Chapter 7. UK

State of Food and Agriculture (SOFA) 2024
Background report

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SUSTAINABLE DEVELOPMENT SOLUTIONS NETWORK
A GLOBAL INITIATIVE FOR THE UNITED NATIONS

FABLE CONSORTIUM

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Highlights

- Working with stakeholders from government, business, civil society and academia, we examined the hidden costs of the UK's agrifood system. We identified detailed opportunities for using UK-specific data and methods to improve the accuracy and relevance of the global SOFA 2023 analysis of hidden costs, especially by using UK land use data.

- Using UK data from the FABLE calculator together with a model that emulates the global burden of disease study, we estimate the hidden costs of the UK's agrifood system as 180 billion 2020 PPP dollars in 2023, mainly from unhealthy diets. This is lower than the 2023 SOFA estimate of 255 billion 2020 PPP dollars, partly because obesity cannot yet be modeled using FABLE.

- The hidden costs are over 5% of the UK's 2020 GDP – similar to the total value added from the whole agrifood sector. This hidden deficit accumulates over time, posing economic risk to the UK, especially through the health impacts that weaken human capital.

- The model estimates that a more sustainable pathway could reduce total hidden costs by around 16% (23 billion 2020 PPP dollars per year) – worth around 686 billion 2020 PPP dollars over the next 30 years.
- The main factor for delivering these benefits is shifting to a healthier and more plant-based diet, with lower consumption of ultra-processed food. Coupled with reduced food waste and increased agricultural productivity, this frees up land for restoration to forest and other ecosystems. Together with the use of agroecological farming methods, this delivers benefits for carbon sequestration and biodiversity while also reducing nitrogen pollution. However, this could result in trade-offs with employment in the agriculture sector which need to be carefully addressed.

- More research is needed on how to encourage consumers to shift to healthier diets. Education is not enough, when consumers live in an environment full of unhealthy food choices, so strong government leadership and a holistic set of policies is needed. Some suggestions are provided in the final section of this chapter.

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7.1 Introduction

The 2023 SOFA report highlighted the hidden environmental, social and health costs of the global agrifood system, including the UK (FAO, 2023). For the UK case study in this chapter, we engaged with stakeholders to examine the hidden costs for the UK in more detail, comparing the SOFA 2023 analysis with national data and identifying opportunities to tailor the methodology and data to suit the UK context. We also worked with stakeholders to identify potential factors for change and entry points for actions to reduce the hidden costs, using the FABLE model (Mosnier et al., 2020).

The UK is approximately 70% farmland: 20% cropland, 5% temporary grass, 25% permanent grass and 20% rough grazing (including mountain and moorland areas). There has been little change in these proportions over the last 40 years apart from some loss of rough grazing and increase in permanent grassland (Defra, 2023).

There are large regional differences: Scotland and Wales have a much higher proportion of rough upland sheep grazing, while Northern Ireland focuses on dairy farming. Cropland covers 32% of England, but just 4% of Wales (based on UKCEH, 2020). Some of the most fertile cropland is on drained fenland in the east of England, where the fine peat soils produce very high GHG emissions as well as being vulnerable to wind erosion. Much of this area is also at risk of flooding due to sea-level rise.

Farming employs 1.5% of the UK workforce, but this ranges from 1.2% in England to over 6% in Northern Ireland (Defra, 2019). Many small farms are struggling financially: 20% of farms make a loss from farming activities, and many rely heavily on subsidies and diversified income sources such as tourism. The average age of farmers is 55, and many suffer from poor mental health. Most food is sold via a few large supermarket chains, who set low prices for farm produce and often change or cancel orders at short notice, leading to high levels of food waste.

The UK imports 50% of all food, up from 30% a few decades ago. Yields are relatively high but have stagnated. Consumption of agrochemicals has decreased in recent years with precision farming, but only 3% of UK production is organic. Following Brexit, England is shifting towards a new agri-environment scheme (ELMS), with basic payments being phased out. As a result, support for some basic agroecological methods such as cover crops is gradually improving. There are similar moves in Wales and Scotland.

Health is a major issue in the UK, with very high levels of obesity as well as growing food poverty, though malnutrition is very rare. The national Eatwell dietary recommendations imply that consumption of animal products should decrease to achieve a healthy diet, and the Net Zero plans also depend on dietary change, but over the last decade this goal has not received government support (the position of the new government in June 2024 is not yet clear).

Stakeholder input and feedback was used to inform the analysis in this chapter. Stakeholders already involved with the FABLE model and pathway development (specifically, those who attended the last online UK FABLE workshop in September 2023), additional food system experts identified in consultation with the Food Systems team at ECI, and economists identified by FAO, were invited to provide feedback. We held two one-hour online workshops as some people could not attend the first one, and one additional session with a single expert. Most of the feedback was obtained directly in the workshops, but we also provided an online survey for people to provide further feedback after the workshops. Only a small number of people responded, but these included a range of highly relevant stakeholders and experts across business (4), research (2), civil society (1), and public administrations (5).

7.2 SOFA 2023 hidden costs analysis

7.2.1 Main cost components and explanations of the results

For the UK, the total hidden costs of the agrifood system are estimated at 255 billion 2020 PPP dollars. Of this, the most important hidden cost is identified as the burden of disease from unhealthy diets (Figure 7-1), which steadily increased from 2016 to reach an estimated 201 billion 2020 PPP dollars in 2020 (Figure 7-2). For comparison, the World Obesity Atlas also reports very high prevalence of obesity in the UK (33% for adults, increasing by 2% per year) but estimated costs are lower at USD 61 billion (World Obesity Atlas 2024).

Figure 7-1: *Hidden economic costs of the UK agrifood system in 2020, from SOFA 2023 (billion 2020 PPP dollars)*

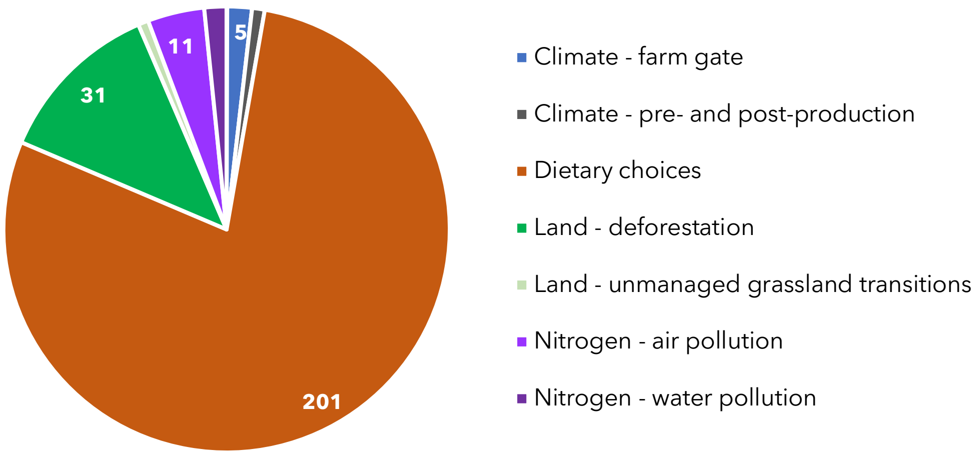
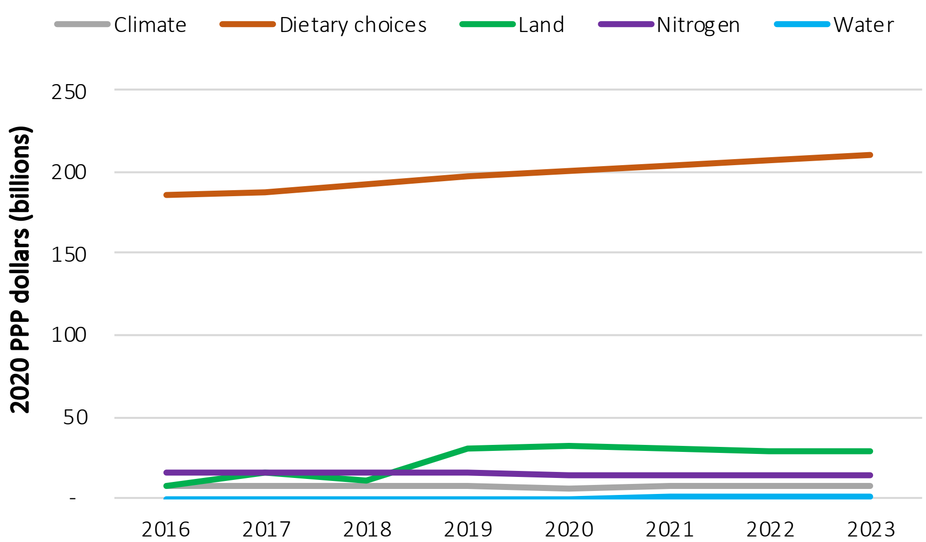
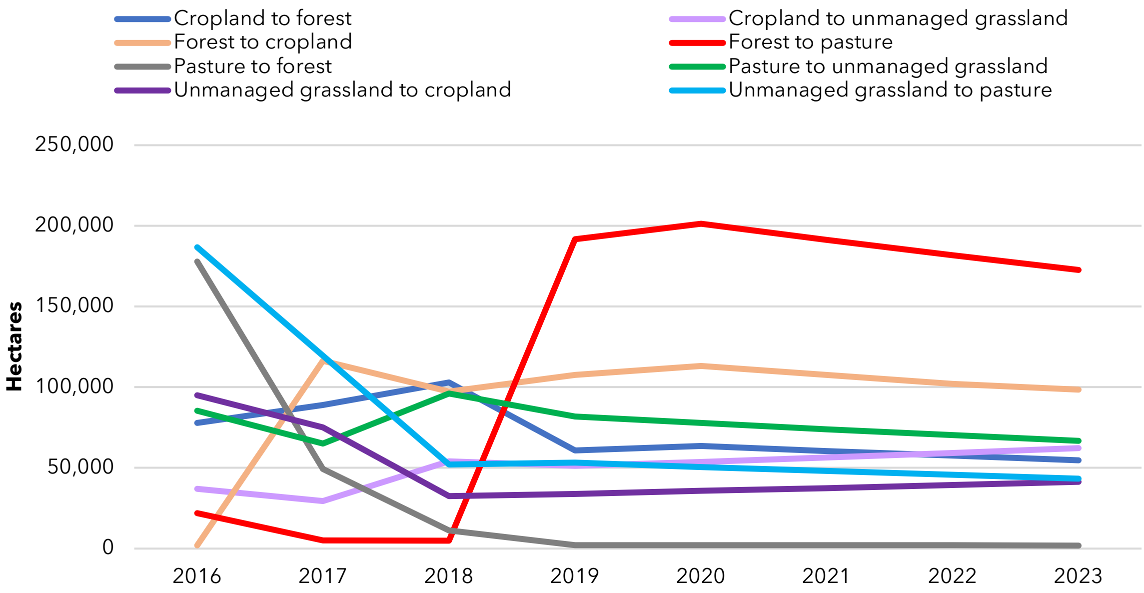


