UK

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This chapter of the 2020 Report of the FABLE Consortium *Pathways to Sustainable Land-Use and Food Systems* outlines how sustainable food and land-use systems can contribute to raising climate ambition, aligning climate mitigation and biodiversity protection policies, and achieving other sustainable development priorities in the UK. It presents three pathways for food and land-use systems for the period 2020-2050: Current Trends, Sustainable Medium Ambition, and Sustainable High Ambition (referred to as “Current Trends”, “Sustainable”, and “Sustainable +” in all figures throughout this chapter). These pathways examine the trade-offs between achieving the FABLE Targets under limited land availability and constraints to balance supply and demand at national and global levels. We developed these pathways in consultation with national stakeholders and experts, including from the Department for Food, Agriculture and Rural Affairs (Defra), the Department for Business, Energy and Industrial Strategy (BEIS), the Department for International Trade (DIT), the Department for Agriculture, Environment and Rural Affairs in Northern Ireland (DAERA), the Scottish Government, the Welsh Government, the Committee on Climate Change, the Royal Society, the Royal Academy of Engineering, and UK Research and Innovation (UKRI), and modeled them with the FABLE Calculator (Mosnier, Penescu, Thomson, and Perez-Guzman, 2019). See Annex 1 for more details on the adaptation of the model to the national context.

Climate and Biodiversity Strategies and Current Commitments

Countries are expected to renew and revise their climate and biodiversity commitments ahead of the 26th session of the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) and the 15th COP to the United Nations Convention on Biological Diversity (CBD). Agriculture, land-use, and other dimensions of the FABLE analysis are key drivers of both greenhouse gas (GHG) emissions and biodiversity loss and offer critical adaptation opportunities. Similarly, nature-based solutions, such as reforestation and carbon sequestration, can meet up to a third of the emission reduction needs for the Paris Agreement (Roe et al., 2019). Countries' biodiversity and climate strategies under the two Conventions should therefore develop integrated and coherent policies that cut across these domains, in particular through land-use planning which accounts for spatial heterogeneity.

Table 1 summarizes how the UK's Nationally Determined Contribution (NDC) and Long Term Low Emissions and Development Strategy (LT-LEDS) treat the FABLE domains; note that we give details of the EU NDC and LT-LEDS as the UK has not yet released its own versions. According to the NDC/LT-LEDS, the UK/EU has committed to reducing its GHG emissions by 80% by 2050 compared to 1990. The UK also has a national commitment through the 2008 Climate Change Act to reduce emissions by 80% from a 1990 baseline by 2050, and in June 2019 this was updated to a new target of net zero GHG emissions by 2050 (BEIS, 2019; Climate Change Act, 2008). This includes emission reduction efforts from agriculture, forestry, and other land use (AFOLU). Envisaged mitigation measures from agriculture and land-use change include increasing tree and hedgerow-planting, increased agricultural productivity and dietary change (reduced consumption of ruminant meat and dairy produce) (CCC, 2018, 2020). Under its current commitments to the UNFCCC, the UK (EU) does not mention biodiversity conservation (EU, 2015).

Table 1 | **Summary of the mitigation target, sectoral coverage, and references to biodiversity and spatially-explicit planning in current NDC, LT-LEDS and the UK net zero target.**

	Total GHG Mitigation					Mitigation Measures Related to AFOLU (Y/N)	Mention of Biodiversity (Y/N)	Inclusion of Actionable Maps for Land-Use Planning[1] (Y/N)	Links to Other FABLE Targets
	Baseline		Mitigation target		Sectors included				
	Year	GHG emissions (Mt CO_2e/yr)	Year	Target					
(EU) NDC (2016)	1990	n/a	2030	At least 40% reduction	Energy, industrial processes, agriculture, land-use change and forestry, and waste	Y	N	N	Forests
LT-LEDS (2018)	1990	780.3	2050	80% reduction	Energy, industrial processes, agriculture, land-use change and forestry, and waste	Y	Y	N	food, water, forests
UK net zero	NA	NA	2050	Net zero GHG emissions	all	Y	Y	N	food, forests

Note. "Total GHG Mitigation" and "Mitigation Measures Related to AFOLU" columns are adapted from IGES NDC Database (Hattori, 2019).
Source: EU (2016)

1 We follow the United Nations Development Programme definition, "maps that provide information that allowed planners to take action" (Cadena et al., 2019).

Table 2 provides an overview of the targets listed in the latest National Biodiversity Strategies and Action Plans (NBSAPs) for each of the four devolved nations in the UK which are related to at least one of the FABLE Targets (CBD, 2020). The NBSAP for England (Defra, 2011) includes nine Outcomes which will be delivered by 22 Priority Actions from 2011-2020. Among these targets, only two are quantified (both for marine biodiversity). Three explicitly refer to agriculture, but none refer to climate change. The NBSAP for Scotland (Scotland & Scottish Government, 2013) contains ten Outcomes and the Welsh NBSAP (Welsh Government, 2015) contains six Objectives and associated actions; these are not quantified but refer to the Aichi targets, the EU Biodiversity Strategy and parallel national policies and programs that may have quantitative targets. A number of the seven goals and 57 actions in Northern Ireland's NBSAP (DOENI, 2015) are quantified, including targets to increase woodland cover from 8% to 12% and restore 240 ha of ancient woodland. Climate change and agriculture are referred to in several places in these NBSAPs. Many of the targets are linked to the FABLE Targets on deforestation and biodiversity (Table 2) but as most of the NBSAP targets are not quantified they cannot be compared directly.

Table 2 | Overview of the NBSAP targets in relation to FABLE Targets (CBD, 2020)

NBSAP Target	Global FABLE Target
England	
(3.3) **Bring a greater proportion of our existing woodlands into sustainable management and expand the area of woodland in England.**	**DEFORESTATION:** Zero net deforestation from 2030 onwards
(1A) **Better wildlife habitats with 90% of priority habitats in favourable or recovering condition and at least 50% of Site of Special Scientific Interest (SSSIs) in favourable condition, while maintaining at least 95% in favourable or recovering condition.**	**BIODIVERSITY:** No net loss by 2030 and an increase of at least 20% by 2050 in the area of land where natural processes predominate
(1B) **More, bigger, and less fragmented areas for wildlife, with no net loss of priority habitat and an increase in the overall extent of priority habitats by at least 200,000 ha.**	**BIODIVERSITY:** No net loss by 2030 and an increase of at least 20% by 2050 in the area of land where natural processes predominate
(1C) **By 2020, at least 17% of land and inland water, especially areas of particular importance for biodiversity and ecosystem services, conserved through effective, integrated and joined up approaches to safeguard biodiversity and ecosystem services including through management of our existing systems of protected areas and the establishment of nature improvement areas.**	**BIODIVERSITY:** No net loss by 2030 and an increase of at least 20% by 2050 in the area of land where natural processes predominate **BIODIVERSITY:** At least 30% of global terrestrial area protected by 2030
(2A-2C) **By 2020, we will have put in place measures so that biodiversity is maintained, further degradation has been halted and where possible, restoration is underway, helping deliver good environmental status.**	**BIODIVERSITY:** No net loss by 2030 and an increase of at least 20% by 2050 in the area of land where natural processes predominate
(3.8) **Reform the water abstraction regime. The new regime will provide clearer signals to abstractors to make the necessary investments to meet water needs and protect ecosystem functioning. We will also take steps to tackle the legacy of unsustainable abstraction more efficiently.**	**WATER:** Blue water use for irrigation <2453 km3yr-1

Table 2 | Overview of the NBSAP targets in relation to FABLE Targets (CBD, 2020) (continued)

NBSAP Target	Global FABLE Target
(1D) **Restoring at least 15% of degraded ecosystems as a contribution to climate change mitigation and adaptation.**	**GHG EMISSIONS:** Zero or negative global GHG emissions from LULUCF by 2050 **BIODIVERSITY:** A minimum share of earth's terrestrial land supports biodiversity conservation
Northern Ireland	
(10) **Expand a wide range of forest types and area of broadleaf trees from 8% to 12% of Northern Ireland land area.**	**DEFORESTATION:** Zero net deforestation from 2030 onwards
(16) **Deliver peatland and wetland habitat restoration.**	**BIODIVERSITY:** No net loss by 2030 and an increase of at least 20% by 2050 in the area of land where natural processes predominate
(26) **Protection, enhancement, and management of 4,400 hectares of designated land for biodiversity benefit.**	**BIODIVERSITY:** No net loss by 2030 and an increase of at least 20% by 2050 in the area of land where natural processes predominate
(27) **Management of the remaining 5,900 hectares of non-designated land to maintain and enhance priority habitats and species.**	**BIODIVERSITY:** No net loss by 2030 and an increase of at least 20% by 2050 in the area of land where natural processes predominate
(43) **Positive management of 700 hectares of land for biodiversity benefit.**	**BIODIVERSITY:** No net loss by 2030 and an increase of at least 20% by 2050 in the area of land where natural processes predominate
(48) **Restore 240 hectares of ancient woodland.**	**DEFORESTATION:** Zero net deforestation from 2030 onwards **BIODIVERSITY:** No net loss by 2030 and an increase of at least 20% by 2050 in the area of land where natural processes predominate
Wales	
Objective 2: Safeguard species and habitats of principal importance and improve their management; Objective 3: Increase the resilience of our natural environment by restoring degraded habitats and habitat creation; Objective 4: Tackle key pressures on species and habitats	**BIODIVERSITY:** No net loss by 2030 and an increase of at least 20% by 2050 in the area of land where natural processes predominate
Scotland	
Outcomes include: Quality and quantity of our wildlife is improving and flourishing; Sustainable land and water management; Ecosystems are restored to good health.	**BIODIVERSITY:** No net loss by 2030 and an increase of at least 20% by 2050 in the area of land where natural processes predominate

The UK's policies for safeguarding agrobiodiversity have until recently derived from mechanisms within the Common Agricultural Policy, EU environment legislation and local implementation policies. Strategies to support landscape-scale species recovery and wider ecosystem services now derive from the English Government's 25 Year Environment Plan and equivalent measures in devolved administrations, for example to reduce and reverse the decline in pollinators in Wales funded by the Welsh government's nature fund.

