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The Food and Land Use Coalition

2019 Report of the FABLE Consortium

Pathways to Sustainable Land-Use and Food Systems

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2019 Report of the FABLE Consortium

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

USA

Grace C. Wu*[1], Justin Baker[2], Gordon McCord[3]

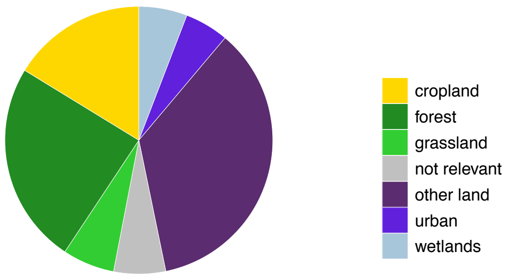
[1]The Nature Conservancy and Berkeley Lab, California, USA. [2]RTI International, Research Triangle Park, USA. [3]University of California, San Diego, USA
*Corresponding author: grace.cc.wu@tnc.org

Land and food systems at a glance

A description of all units can be found at the end of this chapter

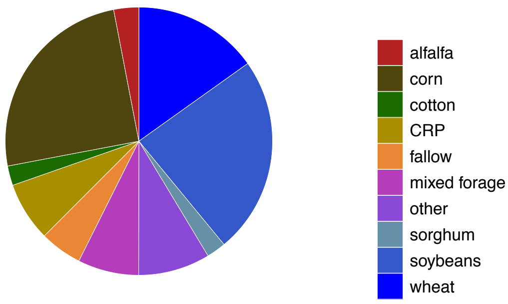
Land & Biodiversity

Fig. 1 | Area by land cover class in 2016



Source: Multi–Resolution Land Characteristics (MRLC) Consortium (2019)

Fig. 2 | Share of harvested area by crop in 2015



Source: US Department of Agriculture (2016)

No annual deforestation in 2015

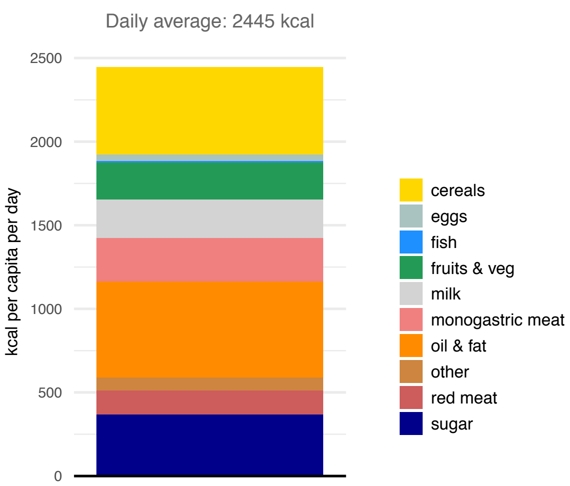
(FAOSTAT, 2019)

Endangered or threatened species: 2,275

(U.S. Fish and Wildlife Service, 2019)

Food & Nutrition

Fig. 3 | Daily average intake per capita at the national level in 2015



Source: US Department of Agriculture (2018)

Share of undernourished in 2015: 3 - 4.5%

(World Bank, 2019; U.S. Department of Agriculture, 2019a)

Share of obese in 2015: 39.6% of adults and 18.5% of children

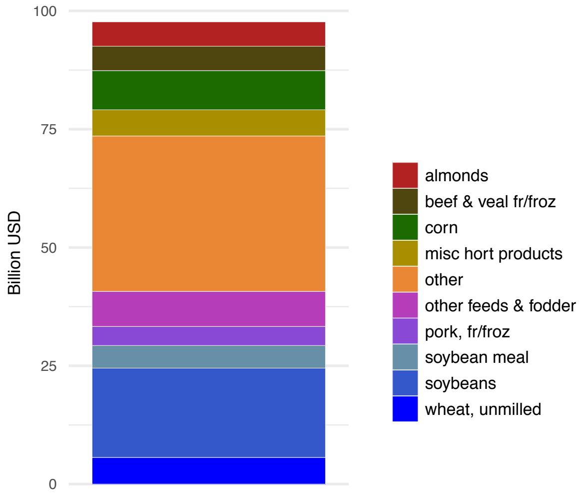
(Hales et al., 2017)

or 24.4% overall

(Ng et al., 2014)