Figure 7-2*: Trends in main hidden economic cost estimates for the UK from SOFA 2023 (billions 2020 PPP dollars)*



The next highest cost was land use change, estimated as 32 billion 2020 PPP dollars. The data appears to fluctuate considerably between 2016 and 2019 and does not match known patterns in the UK (Figure 7-3). The smoothing of the trend after 2020 is because these figures were extrapolated.

Figure 7-3: *Apparent large fluctuations in HILDA+ land use data for the UK from 2016 to 2020*



The third highest cost is 15 billion 2020 PPP dollars from nitrogen emissions, of which 11 billion is from air pollution and the rest from water pollution. This has been gradually declining since 2016, in line with the decreased use of nitrogen fertilizers in the UK due to the uptake of precision farming techniques. This is followed by 7 billion 2020 PPP dollars from greenhouse gas emissions, of which 5 billion is from farm emissions and the rest from pre- and post-production. This relatively low cost may reflect the limited scope of the climate impacts included (agricultural productivity losses and human health impacts from heat stress). Also, the SOFA 2023 methodology paper states that new modeling has increased the social cost of GHGs by 60% since the 2023 analysis. For comparison, a UK study using higher unit costs estimated total costs of GHG emissions from food production as £9.7 bn (16 billion 2020 PPP dollars), more than double the SOFA estimate (Fitzgerald et al., 2019).

The estimated cost of water use is much smaller, at 77 million 2020 PPP dollars, reflecting the relatively low use of irrigation in the UK. Poverty impacts are also low, at 32 million 2020 PPP dollars, reflecting UK laws on the minimum wage – though there are still cases of illegal work where these laws are flouted. The cost of undernourishment is shown as being zero, in line with FAOSTAT figures, although food insecurity is growing in the UK (see below).

7.2.2 Comparison of SPIQ data with national datasets

Impact quantities

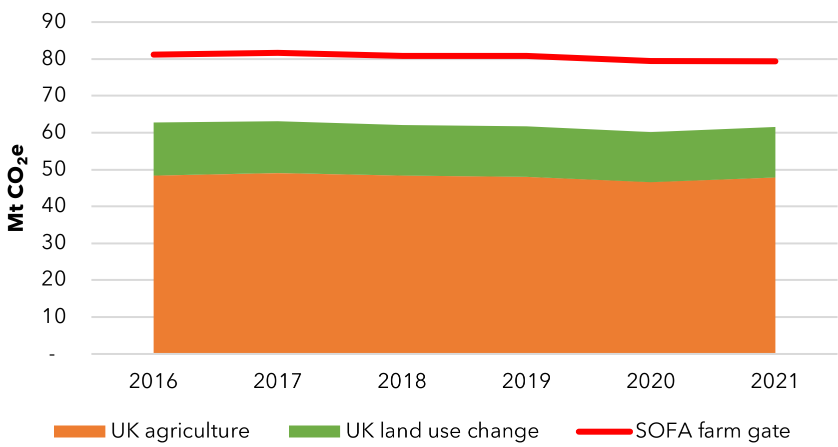
Land use transitions are taken from the HILDA+ dataset – a satellite-derived annual global dataset at 1km resolution. This indicates surprising results for the UK, with an apparent large conversion of unmanaged grassland to pasture at the same time as conversion of pasture to forest in 2016 and

2017. This then gives way to the opposite trend, with apparent large-scale conversion of forest to pasture from 2019 onwards, and forest to cropland from 2017 onwards (Figure 7-3). None of these trends are supported by UK-level datasets such as the UK Greenhouse Gas Inventory (Brown et al, 2022), which shows much smaller transitions (Table 7-1). Also, not all land use transitions are included in the FAO analysis. Those excluded include cropland to pasture, pasture to cropland, forest to unmanaged grassland, unmanaged grassland to forest, and any transitions involving settlements. This could be because some of these are not thought to create significant externalities, and some are not related to the food and farming sector.

As noted by the SOFA 2023 methodology paper, the HILDA+ dataset is prone to misclassification. For the UK, we suspect that commercial forestry plantations that have been felled ready for replanting are classed incorrectly as transitions from forest to cropland or pasture, leading to a high apparent deforestation rate that does not match reality. Also, land use in the UK is highly fragmented and this is very likely to lead to inaccuracies at the HILDA+ resolution of 1km grid cells.

GHG emissions do not match the UK Greenhouse Gas Inventory (GHGI). Farm gate emissions should correspond to UK GHGI agriculture emissions plus land use change involving cropland and grassland but are significantly higher (Figure 7-4). While methane emissions in SOFA 2023 are very similar to those in the UK GHG Inventory, CO_2 and N_2O emissions are higher (Table 7-2). GHG emissions from UK land use change are zero in FAOSTAT, which only considers biomass burning (almost zero in the UK) and net forest conversion (positive in the UK), not transitions from cropland to pasture, or from unmanaged grassland to improved pasture or cropland. However, exclusion of these UK GHGI emissions would be expected to reduce the SOFA estimates, not increase them. The UK added a large new source of emissions from drained organic soils (i.e., peat) to their inventory in 2022, but this also does not explain the difference because it has already been incorporated into FAOSTAT and the SOFA analysis (under farm gate emissions, not land use change). The differences must be due primarily to the use of the Tier 1 methodology for FAOSTAT compared to the more detailed Tier 2 methodology for the UK GHGI. It was not possible to provide a UK-specific estimate for GHG emissions from pre- and post-processing because these figures are not shown in the UK GHGI.

Figure 7-4: *Comparison between SOFA 2023 farm gate GHGs for the UK and the UK GHG Inventory*



Note: All figures have been converted to Mt CO_2e using AR5 conversion factors (28 for CH_4 and 285 for N_2O).

