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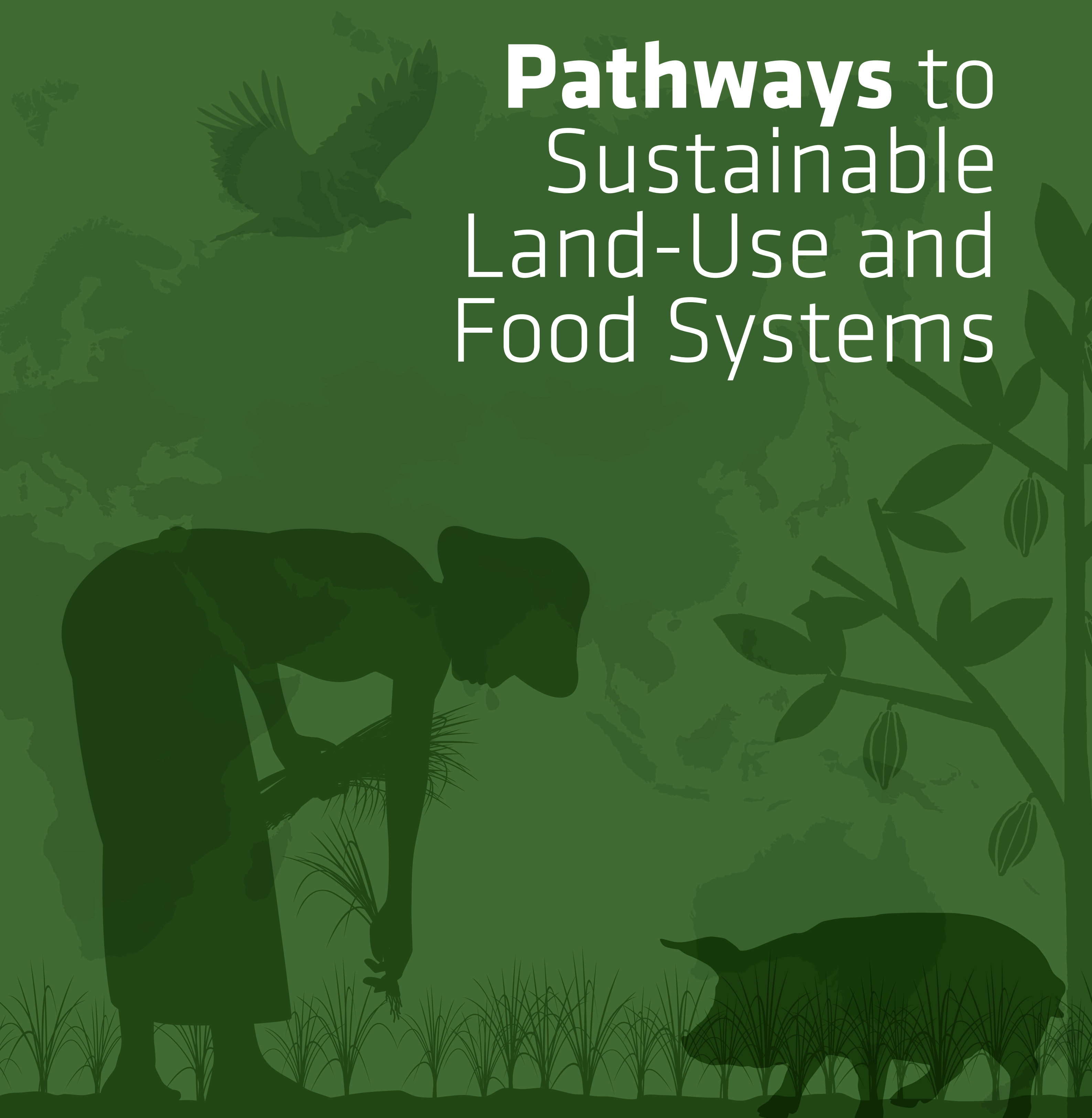
SUSTAINABLE DEVELOPMENT SOLUTIONS NETWORK
A GLOBAL INITIATIVE FOR THE UNITED NATIONS

The Food and Land Use Coalition

2020 Report of the FABLE Consortium

Pathways to Sustainable Land-Use and Food Systems



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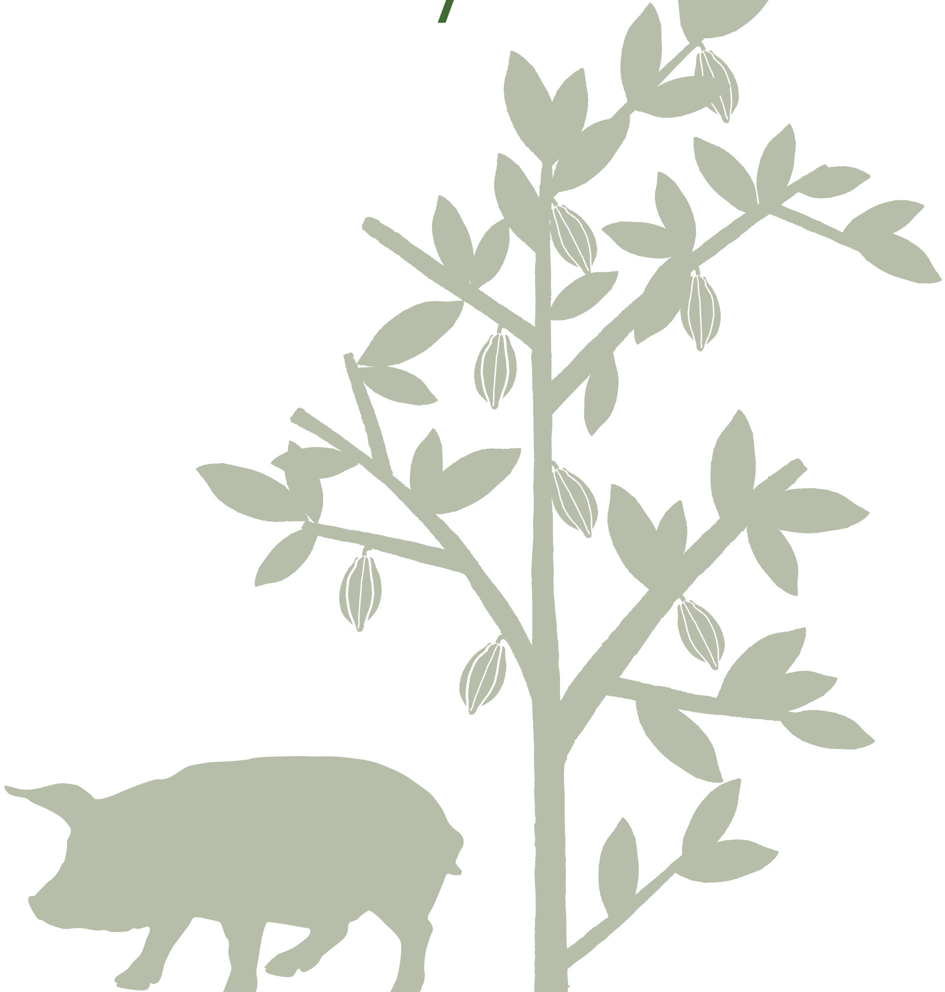
2020 Report of the FABLE Consortium

Pathways to Sustainable Land-Use and Food Systems in the United States by 2050



United States of America

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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 United States (e.g., healthier diets). 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 using government sources and academic literature, 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 US's NDC and Long-Term Low Emissions and Development Strategy (LT-LEDS) treat the FABLE domains. According to its 2016 NDC and LT-LEDS, the US previously committed to reducing its GHG emissions by 26-28% by 2025 compared to 2005 and to 80% below 2005 levels by 2050, respectively. These emission reduction projections include abatement efforts from agriculture, forestry, and other land use (AFOLU). However, envisaged mitigation measures from agriculture and land-use change are not explicit in the US LT-LEDS or NDC. Under its commitments to the UNFCCC submitted in 2016, the US does not mention biodiversity conservation.

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

	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					
NDC (2016)	2005	5,999 million	2025	26-28% reduction	Energy, industrial processes, agriculture, land-use change and forestry, and waste	Y	N	N	Food, water, forests
LT-LEDS (2016)	2005	5,999 million	2050	80% reduction	Energy, industrial processes, agriculture, land-use change and forestry, and waste	Y	N	N	Food, water, forests

Note. The NDC "Total GHG Mitigation" and "Mitigation Measures Related to AFOLU" columns are adapted from IGES NDC Database (Hattori, 2019)
Source: US (2016a) for the NDC and US (2016b) for the LT-LEDS

Although the US helped establish the United Nations Environment Programme that started the negotiations to develop the Convention on Biological Diversity, the US is not a contracting party to the CBD. As a result, the US does not have an NBSAP.

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

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 US.

Our Current Trends Pathway corresponds to the lower boundary of feasible action. It is characterized by medium population growth (from 334 million inhabitants in 2020 to 400.4 million in 2050), no constraints and agricultural expansion, a low afforestation target corresponding to the amount of land remaining in the Conservation Reserve Program (5.7 Mha), no change in the extent of protected areas, medium productivity increases in the agricultural sector, no change in diets, no change in the imports or exports of agricultural commodities, and historic rates of change in ruminant density per hectare of pasture (which is a declining) (see Annex 2). This corresponds to a future based on current policy and historical trends that would also see considerable progress with regards to crop and livestock productivity (US Department of Agriculture [USDA], 2020a). 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 corn, nuts, peas, rapeseed, rice, soyabean, sugarbeet, sugarcane, sunflower, wheat, and millet (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 a high boundary of feasible action. Compared to the Current Trends Pathway, we assume that this future experiences the same population growth, no constraints and agricultural expansion, a high afforestation target (40 Mha), an increase in the extent of protected areas from 13.2% to 19.2%, high productivity increases in the agricultural sector, a shift in average diets towards the Healthy-Style Diet for Americans (US Department of Health and Human Services [HSS] & USDA, 2015), no change in the imports of agricultural commodities, but a growth in exports for several agricultural commodities (corn, soybean, wheat, beef, soycake, pork, chicken, milk, and eggs), and slightly higher intensity of ruminant density per hectare of pasture compared to the Current Trends Pathway (see Annex 2). This corresponds to a future guided by the US's LT-LEDS, that would also see considerable progress with regards to healthier diets. 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 efforts were made to achieve both reforestation as well as bioenergy needs from the land sector. Compared to the Sustainable Medium Ambition Pathway, we assume that this future would lead to use of the land sector to supply biofuels needed to achieve net zero or net negative emissions for the energy and industrial sectors (Williams et al., Manuscript submitted for publication), while also expanding protected areas to 30% of total land area—all made possible by greater productivity and healthier diets (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.