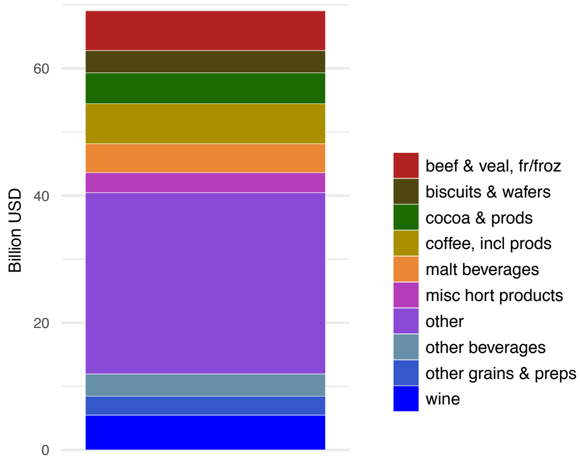
Trade

Fig. 4 | Main agricultural exports by value in 2015



Source: US Department of Agriculture (2019)

Fig. 5 | Main agricultural imports by value in 2015



Source: US Department of Agriculture (2019)

Surplus in agricultural trade: More than USD 10 billion, but declining since 2015

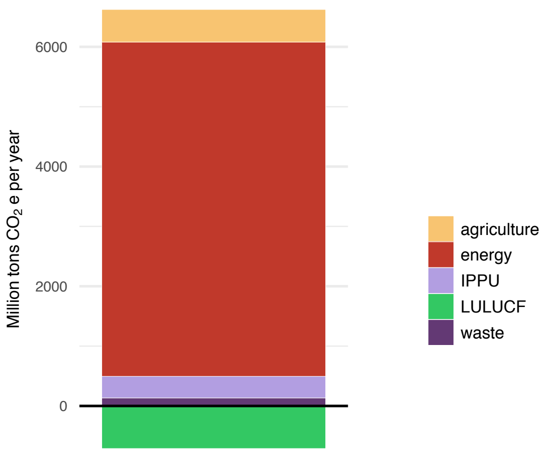
(U.S. Department of Agriculture, 2018)

Top exporter in the world in 2016

(World Bank, 2016)

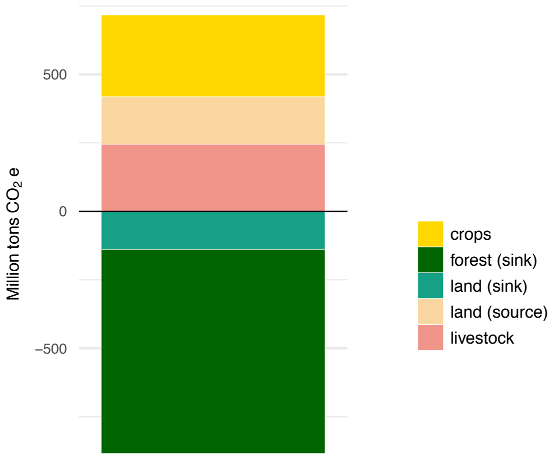
GHG Emissions

Fig. 6 | GHG emissions by sector in 2015



Source: US Environmental Protection Agency (2017a)

Fig. 7 | GHG emissions from agriculture and land use change in 2015



Source: US Environmental Protection Agency (2017a)

Main assumptions underlying the pathway towards sustainable land-use and food systems

For a detailed explanation of the underlying methodology of the FABLE Calculator, trade adjustment, and envelope analysis, please refer to sections 3.2: Data and tools for pathways towards sustainable land-use and food systems, and 3.3: Developing national pathways consistent with global objectives.

GDP GROWTH & POPULATION

	GDP per capita	Population
Scenario definition	GDP per capita is expected to increase from USD 16.6 tln, or USD 51,886 per capita, in 2015 to USD 31.8 tln, or USD 79,817 per capita, in 2050 (SSP2 selected)	The population is expected to increase by 0.6% per year between 2015 and 2050 from 319 mln to 398 mln (SSP2 selected)
Scenario justification	This is based on combined long-term projections from U.S. Congressional Budget Office, U.S. Department of Agriculture, The World Bank, IMF, United Nations, OECD, European Commission, and The Economist Intelligence Unit, which were aggregated by Knoema (2019).	Based on The US Census Bureau's report, "Projections of the Size and Composition of the US Population: 2014 to 2060" (Colby and Ortman, 2015).

