it would be possible to predict where in the world such land use would be displaced to and what environmental impacts might take place as a result of this alternative production. However, it may be possible in future to combine with integrated land use modelling, which can be used to predict the implications of policy and/or market interventions on land use and predict the consequences of these on domestic impacts (Harrison *et al.* 2023). For example, the Welsh Government have co-created the Environment and Rural Affairs Monitoring & Modelling Programme (ERAMMP) Integrated Modelling Platform (IMP) for Wales. Its modelling framework comprises eleven component models (covering agriculture, forestry, land use decisions, biodiversity and ecosystem services related to carbon, water quality and air quality) and evaluates the impacts of Welsh Government policy interventions and external drivers on Welsh agricultural, socio-economic, and ecosystem service outcomes (*ibid*). A displacement model could follow-on from calculations such as these, considering what reliance the UK will have on imported commodities under different scenarios and comparing the predicted domestic and internationally displaced impacts to give a more holistic understanding of the trade-offs at a global scale.

1.3.1. UK policy context – domestic production

In 2022, 18% of the UK's commodity consumption of crop commodities, cattle and timber, came from domestic production – totalling 24.5M tonnes (GEIC Indicator 2024).

Currently, 70% of land in the UK is devoted to agriculture (Pettorelli *et al.* 2024) and the UK Government is continuing to support farmers in provision of a more resilient domestic food supply (Defra 2024a). Over the last 30 years land use has been stable for most crops, allowing for fluctuations in prices and weather conditions (Defra 2021a). However, there are many other UK policy priorities that raise competition for land availability and the country's total agricultural area is in decline (Savills 2019). It is important at this stage to acknowledge that all of the policy areas set out below are priorities for the UK with good reason, and this report does not make an attempt to rank commodity production above others, but just to set out a framework for holistically understanding the trade-offs between domestic and displaced land uses, which is a key current evidence gap when considering such policies.

The Campaign to Protect Rural England (CPRE) reported that between 2010 and 2022 over 14,000 hectares of agricultural land identified as Best and Most Versatile in the Agricultural Land Classification, were lost to development – including the building of 287,864 houses (CPRE 2022). This competition is likely to intensify as the UK's population is predicted to grow to 73.7 million by 2036 (Robards 2024), and with the current government's pledge to build 1.5 million new homes over the next parliamentary term (Labour 2024).

In 2022, the UK Government also committed to designating 30% of the UK's land for nature by 2030 (30by30) at the UN Convention on Biological Diversity Summit COP15, as part of the ambitious Kunming-Montreal Global Biodiversity Framework (UNEP 2022). The most recent report detailing England's progress towards this target shows only approximately 7.1% of land currently designated – with a proportion of that currently in unfavourable condition (Defra 2024b). It is therefore possible to assume that a large area of land will also need to be designated within the next 6 years, potentially putting further pressure on the land available for crop production.

Since the UK left the European Union (EU) and therefore the EU Common Agricultural Policy in 2020, the four Governments of the UK have begun developing new agricultural subsidy schemes. Although the four nations are at different stages of progress and various interim schemes are in place across the UK, they are all placing new emphasis on sustainable environmental management, alongside food production (Marshall & Mills-Sheehy 2021). In England and Wales, the proposed Environmental Land Management and Sustainable Farming Schemes will offer subsidies to farmers for providing environmental and climate goods and services on their land (Defra 2023b; Welsh Government 2022). This will include payments for protection and enhancement of on-farm features and habitats such as hedgerows, woodland, naturalised riparian corridors, wildflower meadows and wetlands. This is, again, likely to involve taking some area of land out of agricultural production.

In England, Defra are developing a Land Use Framework which will provide a toolkit to support decision making on land use to meet statutory environmental and nature targets set out under the Climate Change Act and Environment Act (HM Government 2025). This framework adopts a multifunctional land use model underpinned by land use data to guide informed decisions by farmers and land managers on making space for nature, water, emissions reduction, housing and infrastructure whilst protecting the most productive agricultural land (HM Government 2025). Analysis by Defra shows that 19% of agricultural land will change use, including 9% which will be taken out of food production completely to be used for environmental and climate benefits (HM Government 2025). It is expected that any loss of domestic food production land will be offset by productivity improvements and technological innovations. However, this assumption has been questioned considering the increasing pressures on food production from extreme weather, climate change and geopolitical tensions which may alter current levels of food production, with or without land use change, and lead to increased reliance on food imports (NFU 2025; University of Exeter 2025).

Similarly, in planning and development, Biodiversity Net Gain (BNG) policies have been adopted into policy across the UK. In England, BNG is mandatory under the Town and Country Planning Act (as inserted by Schedule 14 of the Environment Act 2021) and developers must deliver a BNG of 10%. This means developers must use a specified metric to prove that their scheduled activities will result in more or better-quality natural habitat than there was before development (Defra 2023c). The Scottish Government and NatureScot are currently adapting this metric to implement something similar in Scotland (Newham 2024). Meanwhile Wales and Northern Ireland do not use a metric but put emphasis on proactive consideration of biodiversity and wider ecosystem benefits on a case-by-case basis within the design and planning process. Any planning proposal must demonstrate that the works will both maintain and enhance biodiversity and build resilient ecological networks (CIEEM 2022; Madden, 2020). This could mean the land area required for a development is increased with the addition of biodiversity-positive design elements or offset by activity on land elsewhere in the country – for example, woodland or wetland creation.