Brief Description of National Pathways

Among possible futures, we present three alternative pathways for reaching sustainable objectives, in line with the FABLE Targets, for food and land-use systems in the UK.

Our Current Trends Pathway corresponds to the lower boundary of feasible action. It is characterized by medium population growth (from 67 million inhabitants in 2020 to 75 million in 2050), no constraints on agricultural expansion, a low afforestation target, no change in the extent of protected areas, low productivity increases in the agricultural sector, no change in diets or food waste, and continued urban expansion in line with UK government house building targets (cf. Annex 2). This corresponds to a future based on current policy and historical trends but with a levelling off of historical crop and livestock productivity improvements, except for milk yield where a modest improvement continues. Moreover, as with all FABLE country teams, we embed this Current Trends Pathway in a global GHG concentration trajectory that would lead to a radiative forcing level of 6 W/m^2 (RCP 6.0), or a global mean warming increase likely between 2°C and 3°C above pre-industrial temperatures, by 2100. Our model includes the corresponding climate change impacts on crop yields by 2050 for rapeseed, sugar beet and wheat (see Annex 2).

Our Sustainable Medium Ambition Pathway represents a future in which significant efforts are made to adopt sustainable policies and practices and corresponds to an intermediate boundary of feasible action. Compared to the Current Trends Pathway, we assume that this future would lead to higher rates of tree planting, higher agricultural productivity, an extra 0.5Mha of protected areas, and lower food waste and consumption of ruminant meat and dairy produce (see Annex 2). This corresponds to a future based on the adoption and implementation of measures corresponding to the medium ambition scenario in the CCC land use and climate change report, a key document informing UK government policy (CCC, 2018). With the other FABLE country teams, we embed this Sustainable Medium Ambition Pathway in a global GHG concentration trajectory that would lead to a lower radiative forcing level of 2.6 W/m^2 by 2100 (RCP 2.6), in line with limiting warming to 2°C.

Our Sustainable High Ambition Pathway represents a future in which very ambitious climate targets are achieved, in line with the UK government commitment for net zero GHG emissions by 2050 and corresponds to the highest boundary of feasible action. Compared to the Sustainable Medium Ambition Pathway, we assume that this future would lead to much higher rates of tree planting, higher agricultural productivity, a higher protected area of natural habitats, lower rates of urban expansion, lower food waste and lower consumption of meat and dairy produce (see Annex 2). As in the Sustainable Medium Ambition Pathway, we embed this Sustainable High Ambition Pathway in a global GHG concentration trajectory that would lead to a lower radiative forcing level of 2.6 W/m^2 by 2100 (RCP 2.6), in line with limiting warming to 2°C.

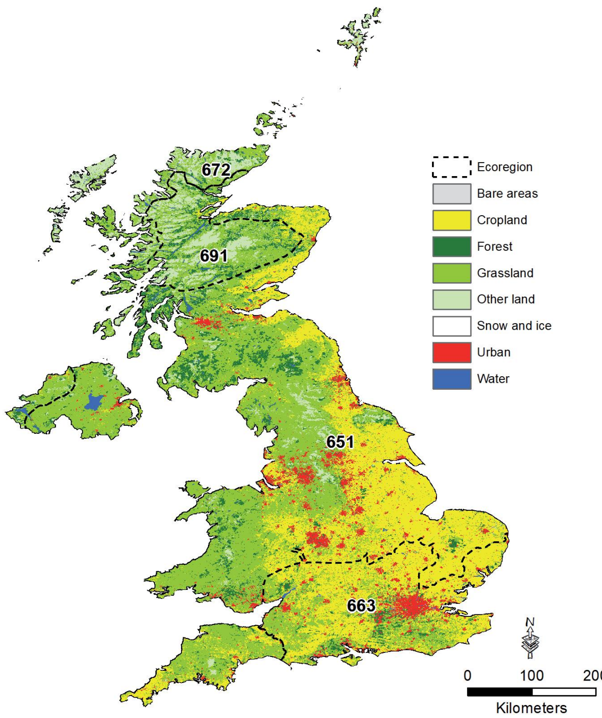
Land and Biodiversity

Current State

In 2015, according to FAOSTAT land cover data (the default FABLE dataset), the UK was covered by 24% cropland, 46% grassland, 12% forest, 4% urban and 12% other natural land. These figures are slightly different from the main national dataset, the UK Land Cover Map (Rowland et al., 2017), but we use FAO data because it provides a consistent historic time series. Arable land is concentrated in eastern, central and southern England, with pasture predominating in western England, Wales, Northern Ireland and southern Scotland (Map 1). Forest and other natural land are highly dispersed across the country but larger areas are found in the upland parts of Wales, Scotland, and northern and south-western England. Biodiversity in the UK faces a range of threats including fragmentation and loss of habitat for housing and infrastructure development, soil and water pollution and nutrient enrichment from agriculture, use of pesticides, climate change impacts and invasive species.

We estimate that land where natural processes predominate[2] accounted for 21% of the UK's terrestrial land area in 2015 (Map 2). The 672-North Atlantic moist mixed forests and the 691-Caledon conifer forests ecoregions, both in Scotland, hold the greatest share of land where natural processes predominate, with far less in the other eco-regions (Table 3). Across the country, while 6.7 Mha (27.6%) of land is under formal protection, falling just short of the 30% zero-draft CBD post-2020 target, only 64% of land where natural processes predominate is formally protected. This indicates that many areas important for biodiversity may be at risk without action to better protect them.

Map 1 | Land cover by aggregated land cover types in 2010 and ecoregions

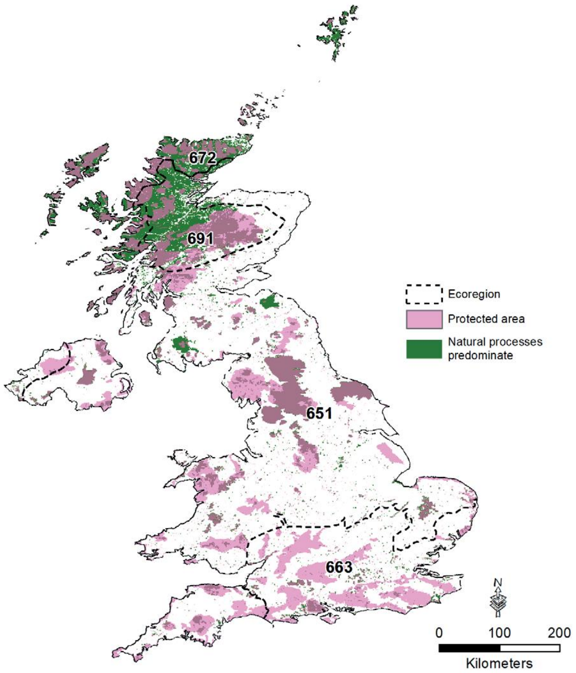


Notes. Correspondence between original ESA CCI land cover classes and aggregated land cover classes displayed on the map can be found in Annex 3.
Sources. countries - GADM v3.6; ecoregions – Dinerstein et al. (2017); land cover – ESA CCI land cover 2015 (ESA, 2017)

2 We follow Jacobson, Riggio, Tait, and Baillie (2019) definition: "Landscapes that currently have low human density and impacts and are not primarily managed for human needs. These are areas where natural processes predominate, but are not necessarily places with intact natural vegetation, ecosystem processes or faunal assemblages".

Approximately 33% of the UK's cropland was in landscapes with at least 10% natural vegetation in 2019. These areas are most widespread in the 672-North Atlantic moist mixed forests and the 691-Caledon conifer forests ecoregions where much of the land is unsuitable for producing crops, due to poor soil conditions and a cool and wet climate.