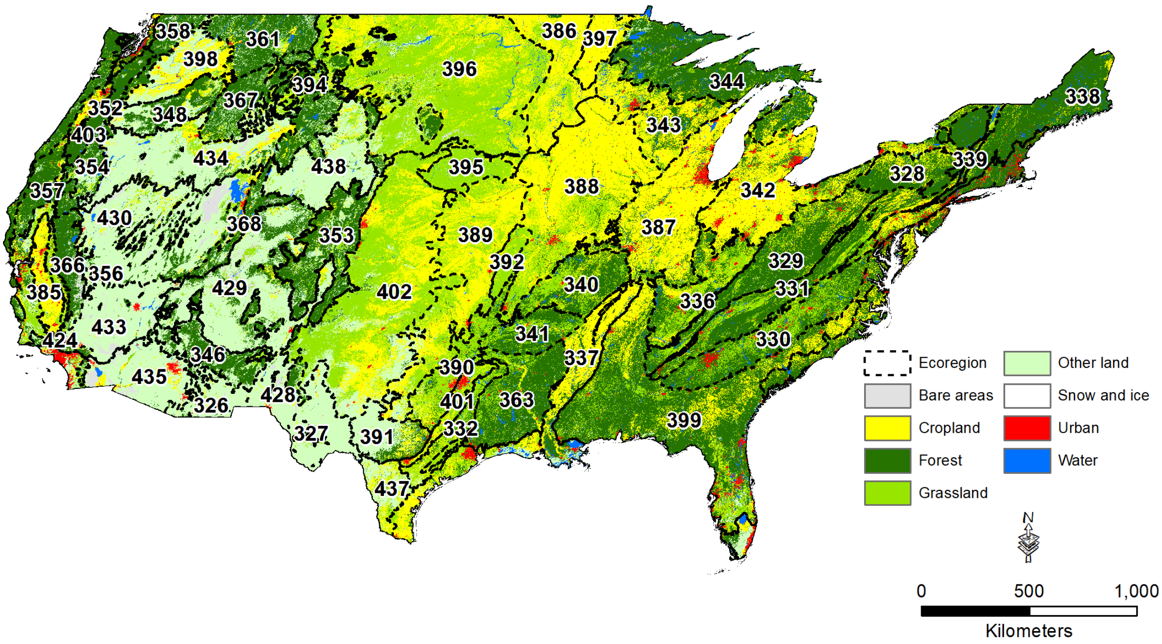
Land and Biodiversity

Current State

In 2010, the US was covered by 17.3% cropland, 27.2% pastureland, 33.2% forest, 1.4% urban, and 22.9% other natural land. Most of the agricultural area is located in the midwestern states while forest and other natural land can be mostly found in western states (Map 1). The greatest threats to biodiversity in the US are habitat loss and habitat degradation. While several policies are in place for biodiversity conservation, the most prominent being the Endangered Species Act, it takes an average of 12 years for species to be listed as endangered or threatened (Puckett et al., 2016) and only 5% of listed species receive adequate conservation funding (Evans et al., 2016).

We estimate that land where natural processes predominate[2] accounted for 45% of the US's terrestrial land area in 2010 (Map 2). The Interior Alaska-Yukon lowland taiga holds the greatest share of land where natural processes predominate, followed by the Great Basin shrub steppe and Colorado Plateau shrublands (Annex 4). Across the country, while 121.4 Mha of land is under formal protection (or about 13.2%), falling short of the 30% zero-draft CBD post-2020 target, only 25.8% of land where natural processes predominate is formally protected.

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

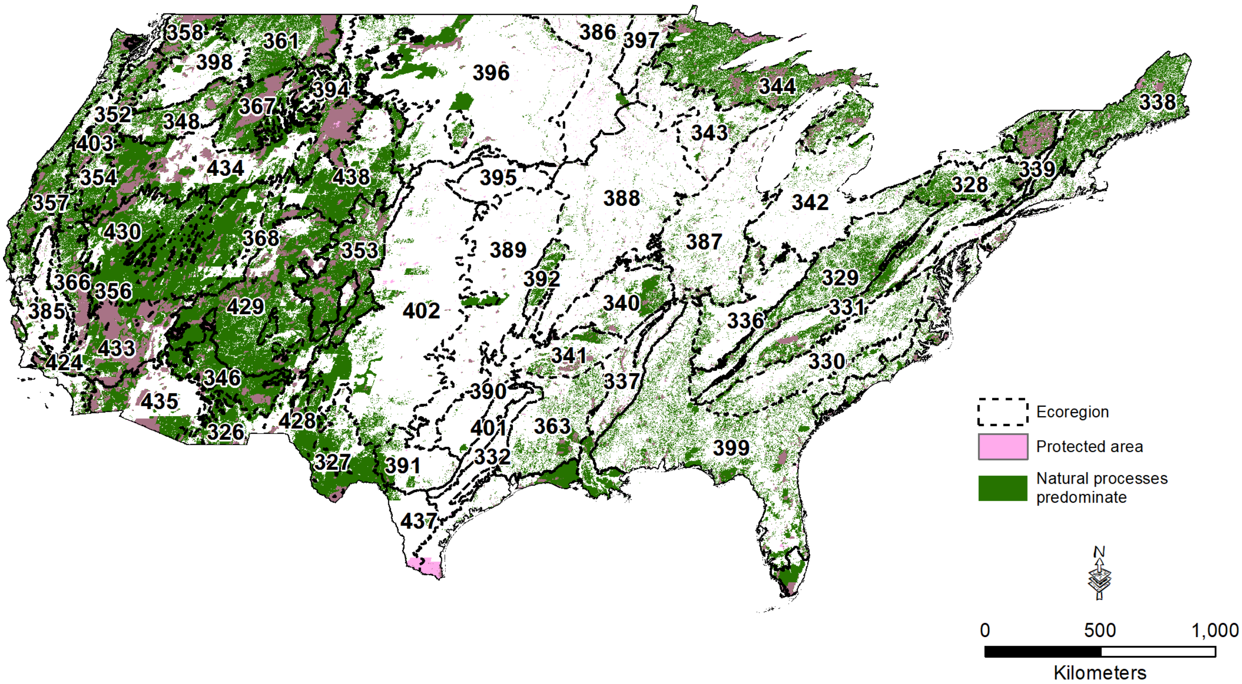


Sources: countries - GADM v3.6; ecoregions – Dinerstein et al. (2017); land cover – ESA CCI land cover 2015 (ESA, 2017)
Notes: The map does not display Alaska and Hawaii, which are included in the national statistics (Annex 4). Correspondence between original ESACCI land cover classes and aggregated land cover classes displayed on the map can be found in Annex 3.

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 33.9% of US cropland was in landscapes with at least 10% natural vegetation in 2010. These relatively biodiversity-friendly croplands are most widespread in Northern Shortgrass prairie, followed by Central-Southern US mixed grasslands and Western shortgrass prairie.

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



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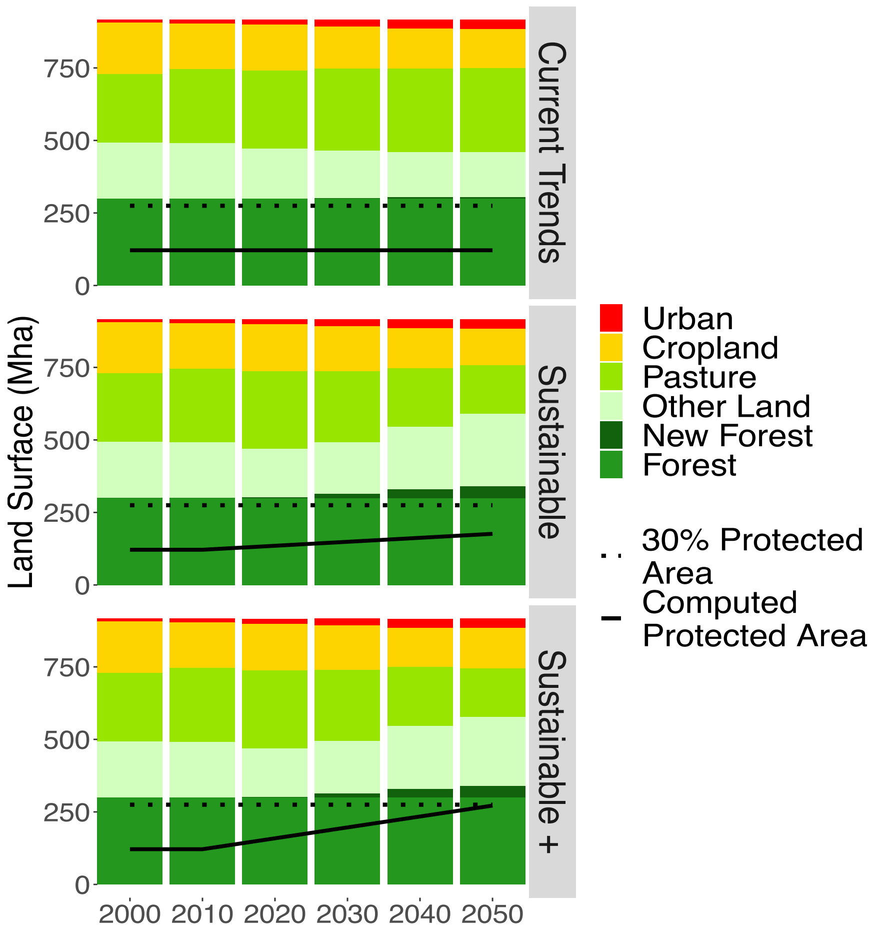
Sources: countries - GADM v3.6; ecoregions – Dinerstein et al. (2017); protected areas – UNEP-WCMC and IUCN (2020); natural processes predominate comprises key biodiversity areas – BirdLife International (2019), intact forest landscapes in 2016 – Potapov et al. (2016), and low impact areas – Jacobson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

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, 5.7 Mha reforested or afforested by 2050, and protected areas remain at 121.4 Mha, representing 13.2% 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 in pastureland area and a decrease in cropland area. This trend evolves over the period 2030-2050: pastureland area continues to increase and cropland area continues to decrease, but at lower rates (Figure 1). Pasture expansion is mainly driven by the increase in demand for beef due to population growth while livestock productivity per head remains constant and ruminant density per hectare of pasture remains constant over the period 2020-2030. Between 2030-2050, continued cropland reduction, pastureland expansion, and other land reduction are explained by the steady growth of urban areas, modest reforestation, increases in beef demand and no change in ruminant density per hectare of pasture, and continued increases in crop productivity. This results in a slight reduction in land where natural processes predominate by 4% by 2030 and by 5% by 2050 compared to 2010, respectively.