In addition to this, the UK and each of the devolved Governments has specific woodland creation targets. These are inextricably linked to the UK commitment to achieve net zero emissions by 2050, and the previous Conservative Government had committed to planting 30,000 hectares of woodland by March 2025 (UK Environmental Audit Committee 2023). In fact, the UK Committee on Climate Change (CCC) recommends that 30,000 hectares of new woodland should be planted in the UK every year until 2050 (CCC 2020) – equating to around 780,000 hectares. Theoretically, if 100% of this planting was to occur on land currently used for agriculture, this could displace ~8,864 farms, based on average English farm size of 88 hectares.

Finally, the renewable energy sector is also competing for land. The British Energy Security Strategy and Net Zero Strategy set out aims to fully decarbonise the British power sector by 2035, whilst doubling electricity power generation. Planning authorities are encouraged within these strategies to consider the urgency with which the UK needs to develop renewable energy sources and identify potential land available for this purpose in development plans at all levels (local, regional and national). For example, Wales' National Development Framework sets out areas that have been "pre-assessed for wind energy" to encourage conversion of land to development for this purpose (Welsh Government 2021).

With the multiple competing and interacting demands on land outlined above, trends for UK domestic production and implications on international displacement should be a major consideration in future-casting.

While consumption-focused policy also exists in the UK (for example, the UK Government has committed to implement the Due Diligence Act – with regulation placed on UK businesses to ensure supply chains for key forest risk commodities are produced on land acquired and used legally), this section has focused on policy impacting our domestic production. As Figure 1 demonstrates, it is a reduction in domestic produce that is likely to result in greater importation and displacement of environmental impacts associated with production to other parts of the world.

2. Discussion

The complexity of changing commodity demand, factors influencing production, global trade patterns and global stability make the exact calculation of causalities related to a single country's consumption almost impossible (Sandström 2018; Weinzettel *et al.* 2013). Therefore, we cannot say that a change in land use in the UK will undoubtedly displace the food production and cause environmental impacts in a specific other country.

It is for this reason that this report attempts to identify plausible assumptions that can be used to help estimate these causalities, starting by examining existing literature and examples around this to draw out recommendations.

With the UK context in mind, there is a need to look forward and predict where we might be displacing impacts to, with trends showing less land available for domestic production, and increasing demand for commodities. This discussion draws out some conclusions around the assumptions to make in any modelling of this kind.

As other literature reviews point out (Weinzettel *et al.* 2013), this review found the evidence base currently available lacking in empirical studies that track and relate land use changes in interconnected places, in both source and target countries. The existing evidence-base is also mixed, with publications using different assumptions, applied in a range of contexts. This made this evidence review relatively challenging to identify assumptions that have previously been applied in different contexts and could therefore be considered broadly applicable or best practice.

2.1. Where will displacement occur?

A key question in establishing global impacts from UK consumption, is which country or region of the world the impacts are going to be displaced to.

It would be possible when modelling, but likely too simplistic, to assume existing suppliers pick up additional demand in proportion with the amount of any commodity they currently supply. Error around this assumption is likely to be extremely high because not only do ecosystem services change and degrade over time (Bateman *et al.* 2022) but also patterns of international trade can vary greatly.

Schmitz (2012) recommends modelling a 10% trade barrier reduction each decade until 2045 to reflect a more realistic trade policy scenario. This assumption would imply that international trade is going to continue growing and diversifying, with the UK making new trade partners over time, rather than increasing trade with existing ones. However, it remains difficult to establish the countries with which it is more likely the UK will trade commodities with. For example, there is no relationship between development status (i.e. a more- or less-developed country) and net trade (Meyfroidt *et al.* 2013). Additionally, the trend of trade liberalisation that Schmitz (2012) reports appears to be no longer stable enough to model against, with the World Bank reporting that global trade has declined significantly since the early 2010s and most countries are enacting more restrictive rather than liberalised trade policies (Kose & Mulabdic 2024).

In a UK-context, previous trading patterns are not necessarily a good predictor of future relationships, as EU Exit in 2020 (particularly leaving the EU Single Market and Customs Union) significantly changed the UK's trading patterns. The impact of the UK's new trading relationship with the EU has not yet been fully realised (Defra 2021a) and several other new trade agreements are still in negotiation (Webb 2024). Future international trade agreements are, however, going to have a significant impact on how other countries are able to supply the UK with commodities. Therefore, trade agreements should be overlaid with any modelled prediction of displacement to ensure the prediction is viable.

Assuming consistency in UK suppliers and proportional production values also does not consider limitations impacting producer countries; for example, whether their land availability and export capacity will be able to accommodate additional demand from the UK (ADAS 2024). The OECD Environmental Outlook to 2050 (OECD 2012) presents a baseline scenario for 2050, which models pressures on the environment in line with population and wealth estimates. This scenario includes an analysis of changes in land area used for agriculture. As the discussion in Section 1.3 illustrates, there are many factors affecting how much land may be cultivated for agricultural purposes in each country. This will be affected by in-country policies and demands, and the OECD baseline scenario shows trends in agricultural land area differing greatly across regions; with agricultural area predicted to decrease by 17% in BRICS and 2% in OECD countries, while expanding in the rest of the world. “On a global scale, the area of agricultural land is expected to peak before 2030 and decline thereafter” (OECD 2012).

Therefore, an assumption based on a country’s capacity to produce and trade commodities might be better used to predict displacement.