Map 2 | Land where natural processes predominated in 2010, protected areas and ecoregions



Notes. Protected areas are set at 50% transparency, so on this map dark purple indicates where areas under protection and where natural processes predominate overlap.
Sources. countries - GADM v3.6; ecoregions – Dinerstein et al. (2017); protected areas – UNEP-WCMC and IUCN (2020); natural processes predominate comprises key biodiversity areas – BirdLife International (2019), intact forest landscapes in 2016 – Potapov et al. (2016), and low impact areas – Jacobson et al. (2019)

Table 3 | Overview of biodiversity indicators for the current state at the ecoregion level[3]

	Ecoregion	Area (1,000 ha)	Protected Area (%)	Share of Land where Natural Processes Predominate (%)	Share of Land where Natural Processes Predominate that is Protected (%)	Share of Land where Natural Processes Predominate that is Unprotected (%)	Cropland (1,000 ha)	Share of Cropland with >10% Natural Vegetation within 1km² (%)
651	Celtic broadleaf forests	15,291	23	13	80	20.2	4,528	32
663	English Lowlands beech forests	4,498	32	7	71	28.7	2,240	35
672	North Atlantic moist mixed forests	2,023	44	70	51	49.5	23	85
691	Caledon conifer forests	2,166	46	68	53	46.8	58	59

Sources. countries - GADM v3.6; ecoregions – Dinerstein et al. (2017); cropland, natural and semi-natural vegetation – ESA CCI land cover 2015 (ESA, 2017); protected areas – UNEP-WCMC and IUCN (2020); natural processes predominate comprises key biodiversity areas – BirdLife International 2019, intact forest landscapes in 2016 – Potapov et al. (2016), and low impact areas – Jacobson et al. (2019)

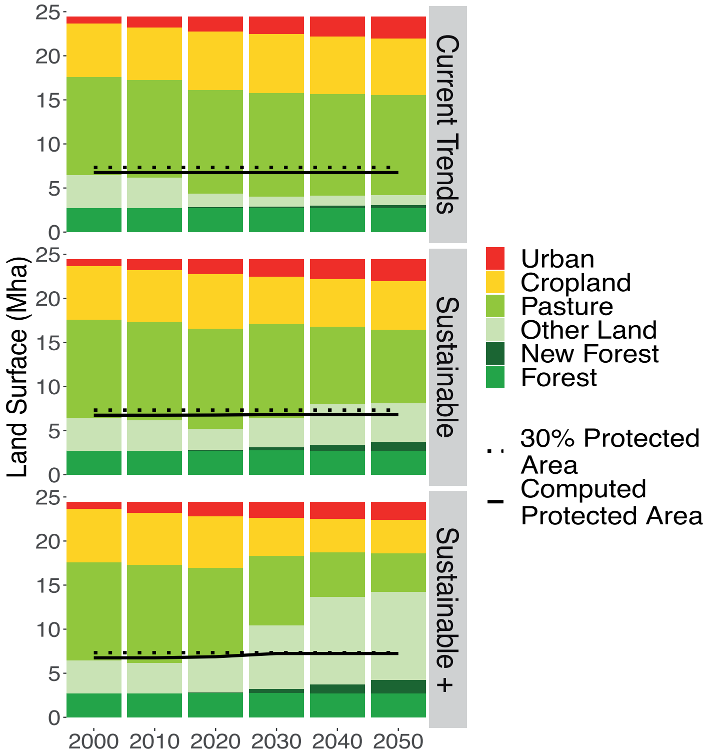
3 The share of land within protected areas and the share of land where natural processes predominate are percentages of the total ecoregion area (counting only the parts of the ecoregion that fall within national boundaries). The shares of land where natural processes predominate that is protected or unprotected are percentages of the total land where natural processes predominate within the ecoregion. The share of cropland with at least 10% natural vegetation is a percentage of total cropland area within the ecoregion.

Pathways and Results

Projected land use in the Current Trends Pathway is based on several assumptions, including no constraints on land conversion beyond protected areas, a target of 360Mha reforested or afforested by 2050 (of which only 326 ha is achieved, due to a shortage of available 'other natural land'; see below), and protected areas remaining at 6.7Mha, representing 27.6% of total land cover (see Annex 2).

By 2030, we estimate that the main changes in land cover in the Current Trends Pathway will result from an increase of urban, forest, cropland and pasture area and a large decrease of other natural land area (such as heathland, scrub, bog and wetland) so that all the unprotected other natural land is lost by 2025, meaning that afforestation targets cannot be achieved. This trend evolves over the period 2030-2050: urban and new forest area further increase, and cropland and pasture area decrease slightly due to continued afforestation and urban development coupled with productivity increases, with no further loss of other natural land because all the remaining land is protected (Figure 1). The expansion of the planted area for wheat, barley and rapeseed explains 92% of total cropland expansion between 2010 and 2030. For wheat, 48% of expansion is explained by an increase of internal demand for biofuels and non-food products and 32% by an increase of demand for animal feed. For barley, 69% of expansion is due to an increase of demand for animal feed and 51% an increase of demand for non-food products (these shares add up to more than 100% because they are partly offset by a decrease in exports). Finally, for rapeseed, 100% of the expansion results from an increase of demand for non-food products. Pasture expansion is driven by the increase in food consumption of beef, lamb, and milk while livestock productivity per head remains

Figure 1 | Evolution of area by land cover type and protected areas under each pathway



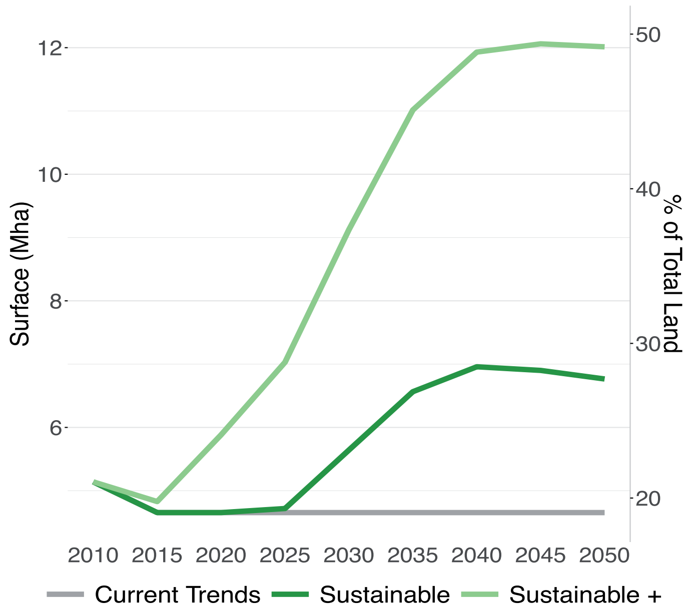
Source. Authors' computation based on FAOSTAT (FAO, 2020) for the area by land cover type for 2000, and the World Database on Protected Areas (UNEP-WCMC & IUCN, 2020) for protected areas for years 2000, 2005 and 2010.

constant for meat but increases for milk, and ruminant density per hectare of pasture remains constant over the period 2020-2030. Between 2030-2050, further expansion of farmland to meet the growing demand for food is impossible because the only remaining land is either urban, forest (it is assumed that deforestation is not allowed) or protected areas. The continued growth in urban areas coupled with the continued steady afforestation rate then drives a contraction of farmland. This results in a decrease in food consumption per capita, although this does not drop below the minimum needed for a healthy diet. Land where natural processes predominate therefore stabilizes at 19% from 2030 onwards, compared to 21% in 2010. This includes protected areas plus existing forest.

In the Sustainable Medium Ambition and Sustainable High Ambition Pathways, assumptions have been changed to reflect UK scenarios for afforestation to meet climate change commitments (CCC, 2018, 2020), and plans to set aside land for nature recovery (HM Government, 2018). The main assumptions include 1 and 1.5Mha reforested or afforested by 2050, and protected areas increase from 27.6% of total land in 2020 to 29.7% and 31.4% in 2050 (see Annex 2). Note that the FABLE Calculator assumes that around 80% of the new 0.5Mha protected area in the Sustainable Medium Ambition Pathway is farmland (based on the current mix of land use types in UK protected areas), and this is excluded from the protected area shown in Figure 1. In contrast, the additional 0.42Mha protected area in the Sustainable High Ambition Pathway is all peatland.

Compared to the Current Trends Pathway, we observe the following changes regarding the evolution of land cover in the UK in the Sustainable Medium Ambition and Sustainable High Ambition Pathways: (i) no change in deforestation because we assume no deforestation is allowed in any scenario, (ii) reversal of the loss of natural land, (iii) decrease in agricultural land, and (iv) increase in reforested/afforested land, as well as (v) lower increase in urban expansion in the Sustainable High Ambition Pathway. In addition to the changes in assumptions regarding land-use planning, these changes compared to the Current Trends Pathway are explained by increased agricultural productivity coupled with decreased demand for meat and dairy consumption due to a shift to healthier and more sustainable diets. This leads to an increase in the area where natural processes predominate: the area stops declining by 2025 and increases by 27% between 2025 and 2050 in the Sustainable Medium Ambition Pathway and by 57% in the Sustainable High Ambition Pathway (Figure 2).

Figure 2 | Evolution of the area where natural processes predominate



GHG emissions from AFOLU

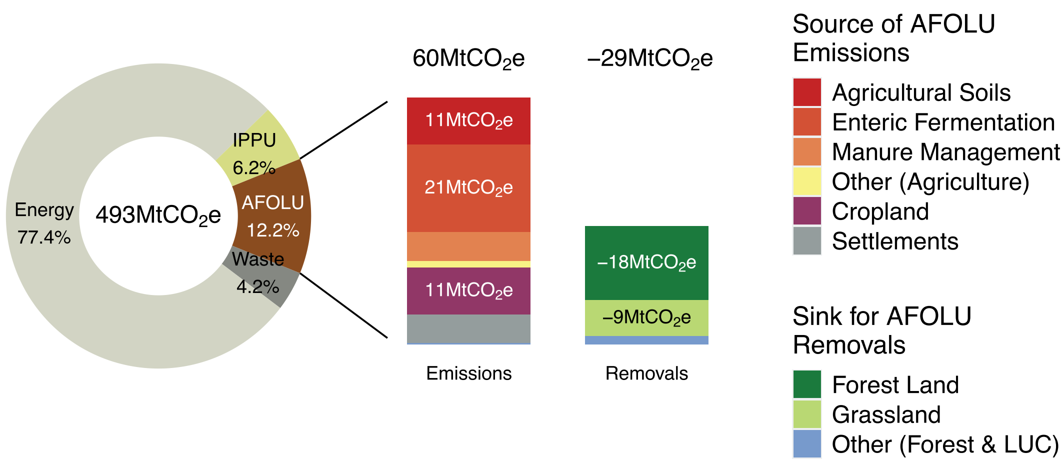
Current State

Direct GHG emissions from Agriculture, Forestry and Other Land Use (AFOLU) accounted for 12% of total emissions in 2017 (Figure 3). Enteric fermentation is the principle source of AFOLU emissions, followed by emissions from cropland and agricultural soils, manure management and settlements. This can be explained by the high population density in the UK which leads to a high proportion of land area being occupied by farmland, coupled with ongoing losses due to settlement expansion. Forestry is currently less significant: forest cover is gradually increasing from a very low base (Forest Research, 2019), though existing woodlands are still lost due to major infrastructure development (Woodland Trust, 2019).