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

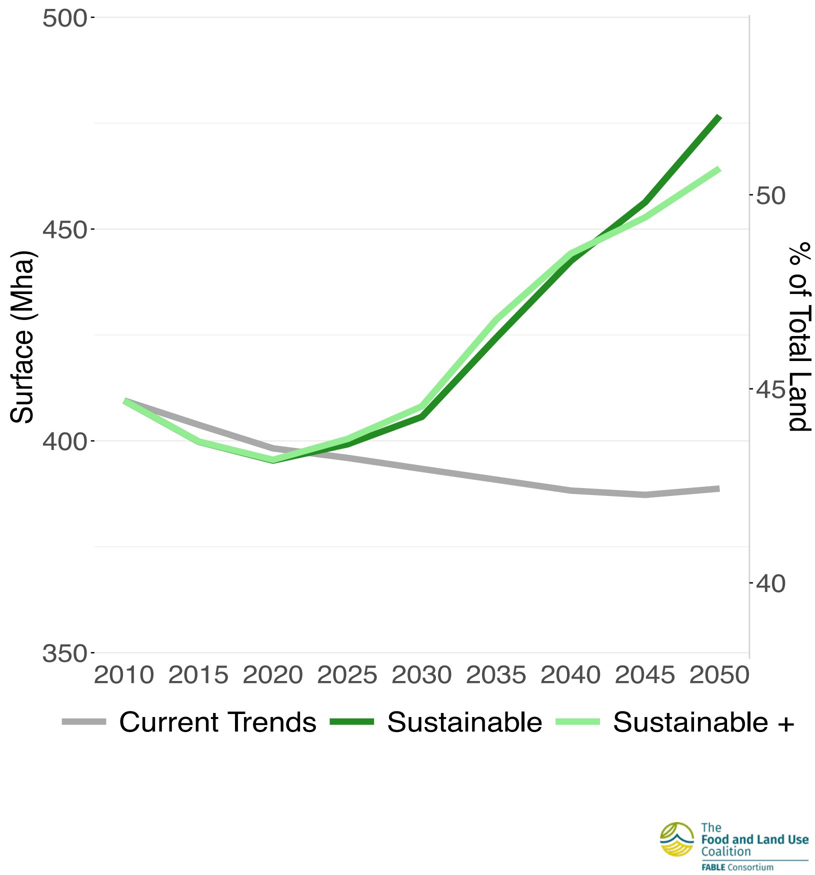


Source. Authors' computation based on FAOSTAT (FAO, 2020) for the area by land cover type for 2000, and the World Database on Protected Areas (UNEP-WCMC & IUCN, 2020) for protected areas for years 2000, 2005 and 2010.

In the Sustainable Medium Ambition and Sustainable High Ambition Pathways, assumptions on protected areas have been changed from 13% under the Current Trends Pathway to 19% and 30% protection by 2050, respectively, the latter of which is informed and inspired by the 30x30 challenge, or protecting 30% of land and ocean by 2030. The only other assumptions changed under the Sustainable High Ambition Pathway is the use of land for growing dedicated bioenergy feedstocks, miscanthus and switchgrass, consistent with US Deep Decarbonization Pathways assumptions for achieving economy-wide net zero emissions by 2050 (see Annex 2).

Compared to the Current Trends Pathway, we observe the following changes regarding the evolution of land cover in the US in the Sustainable Medium Ambition and Sustainable High Ambition Pathways: (i) significant growth in forested land due to reforestation policies, (ii) significant growth in the area of other land, (iii) significant reduction in the extent of pastureland, and (iv) very slight decline in the extent of cropland by 2050 with a slight increase between 2020 and 2040. In addition to the changes in assumptions regarding land-use planning, these changes compared to the Current Trends Pathway are largely explained by dietary shifts and crop productivity improvements. Changes in dietary preferences and crop productivity lead to an increase in the area where natural processes predominate: the area stops declining by 2030 and increases by 16% between 2010 and 2050 (Figure 2).

Figure 2 | Evolution of the area where natural processes predominate



GHG emissions from AFOLU

Current State

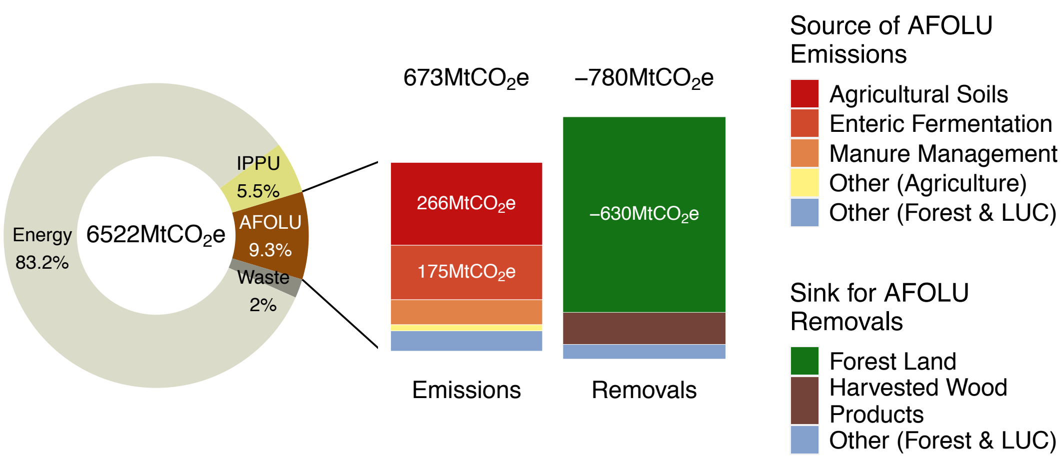
Direct GHG emissions from Agriculture, Forestry, and Other Land Use (AFOLU) accounted for 9.3% of total emissions in 2010 (Figure 3). Agricultural soils (e.g., N_2O) is the principle source of AFOLU emissions, followed by enteric fermentation, croplands, and manure management; together enteric fermentation and manure management due to livestock encompasses the largest share of AFOLU emissions. Emissions from agricultural soils (non-CO_2) can be explained by the widespread use of fertilizers, nitrogen-fixing crops, soil drainage properties, how crops are irrigated (US Environmental Protection Agency, 2015), and the growth in consumption of livestock products.

Pathways and Results

Under the Current Trends Pathway, annual AFOLU GHG emissions reported by the FABLE Calculator stand at 408 Mt CO_2e/yr) in 2020, decrease to 326 Mt CO_2e/yr in 2030, and further decrease to 181 Mt CO_2e/yr in 2050 (Figure 4). In 2050, livestock remains the largest source of emissions (249 Mt CO_2e/yr) while land use change, including slower growth of pastureland coupled with a continued increase in reforestation, acts as a sink (-144 Mt CO_2e/yr). Over the period 2020-2050, the strongest relative increase in GHG emissions is computed for livestock (1.5%) while emissions reductions are observed for crop production and due to land use change (13.8% from crops, 283% from land use change).

In comparison, the Sustainable Medium Ambition Pathway leads to a reduction of AFOLU GHG emissions by 325% and the Sustainable High Ambition Pathway to a reduction by 374% by 2050 compared to the Current Trends Pathway

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)

(Figure 4). The potential emissions reductions under the Sustainable Medium Ambition Pathway is dominated by a reduction in GHG emissions primarily from livestock and crops in addition to 40 Mha reforestation leading to -600 Mt CO_2e/yr by 2050 (Figure 5). Dietary changes that reduce the demand for red meat, increased crop productivity, and ambitious reforestation targets are the most important drivers of this reduction. Under the Sustainable High Ambition Pathway, GHG emissions are further avoided from fossil fuels due to an increase in biofuels production. However, the GHG benefits due to miscanthus and switchgrass biomass feedstocks are modest (-21 Mt CO_2e/yr).

Compared to US commitments under UNFCCC (Table 1), our results show that AFOLU mitigation interventions tracked by the FABLE Calculator (agricultural emissions and land use change, not including the current land use sink) could contribute to as much as 12.3% and 14.1% of its total GHG emissions reduction objective by 2050 in the Sustainable Medium Ambition and Sustainable High Ambition Pathways, respectively. Such reductions could be achieved through the following policy measures: setting ambitious reforestation targets, encouraging shifts towards a healthier diet, and increasing crop productivity to relax extensive margin pressure on agricultural land use. It is important to note that our analysis only considers mitigation opportunities through land use change and crop production shifts. This approach misses important mitigation opportunities through improved forest management (Baker et al., 2017; Van Winkle et al., 2017), forest planting to increase stand productivity (Wade et al., 2019), mitigation strategies on working agricultural lands such as conservation tillage, and livestock sector mitigation strategies to reduce enteric fermentation emissions or capture methane emissions from hog and dairy operations (Murray et al., 2005). Thus, mitigation potential represents a lower bound for these land use and crop production trajectories.