One option, suggested by the findings of Weinzettel *et al.* (2013), might be to assume that production demand will be displaced to countries with the greatest amount of biologically productive land available per capita. "Biocapacity is the area of biologically productive area to provide food, fibre, and timber, accommodate urban infrastructure, and absorb excess CO_2” under current management practices. While it is not a perfect measure of land available for production of exportable commodities, considering biocapacity *in terms of the production country’s population (per capita)* goes some way to estimating the extent of land utilised for domestic consumption vs exportable commodities. Weinzettel *et al.*’s analysis showed that exports are highly correlated with greater per-capita biocapacity. The Global Footprint Network (2024) shows the global average as 1.6 global hectares per capita, then breaks this down to country level. Ranking countries by their biocapacity per capita highlights those with the greatest capacity to expand crop production; including perhaps by increasing their trade with the UK under displacement scenarios. While this is a useful metric, it should be noted that assumptions around the relationship between land availability per capita and commodity production are large, and it does not include commodity-specific detail. This option would also fail to consider political and economic capacity for commodity expansion.

Table 1. Top 10 countries ranked according to their biocapacity available per capita (Global Footprint Network, Open Data Platform (footprintnetwork.org)).

Rank	Country	Biocapacity per capita (in global hectares)
1	French Guiana	91.8
2	Suriname	77.0
3	Guyana	71.4
4	Gabon	18.0
5	Faroe Islands	15.2
6	Canada	14.5
7	Mongolia	14.2
8	Niue	14.0
9	Iceland	13.8
10	Bolivia	13.7

Schmidt (2008) and ADAS (2024) suggest the region most likely to take on displacement of a crop can be assumed as the marginal suppliers (i.e. the regions or countries most likely to increase production of a particular crop in response to rising demand). Both studies identify this supplier as that with the largest predicted increase in production over a 10-year period. This seems a rational and well-reasoned assumption, based on the idea that as land becomes increasingly scarce, production will slow. However, ADAS were unable to implement the method for each individual commodity of interest (by comparing the average value for the most recent 5-year period against the preceding 5-year period) within the timescale of their project, suggesting that the data gathering and manipulation could be time intensive.

A less resource intensive option (although introducing its own additional modelling assumptions and unquantified uncertainties) could be to utilise the International Food Policy Research Institute (IFPRI)'s Impacts of Alternative Investment Scenarios Tool (IFPRI 2017), which can be used to predict the region with the greatest increase in supply of each commodity listed. The 2050 reference scenario used in their modelling "is based on "middle-of-the-road" assumptions about changes in population and income (SSP 2) along with rapid climate change (RCP 8.5/HadGEM). It is also possible to view and filter results by different future investment scenarios, where it anticipates changing impacts with investment in research and development, irrigation and infrastructure. A limitation of using this data source is that the information provided is at a slightly lower resolution, and applies to world regions, rather than countries. Similarly, the OECD-FAO Agricultural Outlook 2024-2033 report provides a comprehensive analysis of the ten-year prospects for eight types of agricultural commodity and fish markets at national, regional, and global levels (OECD/FAO 2024). It uses the OECD-FAO Aglink-Cosimo model of global agricultural markets and input from country and commodity experts to predict growth in commodity production up to 2033 at both country and regional scales. A further comparison of the IFPRI and OECD-FAO models may be required to understand which might function best in the context of displacement modelling, and limitations such as not accounting for increases in extreme weather events due to climate change should be noted.

Another option could be consideration of the potential for increased supply based on locations where yield-growth potential is highest. Such information is provided at yieldgap.org. If taking such an approach, consideration would need to be given to the fact that in this case, yields could increase without additional land displacement. However, other impacts related to agricultural intensity (such as nitrogen or phosphorus pollution, or scarcity-weighted water use) could still increase. Yield increases are likely to result from a combination of both agricultural expansion and closing yield gaps, and only in cases where countries have the socio-economic capacity to drive yield increases.

Where country-specific displacement figures are not required, a lower resolution model may suffice. The UK Agricultural Market Model (UKAMM) (Defra 2021b) for example, is a 'three-country' model. Rather than modelling each of the UK's trading partners separately, UKAMM aggregates the UK's trading partners into two blocs: the European Union (EU) and the rest of the world (RoW). However, the environmental impacts associated with production of a particular commodity vary greatly depending on where in the world this is taking place, so spatial data are key to answering questions related to displacement footprints.

Commodity price is another key consideration (when combined with access to UK markets – see below). Modelling experiments show that in international context, trade exports are increased from regions that show comparative advantage with lower agricultural prices (Meyfroidt *et al.* 2013). This would infer that the country most likely to take on displacement of UK food demands are those countries with the cheapest commodity prices. This common-sense approach appears to be well-evidenced and was also applied to carbon calculations within ADAS' carbon displacement framework for Defra (2024), where it was assumed that countries with the lowest production costs would be prioritised for supplying additional beef to make up for any shortfalls in UK production.

Another factor that could be considered is competitive access to UK markets, for example considering tariff rates and estimating thresholds at which these prohibit trade. However, if the UK increases purchases from a given country, that does not necessarily mean the increase in production happens there: they might divert exports from other countries. It therefore seems reasonable to assume that if a change in UK policy results in greater global demand that the increase in production will occur in places that have lowest cost/greatest biocapacity, even if the UK does not directly increase imports from that country. This is therefore not considered a key assumption to include in modelling; but would be important to include and understand if interested in direct trade as a lever for change.

Many of the factors explored in this section are likely to interact in complex ways. Whilst an initial model is unlikely to capture all of them and is likely to rely on a short-run approach (predicting immediate changes rather than longer-term changes into the future, for example with differences in climate change and populations levels), an iterative approach to model development could integrate an increasing amount of them over time and as new information becomes available. It should also be noted that any high-level approach taken is likely to not account for the fact that these factors may affect different commodities in different ways, which is another area that could be investigated further when improving the model rather than developing an initial minimum viable product.