Pathways and Results

Under the Current Trends Pathway, annual GHG emissions from AFOLU decline from 52 $MtCO_2e$/yr in 2015 to 43.6 $MtCO_2e$/yr in 2030, and 38.5 $MtCO_2e$/yr in 2050, because agricultural emissions decline as farmland is converted to urban areas or afforested. Over the period 2020-2050, emissions from agriculture decrease by 3.6% due to the loss of farmland. This is partly offset by land use change emissions as farmland and natural land are converted to urban areas (Figure 4). In 2050, agriculture is the largest source of emissions (40 $MtCO_2e$/yr, of which 27 $MtCO_2e$ is from livestock and the rest from crops), while carbon sequestration from afforestation acts as a sink (-2.4 $MtCO_2e$/yr).

Figure 3 | Historical share of GHG emissions from Agriculture, Forestry, and Other Land Use (AFOLU) to total AFOLU emissions and removals by source in 2017



Note. IPPU = Industrial Processes and Product Use
Source. Adapted from GHG National Inventory (UNFCCC, 2020)

In comparison, the Sustainable Medium Ambition Pathway leads to a reduction of AFOLU GHG emissions by 36% and the Sustainable High Ambition Pathway leads to a reduction by 123% (i.e. turning net emissions into a net sink) by 2050 compared to the Current Trends Pathway (Figure 4). The potential emissions reductions under the Sustainable Medium Ambition Pathway are dominated by increased sequestration from afforestation and regeneration of farmland to natural land, and a reduction in GHG emissions from agriculture. Increased agricultural productivity and dietary change are the most important drivers of this reduction, because they reduce direct emissions from ruminant livestock as well as freeing up farmland for afforestation and regeneration to natural land (Figure 5). Under the Sustainable High Ambition Pathway, GHG emissions from agriculture are further reduced due to ambitious dietary change and productivity improvements, and sequestration from regeneration of farmland to natural land and afforestation is also increased.

Compared to the UK's commitments under UNFCCC (Table 1), our results show that AFOLU could contribute up to 9% (27 $MtCO_2e$) of its total GHG emissions reduction objective of reducing emissions by 40% by 2030 under the Sustainable High Ambition Pathway. Such reductions could be achieved through ambitious policy measures: a shift to the Eatwell national healthy diet; improved agricultural productivity; protection and restoration of peatland, forests, semi-natural grassland and other natural land; new woodland creation at a rate of 50 kha per year; and reducing the land required for new housing developments by half. These measures could be particularly important when considering options for NDC enhancement and achieving the UK Net Zero target.

Figure 4 | Projected AFOLU emissions and removals between 2010 and 2050 by main sources and sinks for the Current Trends Pathway

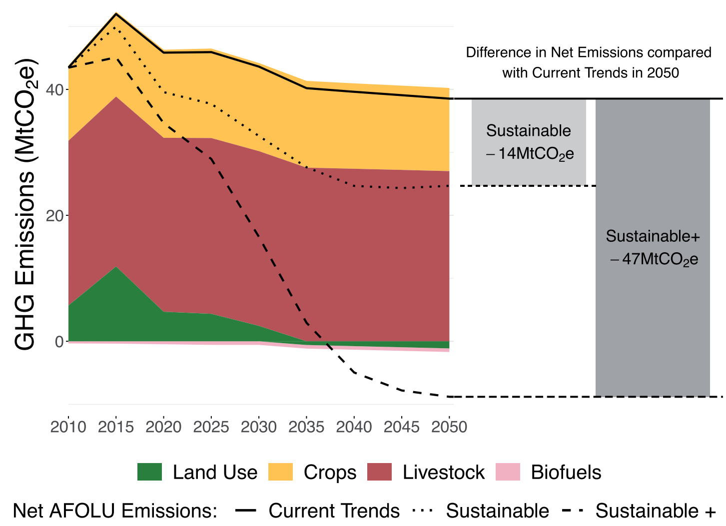
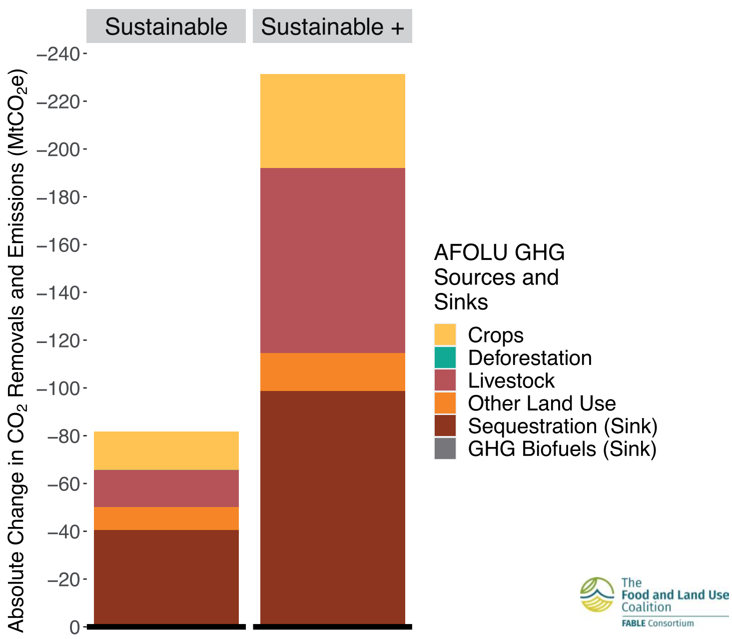


Figure 5 | Cumulated GHG emissions reduction computed over 2020-2050 by AFOLU GHG emissions and sequestration source compared to the Current Trends Pathway



Food Security

Current State

The "Triple Burden" of Malnutrition

Undernutrition

0.6% of the population undernourished in 2017. This share has increased from 0.5% in 2000 (Institute for Health Metrics and Evaluation [IHME], 2020).

No data on children under 5 stunted and wasted, but 10% of children live with adults who report severe food-insecurity (The Food Foundation, 2017).

Micronutrient Deficiency

9.8% of women and 9.5% of children under 20 suffer from dietary iron deficiency in 2017, (IHME, 2020).

2% of the population are deficient in vitamin A (GBD), which can notably lead to blindness (WHO, n.d.) and child mortality, and 1.5% are deficient in iodine, which can lead to developmental abnormalities (IHME, 2020).

Overweight/ Obesity

29% of adults and 15% of children were obese in 2018. These shares have increased since 1993 but have been stable since 2000 (NHS, 2020).

63% of adults and 28% of children were overweight in 2018. These shares have increased since 1993 but have been stable since 2000 (NHS, 2020).

Disease Burden due to Dietary Risks

14.8% of deaths are attributable to dietary risks (IHME, 2020).

Dietary risks also lead to/cause 1.6 million disability-adjusted life years (DALYs), or years of healthy life lost due to an inadequate diet (IHME, 2020).

9.6% of the population suffers from diabetes and 11.4% from cardiovascular diseases (responsible for 29% of all UK deaths), which can be caused by dietary risks (IHME, 2020).

Table 4 | Daily average fats, proteins and kilocalories intake under the Current Trends, Sustainable Medium Ambition, and Sustainable High Ambition Pathways in 2030 and 2050

	2010	2030			2050		
	Historical Diet (FAO)	Current Trends	Sustainable Medium Ambition	Sustainable High Ambition	Current Trends	Sustainable Medium Ambition	Sustainable High Ambition
Kilocalories (MDER)	2,983 (2,086)	2,896 (2,078)	2,972 (2,078)	2,727 (2,078)	2,736 (2,075)	2,974 (2,075)	2,149 (2,075)
Fats (g) (recommended range)	132 (66-99)	129 (66-99)	132 (66-99)	108 (61-91)	124 (66-99)	133 (66-100)	53 (48-72)
Proteins (g) (recommended range)	87 (75-261)	84 (75-261)	86 (75-261)	86 (68-240)	80 (75-261)	85 (75-261)	86 (54-189)

Notes. Minimum Dietary Energy Requirement (MDER) is computed as a weighted average of energy requirement per sex, age class, and activity level (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015) and the population projections by sex and age class (UN DESA, 2017) following the FAO methodology (Wanner et al., 2014). For fats, the dietary reference intake is 20% to 30% of kilocalories consumption. For proteins, the dietary reference intake is 10% to 35% of kilocalories consumption. The recommended range in grams has been computed using 9 kcal/g of fats and 4kcal/g of proteins.