Figure 4 | Potential AFOLU emissions reductions by 2050 by trajectory compared to Current Trends

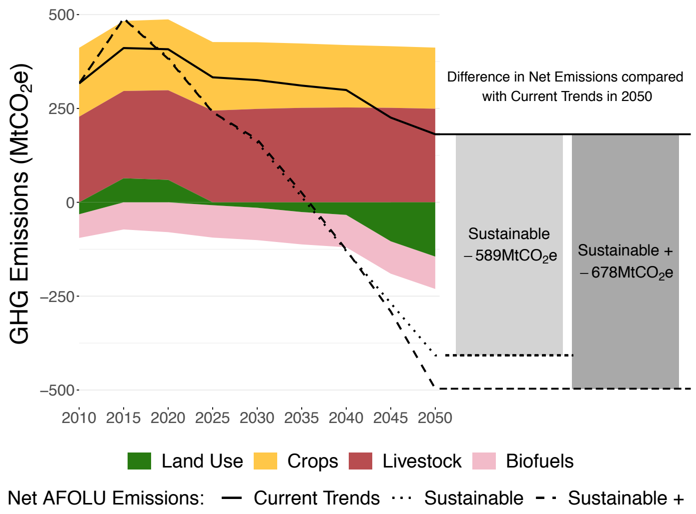
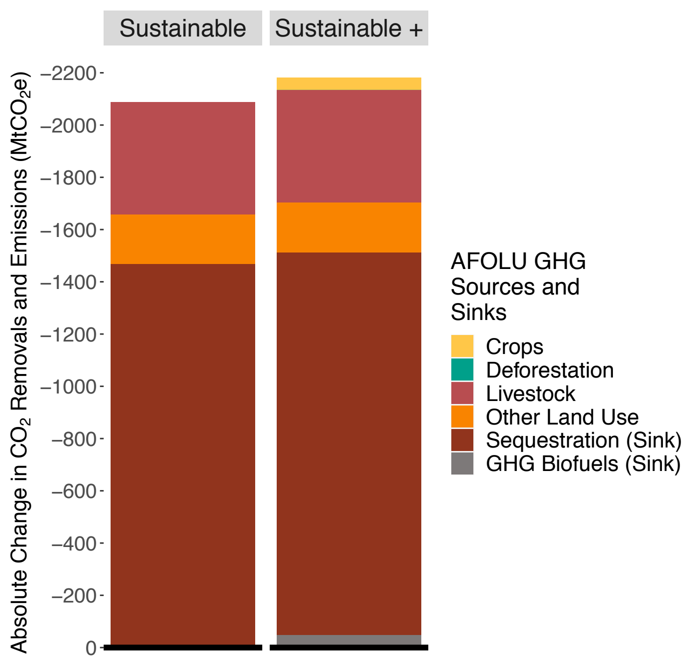


Figure 5 | Cumulated GHG emissions reduction computed over 2020–2050 by AFOLU GHG emissions and sequestration source compared to the Current Trends Pathway



Food Security

Current State

Undernutrition	Micronutrient Deficiency	Overweight/ Obesity
3-4.5% of the population undernourished in 2015. (USDA, 2019a; World Bank, 2019)	13.3% of women and 8.5% of children suffer from anemia in 2016, which can lead to maternal death (World Health Organization, 2020).	24.4% of the population, and 39.6% of adults and 18.5% of children were obese in 2015. These shares have increased since 1980 (Hales et al., 2017; Ng et al., 2014).
2.1% of children under 5 stunted and 0.4% wasted in 2012 (World Bank, 2020a, 2020b).	49% of adults do not meet the Estimated Average Requirement of vitamin A (Fulgoni et al., 2011), and 12% are deficient in iodine, which can lead to developmental abnormalities (Caldwell et al., 2011).	70.9% of adults were overweight in 2013-2016. These shares have increased since 1988 (Centers for Disease Control and Prevention [CDCP], 2020b).

Disease Burden due to Dietary Risks

About 20% of deaths are attributable to dietary risks, or 170.7 deaths per year (per 100,000 people) in 2017 ((Afshin et al., 2019) supplementary info Table 7).

Dietary risks also lead to/cause 3,982 disability-adjusted life years (DALYs), or years of healthy life lost due to an inadequate diet ((Afshin et al., 2019) supplementary info Table 7).

10.5% of the population suffers from diabetes (CDCP, 2020a) and 48% of adults suffer from cardiovascular diseases, which can be due to/caused by dietary risks (Benjamin Emelia J. et al., 2019).

Table 3 | Daily average fats, proteins, and kilocalorie 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)	2,872 (2,079)	2,867 (2,075)	2,753 (2,075)	2,753 (2,075)	2,866 (2,078)	2,544 (2,089)	2,544 (2,089)
Fats (g) (recommended range)	139.9 (64-96)	141 (64-96)	126 (61-92)	126 (61-92)	141 (64-96)	99 (57-85)	99 (57-85)
Proteins (g) (recommended range)	93 (72-251)	92 (72-251)	90 (69-241)	90 (69-241)	92 (72-251)	86 (64-223)	86 (64-223)

Notes. Minimum Dietary Energy Requirement (MDER) is computed as a weighted average of energy requirement per sex, age class, and activity level (HSS and USDA, 2015) and the population projections by sex and age class (UN DESA, 2017) following the FAO methodology (Wanner et al., 2014). 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.

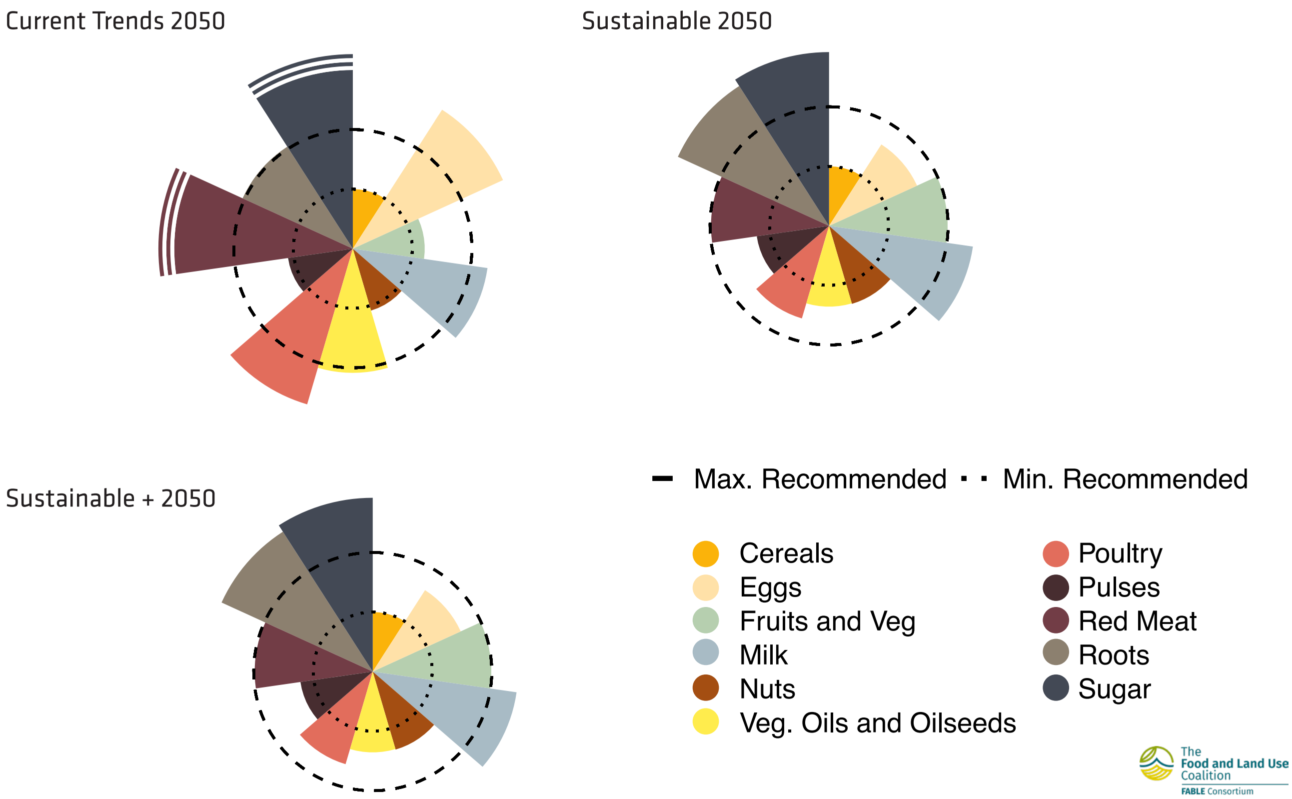
Pathways and Results

Under the Current Trends Pathway, compared to the average Minimum Dietary Energy Requirement (MDER) at the national level, our computed average calorie intake is 38% higher in both 2030 and 2050 (Table 3). The current average intake is mostly satisfied by cereals, oil and fat, and milk and animal products, which represent 32% of the total calorie intake. We assume that the consumption of animal products per capita will stay the same between 2020 and 2050. Compared to the EAT-Lancet recommendations (Willett et al., 2019), red meat, pork, milk, oils and fats, poultry, sugar, eggs, animal fats, and eggs are over-consumed while cereals, fish, fruits and vegetables, pulses, and nuts are under-consumed in 2050 (Figure 6). Moreover, fat intake per capita exceeds the dietary reference intake (DRI) in 2030 and 2050 (Table 3). This can be explained by high consumption of oils and fats and animal fats (Figure 6).