2.2. Impact of production and consumption trends on displacement modelling

As established above, the data sources underlying the GEIC Indicator can be used to establish current yield patterns, trade of commodities and resultant biodiversity impacts. The indicator is updated annually, therefore the data presented will respond, although with a short lag time, to changing trends in global production and consumption. It could be assumed in modelling that the most recent yield patterns and biodiversity impacts will continue. This could potentially be useful in time-constrained / simplicity-bound projects or when modelling very short-term trends where global conditions are assumed to be stable. However, a limitation of this approach is that it does not account for changes in global production and consumption trends, that will impact yield and biodiversity values in the future.

The Food, Agriculture, Biodiversity, Land-use and Energy (FABLE) Calculator is a land-use model that has been used in the UK context to consider land-use and food systems under three different scenarios (Smith *et al.* 2024). These include:

- A pathway based on current trends over the last 10 years.
- A pathway based on the Balanced Net Zero pathway developed by the UK Climate Change Committee to meet the national Net Zero target.
- A pathway based on the ambitious high-level options developed by the UK Climate Change Committee for delivering Net Zero faster and also includes stronger actions for biodiversity.

Each scenario run by the model contains a set of assumptions for factors that could have a significant impact on production and consumption. It would therefore be logical to assume that this list of factors (copied below) is also a good starting point to use when considering factors which might affect displacement:

- Macroeconomic conditions.
- Land use.
- Productivity and management.
- Trade.
- Food (consumer preference).
- Use of biofuels.
- Water.

The influence of these factors on production across the globe and on UK consumption means that displacement modelling must either: acknowledge a degree of error in assuming no responsive change; or include a multiplication factor to account for some/all of these changes.

Several specific factors that are considered as having the potential to significantly impact any modelling of displacement are discussed below.

2.2.1. Changing yields per hectare

Rather than agriculture only expanding into new land areas, yield improvement through technological and scientific innovation is predicted to increase productivity; although perhaps at a slower rate than in the previous few decades (OECD 2012). This could, for example, be through the introduction of new machinery or uptake of climate-resilient crop species. In fact, it is claimed that "ninety percent of the growth in crop production globally (80 percent in developing countries) is expected to come from higher yields and increased cropping intensity, with the remainder coming from land expansion" (FAO 2009).

Innovation of technologies and practices is also relevant to crop production within the UK. The simplest assumption would be to assume that if 100 ha of agricultural land is converted out of production in the UK, then domestic production will decrease, and the demand is displaced to another jurisdiction. It could be the case that increases in yields from existing UK agricultural land can make up some of that difference. For example, the assumptions used in the UK's FABLE model under the National Commitment scenario (based on the Climate Change Committee's Balanced Net Zero pathway) are: crop productivity +34%, milk yield +18% and chicken yield +10%, by 2050 (Smith *et al.* 2024). This implies that the UK's domestic productivity is likely to increase over time, which would affect our reliance on imports if other factors (e.g. population) were to remain constant.

In a few areas of the world in mid and high latitudes, yields are also likely to increase under climate change scenarios that increase temperatures, precipitation and crop fertilisation from atmospheric CO_2 (OECD 2008).

In contrast to this, the OECD's Environmental Outlook (2008) predicts that overall "unconstrained climate change will eventually lead to aggregate productivity losses in agriculture and food security problems, water stress, sea-level rise… loss of biodiversity and other ecosystem services", particularly affecting water-stressed areas such as Southern Europe, Northern Africa and parts of the Americas. Similarly, Hultgren *et al.* (2025) estimate that global production will decline by the equivalent of 120 kcal per person per day (4.4% of recommended kcal intake) for every 1°C rise in temperature. Although there are numerous initiatives attempting to reduce the impacts and adapt to climate change, there is no doubt that productivity losses will be felt in a changing climate, with Ahmed *et al.* (2023) predicting that each 1 ºC in temperature rise will cause losses in yield of between 3% and 8% for several globally important crop species (wheat, rise, maize and soybean). Hedlund *et al.*

(2022) demonstrate how such effects, and their implications on trade, are likely to differ across different commodities and production locations.

It is also worth noting that when Forest, Land and Agriculture (FLAG 2022) projected global yield values into 2050, they decreased them across the board by 1%, to adjust for changes in yield that may occur due to the adoption of new (increasingly regenerative) farming practices – particularly in developed nations. This shift in practice is exemplified in new farming schemes being developed in the UK, as discussed in Section 1.3.1.

2.2.2. Changing environmental impact per hectare

Environmental impacts per hectare of crop production may also change over time and need to be considered in modelling.

Increasing crop yields through intensification is considered by some to be a threat to achieving environmental sustainability (Deitrich *et al.* 2012, Sarkodie & Owusu 2022) and may increase biodiversity impact per hectare with higher risk of groundwater depletion or pollution, ozone pollution (OECD 2012), and reduced soil health.

Conversely, FLAG's (2022) predicted increase in regenerative farming also implies that, at least in some parts of the world, biodiversity impacts per hectare may be on a downward trend. Benefits of regeneration are difficult to quantify in a generalised way, as they are specific to the soil type, management practices, crop type and topography, among other things. However, Rehberger *et al.* (2023) present an evidence review in which they summarise the outcomes of regenerative farming methods (Figure 2). These may contribute to overall decreasing biodiversity impact per hectare of commodity production. In the UK context, the FABLE study acknowledges it is too soon to understand whether new agri-environment schemes will encourage uptake of regenerative practices but models an increase to 50% of farmland under agroecological practices by 2030 under the Global Sustainability scenario (Smith *et al.* 2024). This will undoubtedly need consideration in modelling the UK's demand for commodities from overseas. It also indicates that these sorts of changes will be occurring in jurisdictions from which the UK is importing commodities and will have implications for biodiversity impacts per hectare of land use.