Table 7-1*: Comparison of HILDA+ land use change for the UK and UK Greenhouse Gas Inventory (hectares), for categories and years that are comparable (UK GHGI does not include a category for unmanaged grassland and currently only goes up to 2020)*

Year	HILDA+ cropland to forest	UK GHGI cropland to forest	HILDA+ forest to cropland	UK GHGI forest to cropland	HILDA+ forest to pasture	UK GHGI forest to grassland	HILDA+ pasture to forest	UK GHGI grassland to forest	HILDA+ cropland to unmanaged grassland	HILDA+ pasture to unmanaged grassland	HILDA+ unmanaged grassland to cropland	HILDA+ unmanaged grassland to pasture
2016	77,964	700	1,999	0	21,841	1,500	177,910	5400	36,871	85,622	95,036	186,762
2017	89,100	600	116,389	0	5,073	1,400	49,437	7600	29,467	65,094	75,130	119,529
2018	102,966	1,900	97,445	0	5,090	1,200	11,184	10200	53,900	96,114	32,522	52,135
2019	60,680	1,100	107,746	0	191,743	1,100	2,268	11900	51,241	81,956	34,002	53,212
2020	63,714	700	113,133	0	201,330	1,400	2,155	11800	53,803	77,858	35,702	50,551
2021	60,528		107,477		191,264		2,047		56,494	73,965	37,487	48,024
2022	57,502		102,103		181,700		1,945		59,318	70,267	39,362	45,622
2023	54,719		98,571		172,615		1,847		62,284	66,754	41,330	43,341

***Table 7-2**: Comparison of GHG emissions in FAO SOFA and the UK Greenhouse Gas Inventory (all figures converted into $MtCO_2e$)*

		2016	2017	2018	2019	2020	2021
UK GHGI							
Agriculture	CO_2	6	6	6	6	6	6
Agriculture	CH_4	28	29	28	28	28	28
Agriculture	N_2O	14	14	14	14	13	14
	All GHGs	**48**	**49**	**48**	**48**	**47**	**48**
Land use change	CO_2	11	10	10	10	10	10
Land use change	CH_4	3	3	3	3	3	3
Land use change	N_2O	0	0	0	0	0	0
	All GHGs	**14**	**14**	**14**	**14**	**14**	**14**
Ag + LUC	CO_2	17	17	16	16	16	16
Ag + LUC	CH_4	32	32	31	31	31	31
Ag + LUC	N_2O	14	15	14	15	14	14
	All GHGs	**63**	**63**	**62**	**62**	**60**	**62**
SOFA							
Farm gate	CO_2	28	29	28	29	29	29
Farm gate	CH_4	31	31	31	31	30	30
Farm gate	N_2O	21	22	21	22	21	21
	All GHGs	**81**	**82**	**81**	**81**	**79**	**79**

Nitrogen emissions to air in the form of ammonia (NH_3) in SOFA were taken from the EDGAR database. These estimates appear to be larger than the estimates of NH_3 emissions to air from agriculture in the National Atmospheric Emissions Inventory (NAEI) but smaller than those in the UK Environmental Accounts (the "Blue Book", Office for National Statistics, 2021). Note that the UK data in the Blue Book is presented in SO_2 equivalents (i.e., acidification potential compared to SO_2). To convert it to tonnes, we divided by the acidification potential of NH_3 (1.88) and NOx (0.7) (Table 7-3). We are still investigating the reasons for these differences.

For hidden costs of nitrate pollution in water, we have not yet found a suitable source of UK data for comparison.

***Table 7-3**: Comparison of results of SOFA 2023 and UK Blue Book for ammonia (NH_3) and nitrogen oxides (NOx) emissions into air from agriculture*

NH_3	SOFA	Blue Book Air emissions Ammonia (NH_3)-Agriculture, forestry and fishing		Ratio blue book to SOFA	NAEI	Ratio NAEI to SOFA
	kt NH_3	kt SO_2 equivalent	kt NH_3		kt NH_3	
2016	**449**	459	**244**	54%	**239**	53%
2017	**456**	463	**246**	54%	**241**	53%
2018	**452**	457	**243**	54%	**238**	53%
2019	**452**	455	**242**	54%	**237**	52%
2020	**427**	435	**231**	54%	**227**	53%
2021	**406**	443	**236**	58%	**231**	57%

NOx	SOFA	Blue Book Air emissions Ammonia (NOx)-Agriculture, forestry and fishing		Ratio blue book to SOFA	NAEI	Ratio NAEI to SOFA
	kg NOx	kt SO_2 equivalent	kt NOx		kt NOx as NO_2	
2016	**46**	51	**73**	157%	**28**	60%
2017	**47**	51	**73**	155%	**29**	61%
2018	**47**	49	**70**	150%	**29**	61%
2019	**47**	44	**63**	135%	**29**	61%
2020	**44**	41	**59**	133%	**27**	61%
2021	**42**	42	**60**	143%	**27**	66%

Dietary choice impacts are estimated as DALYs, from analysis of the Global Burden of Disease study. We have not found any additional UK datasets to compare against the SOFA analysis. However, there have been several other studies of diet-related health costs. These include a study that compiled estimates from various literature sources to estimate diet-related healthcare costs of GBP 45 billion in 2015, although this includes GBP 17 billion for treating malnutrition (mainly for elderly people) which may be related to other illness or ageing, not the agrifood system (Fitzgerald et al., 2019). This is the healthcare cost only, but it can be used to derive an estimate of lost productivity using the observation that productivity losses are about twice as high as direct healthcare costs in Europe (Candari et al., 2017). Converting to 2020 PPP would give an estimate of around 93 billion PPP dollars in lost productivity if malnutrition costs are excluded, or 150 billion if they are included, both lower than the SOFA estimate of 201 billion 2020 PPP dollars. The study also estimated further healthcare costs from food production (nitrates in drinking water, antibiotic resistance, food poisoning and pesticides) as a further GBP 10.5 billion, equating to 35 billion 2020 PPP dollars in productivity losses. A 2023 study estimated the cost of lost productivity as GBP 150 billion (188 billion 2020 PPP dollars) per year, equivalent to 7% of GDP, with another GBP 70 billion (88 billion 2020 PPP) from lost tax income, benefits payments and costs to the NHS (Oxera, 2023). This is the total cost for all health problems, only a portion of which will be diet-related, so again this is lower than the SOFA estimate. An older study estimated costs of GBP 11 billion in 2007 ($13.7 billion 2020 PPP dollars) for poor diet and obesity combined (Scarborough et al., 2011); this figure was incorporated into the Fitzgerald et al. study along with other health impact categories.

For **undernourishment** the costs are shown as being zero, in line with official figures, but food insecurity is a growing problem in the UK. Surveys estimate that 6% of households were food insecure in 2021/22 (UK Government, 2023) and 15% in January 2024 (Food Foundation, 2023). A rough estimate in 2015 put the cost of treating malnutrition in the UK at GBP 17 billion per year, mainly amongst the elderly, although it is not clear how much of this could be attributed to the agri food system (Fitzgerald et al. 2019).

National data for the other impact quantities (nitrate pollution in water, water consumption for agriculture, and poverty among agricultural workers) have not been found.

Review of unit costs to GDP

For **GHG emissions**, the GHG costs only include limited impacts: agricultural productivity losses and productivity losses associated with heat stress in workers. We would expect the true costs of GHG emissions to be higher if other climate impacts could be taken into account, such as impacts on infrastructure and loss of life from storm damage and flooding, as well as climate feedback and tipping points. Also, climate change costs using standard economic methods assume "optimal abatement", where governments always make the right decisions about how much to mitigate climate emissions. In 2019, a UK study noted that estimates of the social cost of carbon varied from USD 21 to USD 900 per tonne: using an estimate of USD 220 per tonne they estimated total costs of GHG emissions from food production as GBP 9.7 billion, or 16 billion 2020 PPP dollars, more than double the SOFA estimate of 7 billion 2020 PPP dollars (Fitzgerald et al. 2019). The SOFA costs are also seven times lower than the carbon value used by the UK government, which uses a mitigation cost approach (i.e., the cost of reaching the UK's climate targets), with a value of GBP 241 (USD 369) in 2020. If these costs were applied, the hidden cost of GHGs would increase from 7 billion 2020 PPP dollars to around 48 billion 2020 PPP dollars. Use of mitigation costs is not in line with the overall SPIQ approach used for SOFA 2023, but UK stakeholders thought it would be more appropriate for a UK national analysis.

For **land use transitions**, ecosystem service costs were taken from the ESVD database. This contains over 4,800 individual estimates of value per hectare per year of ecosystem services across 92 countries, 15 biomes, and 23 ecosystem services. "Outliers" with particularly high values were removed. Remaining values were aggregated into HDI tiers (low development, medium development, high development, and very high development) and into groups of provisioning, regulating, and cultural services, with the total value for ecosystem services in an HDI tier being the sum of the provisioning, regulating, and cultural ecosystem services. Efforts were made to exclude carbon sequestration to avoid double counting with the GHG emissions category. Nevertheless, the aggregation leads to very high uncertainty: typically, the interquartile range of ecosystem service costs is greater than an order of magnitude. As noted by the SOFA 2023 methodology report, accuracy could be improved by using a mechanistic model such as Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) for country-specific analysis in future. For comparison, a 2019 UK study estimated the costs of biodiversity and ecosystem services losses and soil degradation from food production as GBP 11.4 billion, or 19 billion 2020 PPP dollars, less than the SOFA estimate of 30 billion 2020 PPP dollars (Fitzgerald et al. 2019), but the SOFA estimate is affected by the incorrect estimate of deforestation rates.

The results for the **Agricultural externalities impact ratio** (AEIR) are very high for the UK – over USD 2 of external costs are generated for every USD 1 of agricultural value added. This is attributed to intensive use of agricultural inputs, particularly nitrogen emissions, for sectors that provide a low percentage of total GDP. Although nitrogen fertilizer use is on a declining trend in the UK due to the adoption of precision agriculture, and is not believed to be excessive, there is a high marginal health cost because there are high population densities with very high labor productivity. Also, the agricultural sector provides a low percentage of total GDP, so costs per unit output are high. The AEIR is also affected by the discrepancies in the HILDA+ land use dataset (see above), which could be improved by using UK-specific data.