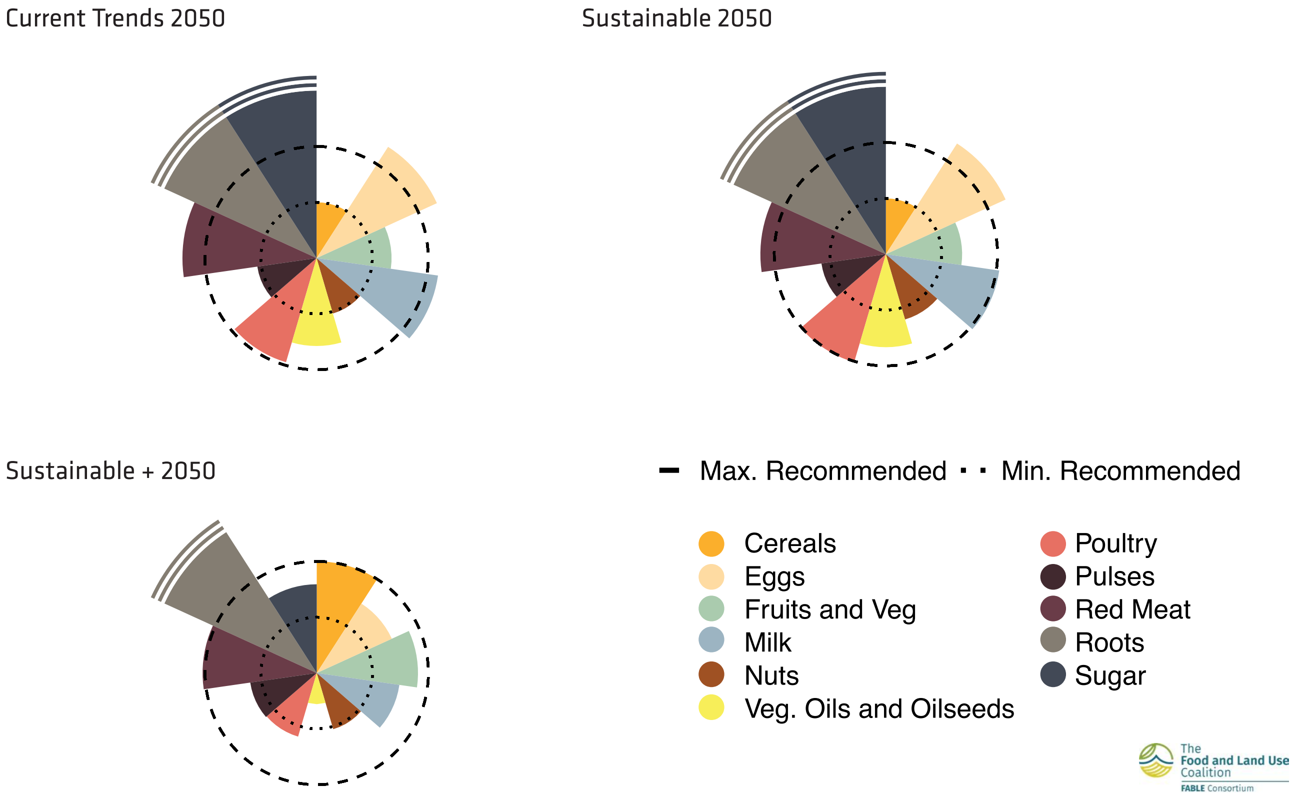
Pathways and Results

Under the Current Trends Pathway, compared to the average Minimum Dietary Energy Requirement (MDER) at the national level, our computed average calorie intake is 39% higher in 2030 and 32% higher in 2050 (Table 4). The current average calorie intake is mostly satisfied by cereals, oils and sugar, and animal products represent 31% of the total calorie intake. We assume that diets will remain constant between 2020 and 2050. Compared to the EAT-Lancet recommendations (Willette et al., 2019), roots, sugar, red meat, eggs, and milk are over-consumed while no food categories are under-consumed in 2050 (Figure 6). Moreover, fat intake per capita exceeds the dietary reference intake (DRI) in 2030 and 2050 (Table 4).

Under the Sustainable Medium Ambition Pathway, we assume that diets will transition towards the CCC "medium ambition" diet, in which consumption of ruminant meat and milk decreases by 20%, being replaced by pork and chicken (CCC, 2018). Under the Sustainable High Ambition Pathway, we assume that diets transition towards the UK "Eatwell" diet, which is a healthy diet according to UK government guidelines, with a much lower intake of sugar and animal products, and higher intake of pulses, fish, fruit and vegetables. The excess of the computed average intake over the MDER increases slightly to 43% in 2030 and 2050 under the Sustainable Medium Ambition Pathway (which is designed to meet climate objectives rather than health guidelines), and decreases to 32% in 2030 and 4% in 2050 under the Sustainable High Ambition Pathway. Compared to the EAT-Lancet recommendations, in the Sustainable Medium Ambition Pathway only the consumption of milk changes to fall within the recommended range, while in the Sustainable High Ambition Pathway the consumption of sugar, eggs, red meat, and milk fall within the recommended range by 2050 (Figure 6), the consumption of vegetable oils falls below the minimum recommended amount (because the Eatwell diet was modelled to be as close as possible to the current UK diet but this is based on surveys which under-report consumption of some foodstuffs), and the fat intake per capita is lower than the dietary reference intake (DRI) in 2050 (Table 4), showing a major improvement compared to the Current Trends Pathway.

Comprehensive policy measures will be important to promote this shift in diets, building on the range of existing UK actions (WCRF, 2020) such as further marketing of the Eatwell diet, integrating nutrition advice into education and primary care, refining guidelines for public sector purchasing of food and improving access to affordable plant-based food choices, as well as supply-side measures such as supporting UK growers and processors of plant-based protein sources (nuts, beans, and pulses).

Figure 6 | Comparison of the computed daily average kilocalories intake per capita per food category across pathways in 2050 with the EAT-Lancet recommendations



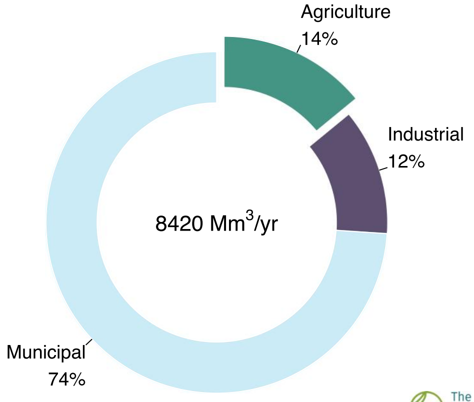
Notes. These figures are computed using the relative distances to the minimum and maximum recommended levels (i.e. the rings), therefore, different kilocalorie consumption levels correspond to each circle depending on the food group. The EAT-Lancet Commission does not provide minimum and maximum recommended values for cereals: when the kcal intake is smaller than the average recommendation it is displayed on the minimum ring and if it is higher it is displayed on the maximum ring. The discontinuous lines that appear at the outer edge of sugar and roots indicate that the average kilocalorie consumption of these food categories is significantly higher than the maximum recommended.

Water

Current State

The UK is characterized by a temperate oceanic climate with 1220 mm average annual precipitation that occurs all year round, but with more in the months of October to January (Met Office, 2019). According to the default FABLE dataset (used for this round of modeling), the agricultural sector represented 14% of total water withdrawals in 2016 (Figure 7; FAO, 2017), though more recent UK data indicates a share of 9% (Environment Agency, 2020). In 2016, only 3% of arable land was equipped for irrigation (FAO AQUASTAT, 2016). The two most important irrigated crops, potatoes and other vegetables, accounted for 52% and 27% of total harvested irrigated area in 2007 (FAO, 2017). The UK exported 7% of potatoes and 12% of other vegetables in 2010 (FAO, 2020).

Figure 7 | Water withdrawals by sector in 2016

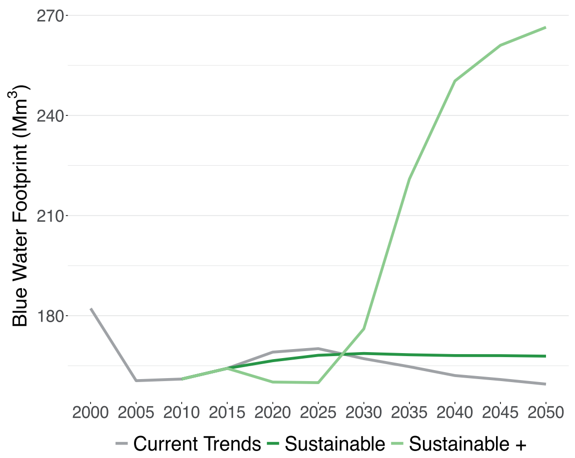


Source. Adapted from AQUASTAT Database (FAO, 2017)

Pathways and Results

Under the Current Trends Pathway, annual blue water use decreases between 2000-2015 (182 and 164 Mm^3/yr), before reaching 167 Mm^3/yr and 160 Mm^3/yr in 2030 and 2050, respectively (Figure 8), with potatoes and other vegetables accounting for 47% and 42% of computed blue water use for agriculture by 2050[4]. Under the Sustainable Medium Ambition Pathway, blue water footprint in agriculture reaches 169 Mm^3/yr in 2030 and 168 Mm^3/yr in 2050, respectively. Under the Sustainable High Ambition Pathway, the blue water footprint increases to 266 Mm3/yr in 2050. The increase in water use in the Sustainable High Ambition Pathway is due to greater production of potatoes and other vegetables. We did not assume any changes in the water-use efficiency of irrigation.

Figure 8 | Evolution of blue water footprint in the Current Trends, Sustainable Medium Ambition, and Sustainable High Ambition Pathways



4 We compute the blue water footprint as the average blue fraction per tonne of product times the total production of this product. The blue water fraction per tonne comes from Mekonnen and Hoekstra (2010a, 2010b, 2011). In this study, it can only change over time because of climate change. Constraints on water availability are not taken into account.