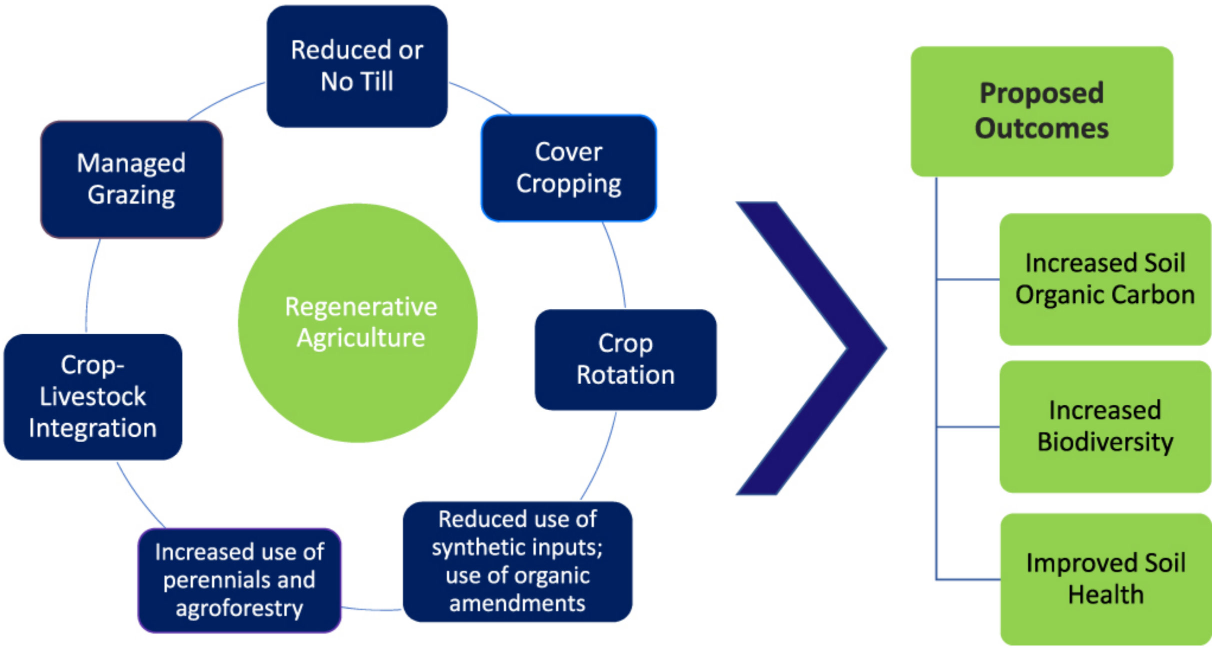

Figure 2. Diagrammatic representation of proposed outcomes associated with regenerative agriculture (Reproduced from Rehberger *et al.* 2023, in line with IOP Science's Copyright statement).

2.2.3. Increasing UK compliance costs

New agricultural regulations in the UK, such as the Control of Agricultural Pollution (Wales) Regulations 2021, and subsidy schemes (as discussed in Section 1.3.1) are placing emphasis on sustainable environmental management, alongside food production (Marshall & Mills-Sheehy 2021). Compliance with these regulations and/or scheme requirements incur costs for landowners and managers that go above those associated purely with production. For example, construction of slurry storage, planting of broadleaf woodland, creation of buffer strips and lowering livestock stocking densities can all be costly changes for UK producers. If UK producers cannot achieve profitability (i.e. absorb compliance costs and/or achieve equal value subsidies as in previous years) they may not be able to compete with imported commodity prices (ADAS 2024) and increase displacement as a result.

As this is a dynamic space, with new agricultural regulations and subsidy schemes currently coming into force across the UK, it is very difficult to predict how production behaviours will change and whether / to what extent this could drive displacement. Defra's Carbon Displacement Framework (ADAS 2024) notes the potential, but assumes no change in modelling, which seems sensible currently.

2.2.4. Changes in UK exports

The UK's current price and volume measure of exports has stayed broadly consistent over the last five years (ONS 2024). The UK's FABLE scenarios (Smith *et al.* 2024) and Defra's Carbon Displacement Framework (ADAS 2024) also assume no change in exports within their models. It therefore appears reasonable to assume no change in UK exports when modelling displacement.

However, it is worth noting that it may be interesting to model a scenario where UK policies lead to greater consumption of domestic supply, to understand how this might reduce or change the displacement of impacts of UK consumption across the globe; or a scenario in which increased land use for non-agricultural purposes (tree planting, urban expansion) leads to a decrease in production destined for exports as well as for domestic consumption.

2.2.5. Changes in UK consumer demand

Changing UK consumer demand, through our willingness to pay and our favour for different commodities, crop types and production processes, is likely to drive different patterns of displacement over time. For example, on a global scale, beef is expected to show a much smaller degree of production growth than poultry in the coming decade, reflecting weakening demand as consumers increasingly prefer poultry; given that it is perceived as a healthier option and has a lower price-point (Wilkins 2021). In the UK, we have also seen a rise in demand for organic, fairtrade and RSPCA-assured products since 2017 (Wunsch 2024). The assumption used in the UK's FABLE model under the National Commitment scenario (based on the Climate Change Committee's Balanced Net Zero pathway) is that the UK will see a 20% reduction in meat and dairy consumption by 2030, having been replaced with plant-based foods (Smith *et al.* 2024), although the realism of this assumption remains untested.