Under the Sustainable Medium Ambition Pathway, we assume that diets will transition towards a “Healthy US-Style Pattern” as determined in the Dietary Guidelines for Americans by the USDA and Department of Health and Human Services (HSS & USDA, 2015). The same assumptions are made under the Sustainable High Ambition Pathway. The ratio of the computed average intake over the MDER decreases to 32% in 2030 and 22% in 2050 under the Sustainable Medium Ambition and Sustainable High Ambition Pathways. Compared to the EAT-Lancet recommendations, only the consumption of roots and milk remains outside of the recommended range with the consumption of red meat, sugar, eggs, and poultry being now within the recommended range in 2050 (Figure 6). Moreover, the fat intake per capita is closer to being within the dietary reference intake (DRI) in 2030, showing some improvement compared to the Current Trends Pathway.

Implementing dietary interventions with quantified food preference impacts such as pricing strategies and product placement at retailers; menu labeling and healthy default choices in restaurants; adding more vegetables and fruits to the Supplemental Nutrition Assistance Program; and providing plant-based meat alternatives in workplaces and schools will be particularly important to promote this shift in diets (Anderson Cheryl A.M. et al., 2019).

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



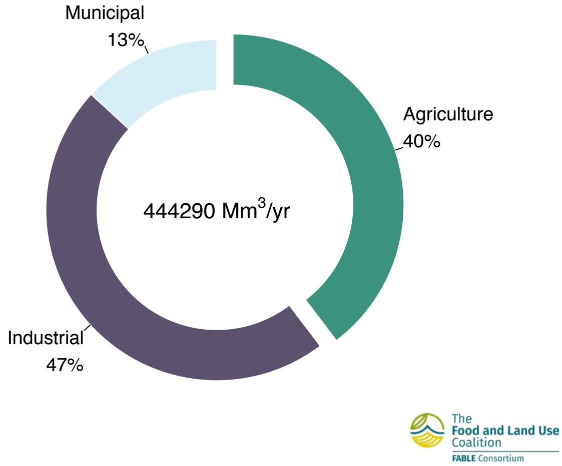
Notes. These figures are computed using the relative distances to the minimum and maximum recommended levels (i.e. the rings) i.e. different kilocalorie consumption levels correspond to each circle depending on the food group. The EAT-Lancet Commission does not provide minimum and maximum recommended 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 the sugar and red meat indicate that the average kilocalorie consumption of these food categories is significantly higher than the maximum recommended.

Water

Current State

The US is characterized by temperate climatic conditions suitable for agricultural production with 715 mm average annual precipitation that mostly occurs over the period April to September in the Midwest, where most of the agricultural land is located. The agricultural sector represented 40% of total water withdrawals in 2015 (FAO AQUASTAT) (Figure 7). Moreover, in 2012, about 7.6% of agricultural land was equipped for irrigation (FAO AQUASTAT). The three most important irrigated crops, corn, hay and forage production, and soybeans, account for 25%, 18%, and 14% of total harvested irrigated area (USDA, 2019c). The US exported 14.3% of corn, 48% of soybean in 2018/2019 and 2017/2018, respectively (Iowa Farm Bureau, 2019; US Grains Council, 2020).

Figure 7 | Water withdrawals by sector in 2015

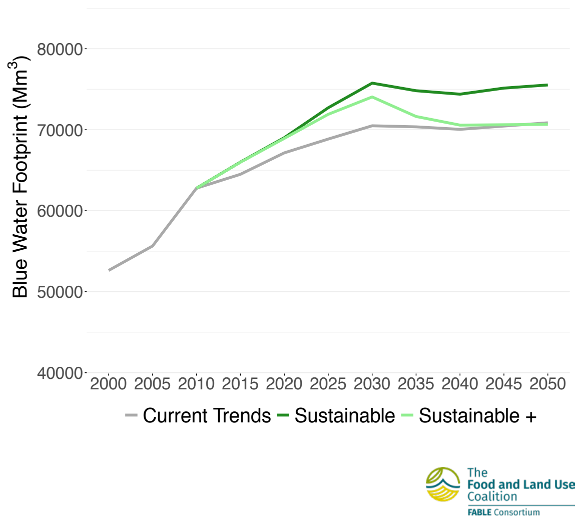


Source. Adapted from AQUASTAT Database (FAO, 2017)

Pathways and Results

Under the Current Trends Pathway, annual blue water use increases between 2000 and 2015 (52,600 Mm^3/yr and 64,500 Mm^3/yr), before reaching 70,500 Mm^3/yr and 70,900 Mm^3/yr in 2030 and 2050, respectively (Figure 8), with corn, rice, and soybean accounting for 37%, 12%, and 10% of computed blue water use for agriculture by 2050[3]. In contrast, under the Sustainable Medium Ambition and Sustainable High Ambition Pathways, the blue water footprint in agriculture reaches, respectively, 75,800 Mm^3/yr and 74,000 Mm^3/yr in 2030, and 75,500 Mm^3/yr and 70,700. Mm^3/yr in 2050. This is explained by changes in the crop composition across pathways such as shifts to production of corn and soybean due to a decline in internal food demand despite increasing exports, as well as climate change impacts.

Figure 8 | Evolution of blue water footprint in the Current Trends and Sustainable Pathways



3 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 Koekstra (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

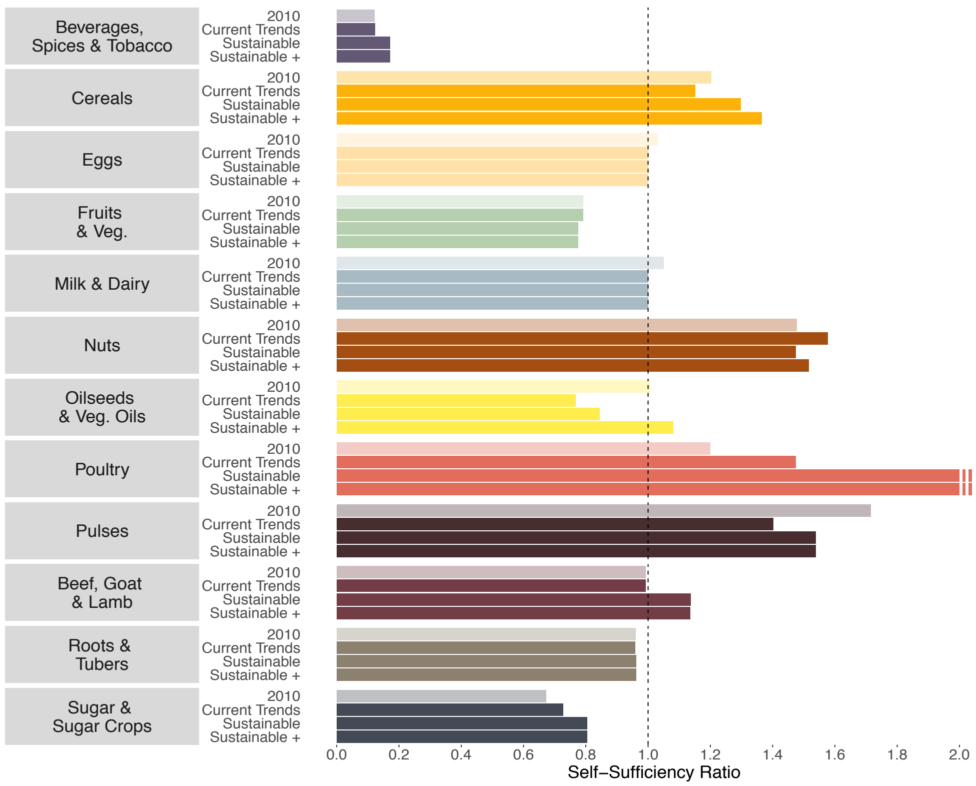
The COVID-19 crisis exposes the fragility of food and land-use systems by bringing to the fore vulnerabilities in international supply chains and national production systems. Here we examine two indicators to gauge the US's resilience to agricultural-trade and supply disruptions across pathways: the 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

Currently (as of 2010), the US is self-sufficient in the vast majority of key product groups, with the notable and critical exceptions being fruits and vegetables and sugar.

Under the Current Trends Pathway, we project that the US would be self-sufficient in cereals, eggs, milk and dairy, nuts, poultry, pulses, beef, and roots in 2050, with self-sufficiency by product group remaining stable for the majority of products (except oil seeds and vegetable oils) from 2010 – 2050 (Figure 9). The product groups where the country

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. The discontinuous lines on the right side of the figure, as appear for poultry, indicate a high level of self-sufficiency in this category.

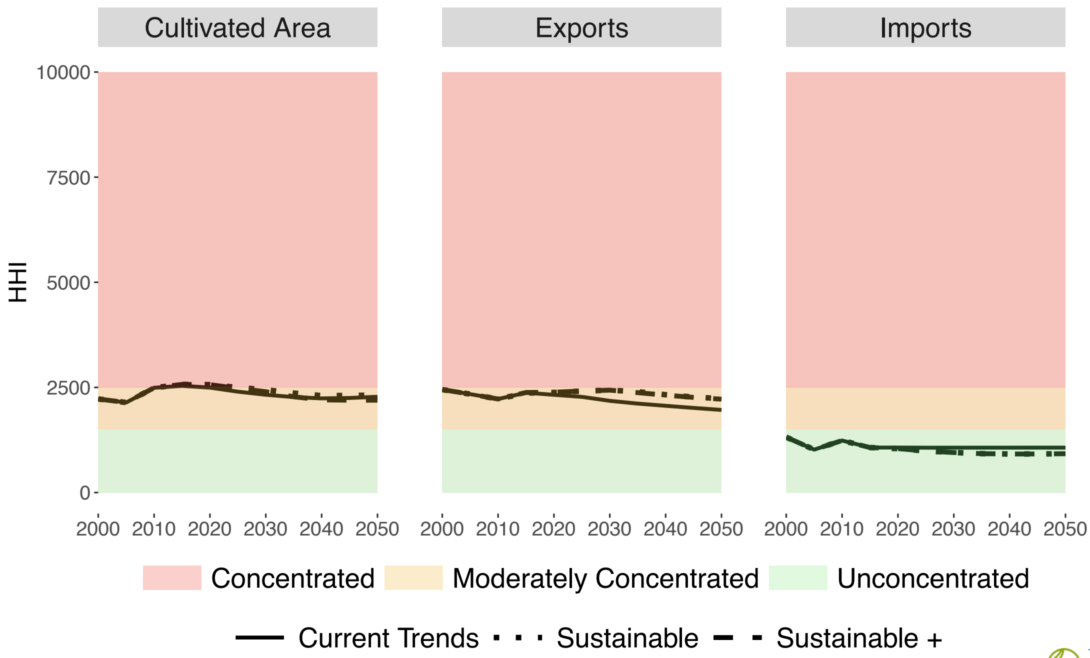
depends the most on imports to satisfy internal consumption are beverages, spices and tobacco, fruits and vegetables, oilseeds and vegetable oils, and sugar, and this dependency will remain stable until 2050. Under the Sustainable Medium Ambition Pathway, the US remains self-sufficient in all the same products as under Current Trends by 2050, representing the same level of self-sufficiency. Finally, under the Sustainable High Ambition Pathway, self-sufficiency resembles the Sustainable Medium Ambition Pathway, except that the US would be self-sufficient in oilseeds and vegetable oils, since no changes to volume of imports and exports, productivity, food crop cultivation, diets were assumed.