TRADE

	Imports	Exports
Scenario definition	The share of the US consumption which is imported evolves: - from 38% in 2010 to 75% in 2050 for fish, - from 4% in 2010 to 8% in 2050 for tomatoes, - from 10% in 2010 to 21% for oranges, - from 15% in 2010 to 29% in 2050 for vegetables, and - from 14% in 2019 to 27% in 2050 for fruits. - Remains constant at 2010 share for other products	The exported quantity in 1000 t changes: - from 44% in 2010 to 54% in 2050 for wheat, - from 97% in 2010 to 92% in 2050 for soybean, - from 14.4% in 2010 to 23.3% in 2050 for corn, - from 9.2% in 2010 to 30% in 2050 for beef (from 1.1 mln tons to 3.3 mln tons), - from 18% in 2010 to 40% for chicken, and - from 12.2% in 2020 to 30% for pork. - Remains constant at 2010 quantity for other products
Scenario justification	The import assumptions reflect changes in dietary assumptions in the sustainable pathway scenario i.e. more fish, fruits, and vegetable consumption.	The assumption that US exports will increase is based on the expectation that global demand for grains and oilseeds will grow. Beef, chicken, and pork exports increase in alignment with reduced domestic demand for meat due to healthy dietary shifts and an anticipated increase in absolute beef demand globally due to the growing middle class in China and in an attempt to offset additional deforestation due to increased beef production Brazil.

Scenario signs no change small change large change

LAND	Land conversion	Afforestation
Scenario definition	We assume that there will be no constraint on the expansion of agricultural land beyond existing protected areas and under the total land boundary.	We assume a high level of afforestation with a total targeted afforested area of 40 Mha by 2050.
Scenario justification	The US has no land use policy prohibiting land conversion at the national level.	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 CO2 removal technologies are employed (The White House Council on Environmental Quality, 2016), 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 analysis (Fargione et al., 2018).

BIODIVERSITY	Protected areas
Scenario definition	The protected areas increase from 11% of total land in 2015 to 50% in 2050. However, this target does not assume that all land categorized to meet this target will meet the strict management standards of other state or federally protected areas.
Scenario justification	Otherland (grass and shrubland) and forest land cover types together made up almost 50% of land in the conterminous US in 2015. If at least 50% of all land in 2050 were capable of supporting biodiversity, that would effectively mean ensuring no conversion of existing otherland or forestland for human uses.

Scenario signs no change small change large change

FOOD

	Diet (large change)	Food waste (no change)
Scenario definition	Between 2015 and 2050, the average daily calorie consumption per capita decreases from 2,700 kcal to 2,500 kcal. Per capita consumption: - decreases by 50% for beef, - decreases by 50% for other meats, - increases by 5% for milk, - decreases by 47% for oils, - increases by 50% for other, including nuts, - decreases by 50% in eggs, - increases by 40% for pulses, - increases by 38% for roots, - decreases by 3% for sugar, - increases by 76% for fruit and vegetables, and - increases by 200% for fish.	By 2050, the share of final household consumption which is wasted remains stable at 10%.
Scenario justification	Based on the USDA "US Healthy Style Diet" (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015). Adjustments to the current average US diet were made to achieve the "US Healthy Style Diet" by 2050, which was converted from volumetric or weight specifications to calories using representative food types per category (e.g., apples, bananas, carrots, and spinach for "fruit and vegetables").	This is a more optimistic assumption than the official estimates: USDA Economic Research Service estimates that 31% of food produced in 2010 was wasted at the consumer or retail levels (Buzby et al., 2014). But in 2015, the US EPA and USDA announced a goal of reducing food waste by 50% by 2030, relative to 2010 levels, which would mean about 15% of all food produced would be wasted in 2030 (U.S. Department of Agriculture, 2016b).

Scenario signs no change small change large change

PRODUCTIVITY

	Crop productivity	Livestock productivity	Pasture stocking rate
Scenario definition	Between 2015 and 2050, crop productivity increases: - from 9.7 t/ha to 13.7 t/ha for corn, - from 3.1 t/ha to 7.8 t/ha for wheat, and - from 3 t/ ha to 4.4 t/ha for soybean.	Between 2015 and 2050, the productivity per head increases: - from 128 kg/head to 166 kg/ head for beef, - from 1 kg/head to 1.6 kg/head for chicken, and - from 8.8 t/head in 2015 to 10.8 t/head in 2050 for cow's milk.	The average ruminant livestock stocking density remains constant at 0.42 TLU/ha of pastureland between 2015 and 2050.
Scenario justification	Based on US Department of Agriculture (USDA) Agricultural Projections to 2028 report (U.S. Department of Agriculture, 2019b). The following are the actual projections from the report: - Corn increases from 11.08 t/ha in 2017/18 to 12.2 t/ha in 2028 (assuming the same productivity improvement rate, then it is 14.7 in 2050). - Wheat increases from 3.1 t/ha in 2010 to 3.4 t/ha in 2028 (assuming the same productivity improvement rate, then it is 4.2 in 2050). - Soybean increases from 3.3 t/ha in 2010 to 3.6 t/ha in 2028 (assuming the same productivity improvement rate, then it is 4.9 t/ha in 2050).	Based on USDA Agricultural Projections to 2028 report (U.S. Department of Agriculture, 2019b). The following are the actual projections from the report: - USDA does not report productivity per head; instead, national production of 26,187 mln pounds of beef and 93,702,000 cattle in inventory in 2017 were used to calculate the following productivity values. As a result of this calculation, these values may not be directly comparable with those used in the Calculator. - Beef productivity increases from 127 kg/head in 2017 to 148 kg/head in 2028 (assuming the same productivity improvement rate, then it is 201 kg/head in 2050). - The U.S. team was unable to find equivalent stats by head for chicken. - Milk productivity increases from 10.4 t/head in 2017 to 12 t/head in 2028 (assuming the same productivity improvement rate, then it is 16 t/head in 2050)	No data on US national average livestock stocking densities to compare this value with.