For the other cost factors, we have not found relevant UK-specific values for comparison.

7.2.3 Recommendations for tailored country hidden costs analysis

Replacing global database with national datasets

Land cover: The UKCEH Land Cover Map offers a more accurate land cover dataset for the UK. However, there are currently inconsistencies in the methodology between different years in the historic data, so some interpolation would be required to smooth these differences. Future annual updates are expected to use a consistent methodology.

Greenhouse gases: UK-specific figures from the Greenhouse Gas Inventory could be used, following further investigation of the differences listed above. However, there are also opportunities to improve the UK GHGI methodology. Stakeholders recommended that UK carbon prices should be used instead of the SPIQ global average social costs.

Nitrogen: UK-specific figures from the Agricultural Ammonia Inventory and nitrogen emission accounts could be used, following further investigation of the differences listed above. Also, the Environment Agency are about to publish a National Groundwater Nitrogen Inventory and Heat Maps for England, aiming to quantify the nitrogen loading onto land or at risk of being lost (via leaching) to groundwater in 2020 from all sectors with data available.

Environmental data: Other data could be checked against the UK Natural Capital Accounts.

Undernourishment: While undernourishment is officially reported as zero, survey data compiled by the Food Foundation can be used to indicate the prevalence of food insecurity, and difficulty of accessing healthy food, which disproportionately affects disadvantaged households. This cannot substitute directly for the undernourishment indicator, as the unit costs would be different, but it could be used for a parallel indicator more appropriate for the UK.

Worker poverty: There are relatively few people employed in primary production in the UK – far more are employed post-farm gate, where low wage jobs are a major problem (dark kitchens, etc.). There are over 4 million jobs in catering and delivery (not clear if delivery is in scope), and more in processing. Data on earnings is here; farm incomes in England here and see also the Farm Business Survey.

Health: The UK has its own DALY costs which could be used instead of the SOFA ones.

Other data sources: The Economist Impact Unit (EIU) produces a Food sustainability index for every few years – a basket of many indicators including food security, waste and environmental impacts. The Global Farm Metric was mentioned by stakeholders, though this is developed to collect data at farm level.

Need for additional research or in-depth analysis

In addition to using more UK-specific data as listed above, more research could improve some aspects of the analysis.

Ecosystem service impacts of land use change: Use of aggregated data from the ESVD has high uncertainty. It would be better to perform a tailored analysis for the UK using national data on the cost of ecosystem service loss from agri-food activities, including cultural ecosystem services.

Nitrate pollution: In countries with strict regulations on drinking water quality, the cost of water pollution is largely realized as additional water treatment costs rather than health costs. It is not clear whether this is a hidden cost.

Undernourishment: Investigate alternative assessment methods that are more relevant for the UK, based on food insecurity and lack of micronutrients.

Food security / insecurity: Current government statistics for food imports are based on the cost of imported food, not calories or nutrition. Can food security be quantified in terms of nutrition? The FABLE model already does this to some extent.

Worker poverty: For the UK and other developed countries it would be more relevant to consider the difference between incomes and the "living wage" (not the government minimum wage), though this would make it harder to compare across countries. Worker poverty should include consideration of disempowerment, inequality, and mental health and well-being impacts, and the resulting costs. Farmer incomes are often below the living wage, but it is difficult to analyze because farm incomes are closely tied in with the provision of a house, vehicles, etc., which are all part of the business.

Offshoring of impacts: Stakeholders emphasized the need to consider the impacts of imported food that occur in food exporting countries. The FABLE model includes imports and exports, and this could potentially be used to allocate impacts to food-importing countries, although specific export-import country links are not identified.

Trade-offs: The University of Oxford produced a trade-off visualizer (www.susfans.eu) illustrating trade-offs across health, environmental, social and economic outcomes.

The use of PPP to determine the value of health impacts enables the costs to be expressed as a percentage of national GDP. However, it is important to clarify that this does not imply that lives and health are worth less in lower income countries.

Hidden benefits / positive externalities

Examples of hidden benefits could include:

- attractive landscapes for recreation and tourism
- local food culture
- thriving rural communities
- food security
- jobs (are these hidden benefits or market benefits?)

There are several overlapping difficulties in assessing these benefits.

1. Some, such as food culture and landscapes, are highly subjective. There is a difference between intensive agriculture and less intensive landscapes with more hedgerows, trees, and wildlife. Some people might also prefer non-agricultural landscapes such as woodlands and wilderness areas.
2. Some are dependent on context. For example, aesthetic benefits are only delivered where land is accessible and attractive. Similarly, nitrogen fertilizer has a positive impact on under-nourishment (by increasing yields), but over-supply of nitrogen causes hidden costs to the environment and health.
3. Some depend on the counterfactual. When compared with a pre-agricultural landscape, the outcomes for biodiversity and some ecosystem services (e.g., carbon sequestration, flood protection, erosion protection, pollination, clean air and water) would be expected to be consistently negative whilst the outcome for food production and employment would always be positive. However, if comparing a more sustainable food production system to conventional unsustainable production, many environmental outcomes would be positive, while food production could be either positive, negative or neutral depending on the context (e.g., there could be a loss of yield from shifting to less intensive production, but there could also be an increase in long-term yield if climate resilience and overall sustainability is enhanced).
4. Some are delivered only by a subset of the agrifood system. For example, there can be high benefits for well-being, mental health, self-esteem, training and employment from community food production on city farms or community orchards, especially from therapy schemes for disadvantaged people, but this only applies to a tiny subset of the agrifood system.

Boundaries of the study

Stakeholders identified additional aspects of the agrifood system that are not included in the SOFA 2023 analysis. While it may not be possible to monetize these, it could be possible to quantify them in non-monetary terms, or report on them qualitatively. For example, numbers of deaths can be estimated and presented alongside the monetary results for productivity loss so that decision-makers can take into account the loss of life and associated impacts on well-being and society.

Land use: biodiversity impacts, alongside ecosystem service impacts.

Land degradation: e.g., soil erosion, compaction, desertification, salinization. Fitzgerald et al. (2019) assessed soil loss. Farmers are being encouraged to do more soil testing, which will help to build the evidence base.

Water scarcity: loss of water for drinking and sanitation, and the environmental cost of water over-abstraction for biodiversity, such as streams and wetlands drying out, or salinization of groundwater due to over-abstraction in coastal areas.

Phosphate pollution: however, this arises largely from sewage rather than agricultural run-off.

Pesticide use: this is included in terms of GHG impacts, but it also has human health and environmental impacts, including adverse impacts on pollination and biological pest control. Fitzgerald et al. (2019) assessed health impacts.

Anti-microbial resistance: the methodology of Fitzgerald et al. (2019) could be a starting point.

Fishing and environmental impacts on oceans.

Impacts of overexploitation (e.g. over-fishing or over-grazing).

Competition from biofuels.

Animal welfare and plant health: animal welfare has an economic cost, e.g., productivity losses from animals with mastitis.

The Food Ethics Council (FEC) has produced metrics that could be useful.

Cost of death, medical treatment and informal care: for some impacts such as air pollution, only productivity impacts are currently included, not deaths. Treatment costs are deemed to be visible economic exchanges within the economy and, therefore, not considered a hidden cost, or else estimates of the inefficiency in GDP terms associated with these direct costs are not available. However, these treatment costs are not explicitly allocated to the agrifood system in decision-making and therefore they should be included in the analysis, to avoid underestimating total costs.

Modern slavery is a big issue in the agrifood sector but by its very nature is hard to quantify, as it is illegal and therefore hidden and not reported.

Food culture: place-specific food is lost in industrialized food systems.

Environmental costs of packaging and plastic: pollution, litter, and microplastics (including from degrading polytunnels).

7.3 Evolution of hidden costs by 2030 and 2050

7.3.1 FABLE Calculator for the UK

The UK FABLE model includes several adaptations to reflect the country context.

1. The UK model distinguishes intensively farmed ("improved") pasture from rough grassland which is extensively (lightly) grazed at a lower stocking density. This is important in the UK, where there are large areas of rough grassland in some regions, because improved grassland (which is typically fertilized and sown with 2–3 high productivity grasses) is more productive but also has lower biodiversity value and higher environmental impacts.
2. We distinguish between semi-natural woodland (mainly broadleaf in the UK) and commercial plantations (mainly non-native conifers with little biodiversity value).
3. The UK model includes hedgerows and agroforestry (silvopasture and silvoarable).
4. The UK model includes greenhouse gas emissions from inter-farmland transitions (cropland to pasture, pasture to extensive grassland, etc.).
5. We also model emissions from degraded peatland, and how these emissions can be reduced by restoring the peat (e.g., by re-wetting drained peat bogs).