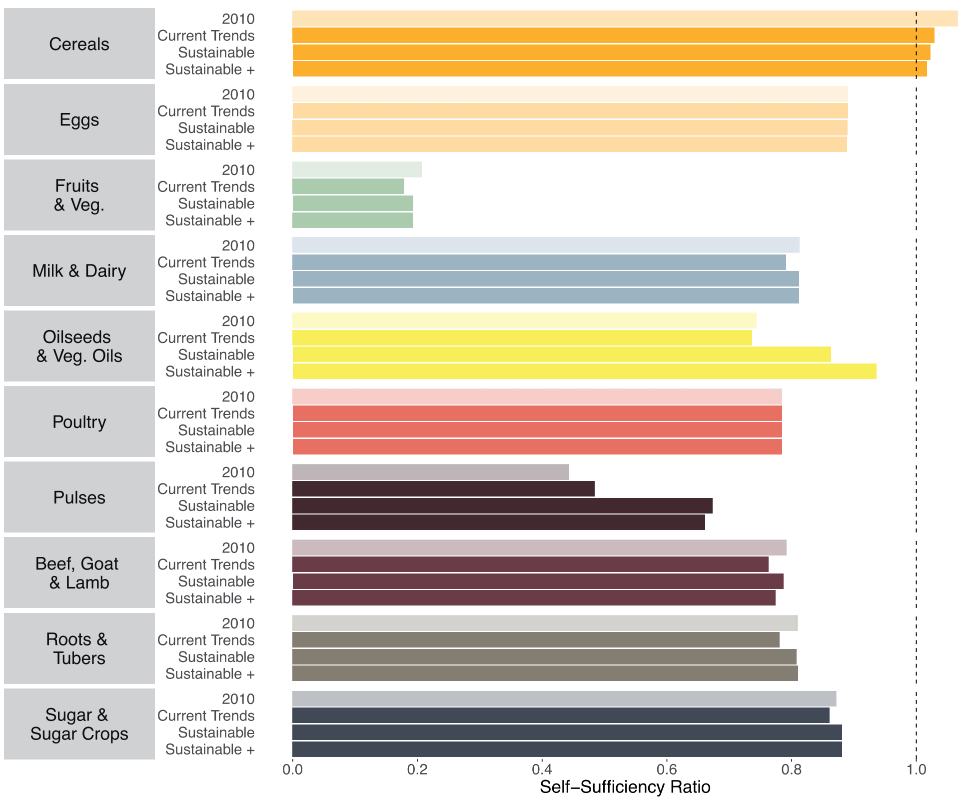
Resilience of the Food and Land-Use System

The COVID-19 crisis exposes the fragility of food and land-use systems by bringing to the fore vulnerabilities in international supply chains and national production systems. Here we examine two indicators to gauge the UK's resilience to agricultural-trade and supply disruptions across pathways: the rate of self-sufficiency and diversity of production and trade. Together they highlight the gaps between national production and demand and the degree to which we rely on a narrow range of goods for our crop production system and trade.

Self-Sufficiency

Self-sufficiency has been declining since a peak in 1984, when the UK produced 78% of all foodstuffs consumed, and 95% of indigenous foodstuffs (those that can be produced in the UK). In 2010 the UK was 62% self-sufficient in all foods and 78% in indigenous foods, and this downwards trend is still continuing (DTI, 2014). The highest reliance on imports is for fruit and vegetables, oilseeds, and spices (FAO, 2020).

Figure 9 | Self-sufficiency per product group in 2010 and 2050



Note. In this figure, self-sufficiency is expressed as the ratio of total internal production over total internal demand. A country is self-sufficient in a product when the ratio is equal to 1, a net exporter when higher than 1, and a net importer when lower than 1.

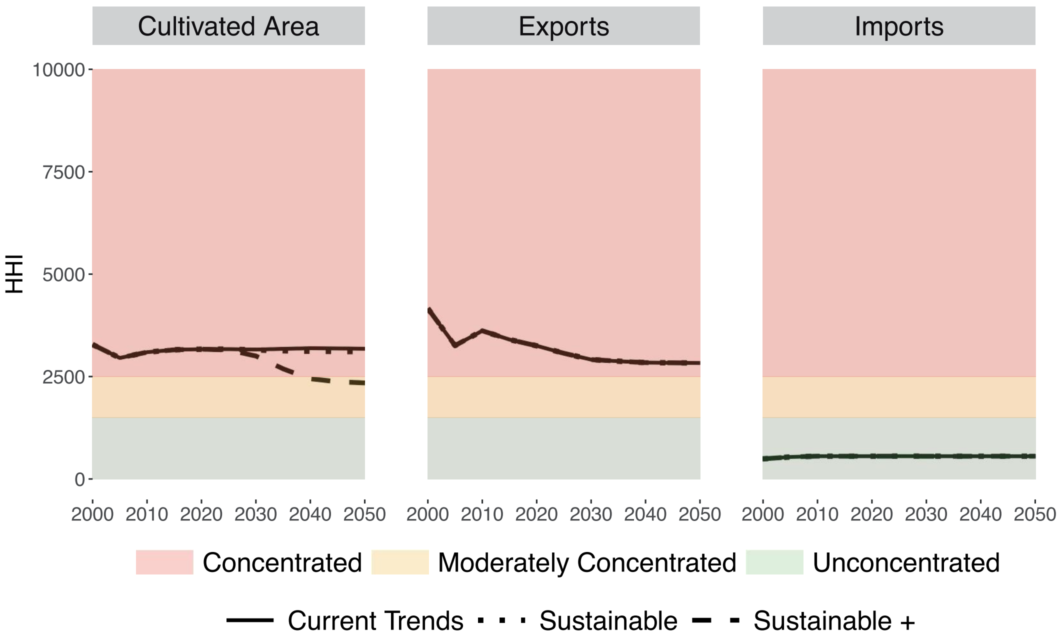
Under the Current Trends Pathway, we project that the UK would continue to be self-sufficient only in cereal production in 2050, with self-sufficiency by product group decreasing slightly for the majority of products from 2010 – 2050 (Figure 9). The product groups where the country depends the most on imports to satisfy internal consumption are fruit and vegetables, and this dependency will increase until 2050. Under the Sustainable Medium Ambition and Sustainable High Ambition Pathways, there are slight improvements in self-sufficiency for most food groups, and especially for oilseed and pulses, as land for food production is freed up and demand for feed crops is reduced due to dietary change and productivity improvements.

Diversity

The Herfindahl-Hirschman Index (HHI) measures the degree of market competition using the number of firms and the market shares of each firm in a given market. We apply this index to measure the diversity/concentration of:

- **Cultivated area:** where concentration refers to cultivated area that is dominated by a few crops covering large shares of the total cultivated area, and diversity refers to cultivated area that is characterized by many crops with equivalent shares of the total cultivated area.
- **Exports and imports:** where concentration refers to a situation in which a few commodities represent a large share of total exported and imported quantities, and diversity refers to a situation in which many commodities account for significant shares of total exported and imported quantities.

Figure 10 | Evolution of the diversification of the cropland area, crop imports and crop exports of the country using the Herfindahl-Hirschman Index (HHI)



We use the same thresholds as defined by the U.S. Department of Justice and Federal Trade Commission (2010, section 5.3): diverse under 1,500, moderate concentration between 1,500 and 2,500, and high concentration above 2,500.

According to the HHI (Figure 10), the planted crop area in 2010 is concentrated on just a few crops (wheat, barley, and oilseed rape), and exports are also concentrated on these crops. However, imports are not concentrated, reflecting the high dependence of the UK on imports across many food groups.

Under the Current Trends Pathway, we project concentration of crop exports to decrease slightly over the period 2010 – 2050 while imports remain un-concentrated and the range of crops planted remains concentrated. This indicates low levels of diversity across the national production system and exports. In contrast, under the Sustainable Medium Ambition and the Sustainable High Ambition Pathways, we project a slight decrease in the concentration of the range of crops planted in 2050, indicating higher levels of diversity across the national production system (Figure 10). This is explained by a reduction of the large proportion of crop area previously needed to grow barley for animal feed.

Discussion and Recommendations

The FABLE results for the UK show that our land-use system faces extreme pressure. With our Current Trends Pathway, urban development and afforestation compete strongly with land for food production, resulting in increased food imports to meet demand from a growing population. Although GHG emissions from AFOLU remain stable at 2015 levels, global emissions will rise as the UK imports more food. In contrast, the Sustainable Pathways show how emissions could be reduced by between 36% and 123%, enabling the AFOLU sector to contribute up to 9% of the UK target of a 40% reduction by 2030. This is consistent with scenarios developed for the UK government (CCC, 2018), designed to deliver AFOLU GHG reductions of between 35% and 80%, as a key part of the UK commitment to Net Zero emissions by 2050. Even with the very ambitious assumptions of the Sustainable High Ambition Pathway, however, it is clear that the majority of emission reductions need to come from decarbonising the economy.

The impacts of future land use change on biodiversity are dramatic. Under the Current Trends Pathway, all the non-forest natural land (semi-natural grasslands, wetlands, heathland, and shrub) except for that which is in protected areas is lost to urban development, afforestation, and expansion of farmland by 2030. This would undermine UK NBSAP targets for protecting and expanding the area of priority habitats and creating nature recovery networks. In addition, the UK would be responsible for additional environmental impacts globally to satisfy the demand for increased food imports. However, our Sustainable Pathways illustrate how dietary change and productivity improvements can free up land for biodiversity and carbon storage, enabling a transition to a healthy and sustainable food supply system.