Scenario signs no change small change large change

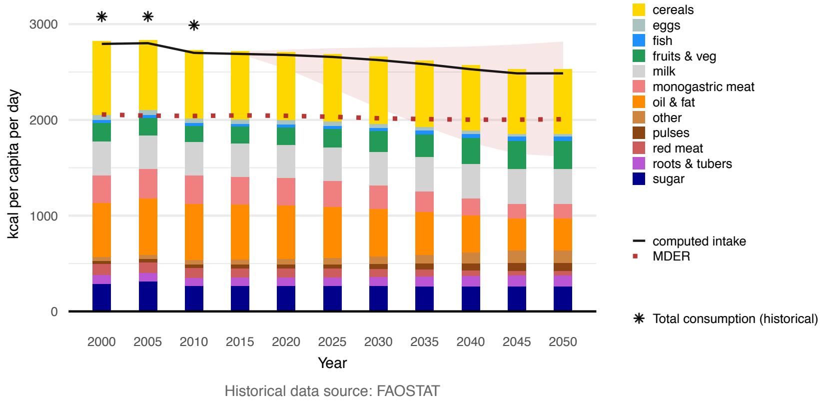
Results against the FABLE targets

The results for FABLE targets as well as "other results" are based on calculations before global trade harmonization.

Food security

Fig. 8 | Computed daily kilocalorie average intake per capita over 2000-2050

Note: The Minimum Daily Energy Requirement (MDER) is computed based on the projected age and sex structure of the population and the minimum energy requirements by age and sex for a moderate activity level. Animal fat, offal, honey, and alcohol are not taken into account in the computed intake. The pink envelope shows the range of the evolution of the daily kilocalorie intake per capita across a large number of combination of scenarios in the US FABLE calculator.

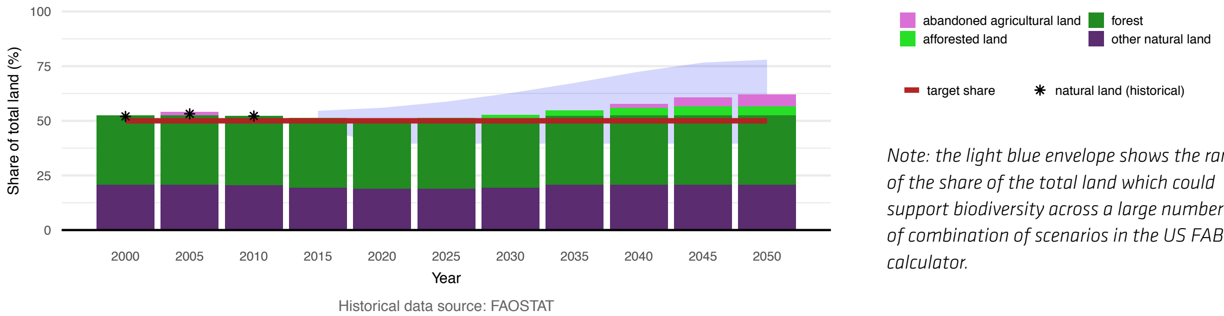


Our results show average daily energy intake per capita decreases from 2,650 to 2,500 kcal/cap/day from 2000-2050. Historical values are 30% lower than FAO's report due to some products not being accounted for in our calculation. Over the last decade, 30% of the food intake came from cereals.

In terms of recommended diet, our results show lower consumption of meats, eggs, oils and higher consumption of fish, fruits and vegetables, roots, and pulses. The computed surplus of average calorie intake compared to the MDER at the national level reduces over time and reaches 20% in 2050. This should not threaten the food security objective as there is a high prevalence of obesity in the US (~40%). However, this shift will be extremely challenging to achieve given that recent USDA projections show increasing per capita meat and egg intake.