7.3.2 Scenathon 2023 pathways assumptions

All pathways assume medium levels of economic growth and population growth, in line with the global SSP2 scenario, which matches recent trends. In the absence of better information, they also assume no change in imports and exports, although this could change as the long-term impacts of Brexit emerge.

Current Trends pathway

The Current Trends (CT) pathway aims to continue policies that are already in place. We assume no dietary change and no change in biofuel demand. We also do not model any change in irrigation, which is not widely used in the UK, although this could change in future. There is no change in crop productivity from current levels (which might be optimistic, as yield losses are expected due to climate change). We assume an 18% increase in milk productivity by 2050 – this is half of current trends, because we assume that the scope for continued increases in yield at the same relatively high rate could be limited by biological constraints and concerns over animal welfare. We assume that the percentage of the herd on extensive grassland decreases by 7%, from 26% to 24%, reflecting the current trend towards intensification.

Tree planting continues at current rates, around 13,000 hectares per year, falling short of government targets. We assume a continuation of the current split of 50:50 broadleaf woodland to conifer plantations.

There is no constraint on agricultural expansion, as there are no laws preventing this in the UK, although in practice the agricultural area is not currently expanding. Protected areas are assumed to stay at the current level of 27%. Note that in the UK, it is estimated that only 3% to 6% of UK land cover is effectively protected and managed for nature – the rest of the 27% consists of National Parks and similar designations which focus on landscape appearance and recreation rather than biodiversity, and designated sites that are in poor condition.

Urban expansion causes pressure on land use. In CT we assume a continuation of current trends, leading to a 50% increase in urban areas by 2050 (from 8% to 12% of UK land cover).

Sustainable pathways

The National Commitments (NC) pathway is based mainly on the Balanced Net Zero (BNZ) pathway developed by the Climate Change Committee (CCC), the government's advisors, to inform the Sixth Carbon Budget (6CB). This is considered by the CCC to be the most widely acceptable pathway for meeting the UK's Net Zero target for 2050 as mandated by the UK Climate Change Act. We have included additional measures that aim to deliver on the government's biodiversity commitment (30% of land protected for nature by 2030), although policies are not yet in place to do this.

The Global Sustainability (GS) pathway is largely based on a set of more ambitious (high level) options presented by the CCC in their Sixth Carbon Budget report as a means of delivering net zero faster. This pathway also includes stronger actions towards the 30x30 nature recovery target. In addition to assuming no constraint on agricultural expansion, the GS pathway assumes no deforestation, to ensure that biodiversity targets are met. We assume that urban expansion is reduced by half due to policies to promote more compact development patterns, limiting the increase in urban area to 25%.

In line with the CCC pathways, we assume that tree planting increases to 36,700 hectares per year for NC and 50,000 hectares per year for GS. In the GS pathway we assume 80% of the woodland created is semi-natural, in line with the need to deliver biodiversity goals. Protected areas are assumed to increase from 27% to 30% in NC and GS, to meet the 30x30 biodiversity target.

The CCC pathways include highly ambitious agricultural productivity assumptions, with a 34% increase in crop productivity. In GS, milk productivity increases by 27%, compared to 18% in CT and NC. For meat production from sheep and cattle grazing, we assume an increase of 10% in NC and GS due to increased stocking density, with a similar increase for chicken production.

In CT, we assume that the percentage of the herd on extensive grassland decreases by 7%, from 26% to 24%, reflecting the current trend towards intensification. In NC we assume the % of herd on extensive grassland decreases by 38%, from 26% to 16%, as the herd shifts to more intensive grazing in line with the CCC BNZ pathway. However, in GS we assume a 14% increase to 30% of the herd on extensive grassland due to the focus on biodiversity targets. We also model the uptake of agroecological options in the NC and GS pathways: increased use of cover crops and uptake of agroforestry and hedgerows. Again, we use more ambitious assumptions for GS than for NC, in view of the need to meet biodiversity targets.

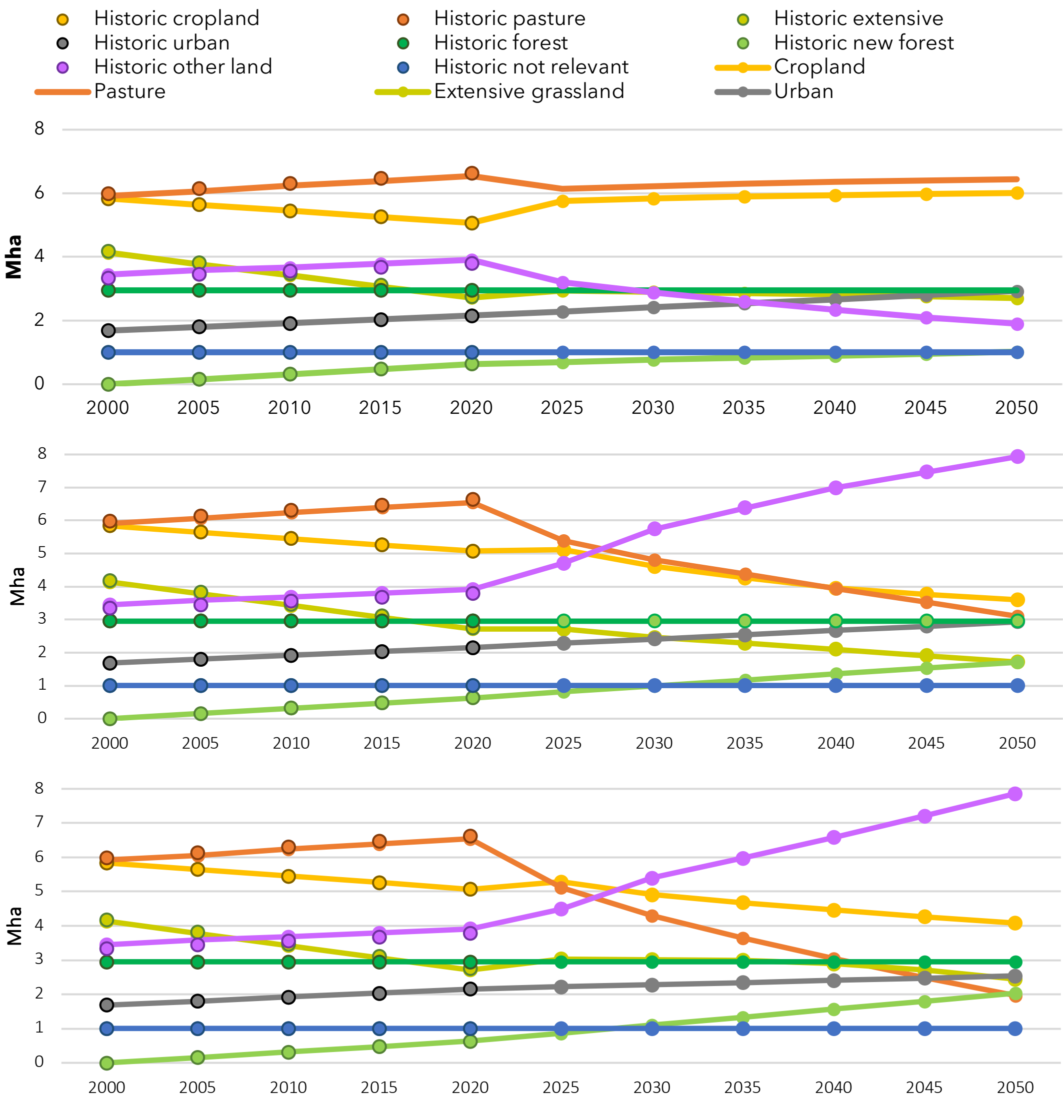
Dietary change is a key component of the CCC pathways. We assume no change for CT, but for NC we assume a 20% cut in meat and dairy by 2030, rising to 35% by 2050 for meat only, to be replaced with plant-based foods (from the BNZ pathway). For GS we use the CCC high ambition assumption of a 50% cut in meat and dairy consumption by 2050. This could entail increased use of lab-grown meat and other novel meat substitutes.

Although the CCC has very ambitious targets for the uptake of woody biofuels such as short-rotation coppice, currently the FABLE model only represents crop-based biofuels such as bioethanol from sugar cane. In the absence of good data, we also do not model any change in irrigation, which is not widely used in the UK, although this could change in future.

7.3.3 Results across the three pathways

For the CT pathway, total agricultural area slowly increases to meet the needs of a growing population, and modest amounts of new forest continue to be planted. Together with continued urban expansion, this results in a steady decrease in non-forest natural land. By 2050, afforestation has increased forest area by 11% compared to 2020, but this is outweighed by a 51% decrease in non-forest natural land, leading to a net loss of 14% in total natural land (extensive grassland, all forest, other natural land, and 'not relevant' land which includes coastal habitats, water and rock). This leads to an increase in GHG emissions, as the emissions from loss of non-forest natural land outweigh the sequestration from afforestation. As there is no dietary change, average consumption of calories continues to be 40% above the MDER, with consumption of fat approximately double the maximum recommended value. This is expected to lead to continuing high rates of obesity and other diet-related non-communicable diseases.