UKAMM (Defra 2021b) models food demand as dependent on population, economic growth and price elasticities of demand (i.e. how responsive demand is to changing commodity price). Predicted values for these factors would need incorporating to model displacement accurately under future scenarios. However, modelling future demand at a single commodity level is extremely complex, and still does not account for factors such as societal trends and awareness of impacts of production or consumption. Defra's Carbon Displacement Framework (ADAS 2024) assumes no change and that UK consumer demand remains stable. Both the Carbon Displacement Framework and UKAMM assume each unit of a given commodity is identical in quality and consumer appeal. Whilst an ideal model would account for this to avoid limitations, it has not been incorporated to date.

2.2.6. Crop substitutability

Even within the same production jurisdiction, "environmental impacts associated with one unit of traded or consumed product are highly variable" (Meyfroidt *et al.* 2013), varying up to 50-fold among producers of the same product (Poore & Nemecek 2018), and subject to unpredictable shocks such as extreme weather (e.g. drought or flooding), diseases or pest outbreaks (e.g. avian flu) or human conflict (e.g. Russia-Ukraine invasion). When a commodity industry collapses in response to a shock of this kind, prices for the commodity rise (Eisenbarth 2022). For example, analysis undertaken by Mottaleb, Kruseman and Snapp (2022) shows that "a 1% decrease in global wheat trade can increase producer's price of wheat by 1.1%" while "a 1% increase in producer's price can reduce wheat consumption by 0.59%." This, in turn, could shift export demand, consumer expenditure, and production pressure to a close substitute commodity (Eisenbarth 2022). The speed and extent of this substitution is also impacted by elasticity of the demand for each commodity, which is a measure of how likely consumers are to increase or reduce our consumption in response to changes in price. If a product has a high elasticity, consumers are more likely to change their habits, reducing their consumption when the price rises and increasing it when the price falls (Defra 2021b).

Due to the unpredictable nature and individual impacts caused by a commodity industry collapse, it has been exceptionally difficult within this review to evidence any general assumptions to inform how crop substitutability could be built into a modelling a future displacement scenario. As other studies have done previously (e.g. Schmidt 2008), the simplest option would be to assume no change in world food security or substitution effects across crops. An alternative approach could be to adopt a 'best case' and 'worse case' scenario approach, analysing multiple options and presenting the range. A future research piece could build on commodity elasticity formulae set out in the UKAMM and develop a framework to suggest the extent of substitution effects on commodity displacement, although this is likely to be complex.

3. Recommendations and next steps

The principle behind global displacement of impacts due to commodity consumption are well-documented and understood. Existing studies have already conducted investigation into displaced carbon emissions associated with consumption (ADAS 2024); environmental impacts associated with consumption of specific commodities (Sandström 2018; Brice *et al.* 2024); and modelling consumption under future scenarios (IFPRI 2017; Smith *et al.* 2024). However, no existing models were found to focus on predicting displacement of environmental impacts associated to UK consumption, across a wide range of individual commodities.

Due to the scale of the ambition to understand the environmental impacts of many commodities across the globe, creation of a model of this kind (or use of an existing model) will rely on some substantial assumptions. It is recommended in this case that an iterative approach is taken; starting with a simple model which relies on the assumption that many factors remain stable and that only attempts to model the immediate future, then if demand for the model is evident, work could continue to a point where it is highly complex and relies on many different data sources.

Regardless of the level of complexity, it certainly appears that pursuing modelling to quantify displacement under different scenarios is worthwhile. Impacts of consumption on climate and nature are globally important, with long term impacts that go beyond jurisdiction boundaries and affect all populations. It is also becoming increasingly relevant in the UK-context with new development and land-use policies, environmental commitments and consumer awareness. Currently the UK has no way of assessing the displaced impacts of land use change, so we cannot give a holistic assessment of whether their global impact is positive or negative.

Below are recommendations based on the content of this report, but further research and trials, using the recommendations within simple models, are required to progress this area of work.

3.1. Recommended assumptions

3.1.1. Where will displacement occur?

These assumptions are necessary for modelling which country any given commodity for UK consumption is likely to be produced in, because of land-use change and decreased UK-domestic production.

Considering the discussion in Section 2, this review recommends that any large-scale model of displacement (looking across many commodities and countries), considers the influence of the factors listed below. Noting the complexity of this task, a model could be developed iteratively, increasing in complexity by including more of these factors over time. One option may be for the outputs to be produced as a series of GIS layers that can be overlaid.

The factors below are listed in recommended order for inclusion:

1. Region of commodity production growth
2. Biocapacity per capita
3. Competitive pricing

Where all three factors cannot be included, for example in early iterations of the model, it should be assumed there is no influence on displacement of those excluded, but this should be clearly communicated alongside results.

Recommendations for methods to allow inclusion of these factors are made in the table below. While the optimum would be to account for all three factors and include all methods as steps within the model, it is possible to assume no change in some of the factors and focus on one or two if required. It should be noted that inclusion of these three would not address all factors of relevance (for example, socio-economic capacity would not be accounted for) and they would only consider short-term implications of displacement, but they could provide a useful starting point.

The comprehensive recommendation is to establish the region of greatest predicted production growth, before overlaying biocapacity and commodity price at the country-level. Ultimately, a set of plausible 'scenarios' for how displacement might occur (across each of these factors, individually and combined) could be modelled, to understand how wide the range of values is depending on the assumptions that you wish to take.