Biodiversity

Fig. 9 | Computed share of the total land which could support biodiversity over 2000-2050



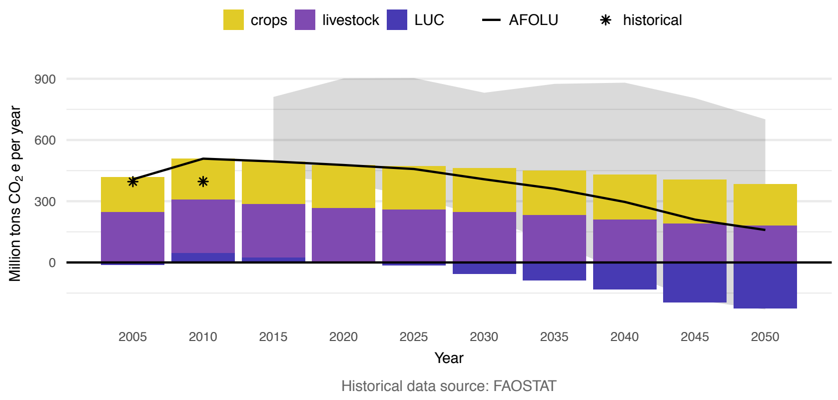
Note: the light blue envelope shows the range of the share of the total land which could support biodiversity across a large number of combination of scenarios in the US FABLE calculator.

Our results show that the Share of Land which can support Biodiversity (SLB) remained fairly constant between 2000-2015 at around 54%. The lowest SLB is computed for the period 2015 to 2030 at 52.4% of total land. This is mostly driven by otherland conversion to cropland. SLB reaches 60% over the last period of simulation 2046-2050. This difference is explained by reaching the afforestation target of 40 Mha and increasing otherland after agricultural land abandonment due to diet shifts.

Compared to the global target of having at least 50% SLB by 2050, our results are above the target. There are no national policy commitments to which the US could calibrate assumptions.

GHG emissions

Fig. 10 | Computed GHG emissions from land and agriculture over 2000-2050



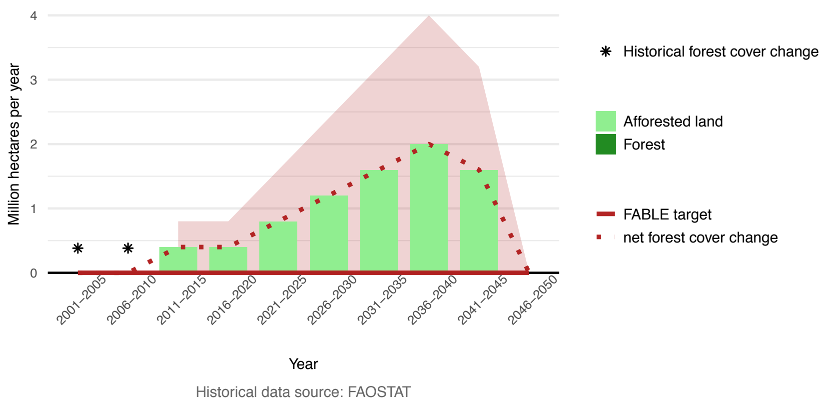
Note: AFOLU (Agriculture, Forestry and Other Land Use) is the sum of computed GHG emissions from crops, livestock and Land Use Change (LUC), emissions and sequestration from forestry are not included. Historical emissions include crops, livestock, land use change and carbon sequestration in grasslands and forests. The grey envelope shows the range of the evolution of the total net AFOLU emissions across a large number of combination of scenarios in the US FABLE calculator.

Our results show annual gross GHG emissions between 320 and 500 Mt CO_2eq from 2000-2050, which decrease over time. Agriculture sector emissions align reasonably with the US GHG Inventory (Environmental Protection Agency, 2017a), but LUC and forest sector emissions diverge substantially. From 2025 onward, LUC emissions are negative (indicating a positive net sink), driven by high levels of reforestation due to the reforestation target and pastureland abandonment. The historic carbon emissions from land use and LUC differ from observed inventory estimates (which indicate a net carbon sink from US LULUCF) and recent projections of forest carbon fluxes that show a declining (e.g., Wear and Coulston, 2015; Latta et al., 2018) or a slightly increasing sink (Tian et al., 2018). These publications, along with the US GHG Inventory, show a significant annual forest carbon flux attributed to aboveground carbon storage on existing forests. This flux source is not represented in the FABLE Calculator, hence we are under-representing the projected LULUCF flux and net abatement potential that the land-use sectors could provide.

Compared to the global target of reducing emissions from agriculture and reaching zero or negative GHG emissions from LULUCF by 2050, our results exceed the target.