Figure 7-5: *Land use under Current Trends (top), National Commitments (middle) and Global Sustainability (bottom)*



Under NC, the combined effects of dietary change, improved productivity and reduced food waste reduce the area of land needed to meet demand for food. Half of all land in the UK is used for grazing livestock or production of livestock feed, so dietary shifts free up a significant amount of land. This allows non-forest natural land ('other land') to double, from 16% to 32% of the UK, while the more ambitious tree planting targets allow forest to increase by 30%. However, extensive grassland declines by 37% due to significant intensification in this pathway. Overall, natural land increases by 37% and land with potential to support biodiversity increases by 28%, from 39% to 54% of the UK (including extensive grassland, semi-natural forest, other natural land, water, coastal habitats and rock). Sequestration from regeneration of natural land and tree growth, as well as reduced livestock emissions due to smaller herd sizes, lead to a 32% decline in GHGs, although the AFOLU sector does not become a net carbon sink. The dietary change scenario does not involve reduced calorie consumption, so calories are still 40% above MDER.

For GS, dietary change is stronger and there is lower urban expansion due to compact development patterns, but this is offset by the shift towards more extensive grazing. Overall, this allows non-forest natural land to double, similar to the NC pathway. Tree planting is higher, leading to a 39% increase in forest area, and extensive grassland declines by 10% as the shift to more extensive grazing is offset by the declining demand for meat. Overall, natural land increases by 45% and land with potential to support biodiversity increases by 38%. This enables greater GHG reductions than for NC, with a decline of 42% by 2050, when the AFOLU sector becomes a net carbon sink absorbing 9 Mt CO_2e per year. As for the other scenarios, overconsumption of calories continues.

7.3.4 What are the most influential factors to reduce the hidden costs by 2030 and 2050?

The key factors for reducing greenhouse gas emissions were dietary change, food waste reduction and crop productivity, with a smaller contribution from agroecological practices. These factors were also projected to play a key role in freeing up land for nature recovery (Figure 7-6) and enabling tree planting. They are also the main factors for reducing nitrogen emissions into air and water, where agroecological practices play a major role (Figure 7-7).

Both the NC and GS pathways reduce the total area of agricultural land required to produce food, and this is predicted to have a negative impact on employment in the agricultural sector (Figure 7-8). This highlights the importance of working with agricultural communities to develop suitable supporting policies, such as enabling them to diversify employment opportunities and increase profit margins.

Figure 7-6: *Decomposition analysis for the UK FABLE model showing the impact of each scenario parameter on the area of non-forest (other) natural land*

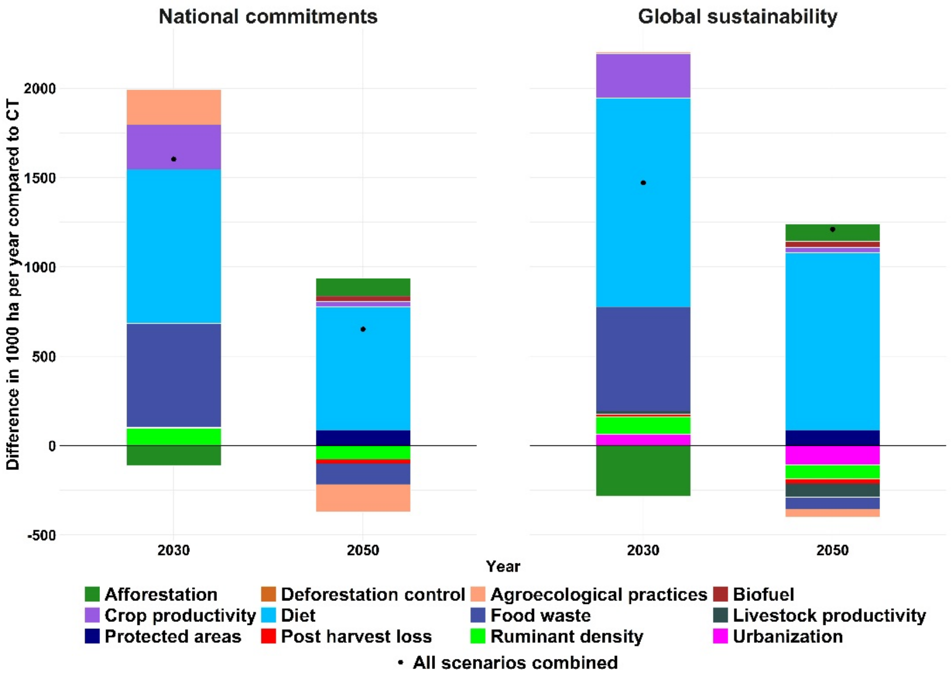


Figure 7-7: *Decomposition analysis for the UK FABLE model showing the impact of each scenario parameter on nitrogen emissions*

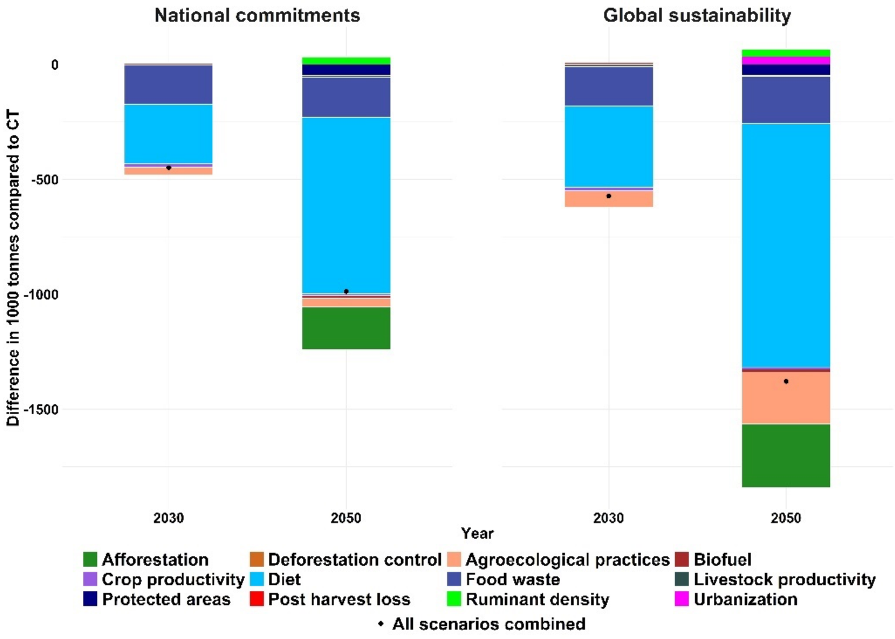
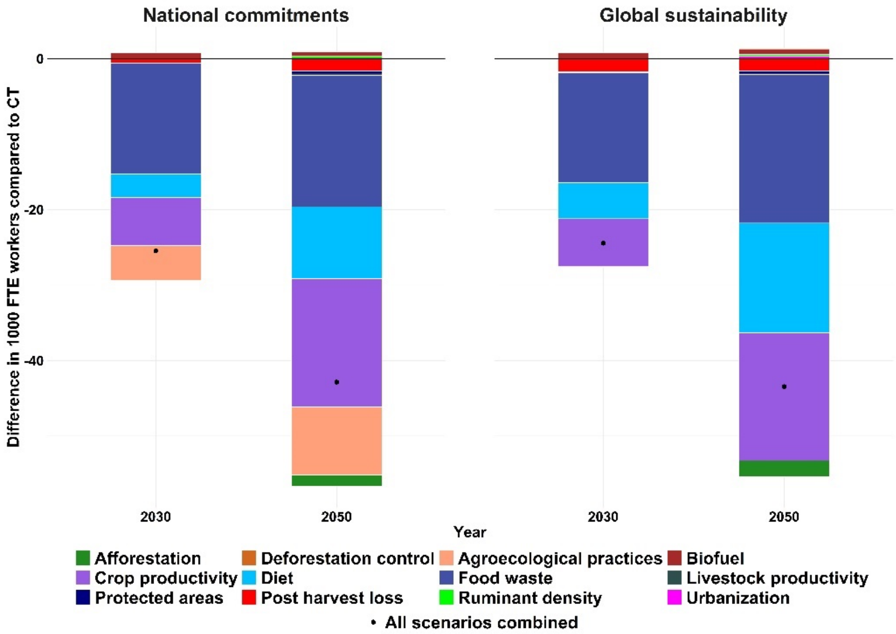


Figure 7-8: *Decomposition analysis for the UK FABLE model showing the impact of each scenario parameter on farm labor*