Table 2. Options for modelling where displacement will occur in a large scale model.

Order of inclusion	Option	Assumption	Method	Limitations
1	**Identify world region(s) of production growth for individual commodities or commodity types**	Commodity production will be displaced to the region(s) with greatest commodity growth predicted by 2030 or 2050 (adjust time frame accordingly).	Use the reference scenario within the International Food Policy Research Institute (IFPRI)'s Impacts of Alternative Investment Scenarios Tool to identify the world region most likely to see growth within production of a certain commodity or commodity type. **This should be used as the first step, prior to inclusion of any following methods.**	Impacts are only estimated at the regional, rather than country, level. IFPRI portal does currently not have all the commodities within scope that the GEIC portal does.
2	**Identify country(ies) with high biocapacity per capita for increased exports**	Commodity production will be displaced to the country(ies) with greatest biocapacity per capita available to increase production.	Use the Global Footprint Network (2024) model and/or FAO's GAEZ (Global Agro-Ecological Zones) data to identify countries with the greatest biocapacity per capita.	Biocapacity per capita is calculated as a single figure per country and is not commodity specific. Biocapacity per capita will change over time and the Global Footprint Network (2024) model will need to be updated to stay accurate.
3	**Identify country(ies) with competitive commodity pricing**	Commodity production will be displaced to the country(ies) with the lowest price at export.	Use commodity price data to identify the country(ies) with the lowest price per unit of this commodity when exported.	This assumes that the UK will continue to trade with the cheapest suppliers. With incoming due diligence acts and voluntary business disclosure measures, this assumption may need revisiting in the near future. It may also be more applicable to certain commodities than others.

3.1.2. Impact of global production trends

At present, the recommendation of this report is to begin modelling displacement while assuming no change in outcomes due to global production trends.

However, in future it may be considered worthwhile to add complexity to the model by considering factors such as yield and/or environmental impact per hectare of production with the countries the UK is predicted to increase displacement to.

Some examples of models which have already considered these aspects, and may be able to be fed into the model, are as follows:

- IFPRI's International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) (IFPRI 2017) can be used to explore scenarios in which countries invest differently in infrastructure, irrigation and research and development.
- OECD-FAO's Agricultural Outlook 2024–2033 (OECD/FAO 2024) is a comprehensive assessment of national, regional and global agricultural commodity markets over the next ten years.
- FABLE pathways scenarios to explore impact of different sustainability scenarios in specific countries (Smith *et al.* 2024).

3.1.3. Impact of UK production and consumption trends

With a dynamic UK landscape surrounding land use policy and subsidies currently, it seems sensible to attribute no impact to changing UK production currently. This could be reviewed in future; for example, after sustainable farming schemes have been fully implemented across the four UK nations.

Considering the stability seen in UK exports over recent years, it is also recommended that we assume no change because of these factors.

Due to the complex nature of predicting fine scale changes in UK consumer demand and preferences, it is recommended these impacts are also assumed as nil. With some lag time, the GEIC indicator will pick elements of this up in its consumption statistics for each country.

3.1.4. Crop substitutability

Currently, it is recommended any modelling assumes no change because of crop substitutability, as significant changes in world food security or crop availability are likely to stem from extremely unpredictable scenarios, such as extreme weather events or human conflict.

3.2. Next steps and future research questions

3.2.1. Analytical scoping

The immediate next phase of work will focus on analytical scoping work, collating relevant datasets and scoping modelling approaches that could contribute towards model development.

3.2.2. Model development

If analytical scoping also concludes that model development would be feasible and funding is available, the next stage will be to go ahead with developing a usable model. This would include the following tasks.

3.2.2.1. Trial using assumptions in displacement model

Findings from this think-piece about where displacement is most likely to occur could be utilised in a pilot study that creates and tests a model that enables us to estimate, for any crop, what the biodiversity impacts would be if a given area of that crop were lost from the UK and had to be sourced from elsewhere. It is recommended that one or two crops that have high potential to be displaced from the UK (e.g. crops currently produced domestically in areas that might most be affected most by competing demands for land use) are chosen to trial the model.

Further research could be conducted to improve assumptions and add complexity to the model over time. This would be particularly useful if some of the core assumptions are developed iteratively, as suggested above.

3.2.2.2. Develop assumptions to better account for future production and consumption trends

Once built, use of the model would need to be trialled under different future production and consumption scenarios. Which scenarios to use will likely require further research, but some potential examples are as follows:

a) Modelling displacement using assumptions or outputs from other models that already consider future scenarios (e.g. OECD-FAO, FABLE, IFPRI).

b) Combining the displacement model with new land use modelling scenarios, such as +10% regenerative farming, or scenarios coming from the Integrated Modelling Platform (part of Wales' ERAMMP).

c) Incorporating information and assumptions around specific commodity elasticities to help understand the potential impacts of crop substitutability. In the first instance these may be able to be derived for specific commodities using formulae set out in the UK Agricultural Market Model (Defra 2021b). Resources such as Poore and Nemecek's meta-analysis of food systems (2018) could be used to help establish key differences in the average environmental impacts associated with a substituted commodity.

3.2.2.3. Widen the scope to include assessment of impacts beyond just environmental

In developing this piece of work, it could be useful to think holistically about the displaced impacts of consumption; and consider factors beyond just environmental impacts. For example, inclusion of socio-economic impacts could be important if using a displacement model to inform well-balanced policy decisions that are good for both people and nature.

3.2.3. Applications of the displacement model

3.2.3.1. Holistic assessment of environmental impacts in UK land use policy changes

Researchers and policy makers in the UK could use a displacement model to understand net change in environmental impacts, on a global scale, because of domestic land use change.