Forests

Fig. 11 | Computed forest cover change over 2000-2050



Our results show no annual deforestation, which is consistent with recent US trends as reported by the FAO (2016). Afforestation results over 2010-2020 are similar compared to other sources that model forest area increase of 5 Mha and historical rate of forest increase of about 705 kha per year between 2007 and 2012 (Wear and Coulston, 2015; Tian et al., 2018). We assume afforestation of 40 Mha from 2015 to 2045: 10% from cropland, 10% from pastureland, and 80% from otherland. While this is significantly higher than current policies and programs in place for incentivizing reforestation (e.g., Conservation Reserve Program target of 9.7 Mha, Hellerstein, 2017), it is consistent with technical feasibility studies (Fargione et al., 2018). The ratio of projected afforestation between cropland and pasture is consistent with findings in Cai et al. (2018).

Compared to the global target of having zero or positive net forest change after 2030, our results are above the target.

Other relevant results for national objectives

Table 1 | Other Results

Variable	Unit	2000	2005	2010	2015	2020	2030	2040	2050
Beef Production. Imports and Exports									
Production (historical)	Mt	12.3	11.2	12.0					
Production (calculated)	Mt	12.1	11.1	11.9	12.2	12.5	12.5	11.4	10.9
Imports (calculated)	Mt	0.2	1.4	0.0	0.0	0.0	0.0	0.0	0.0
Exports (calculated)	Mt	0.0	0.0	0.0	0.2	0.3	1.2	2.6	3.3
Land-Use Change									
Cropland (historical)	Mha	178	168	159					
Cropland (calculated)	Mha	178	168	159	161	161	161	156	143
Pasture (historical)	Mha	236	244	250					
Pasture (calculated)	Mha	232	227	251	255	257	247	213	188
Forest (historical)	Mha	300	302	304					
Forest (calculated)	Mha	300	300	300	300	300	300	300	300
Afforested land (calculated)	Mha	0	0	0	2	4	14	32	40
Other land (historical)	Mha	202	202	202					
Other land (calculated)	Mha	197	210	194	184	176	172	184	213
Urban (calculated)	Mha	9	11	12	14	17	23	31	32

Source historical data: FAOSTAT

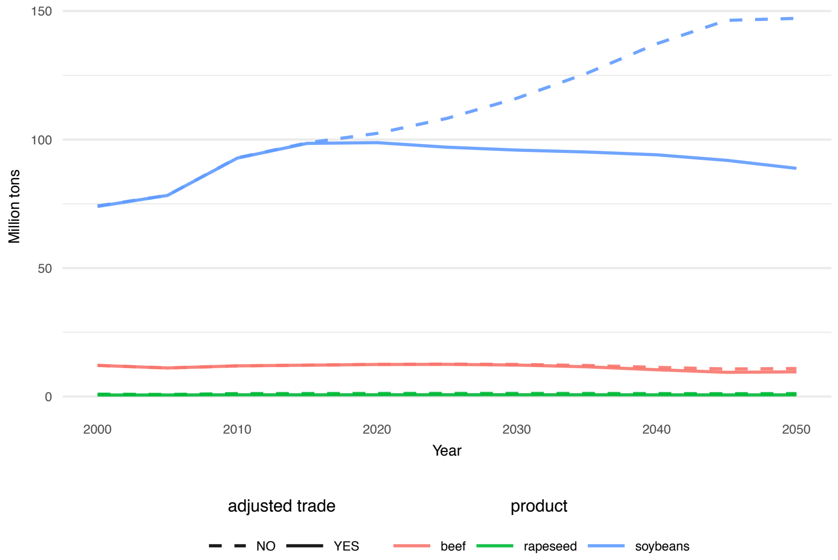
Domestic beef production has historically been high, with imports and exports comprising much smaller fractions of the beef market. Between 2015 and 2050, beef production would peak in 2025 and decline to below 2005 levels by 2050. This trend is due to healthy dietary shifts that reduce beef consumption per capita by 50% by 2050, which allows for the surplus in domestic production to be exported.

Soybean production under a sustainable land-use pathway is expected to continue increasing, primarily to meet export demand. Vegetable production declined between 2000 and 2010, but due to healthy dietary shifts, vegetable production and imports are expected to increase significantly.

The FABLE Calculator is generally able to back-cast historic land-cover trends (with pasture in 2005 being a minor exception). The sustainable land-use pathway designed here results in slightly increasing cropland extent from 2015 until around 2035, after which cropland area begins a slow and steady decline through 2050. Pastureland extent also increases slightly between 2015 and 2025, after which it declines rapidly through 2050. Otherland decreases between 2015 and 2025 due to the combined expansion of cropland, pastureland, and urban areas, but starts to make a steady recovery to 2005 levels by 2050 due to cropland and pastureland contraction.