7.3.5 Impacts on the agrifood system's hidden costs

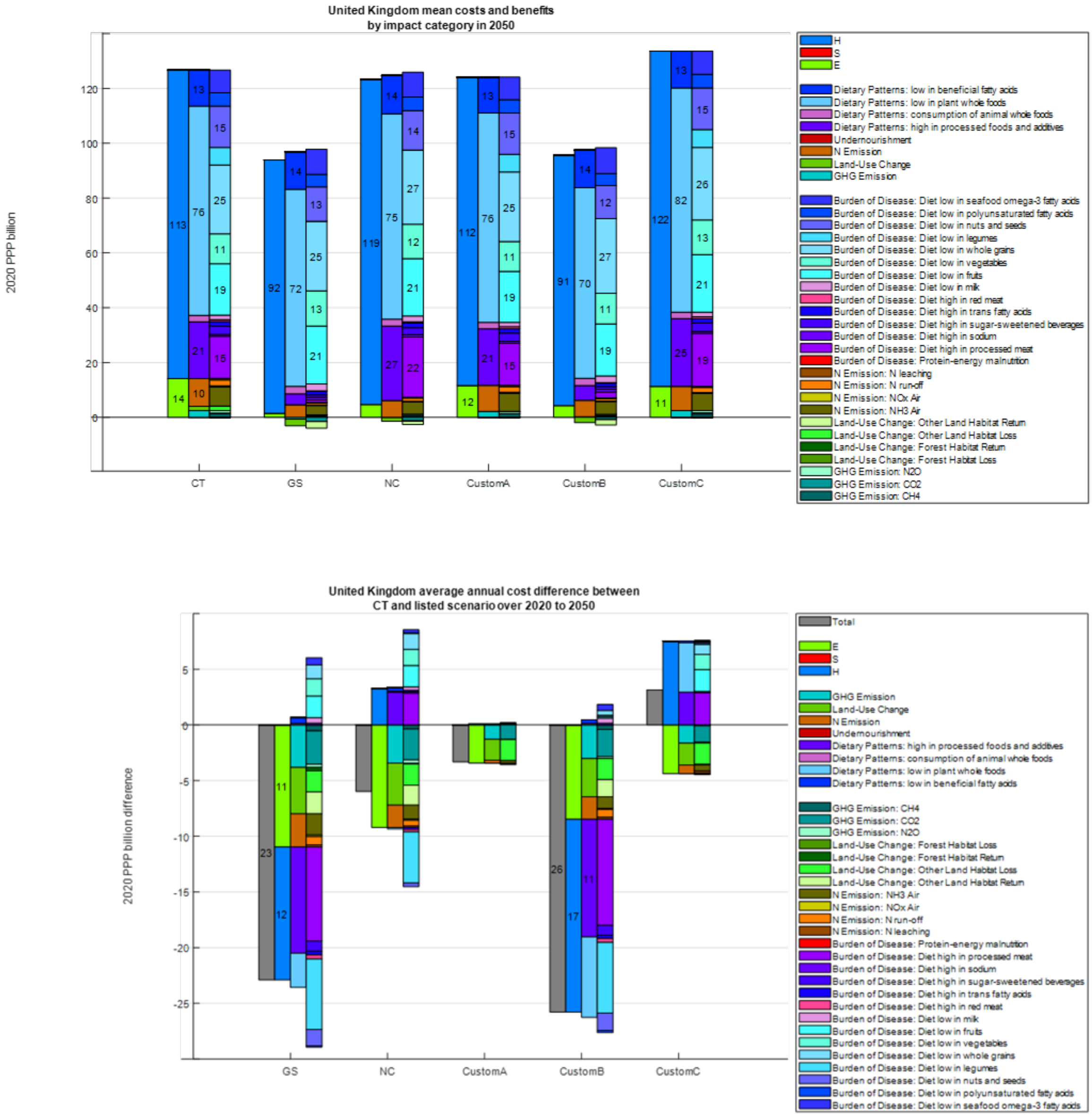
New analysis of hidden costs was carried out based on these FABLE pathways (Lord, 2024). The change in disease burden is estimated in disability-adjusted life years (DALYs) using an emulator of the University of Washington 2017 global burden of disease (GBD). A machine learning approach was used to translate the FABLE diet scenarios into a form suitable for input to the GBD model (see box 7 in FAO 2024). This translation step involved some loss of fidelity compared to the diets, as specified in FABLE. Also, health costs of obesity could not be included in this model.

For the new hidden cost analysis, we made an extra assumption on the future consumption of ultra-processed foods (UPFs) applied to the GS pathway. The UK has one of the highest rates of UPF consumption in the world (Marino et al., 2021), with UPFs forming over 40% of food by weight and over 60% by calories. However, the UK government has not yet set a target to reduce UPF consumption, despite calls by the British Medical Council, although they do agree on action to reduce fat, salt and sugar content of food (UK Parliament, 2023). We assumed an ambitious target for the GS pathway only, of a 50% reduction in UPF consumption by 2050, which would bring UK consumption halfway between current consumption in France and Italy.

The updated analysis estimates current (2023) hidden costs for the UK as 180 billion 2020 PPP dollars, lower than the 2023 SOFA estimate of 255 billion 2020 PPP dollars reported in section 1.2.1 due to the omission of obesity costs. Despite the omission of obesity costs, this is around 5.5% of the UK's 2020 GDP – greater than gross value added from agriculture, forestry, and fishing (~0.6% in 2020) and similar to the total value added from the whole agrifood sector, including manufacturing and retail (~5.5% in 2020) (Defra, 2023). This hidden deficit accumulates over time, posing economic risk to the UK, especially through the health impacts that weaken the human capital which underpins economic activity (Lord, 2024).

The model estimates that the NC pathway could reduce total hidden costs by a relatively modest 4%, around 6 billion 2020 PPP dollars per year. A far greater reduction of around 16% (23 billion 2020 PPP dollars per year) is estimated under the GS pathway (Figure 7-9), worth around 686 billion 2020 PPP dollars over the next 30 years (Lord, 2024). In future work, this potential benefit should be compared to the costs of transition towards a more sustainable agrifood system.

Figure 7-9*: Breakdown of United Kingdom hidden costs in 2050 (top) and annual average hidden cost reduction under alternative pathways compared to CT (bottom) in 2020 PPP dollars.*



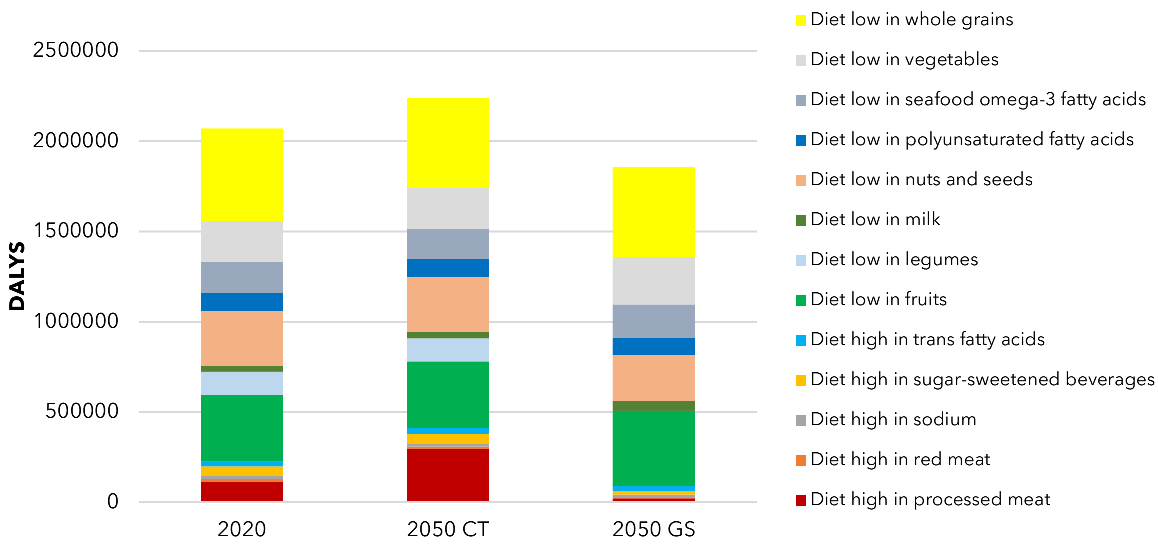
Note: The keys show different levels of detail in the split between cost categories, with the first bars in each group showing the split between health (H), social (S) and environmental (E) costs, the next bars showing a more detailed breakdown, and the third bars the full breakdown.