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 US 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, the diversity of planted crop area in 2010 is concentrated, and moderately concentrated and unconcentrated for crop exports and imports, respectively. Under the Current Trends Pathway, we project moderate and low concentrations of crop exports and imports, respectively, and high to moderate. concentration in the range of crops planted in 2050, trends which generally decrease or stabilize over the period 2010 - 2050. This indicates moderate levels of diversity across the national production system and imports and exports. In contrast, under the Sustainable Medium Ambition Pathway, we project moderate-high and very low concentrations of crop exports and imports, respectively, and moderate-high concentration in the range of crops planted in 2050, indicating overall moderate levels of diversity across the national production system and imports and exports. Finally, under the Sustainable High Ambition Pathway, we project a similar concentration of crop exports and imports, and a slightly lower moderate concentration in the range of crops planted in 2050, indicating moderate levels of diversity across the national production system and imports and exports (Figure 10). This is explained by a change in the share of grains typically used for livestock feed relative to the Current Trends Pathway.

Discussion and Recommendations

This analysis presents a unique assessment of sustainable land use possibilities in the United States, considering potentially competing policy objectives related to healthier diets, climate change mitigation, biodiversity protection, and water conservation. The analysis was conducted in collaboration with the global FABLE community with global sustainable development goal targets in mind, and in the context of calibrated bilateral trade flows using the global FABLE Linker Tool. Broadly, these results show that it is possible for the US to reduce GHG emissions from crop and livestock systems, increase carbon sequestration through reforestation/afforestation, protect biodiversity, and decrease agricultural water footprints while expanding food production to meet the demands of a growing population under alternative dietary preference assumptions and increases in productivity. While these results do not offer insight into the potential economic costs and benefits of sustainable land use scenarios in the US, these projections have several key policy implications that warrant further analysis and consideration.

First, we show that healthier diet assumptions in the US that follow official government agency guidelines (HSS & USDA, 2015) could have important implications for agricultural land use and management trends, offering a range of environmental benefits in addition to improving health outcomes. This result is consistent with recommendations from the EAT-Lancet Report and other US-focused literature on shared socioeconomic pathways and US land use projections (e.g. (Jones et al., 2019)). However, further analysis is needed to understand the potential spatial distribution of land use impacts due to reduced feed grain production and meat consumption and a higher proportion of crop area devoted to fruits, vegetables, and nuts, as spatial detail is necessary to inform land use planning, policy, and management at the regional, state, and sub-state level.

Our results suggest that large scale investments in reforestation/afforestation are possible without substantial sacrifices to crop production if tree planting investments are concentrated on pasturelands and marginally productive croplands—and in particular, alongside dietary preference changes. Changes in land use and crop mixes result in emissions reductions of approximately 589 Mt CO_2e per year by mid-century in the Sustainable Medium Ambition Pathway, or roughly 12.3% of the US LT-LEDS (80% reduction below 2005 levels), though this only allows for mitigation at the extensive land use margin and should be considered as a lower-end estimate of abatement potential from the AFOLU sectors. Intensive margin abatement opportunities, including improved forest management or abatement technologies on working agricultural lands (e.g., soil organic carbon; livestock emissions reduction strategies; (Archibeque et al., 2012; Fargione et al., 2018)), can further contribute to climate mitigation goals. Also, this analysis uses a simplified approach to represent mitigation potential from land use change, assuming a constant sequestration rate for land shifting to forestry in the US In reality, carbon sequestration rates vary considerably across space, forest type, and management regime (Nielsen et al., 2014).

Finally, we do not include emissions displacement from bioenergy in the Sustainable Medium Ambition Pathway, but do include bioenergy emissions displacement from only switchgrass and miscanthus (Langholtz et al., 2016; Williams et al., Manuscript submitted for publication) in the Sustainable High Ambition Pathway which further boosts the US land use sector contributions to LT-LEDS to 678 Mt CO_2e. However, we caution that the bioenergy requirement assumptions by feedstock are highly uncertain as they are dependent on the Billion Ton study's supply curve (Langholtz et al., 2016), whereas the results of energy pathways modeling specify dry tonnes of biomass (biogenic carbon) by price range independent of feedstock (Williams et al., Manuscript submitted for publication). As a result, though the Sustainable High Ambition Pathway is more ambitious from a carbon perspective, by requiring purpose-grown biomass feedstocks, we caution that it is not necessarily more sustainable from a land use or conservation perspective (despite a higher target for protected areas in the High Ambition Pathway). More spatially refined partial equilibrium analyses can improve mitigation projections for bio energy, extensive land use decisions, and intensive margin investments in abatement technologies and other natural climate solutions and to better understand the opportunity costs of these investments (Havlík et al., 2014; Herrero et al., 2013). Nonetheless, this analysis demonstrates how the land use sectors can play a role in long term climate action while considering other policy constraints related to biodiversity and diets.

Future US modeling efforts will focus on additional spatial detail to advance sustainable land use projections. This will include building on the GLOBIOM partial equilibrium model to add US spatial detail for more accurate and spatially-resolved analysis, as well as multi-model assessments in collaboration with other modeling teams (e.g., the US Forest and Agricultural Sector Optimization Model). Future efforts will also focus more on comparing economic outcomes across different scenario assumptions to better quantify potential tradeoffs.

The US food supply system remains strong and analysis at the time of this writing suggests that the COVID-19 pandemic likely will not impact the US food supply. Longer term, however, the picture is less clear. As the import, export, and crop diversity metrics indicate, the US has moderate to high levels of crop variety concentration—making it possibly more susceptible to disruptions in supply chains and international trade as well as more likely to cause food availability issues in its major trade partners. For example, border restrictions impacting migrant workers, plus recent outbreaks in meat processing plants could create labor shortages, limiting food supplies. Already, temporary meat packing plant closures have contributed to short-lived meat price increases throughout the US. If risks of COVID-19 infection to workers at these facilities continue, then this could cause longer-term market impacts and households could face higher meat and dairy prices for prolonged periods. Finally, supply chain disruption resulting from food type preference shifts due to lower commercial and restaurant demand and increased household demand (grocery store purchases) will result in increased post-harvest losses in the short term.

The US FABLE team is also beginning stakeholder engagement with the US policy community focused on land use, sustainability, climate, and agriculture and food systems. Most notably, a SDSN-USA initiative during the second half of 2020 called the “Deep Decarbonization Action Plan” (DDAP) aims to present specific federal and state/local policy proposals for deep decarbonization in the United States in time for the 2020 election season. Anchored in technical pathways for the energy sector from SDSN’s and Institute for Sustainable Development and International Relations’ (IDDRI) Deep Decarbonization Pathways project (Deep Decarbonization Pathways Project, 2015) and in FABLE’s pathway for sustainable land use, the DDAP Land Working Group will bring together policy expertise from across both academia and nonprofit partners. Outreach has already begun to involve policy experts at the US Climate Alliance, American Forests, and other partners with significant policy expertise and working relationships to policymakers, allowing the DDAP Land Working Group to aim for specific policy proposals informed by the FABLE modeling work.

Annex 1. List of changes made to the FABLE Calculator to adapt it to the US context

- Crop productivity updates for corn, soybean, and wheat
- Livestock productivity: chicken productivity updates by adding post-harvest losses
- Grazing intensity (stocking intensity): Modified the livestock stocking density scenarios to add one called "LowerIntensity" which achieves 0.34 TLU/ha by 2050 using a -0.3% rate of change.
- Bioenergy assumptions for corn, soybean; added miscanthus and switchgrass as crops using productivity assumptions from the Billion Ton study (Langholtz et al., 2016).
- Export adjustments for beef and several other commodities
- Added Healthy Style Diet for Americans
- Customized implementation timing

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
SSP2 – The population is expected to reach 400 million by 2050 (from 322 million in 2015), or a 0.6% increase per year, based on SSP2 scenario. Assumes population follows historical patterns (Medium fertility, medium mortality, medium migration, medium education). Based on the US Census Bureau's report, "Projections of the Size and Composition of the US Population: 2014 to 2060", which predicts 398 million Americans in 2050 (Colby & Ortman, 2015).		