Impacts of trade adjustment to ensure global trade balance

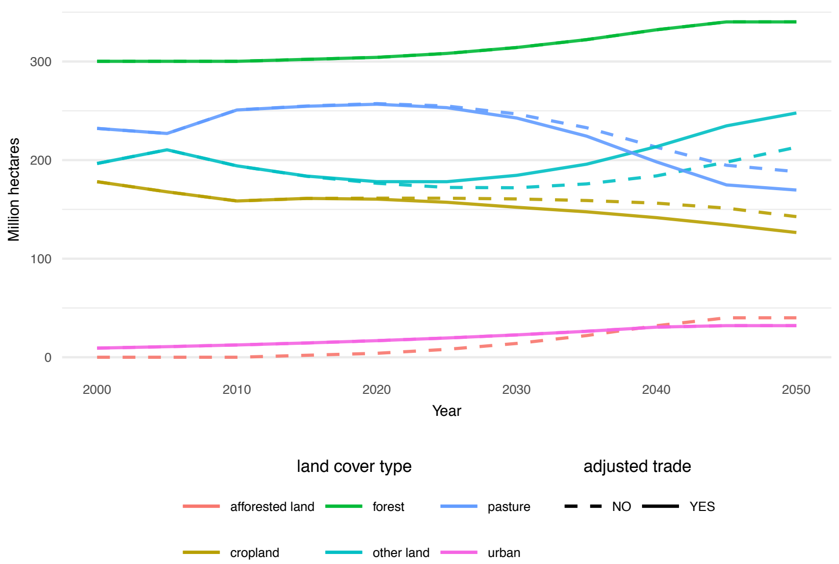
Fig. 12 | Impact of global trade harmonization on main exported/imported commodities over 2000-2050



US exports of soybean, rapeseed, and to lesser extents, wheat and beef were reduced compared to the values presented in the preceding table.

Coffee imports decrease after trade adjustments. In light of reduced imports, and to meet per capita growth projections, US coffee production must increase from 13kt in 2050 to 1.4Mt. This seems unlikely unless Hawaii and Puerto Rico significantly expand production.

Fig. 13 | Impact of global trade harmonization on land use over 2000-2050



The most significant impacts of trade adjustment were on beef and soy exports. As a result, domestic production of these two commodities decreased, causing more cropland to otherland and pasture to otherland conversion. In total, otherland increased about 30 Mha.

Discussion and next steps

In the absence of federal policy targets or results for many of the Sustainable Development Goals explored in this report, the sustainable land-use pathway presented here is based on the US modeling team's assumptions, commitments in the federal government's Mid-Century Strategy report (The White House Council on Environmental Quality, 2016), and the most recent available literature. As a general principle, we strove to meet the four FABLE targets at the national level and participated in the Scenathon with the intention of minimizing international supply chain related land-use impacts.

While nutritional health is not a target, we chose to examine co-benefits of healthy diets on achieving sustainable land use domestically and, through the Scenathon, globally. Of all the assumption modifications made in the Calculator (population, imports, exports, food waste, productivity of crops and livestock, and diets), we find that land-use and land-cover trajectories, as well as greenhouse gas emissions from the agricultural sector, are highly sensitive to diet and productivity assumptions - and it is the combination of the two, rather than one alone, that lead to a sustainable land-use trajectory. If we assumed no crop or livestock productivity changes and current diet composition, there would be an increase in cropland production of 12 Mha by 2050 compared to 2010, but an increase in pastureland of 62 Mha over the same period. However, if we assumed high crop and livestock productivity, there would actually be a decrease in cropland of 12 Mha and an increase in pastureland of 34 Mha (halving the amount of pastureland growth, compared to the BAU productivity and diet scenario). If we assumed only a shift from today's diet to the "Healthy US-style diet" recommended by the USDA, there would be an increase in cropland of 18 Mha, but a decrease in pastureland of 33 Mha. It was the combination of the healthy diet shift and high productivity assumptions that would lead to stable or declining area of cropland and pastureland by 2050 - with about 15 Mha reduction in cropland and 80 Mha reduction in pastureland. Recognizing the drastic reduction in pastureland and the potential for the US to offset deforestation resulting from the potential rising demand for beef globally, we decided to triple the quantity of beef exports from the US by 2050. However, many other countries also adopted sustainable diets in their pathways, and thus, trade adjustments addressed the surplus of beef on the global market by reducing the amount of exports from the US to be just twice the historic quantity (2,200 Mt in 2050 vs. 1,100 Mt in 2010).