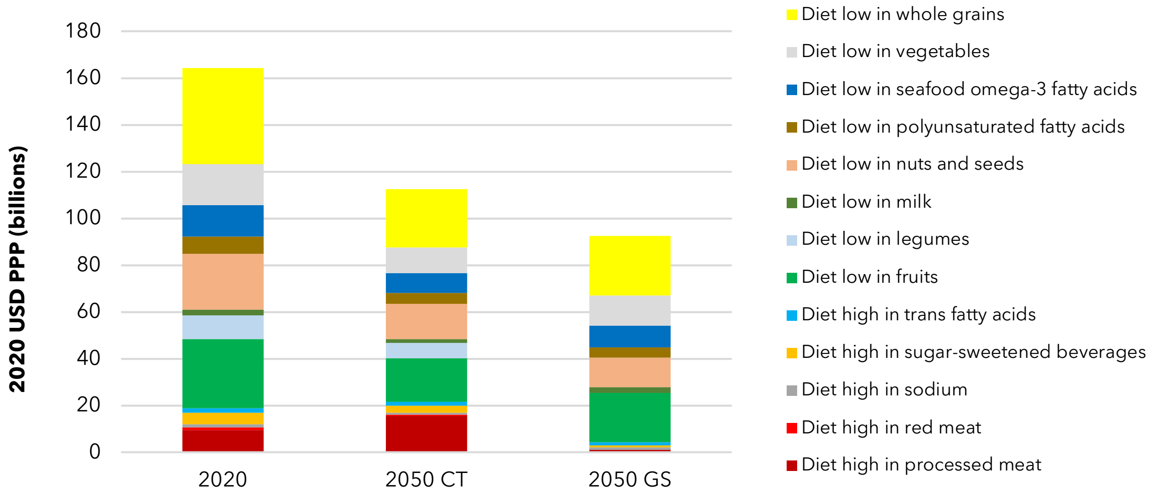
Three key factors have been modeled individually, to illustrate their contributions to the overall reductions in hidden costs: crop productivity (Custom A on Figure 7-9), dietary change (Custom B) and food waste reduction (Custom C). The large reduction in hidden costs for Custom B shows that the main factor for the additional cost reduction in the GS pathway is dietary change, specifically the replacement of meat (especially processed meat) with increased consumption of plant protein (nuts and legumes), together with the large reduction in UPF consumption. The main impact is on human health, as the UK currently has a low intake per capita of legumes and pulses, and the associated hidden costs are eliminated by the large dietary shift towards plant proteins in the GS pathway. This dietary shift results in ~20 billion 2020 PPP dollars of avoided productivity losses from cardiovascular disease and other non-communicable disease outcomes.

However, the potential benefits of dietary change were limited in our pathways because we did not explicitly specify an increase in fruit and vegetable intake. Indeed, the method used to calculate dietary change for the FABLE Calculator inadvertently resulted in a small decrease in fruit and vegetable consumption for both the NC and GS pathways, which had a surprisingly large impact on the results – due partly to the machine learning approach which associates decreased fruit and vegetable consumption with decreased consumption of all wholefoods. In the GS pathway and the dietary change-only scenario (Custom B), this was outweighed by the assumptions on reduced UPF consumption and increased legume consumption, leading to net health benefits. However, in the NC pathway the reduced fruit and vegetable consumption outweighed the benefits of increased legume consumption, leading to a net increase in avoided hidden health costs. Despite the improvements under the GS pathway, there is still a large residual economic burden from underconsumption of plant/whole foods in 2050 of ~70–80 billion 2020 PPP dollars (Figure 7-10). This could be reduced through greater emphasis on shifting to a healthy diet rather than just a low-carbon diet.

Unexpected effects also led to an apparent increase in estimated hidden costs under the food-waste-only scenario (Custom C); this could be because the reduction in food waste canceled out the constraints on food production due to lack of land availability that forced a slight decrease in consumption under CT, leading to greater consumption of the UK's current unhealthy diet.

Figure 7-10: *Estimated reductions in DALYs via the GS pathway (top) and associated savings in hidden costs (bottom)*





Dietary shifts also lead to environmental benefits. This is due to the potential for habitat restoration and CO_2 sequestration on former agricultural land that is no longer required for livestock or feed production, each avoiding around 4 billion 2020 PPP dollars of hidden costs, as well as reduced CH_4 and N_2O emissions from livestock, and reductions in nitrogen pollution from manure and feed crop production (avoiding ~3 billion 2020 PPP dollars). Ambitious crop productivity improvements, small increases in protected areas, and large reductions in food waste all resulted in smaller changes.

While these estimates are associated with a large uncertainty, the conclusion that the GS pathway reduces hidden costs by 2050 is robust, although the smaller benefits of the NC pathway are within the uncertainty range. The analysis indicates that UK national commitments, based largely on the CCC Balanced Net Zero pathway, are not sufficient to mitigate the large future debt and economic risk posed by agrifood system hidden costs, but adopting the more ambitious GS pathway could avoid a larger proportion of hidden costs, principally through a shift away from ultra-processed food and towards more plant-based diets. However, both the NC and GS pathways could be substantially improved by incorporating healthier diets with a higher consumption of fruits, vegetables and wholegrains, rather than only focusing on reduction of meat consumption. This will be explored in future FABLE modeling.

7.4 Entry points for action and foreseen implementation challenges

Consultation with stakeholders established a list of potential entry points to reduce hidden costs.

Make hidden costs more visible. This work by the FAO should help to make hidden costs more visible, and this could be effective if there is greater transparency in the agrifood system, e.g., mandatory disclosure of company impacts, and corporate accountability. It is important to make this analysis of hidden costs relevant to people on the street, not just policymakers. For example, rather than presenting it only as the cost to the UK economy it could be presented as the average cost to households per year or week.

Dietary change. In the UK, as the main source of hidden costs is unhealthy diets, dietary change is an important factor. However, reducing the consumption of animal produce will not necessarily lead to a healthier diet unless the whole diet is changed to consume less fat, sugar and total calories. To illustrate this, the FABLE model took the dietary change modeled as part of the Climate Change Committee's scenarios: a 20% reduction in meat and dairy consumption for the NC pathway and a 50% reduction for the GS pathway. However, neither of these diets reduce fat or total calories to the recommended levels for a healthy diet. For comparison, previous FABLE modeling took the Eatwell healthy diet recommended by the UK government (Smith, Harrison et al 2021), which achieves a healthy balanced diet with lower total calories and fat, as well as increasing the ratio of plant-based to animal products. Similarly, the new hidden cost analysis delivered greater health benefits by assuming a large reduction in consumption of ultra-processed food for the GS pathway. This shows the importance of taking a holistic view that aims to maximize multiple benefits, rather than focusing only on climate change.

Stakeholders agreed that as unhealthy diets are the biggest cost, dietary change is important, but we need more research on how to achieve this. Potential factors include a carbon tax on food; a sugar tax; education about healthy food; warning labels on ultra-processed and high sugar food; emphasizing the benefits of a healthy diet; a reduction in the working week so people have more time to cook healthy food; free school meals; and a less unequal society (as disadvantaged groups have less access to healthy food in the UK). Education alone is not enough, as consumers live in an environment full of unhealthy food choices, so it needs to be backed by strong policy in other areas. The Welsh government is working on a dietary-shift systems map which will identify relevant policy instruments and entry points.

Key levers to reduce the hidden costs of the agricultural food system in the UK:

- **Public procurement** of healthy food with lower environmental impacts (e.g., in schools and hospitals).
- **Agri-environment schemes** including ELMS in England and similar schemes emerging in the other UK nations, provided that uptake is significant.
- **Agroecology,** though this can be contentious amongst farmers. Also, there can be a reduction in production for the first few years. Farmers need extra support during that period.
- **Habitat protection.** This not just about creating more protected areas, but also about providing the resources needed to improve the condition of existing protected areas and manage them properly.
- **Innovation** to reduce the impact of agricultural impacts, e.g., precision farming or less toxic agrochemicals.
- **Pollution regulations** are highly relevant, including around storage and application of manure and slurry.
- **Soil conservation** is very poor in the UK – there is a big policy gap.
- **Food waste reduction, diet change and productivity** increases may not produce the expected reduction in agricultural area, as farmers may export more food instead. Hence changes need to be global. Productivity increases may also lead to a rebound effect by making food production more profitable and/or cheaper, leading to more production and consumption.
- **Energy use** is an easier policy lever, but there is not much energy use on farms, and it is hard to decarbonize.
- **New production methods** including new proteins, vertical farming, etc., will emerge over time. However, some of these methods are currently very energy intensive.
- **Access to information.** It is hard for small- to medium-sized organizations (SMOs) to have a sustainability team, and risky for them to change. Risk sharing mechanisms are needed, e.g., ecosystem service payments.
- **Worker poverty.** In Scotland, farms must pay the living wage to farm workers to get government support. However, this is causing problems, especially for fruit and vegetable producers who are scaling back production. Therefore, this type of measure would need to be implemented together with controls on import of cheaper food, which is politically challenging.

- **Food crime**. More work is needed to expose food crime. Imports of unsafe low-cost food is a big threat, as border checks have declined. The Food Safety Agency fights food crime but focuses on authenticity rather than safety.
- **Pay the true cost for food and support low-income consumers through other measures,** such as income support, universal income, etc. This is a sensitive issue politically though the SOFA work will help to quantify the costs.
- **Joined-up policymaking** is needed to exploit synergies and balance trade-offs, e.g., government departments of health, education, business, agriculture, environment, climate, energy, welfare and social security need a coordinated approach to reduce hidden costs in the agrifood system.
- **Further levers**. Further work should explore the Defra Net Zero pathway levers in the Carbon Budget Delivery Plan. The research underlying those comes from the Clean Growth through Sustainable Intensification report.

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