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 outside beyond existing protected areas and under the total land boundary, as per lack of current policies restricting agricultural expansion in the US (FreeExpansion scenario selected)		
LAND Afforestation or reforestation target (1000 ha)		
We assume total afforested/reforested area to reach 5.7Mha by 2050, which is the amount of remaining land in the national Conservation Reserve Program, which pays farmers to take ecologically sensitive areas out of production and convert it to natural habitat.	We assume an ambitious increase in reforested area to reach 40Mha by 2050. Based on the US Mid-Century Strategy Report, and assumes no other CO_2 removal technologies are deployed (The White House Council on Environmental Quality, 2016). This is double the target set in the US Mid-Century Strategy Report for Deep Decarbonization in the Benchmark scenario, or roughly consistent with reforestation targets assuming no CO_2 removal technologies are employed, a US government report published in November 2016, which lays out a long-term strategy to decarbonize the US economy by 2050. Though high, this level of afforestation is technically feasible based on recent spatially-explicit analysis (Fargione et al., 2018).	We assume an ambitious increase in reforested area to reach 40Mha by 2050. Based on the US Mid-Century Strategy Report, and assumes no other CO_2 removal technologies are deployed (The White House Council on Environmental Quality, 2016). This is double the target set in the US Mid-Century Strategy Report for Deep Decarbonization in the Benchmark scenario, or roughly consistent with reforestation targets assuming no CO_2 removal technologies are employed,. a US government report published in November 2016, which lays out a long-term strategy to decarbonize the US economy by 2050. Though high, this level of afforestation is technically feasible based on recent spatially-explicit analysis (Fargione 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 13% of total land. Based on the lack of policies or administrative action to expand protected areas in the US In fact, 90% of all proposals to downsize or eliminate protected areas in the US occurred since 2000 (Golden Kroner et al. 2019).	Protected areas increase: by 2050 they represent 19% of total land. This assumes that ecoregions with the share of protected areas greater than 2% and less than 25% increase their share to 25% by 2050.	Protected areas increase: by 2050 they represent 30% of total land. This assumes that ecoregions with the share of protected areas greater than 0% and less than 45% increase their share to 45% by 2050. It fulfills the US's share of the 30x30 challenge or protecting 30% of land and ocean by 2030. This is not an official target, but an aspiration one set by non-government experts and researchers. This national target is also aligned with the global FABLE target.

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

Current Trends Pathway	Sustainable Medium Ambition Pathway	Sustainable High Ambition Pathway
From 2020 to 2050, crop productivity changes from: • 11.2 to 13.5 tonnes per ha for maize • 3.4 to 4.1 tonnes per ha for soybean • 3.2 to 3.7 tonnes per ha for wheat Based on USDA projections out to 2028 and then a linear leveling off of annual growth rate from 1% to 0% by 2050 (USDA, 2019b).	From 2020 to 2050, crop productivity changes from: • 11.2 to 15.2 tonnes per ha for maize • 3.4 to 4.6 tonnes per ha for soybean • 3.2 to 4.1 tonnes per ha for wheat Based on linear extrapolation out to 2050 of 2028 USDA projections that assume an annual linear growth rate of 1% for corn, 1% for soybean, and 0.8% for wheat (USDA, 2019b).	

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

Current Trends Pathway	Sustainable Medium Ambition Pathway	Sustainable High Ambition Pathway
From 2015 to 2050, livestock productivity increases: • From 374 kg to 400 kg per head for cattle-beef • From 2.8 to 3.2 kg per head for broiler chickens • From 8.6 tonnes to 9.6 tonnes per head of cattle for milk Slower than the historical growth rate from 2000 to 2015 (USDA, 2020a).	From 2015 to 2050, livestock productivity increases: • From 374 kg to 458 kg per head for cattle-beef • From 2.8 to 4 kg per head for broiler chickens • From 8.6 tonnes to 10.8 tonnes per head of cattle for milk Based on applying the average historical growth rate from 2000 to 2015 (USDA, 2020a).	

PRODUCTION Pasture stocking rate (animal units/ha pasture)

Current Trends Pathway	Sustainable Medium Ambition Pathway	Sustainable High Ambition Pathway
There is no change in pasture stocking rate between 2010 and 2050. By 2050, the average ruminant livestock stocking density is 0.38 TLU/ha for sheep, goats, and cattle.	By 2050, the average ruminant livestock stocking density is 0.34 TLU/ha for sheep, goats, and cattle, declining 0.3% from 0.38 TLU/ha of pasture in 2010. This follows the recent trend in declining livestock stocking rates from 2005 to 2015. Lower intensity grazing is more sustainable because soil organic carbon generally increased with reduced grazing intensity, as does biodiversity of vegetation (Abdalla et al., 2018). A review of several studies in the US of grazing intensity reveals that "light" grazing intensity ranges from 0.29 to 0.44 TLU/ha, depending on the type of animal (heifer or steer) and the region (Reeder et al., 2004; Reeder & Schuman, 2002; Rogers et al., 2005; Schuman et al., 1999)	

PRODUCTION Post-harvest losses

Current Trends Pathway	Sustainable Medium Ambition Pathway	Sustainable High Ambition Pathway
By 2050, the share of production and imports lost during storage and transportation (which varies between commodities) is held at 2010 rates.	By 2050, the share of production and imports lost during storage and transportation is 50% less than 2010 levels. There is very little available information on 2050 targets or projections for post-harvest losses for the US across all food types.	

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

Current Trends Pathway	Sustainable Medium Ambition Pathway	Sustainable High Ambition Pathway
The share of total consumption which is imported is assumed to remain stable to 2050 in order to satisfy political economy concerns. By 2050, the share of total consumption which is imported is: • 100% by 2050 for bananas • 100% by 2050 for pepper • 38% by 2050 for fish	The share of total consumption which is imported is assumed to remain stable to 2050 in order to satisfy political economy concerns. It is particularly the case for the sustainability scenarios in which production of several types of commodities have decreased due to dietary shifts. Rather than for the changes to demand to be made up by increases with imports, we assume that the agricultural sector domestically can respond to these shifts in dietary preferences. By 2050, the share of total consumption which is imported is: • 100% by 2050 for bananas • 100% by 2050 for pepper • 38% by 2050 for fish	

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

Current Trends Pathway	Sustainable Medium Ambition Pathway	Sustainable High Ambition Pathway
The tonnes of exports are kept constant at 2010 levels. For example, by 2050, the volume of exports is: • 48 million tonnes for corn. • 28 million tonnes for soybean • 22 million tonnes for wheat • 5.8 million tonnes for soycake • 1.8 million tonnes for pork	By 2050, the volume of exports is: • 82 million tonnes for corn • 34 million tonnes for soybean • 35 million tonnes for wheat • 13 million tonnes for soycake • 5 million tonnes for pork • 1.1 million tonnes of beef We based these increased export decisions on the trade imbalance after the first iteration of the Scenathon and due to the fact that we had excess production capacity due to reduction in meat intake under this scenario's dietary assumptions.	By 2050, the volume of exports is: • 81 million tonnes for corn • 33 million tonnes for soybean • 34 million tonnes for wheat • 13 million tonnes for soycake • 5 million tonnes for pork • 1.1 million tonnes of beef We based these increased export decisions on the trade imbalance after the first iteration of the Scenathon and due to the fact that we had excess production capacity due to reduction in meat intake under this scenario's dietary assumptions.

United States of America

<table>
<tr><th colspan="3">FOOD Average dietary composition (daily kcal per commodity group)</th></tr>
<tr><th>Current Trends Pathway</th><th>Sustainable Medium Ambition Pathway</th><th>Sustainable High Ambition Pathway</th></tr>
<tr><td>By 2030, the average daily calorie consumption per capita remains at 2,867 kcal and is:

• Cereals: 580
• Fish: 22
• Fruit and vegetables: 142
• Pork: 129
• Milk: 327
• Vegetable oils: 610
• Eggs: 54
• Pulses: 37
• Redmeat: 102
• Roots: 67
• Sugar: 299
• Poultry: 181
• Nuts: 30
• Animal fats: 101
• Beverages and spices: 24
• Other: 2
• Alcohol: 167

Based on (FAO 2010).</td><td colspan="2">By 2030, the average daily calorie consumption per capita decreases to 2,544 kcal and is:

• Cereals: 666
• Fish: 46
• Fruit and vegetables: 299
• Pork: 46
• Milk: 366
• Vegetable oils: 301
• Eggs: 19
• Pulses: 86
• Redmeat: 50
• Roots: 116
• Sugar: 192
• Poultry: 64
• Nuts: 132
• Animal fats: 65
• Beverages and spices: 15
• Other: 2
• Alcohol: 107

Based on USDA dietary guidelines 2015-2020 (Appendix 3. USDA Food Patterns: Healthy US Style Eating Pattern; HSS & USDA, 2015)</td></tr>
<tr><th colspan="3">FOOD Share of food consumption which is wasted at household level (%)</th></tr>
<tr><td>By 2030, the share of final household consumption which is wasted at the household level is 30%, unchanged from 2010. Based on USDA Economic Research Service estimates that 31% of food produced in 2010 was wasted at the consumer or retail levels (Buzby et al., 2014).</td><td colspan="2">By 2030, the share of final household consumption which is wasted at the household level is 15%. Based on US EPA and USDA announced a goal of reducing food waste by 50% by 2030, relative to 2010 levels (USDA, 2016).</td></tr>
</table>

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: • 149 million tonnes of corn production • 7.1 million tonnes of soy oil production • 0.75 million tonnes of rape oil production Based on (USDA, 2020b) (NoChange scenario selected)		By 2050, biofuel production accounts for: • 69 million tonnes of corn production • 1.2 million tonnes of soy oil production • 0.75 million tonnes of rape oil production • 180 million tonnes of miscanthus production • 135 million tonnes of switchgrass production Miscanthus and switchgrass values were estimated using absolute dry tonnes of herbaceous biomass selected in the "100% Renewable Energy" scenario in the latest Deep Decarbonization Pathways Project for the US (Williams et al., Manuscript submitted for publication). Since the herbaceous biomass feedstocks were not specified in the DDPP study, we allocated the herbaceous biomass demand to specific feedstocks using the supply curve in the Billion Ton Study (Langholtz et al., 2016),assuming the 2040 supply would hold into 2050. (DedicatedBiomassFeedstocks scenario selected)

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.	