It is important to anticipate both direct and indirect impacts of environmental resource policies (Lewison *et al.* 2019) and to avoid decision makers having a biased picture of effects that occur only in the immediate vicinity of the land use change.

This is the primary purpose of a displacement model identified at this time.

3.2.3.2. Creation of an environmental impacts accounting protocol

Companies and organisations can currently use the Greenhouse Gas Protocol (GHG Protocol) as an accounting standard for GHG emissions throughout supply chains. The 3 Scope model is used to categorise activities, calculate emissions and target pollution reduction measures.

A displacement model could function as an important tool in developing a similar protocol for other environmental impacts of consumption; for example, in helping to quantify displacement of biodiversity impacts throughout different commodity production chains. Poore and Nemecek (2018) support this, with their meta-analysis of production systems finding that they “support an approach where producers monitor their own impacts, flexibly meet environmental targets by choosing from multiple practices, and communicate their impacts to consumers.”

3.2.3.3. Use of outputs in target-setting and reporting under Multilateral Environmental Agreements (MEAs)

“Adopting adaptive, collaborative approaches that recognise inter-scale impacts is crucial for… addressing global conservation challenges and mitigating displaced impacts effectively” (Lewison *et al.* 2019). Therefore, outputs from a displacement model could become highly important in the context of international MEA negotiations, target-setting and progress reporting.

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Acronyms

Acronym	In full
ADAS	Agricultural Development and Advisory Service
BNG	Biodiversity Net Gain
CCC	Climate Change Committee
CIEEM	Chartered Institute of Ecology and Environmental Management
CPRE	Campaign to Protect Rural England
ERAMMP IMP	Environment and Rural Affairs Monitoring and Modelling Programme Integrated Modelling Platform
EU	European Union
FABLE	Food, Agriculture, Biodiversity, Land-Use, and Energy
FAO	Food and Agriculture Organisation of the United Nations
FLAG	Forest, Land and Agriculture
GEIC	Global Environmental Impacts of Consumption indicator
GHG	Greenhouse gas
GIS	Geographic Information System
HadGEM GCM	HadGEM general circulation model
IFPRI	International Food Policy Research Institute
INVEST	Integrated Valuation of Ecosystem Services and Trade-offs
MEA	Multi-lateral Environmental Agreement
NEVO	Natural Environment Valuation Online Tool
OECD	Organization for Economic Cooperation and Development
RCP 8.5	IPCC's Representative Concentration Pathway 8.5
RoW	Rest of World
SSP 2	IPCC's Shared Socio-Economic Pathway 2 (SSP 2) in which the global population reaches 9.2 billion in 2050, and average incomes reach USD 25,000 per person.
UKAMM	UK Agricultural Market Model

Appendix 1 – Evidence Assessment Method

This report details findings from a literature review, not a fully comprehensive evidence assessment or systematic review. This fits the purpose of this task and its aim to inform understanding of the evidence base surrounding displacement of environmental impacts caused by consumption and trade (Collins *et al.* 2015). However, it is important to note that there are some inherent risks with this method, including that it is not an exhaustive review of literature on this topic, and there is no critical appraisal of the evidence (Collins *et al.* 2015).

Screening

Inclusion and exclusion criteria chosen and followed throughout the literature review.

Inclusion criteria:

- Publications focused on displacement of resources – primarily agricultural outputs or timber.
- Publications focused on displaced environmental impacts – primarily carbon emissions, water consumption, deforestation and impacts on species richness or extinction risk.
- Publications referenced in other papers/reports.
- Existing trade models and statistics.
- Publications, reports or webpages written in English.
- Publications were found on the first two pages of results while using Google Scholar.

Exclusion:

- Publications focused on displacement of peoples, communities or jobs.
- Publications focused on displaced socioeconomic impacts.
- Publications, reports or webpages over 21 years old (pre-2003).
- Publications, reports or webpages written in languages other than English, without an English translation available.

Searches

Note: Key publications referenced in papers found via these searches were also included in the literature review and are discussed in this report.

Table 2. List of searches undertaken as part of literature review.

Date	Database or website	Search terms (where relevant)	References found
24/07/24	Google scholar	“displaced impacts of consumption”	Sandström 2018 Lewison *et al.* 2019
24/07/24	Google scholar	“land use leakage”	Henders 2014 Aukland *et al.* 2003
24/07/24	Google scholar	“Ecologically unequal exchange”	Frey, Gellert & Dahms, 2018

Date	**Database or website**	**Search terms (where relevant)**	**References found**
25/07/24	Google Scholar	“Land use displacement”	Meyfroidt *et al.* 2013
25/07/24	Google Scholar	“international land use displacement assumptions biodiversity impacts per hectare”	Schmidt 2008
22/08/24	Google Scholar	“environmental impact of regenerative agriculture”	Rehberger *et al.* 2023
04/09/2024	Google Scholar	“crop substitution”	Mottaleb, Kruseman and Snapp 2022
04/09/2024	FAOSTAT	N/a	FAOSTAT https://www.fao.org/faostat/en/#data/PP
04/09/2024	GEIC	N/a	https://commodityfootprints.earth/
04/09/2024	ONS International Trade	N/a	International trade - Office for National Statistics (ons.gov.uk)
04/09/2024	UN Comtrade Database	N/a	UN Comtrade
04/09/2024	OECD Trade Indicators	N/a	Indicators | OECD
04/09/2024	HMRC	N/a	https://www.uktradeinfo.com/trade-data/ots-custom-table