The results highlight key trade-offs and synergies in UK food and land-use systems, especially the strong dependence of climate, food, and biodiversity targets on dietary change, and the synergy between climate mitigation and healthy diets. However, there are potential trade-offs between afforestation and biodiversity targets, due to the pressure on other types of natural land. In the ‘current trends’ scenario, despite a relatively modest amount of afforestation, all other types of natural land are eliminated except for that in protected areas. Current targets for expansion of housing and infrastructure may also have significant impacts on our ability to meet climate and biodiversity targets in the face of growing demand for food, if the expansion includes greenfield as well as brownfield development. In the sustainable scenarios, productivity increases help to reduce the trade-offs by enabling more food to be produced per unit area, but these involve ambitious assumptions which are highly uncertain.

It is still too soon to say how the experience of COVID-19 will affect the UK food and land-use system over the next five years. Although global commodity trade has shown resilience (as of November 2020), peaks in demand for certain goods have stressed supply chains and there has been a shortage of migrant workers for production of labor-intensive crops. The pandemic has also highlighted how consumer habits can change rapidly and has raised the profile of nutritional health. Future outcomes are uncertain, but the disruption may create an opportunity to influence and shape the UK food system as society and economy recover over the next five years. Key questions include whether “de-globalization” will lead to political pressure to grow more food locally even when market forces favor imports, whether public perceptions will shift to allow more state intervention to achieve societal goals beyond those produced by the market, whether changes in consumer habits that have emerged during the lock-down might lead to fundamental changes in consumer preferences and nutrition, and what effect may this have on land use. And uncertainty over Brexit still remains, with the threat of ‘no deal’ disruption at the end of 2020 and the unknown outcomes of ongoing trade negotiations with non-EU countries. Exploring scenarios about future food supply and land use has never been more important.

To tackle these challenges and trade-offs we recommend that:

- Existing and emerging national policies within each of the four UK nations of England, Wales, Scotland and Northern Ireland that affect land use (for example, for England these include the 25 Year Plan for the Environment, Environmental Land Management schemes, the Environment and Agriculture Bills and the National Food Strategy) should consider the strong evidence of the essential role that the Eatwell diet and related initiatives could play in reducing GHG emissions and protecting biodiversity. Various evidence-based tools are already available to policy makers to help bring this about. Modelling consumer behavior is likely to become even more important.

- UK farmers, growers and producers should be supported in transitioning to a sustainable food system. A dietary shift towards more fruit and vegetable consumption could present an opportunity to expand this highly profitable sector in the UK.

- Housing and infrastructure development targets should take account of their impacts on the ecosystem services provided by different types of land. The presumption in favor of brownfield development will reduce pressure on other land uses.

- Biodiversity, agriculture, and forestry policies should consider the impact of large-scale afforestation on biodiversity and on food production, as well as using native species or natural regeneration where possible and aligning with nature recovery networks.

- Unprotected peatland should be protected in order to achieve benefits for both biodiversity and carbon. The 0.5Mha nature recovery land in the 25 Year Environment Plan should be given effective protection in the planning system, to avoid encroachment by development.

- The Sustainable Pathways illustrate emissions reduction due to reduced agricultural land area and improved productivity, but land/soil management (including manure management) will also be important on remaining agricultural lands.

The analysis has certain limitations. There is considerable uncertainty over some input parameters and assumptions, including future trends in crop and livestock productivity, the impacts of climate change on yield and future livestock stocking densities. For example, stakeholders advise that policy may shift towards lower stocking densities to reduce environmental impacts, rather than the high densities assumed in our sustainable pathways. There are many differences between actual UK statistics and the global FAOSTAT database that is used as the default in FABLE. In some cases, we have adjusted the input parameters to match more closely UK statistics but in general we use the FAOSTAT figures to ensure consistency with other country teams. Imports and exports were assumed to be fixed at current levels, due to uncertainty over Brexit negotiations (except for the global trade balancing adjustments). The model is not spatial and does not take account of the different contexts of the four devolved nations of the UK. It also does not distinguish between different types of forest (native vs non-native; semi-natural vs commercial plantations) which have different impacts on biodiversity and climate mitigation, or between semi-natural and improved grassland.

We hope to address some of these issues in future work. In particular we aim to secure funding to develop versions of the FABLE Calculator for the UK Devolved Administrations. We would like to extend the UK version of the FABLE Calculator to include peatland emissions, UK-relevant bioenergy crops (coppice and miscanthus) and water efficiency targets and investigate whether agroforestry and hedgerow creation can be included. Distinguishing between improved and semi-natural grassland and semi-natural vs plantation forest would enable the impacts of land use change on biodiversity to be assessed in more detail. We also plan to undertake sensitivity analyses to explore the impact of key assumptions, e.g. on productivity. Finally, we would like to secure funding to explore the spatial implications of the scenarios by developing high resolution spatially-explicit models of the UK food and land-use system coupled to global trade.

Annex 1. List of changes made to the model to adapt it to the national context

- Added in alternative diets: the CCC medium ambition scenario diet and the Eatwell diet (see Annex 2).
- Altered livestock productivity calculation to allow a specific increase above the 2015 value to be set, rather than using the default extrapolation. This allows more precise control over the scenarios.
- Altered crop productivity calculation to allow a specific increase above the 2015 value to be set, rather than using the default extrapolation.
- Added forest planting implementation rate such that the historical values were correct and consistent between pathways; and such that the future values could be specified more precisely based on stakeholder input.
- Altered Protected Area calculation to allow a specified increase in absolute area to be defined (we wanted to be able to include +500 kha of protected land in our scenarios).
- Added in a scenario on Urban Expansion, such that we could differentiate between pathways instead of assuming the same expansion policy between all three.
- Added in custom implementation rate curves for the Post Harvest Loss scenarios, such that we could control these more precisely in line with the stakeholder input.

Annex 2. Underlying assumptions and justification for each pathway

POPULATION Population projection (million inhabitants)		
Current Trends Pathway	**Sustainable Medium Ambition Pathway**	**Sustainable High Ambition Pathway**
The population is expected to reach 75.4 million by 2050 (UN medium projections). Based on UNDESA (2017) (UN Medium Projection scenario selected).	As for Current Trends.	As for Current Trends.

LAND Constraints on agricultural expansion		
Current Trends Pathway	**Sustainable Medium Ambition Pathway**	**Sustainable High Ambition Pathway**
We assume that there will be no constraint on the expansion of the agricultural land beyond existing protected areas and under the total land boundary. Based on lack of any UK policy to constrain expansion.	As for Current Trends.	As for Current Trends.
LAND Afforestation or reforestation target (1000 ha)		
We assume total afforested/reforested area to reach 326Mha by 2050. Based on continuation of average rate of tree planting 2014-2016, i.e. 9,000ha/y (CCC, 2018).	We assume total afforested/reforested area to reach 990Mha by 2050. Based on CCC medium ambition scenario, i.e. 30,000ha/y (CCC, 2018).	We assume total afforested/reforested area to reach 1490Mha by 2050. Based on CCC high ambition scenario, i.e. 50,000ha/y (CCC, 2018).
LAND Urban expansion		
Increase of urban area from 7% of UK land area in 2015 (1.6Mha) to 10.2% (2.5Mha) by 2050, at a rate of 26,000ha/y, based on government projections for future housing needs (CCC, 2018; MHCLG, 2019).	As for Current Trends.	Increase of urban area from 7% of UK land area in 2015 (1.6Mha) to 8.3% (2.0Mha) by 2050, at a rate of 13,000ha/y, based on assumption that land take could be half of Current Trends, e.g. if developments were more compact, following the approach used in (Thomson et al., 2018).

BIODIVERSITY Protected areas (% of total land)

Current Trends Pathway	Sustainable Medium Ambition Pathway	Sustainable High Ambition Pathway
Protected areas remain stable: by 2050 they represent 27.6% of total land. Based on (WDPA, 2020). Includes National Parks, AONBs, local and national nature reserves, SSSIs, Ramsar sites and Natura sites (SACs and SPAs). Within these areas, the FABLE Calculator distinguishes between forests and other natural land, which are assumed to be unavailable for expansion of food production, and farmland, where production can continue.	Protected areas increase: by 2050 they represent 27.9% of total land. Based on assumption that 0.5Mha of land will be set aside for nature recovery, as expressed in 25 Year Environment Plan for England and Wales (HM Government, 2018), and that this area will be protected. Note that the FABLE Calculator currently assumes that this land is the same mix of forest, farmland and other natural land as in currently protected areas. This means that only about 20% of the new protected area is recognized as natural or forest.	Protected areas increase: by 2050 they represent 29.6% of total land. Based on assumption that in addition to the 0.5Mha extra protected land for nature recovery, all unprotected peatland is protected, adding a further 0.42Mha of natural protected land (calculations by UK FABLE team).

PRODUCTION Crop productivity for the key crops in the country (in t/ha)

Current Trends Pathway	Sustainable Medium Ambition Pathway	Sustainable High Ambition Pathway
In 2050, crop productivity remains at: • 7.7 tons per ha for wheat (7.1 with climate change impacts). • 5.7 tons per ha for barley. • 43.9 tons per ha for potatoes. Based on FAOSTAT historic yields for 2010.	By 2050, crop productivity reaches: • 10.7 tons per ha for wheat (10.1 with climate change impacts). • 7.9 tons per ha for barley. • 61 tons per ha for potatoes. Based on assumption that yields for all crops increase by 39% from the 2010 value, in line with the revised CCC medium projection (CCC, personal communication, 2020).	By 2050, crop productivity reaches: • 12.7 tons per ha for wheat (12.0 with climate change impacts). • 9.4 tons per ha for barley. • 72.4 tons per ha for potato. Based on assumption that yields for all crops increase by 65% (from stakeholder discussions).