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)

Annex 4. Overview of biodiversity indicators for the current state at the ecoregion level[4]

	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 at > 10% natural vegetation within 1km²(%)
0	Rock and Ice	2797.391	62.2	55.2	59.9	40.1	0.082	100
326	Sierra Madre Occidental pine-oak forests	142.646	65.3	92.5	66.8	33.2	1.068	99.2
327	Sierra Madre Oriental pine-oak forests	371.191	15.6	69.3	16.5	83.5	0.277	100
328	Allegheny Highlands forests	7328.939	2.4	48.9	4.2	95.8	212.668	79
329	Appalachian mixed mesophytic forests	18177.539	3	41.8	6.4	93.6	287.68	85.2
330	Appalachian Piedmont forests	16649.703	1.1	19.4	4.3	95.7	143.571	96
331	Appalachian-Blue Ridge forests	16360.194	5.4	35.1	14	86	706.011	66.4
332	East Central Texas forests	5592.954	0.5	1.3	16	84	484.344	87.1
333	Eastern Canadian Forest-Boreal transition	1.203	0	1.9	0	0	0.018	5.6
334	Eastern Great Lakes lowland forests	4048.532	1.3	18.3	3.9	96.1	630.044	63.7
336	Interior Plateau US Hardwood Forests	12375.712	2.8	14.9	15.1	84.9	1177.102	61.8
337	Mississippi lowland forests	11554.262	7.8	29.9	18.2	81.8	6926.191	16.2
338	New England-Acadian forests	16932.843	11.6	65.9	15.8	84.2	214.291	76.5
339	Northeast US Coastal forests	7338.533	3.3	10.8	13	87	449.053	69.4
340	Ozark Highlands mixed forests	10658.501	4	23.6	14.7	85.3	213.286	76.8
341	Ozark Mountain forests	6965.461	12.1	32.1	34.8	65.2	113.739	57.5
342	Southern Great Lakes forests	20317.789	1.1	7.4	7.2	92.8	12314.559	23.6
343	Upper Midwest US forest-savanna transition	13643.006	3.8	14.8	15.5	84.5	5708.151	45.3

4 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.

United States of America

	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 at > 10% natural vegetation within 1km²(%)
344	Western Great Lakes forests	21544.308	16.3	69.7	21.2	78.8	697.748	66
346	Arizona Mountains forests	11118.532	10.2	90.2	11.2	88.8	14.174	97.9
347	Atlantic coastal pine barrens	1421.599	20	26	56.5	43.5	153.115	62.5
348	Blue Mountains forests	7091.559	10	56.2	16.9	83.1	467.539	54.9
349	British Columbia coastal conifer forests	154.28	96	99.8	96.1	3.9	0.144	100
351	Central Pacific Northwest coastal forests	4067.648	8.3	63.6	12.1	87.9	21.097	83.7
352	Central-Southern Cascades Forests	5886.951	17.9	79.7	21.9	78.1	15.612	91.4
353	Colorado Rockies forests	14591.534	14.3	78.9	17.4	82.6	199.435	93.1
354	Eastern Cascades forests	5328.215	7.1	65.3	9.3	90.7	284.628	51.2
356	Great Basin montane forests	891.288	49.4	97.8	50.5	49.5	11.542	98.5
357	Klamath-Siskiyou forests	4839.941	15.7	83.1	18.7	81.3	197.848	64.5
358	North Cascades conifer forests	2883.045	42.7	85.1	49.1	50.9	33.075	78.6
359	Northern California coastal forests	1359.331	19	73.8	23.6	76.4	9.904	97.2
360	Northern Pacific Alaskan coastal forests	6080.004	41.3	87.8	42.6	57.4	0.048	100
361	Northern Rockies conifer forests	10078.462	12.4	74.8	16.3	83.7	500.118	50
363	Piney Woods	15257.479	3.3	25.5	10.9	89.1	454.661	62.1
364	Puget lowland forests	1691.345	6.8	24.5	18.1	81.9	196.416	48.1
366	Sierra Nevada forests	5319.048	33	78.1	41.4	58.6	77.128	90.2
367	South Central Rockies forests	17676.946	30.5	78.6	38	62	359.8	86.1
368	Wasatch and Uinta montane forests	4575.02	9	63.2	13.3	86.7	86.446	77.3
369	Alaska Peninsula montane taiga	4738.935	82.7	89.6	81.9	18.1	0	0

	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 at > 10% natural vegetation within 1km^2(%)
371	Cook Inlet taiga	2754.208	30.9	90.3	33.3	66.7	10.519	64.4
372	Copper Plateau taiga	1719.222	29.5	98.1	29.8	70.2	0.565	98.9
375	Interior Alaska-Yukon lowland taiga	40375.202	33	98.2	33	67	38.158	45
384	Western Gulf coastal grasslands	7539.74	15.1	27.4	18	82	2921.827	40.2
385	California Central Valley grasslands	4641.757	4.2	10.3	24	76	3333.649	13.4
386	Canadian Aspen forests and parklands	13479.102	2.5	4.5	20	80	9973.446	22.4
387	Central US forest-grasslands transition	22858.296	2.7	8.9	18.6	81.4	15231.917	21.2
388	Central Tallgrass prairie	34277.944	1.6	3	23.1	76.9	22281.066	20
389	Central-Southern US mixed grasslands	27544.796	0.7	1.4	30.4	69.6	13818.664	37.4
390	Cross-Timbers savanna-woodland	8841.934	1.1	2.9	22.4	77.6	778.955	88.6
391	Edwards Plateau savanna	7520.742	1.3	20.5	4	96	700.299	85.3
392	Flint Hills tallgrass prairie	2797.676	1.8	51.6	3	97	366.302	62.5
393	Mid-Atlantic US coastal savannas	7800.107	10.8	31.9	27.3	72.7	1507.429	65.8
394	Montana Valley and Foothill grasslands	8516.214	4	28.2	9.4	90.6	1152.428	69.3
395	Nebraska Sand Hills mixed grasslands	5916.429	1.5	1.4	73.9	26.1	365.128	59.2
396	Northern Shortgrass prairie	49522.636	2	11.3	14.4	85.6	11962.205	47
397	Northern Tallgrass prairie	4502.942	4.6	7.2	39.2	60.8	4106.711	8.8
398	Palouse prairie	8309.87	4.1	20.5	15.9	84.1	3746.626	23.9
399	Southeast US conifer savannas	52180.677	4	27.5	11.3	88.7	5795.546	67.4
400	Southeast US mixed woodlands and savannas	2.761	12.3	24.8	18	82	0.123	57.7
401	Texas blackland prairies	4351.485	0.4	0.6	25.7	74.3	919.079	65.8

United States of America

	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 at > 10% natural vegetation within 1km²(%)
402	Western shortgrass prairie	48807.714	0.8	12.7	2.7	97.3	13865.852	36
403	Willamette Valley oak savanna	1488.557	1.9	15.2	6	94	674.559	26.2
404	Ahklun and Kilbuck Upland Tundra	5055.961	64.8	97	64.5	35.5	0	0
405	Alaska-St. Elias Range tundra	14073.245	37.8	86.9	34.2	65.8	5.969	96.7
406	Aleutian Islands tundra	1166.35	98	85	97.5	2.5	6.674	91.8
407	Arctic coastal tundra	4869.864	3.9	85.2	4.2	95.8	0	0
408	Arctic foothills tundra	12340.389	20.4	97.6	20.3	79.7	0	0
409	Beringia lowland tundra	14866.532	65.5	88.2	65	35	1.262	98.3
410	Beringia upland tundra	4628.804	20.1	97.7	19.5	80.5	0.009	100
411	Brooks-British Range tundra	13312.139	69.8	99	69.7	30.3	0	0
416	Interior Yukon-Alaska alpine tundra	11445.23	31.2	99.7	31.3	68.7	0.871	97.6
419	Ogilvie-MacKenzie alpine tundra	1067.177	29.3	98.8	29.1	70.9	0	0
420	Pacific Coastal Mountain icefields and tundra	8051.337	48.7	70.4	44.4	55.6	3.052	98.6
422	California coastal sage and chaparral	2100.64	7.7	27.8	24.4	75.6	106.521	69.4
423	California interior chaparral and woodlands	7204.237	5.9	23.9	18	82	817.114	81
424	California montane chaparral and woodlands	1588.158	29.5	79.2	36.5	63.5	54.396	94.4
425	Santa Lucia Montane Chaparral & Woodlands	471.688	26.8	57.2	44.7	55.3	22.783	97
428	Chihuahuan desert	19922.872	6	63.7	8.8	91.2	287.407	49.8
429	Colorado Plateau shrublands	28395.985	11	77.1	13.9	86.1	566.594	62.1
430	Great Basin shrub steppe	30126.797	7.7	84.1	9	91	1021.574	62.6
433	Mojave desert	12761.15	45.5	82	54.8	45.2	48.921	76.1

	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 at > 10% natural vegetation within 1km²(%)
434	Snake-Columbia shrub steppe	19329.658	15.8	55.9	26.8	73.2	2244.6	34
435	Sonoran desert	11869.828	19.2	47.5	39.4	60.6	634.012	34
437	Tamaulipan mezquital	5368.314	6.4	7.6	3.8	96.2	1363.909	76.1
438	Wyoming Basin shrub steppe	13276.438	3.5	55.9	5.3	94.7	529.427	81.2
581	Everglades flooded grasslands	1988.43	14.7	57.2	24	76	343.81	23.2
612	Bahamian-Antillean mangroves	376.928	86.1	70	94.7	5.3	1.672	82.5
623	Hawai'i tropical moist forests	670.724	13	70	18.2	81.8	84.564	53.8
636	Hawai'i tropical dry forests	659.281	15.7	45.4	29.4	70.6	106.944	36.8
639	Hawai'i tropical high shrublands	185.714	43	97.8	43	57	0	0
640	Hawai'i tropical low shrublands	144.352	8.3	35.8	17.9	82.1	20.888	46.2
641	Northwest Hawai'i scrub	0.049	100	71.4	88.6	11.4	0	0

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)

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

km^2 – square kilometer

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 – tonne per hectare, measured as the production divided by the planted area by crop by year

t/TLU, kg/TLU, t/head, kg/head- tonne per TLU, kilogram per TLU, tonne 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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