PRODUCTION Livestock productivity for the key livestock products in the country (in kg/head of animal unit)

Current Trends Pathway	Sustainable Medium Ambition Pathway	Sustainable High Ambition Pathway
By 2050, livestock productivity *(annual production / average herd size, not carcass weight)* reaches: • 7,971 kg per head for milk. • 85 kg per head for cattle meat. • 13.7 kg per head for chicken meat. Based on assumption that milk yield increases by 18%, half the current rate, while other yields remain at 2015 levels, using UK agriculture statistics (Defra, 2019).	By 2050, livestock productivity reaches: • 7,971 kg per head for milk. • 85 kg per head for cattle meat. • 15.3 kg per head for chicken meat. Based on assumption that milk yield increases by 18%, half the current rate; cattle remains the same as productivity is assumed to increase via changes to stocking density; poultry assumed to increase proportional to the assumed increases in stocking density for cattle.	By 2050, livestock productivity reaches: • 8,669 kg per head for milk. • 85 kg per head for cattle meat. • 15.3 kg per head for chicken meat. Based on increase of 27% for milk yield, 75% of the current rate of increase; no further increase for cattle or chicken, to reflect animal welfare and physiology constraints / limits to further yield increases.

PRODUCTION Pasture stocking rate (in animal units/ha pasture)

By 2050, the average ruminant livestock stocking density is 1.1 TLU/ha. Based on assumption that the stocking density remains unchanged from the value in 2010 according to FAOSTAT (herd numbers divided by pasture area).	By 2050, the average ruminant livestock stocking density is 1.2 TLU/ha. Based on increase of 10% from 2015, the same % increase as in CEH Rothamsted high ambition scenario (Thomson et al., 2018).	By 2050, the average ruminant livestock stocking density is 1.7 TLU/ha. Based on increase of 50% from 2015, the same % increase as in CCC high ambition scenario (CCC, 2018), and guidance on potential densities (AHDB, 2016).

PRODUCTION Post-harvest losses

By 2050, the share of production and imports lost during storage and transportation is 1% for crop products and unknown (assumed zero) for livestock products. Based on FAOSTAT data and assumption of no change from present day, but data is patchy.	By 2050, the share of production and imports lost during storage and transportation is 0.5%. Based on assumption of a 50% reduction in losses compared to 2015, i.e. achieving the SDG 12.3 target to halve consumer and retail waste but by 2050 rather than 2030 (WRAP, 2020).	By 2030, the share of production and imports lost during storage and transportation is 0.5%, i.e. the target is achieved earlier than the Sustainable scenario. Based on assumption of a 50% reduction in losses compared to 2015 in line with the Courtauld 2025 Commitment (reduction of 20% across supply chain between 2015-2025) and SDG 12.3 target (halve consumer and retail waste by 2030) (WRAP, 2020).

TRADE Share of consumption which is imported for key imported products (%)

Current Trends Pathway	Sustainable Medium Ambition Pathway	Sustainable High Ambition Pathway
By 2050, the share of total consumption which is imported remains at the 2015 values: • 53 % for other vegetables. • 88 % by 2050 for apples. • 25 % by 2050 for beef. Based on stakeholder discussions and agreement that the outcome of Brexit trade negotiations and the design of the replacement agricultural support scheme were too uncertain to allow meaningful projections of future change.	As for Current Trends.	As for Current Trends.

TRADE Evolution of exports for key exported products (1000 tons)

By 2050, the volume of exports remains at the 2015 values: • 1.8Mt by 2050 for wheat. • 1.1Mt by 2050 for barley. • 0.3Mt by 2050 for rapeseed oil. Based on stakeholder discussions and agreement that the outcome of Brexit trade negotiations and the design of the replacement agricultural support scheme were too uncertain to allow meaningful projections of future change.	As for Current Trends.	As for Current Trends.

FOOD Average dietary composition (daily kcal per commodity group)

Current Trends Pathway	Sustainable Medium Ambition Pathway	Sustainable High Ambition Pathway
By 2030, the average target daily calorie consumption per capita is 2,983 kcal and is: • 168 kcal for fruit and vegetables. • 83 kcal for ruminant meat. • 119 kcal for animal fats. Based on assumption of no change in current diet as in FAOSTAT.	By 2030, the average target daily calorie consumption per capita is 2,894 kcal and is: • 167 kcal for fruit and vegetables. • 78 kcal for ruminant meat. • 119 kcal for animal fats. Based on CCC medium ambition scenario (20% reduction in red meat and milk consumption by 2050) (CCC, 2018).	By 2030, the average target daily calorie consumption per capita is 2,739 kcal and is: • 196 kcal for fruit and vegetables. • 75 kcal for ruminant meat. • 98 kcal for animal fats. Based on meeting the Eatwell diet recommendations by 2050 (PHE, 2020; Scarborough et al., 2016).

FOOD Share of food consumption which is wasted at household level (%)

Current Trends Pathway	Sustainable Medium Ambition Pathway	Sustainable High Ambition Pathway
By 2030, the share of final household consumption which is wasted at the household level is 14%. Based on assumption of no change from current levels (WRAP, 2020).	By 2030, the share of final household consumption which is wasted at the household level is 12.5%. Based on CCC medium ambition scenario in which the share which is wasted decreases linearly by 20% from 2010 to 2050, from 14% to 11% (CCC, 2018).	By 2030, the share of final household consumption which is wasted at the household level is 7 %. Based on Courtauld 2025 Commitment (reduction of 20% across supply chain between 2015-2025) and SDG 12.3 target (halve consumer and retail waste by 2030 (WRAP, 2020).

BIOFUELS Targets on biofuel and/or other bioenergy use

Current Trends Pathway	Sustainable Medium Ambition Pathway	Sustainable High Ambition Pathway
By 2050, biofuel production accounts for: • 226kt of corn production. • 909kt of wheat production. Based on OECD Aglink projections until 2028; stable afterwards. In future this could be modified to reflect UK policy to use coppice wood and miscanthus grass rather than food crops.	By 2050, biofuel production accounts for: • 231kt of corn production. • 1143kt of wheat production. Based on OECD Aglink projections until 2028; stable afterwards.	By 2050, biofuel production accounts for: • 215kt of corn production. • 1053kt of wheat production. Based on OECD Aglink projections until 2028; stable afterwards.

CLIMATE CHANGE Crop model and climate change scenario

Current Trends Pathway	Sustainable Medium Ambition Pathway	Sustainable High Ambition Pathway
By 2100, global GHG concentration leads to a radiative forcing level of 6 W/m2 (RCP 6.0). Impacts of climate change on crop yields are computed by the crop model GEPIC using climate projections from the climate model HadGEM2-E without CO_2 fertilization effect.	By 2100, global GHG concentration leads to a radiative forcing level of 2.6 W/m2 (RCP 2.6). Impacts of climate change on crop yields are computed by the crop model GEPIC using climate projections from the climate model HadGEM2-E without CO_2 fertilization effect.	By 2100, global GHG concentration leads to a radiative forcing level of 2.6 W/m2 (RCP 2.6). Impacts of climate change on crop yields are computed by the crop model GEPIC using climate projections from the climate model HadGEM2-E without CO_2 fertilization effect.

Annex 3. Correspondence between original ESA CCI land cover classes and aggregated land cover classes displayed on Map 1

FABLE classes	ESA classes (codes)
Cropland	Cropland (10,11,12,20), Mosaic cropland>50% - natural vegetation <50% (30), Mosaic cropland><50% - natural vegetation >50% (40)
Forest	Broadleaved tree cover (50,60,61,62), Needleleaved tree cover (70,71,72,80,82,82), Mosaic trees and shrub >50% - herbaceous <50% (100), Tree cover flooded water (160,170)
Grassland	Mosaic herbaceous >50% - trees and shrubs <50% (110), Grassland (130)
Other land	Shrubland (120,121,122), Lichens and mosses (140), Sparse vegetation (150,151,152,153), Shrub or herbaceous flooded (180)
Bare areas	Bare areas (200,201,202)
Snow and ice	Snow and ice (220)
Urban	Urban (190)
Water	Water (210)

Units

°C – degree Celsius

% – percentage

/yr – per year

cap – per capita

CO_2 – carbon dioxide

CO_2e – greenhouse gas expressed in carbon dioxide equivalent in terms of their global warming potentials

g – gram

GHG – greenhouse gas

ha – hectare

kcal – kilocalories

kg – kilogram

kha – thousand hectares

km^2 – square kilometer

km^3 – cubic kilometers

kt – thousand tons

m – meter

Mha – million hectares

Mm^3 – million cubic meters

Mt – million tons

t – ton

TLU – Tropical Livestock Unit is a standard unit of measurement equivalent to 250 kg, the weight of a standard cow

t/ha – ton per hectare, measured as the production divided by the planted area by crop by year

t/TLU, kg/TLU, t/head, kg/head- ton per TLU, kilogram per TLU, ton per head, kilogram per head, measured as the production per year divided by the total herd number per animal type per year, including both productive and non-productive animals

USD – United States Dollar

W/m^2 – watt per square meter

yr – year

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