These productivity and diet assumptions enable ambitious natural climate solution implementation in ways that do not compete for productive uses of land. Of the 95 Mha of crop and pastureland that could be taken out of productive use by 2050, 40 Mha could be reforested as one of many activities making up a suite of mitigation and sequestration targets necessary to achieve 80% economy-wide greenhouse gas reductions below 2005 levels by 2050, as outlined in the US Mid-Century Strategy report (The White House Council on Environmental Quality, 2016). The 40 Mha target is approximately consistent with meeting the reforestation target needed if no other CO2 removal technologies were deployed by 2050 (e.g., Bioenergy with Carbon Capture and Sequestration or Direct Air Capture) (The White House Council on Environmental Quality, 2016).

We have identified six key limitations of the US FABLE Calculator that warrant additional consideration in future iterations.

First, we do not explicitly include bioenergy, including first- and second-generation biofuels expected under the US federal Renewable Fuels Standard requirements, which, if met, would require a large allocation of US land resources (Environmental Protection Agency, 2015). Furthermore, several longer-term climate stabilization pathways (The White House Council on Environmental Quality, 2016) and Intergovernmental Panel on Climate Change (2018) rely heavily on large-scale investments in technologies like bioenergy with carbon capture and sequestration (BECCS) to produce negative emissions sources. Understanding the impacts on other land uses are a critical component of trade-offs between these very different climate mitigation pathways. We currently do not account for the land resource requirements of BECCS expansion in the US to hit climate stabilization targets; instead, we focus on land use activities that increase carbon sequestration on the landscape (e.g., re/afforestation).

Second, we do not account for the land use requirements of other conventional (natural gas) or renewable (wind and solar) energy technologies, which could have significant land requirements by mid-century. Trainor et al. (2016) anticipate that the total land use requirements, which account for spacing between wind turbines and natural gas wells, would be equivalent to the land area of the state of Texas, and direct land requirements would be equivalent to the land area of the state of South Dakota.

Third, we do not consider the role of forest management on land-use and carbon outcomes. Management interventions in forestry can increase carbon uptake (Tian et al., 2018), but can also raise important biodiversity concerns when switching from naturally regenerated stands to monoculture plantations (Paillet et al., 2010). Future iterations of this Calculator and land-sector projections should attempt to differentiate between naturally regenerated (non-managed) and planted (intensively managed) forest systems.

Also, in developing the US sustainable land-use pathway the US FABLE team identified several data inconsistencies between FAO sources that provide the basis of the FABLE Calculator and more detailed US sources. While US statistics are the primary source for FAO reported US data, information is aggregated in a way that makes calibration difficult for the US Calculator. One example is the FAO land use categorization system that is used in the Calculator - this system differs from land-use categories defined in widely utilized land-use/land-cover statistics in the US, including the USDA Major Land Use Database, the Natural Resources Inventory, and National Land Cover Database. US land-use/land-cover datasets are often used to calibrate land resource availability in US-focused models (Jones et al., 2019). Moving from a more detailed land categorization system to the FAO aggregates presents challenges in reconciling differences in key land categories such as cropland (e.g., the FAO does not distinguish between "cropland," which is used for direct crop production, and "cropland pasture," which is not actively cultivated for crop production but is part of the permanent crop rotation in the US). Future efforts will identify key underlying data differences in coordination with other members of the FABLE Consortium, as well as approaches to better reconcile global and national data inconsistencies.

Fourth, while we account for potential land resource constraints on pursuing different biodiversity, climate, and healthy diet policy aspirations, we do not explicitly address other resource constraints. For instance, water availability and quality can limit growth in agricultural production (and forestry), and could pose local constraints for future investments in specialty crop production to hit healthy diet targets, though these dietary pathways can be water-saving globally relative to business as usual (Willett et al., 2019). Furthermore, agricultural water requirements could increase substantially with bioenergy or BECCS expansion for longer-term climate mitigation goals (Beringer et al., 2011). Climate change could exacerbate this concern in some regions of the US as higher temperatures and shifting precipitation patterns increase the demand for irrigation water (Environmental Protection Agency, 2017b; Baker et al., 2018). Future integrated assessment modeling efforts that explicitly recognize regional water constraints could inform future versions of this Calculator, resulting in more robust trade-off analysis of alternative land-sector pathways.

Fifth, average diet assumptions are overly simplistic, and given that the Calculator is a demand-driven model, more accurately or realistically representing the demand for specific food types will be important for improving the model. Additionally, assuming an average "US-Style Healthy Diet" for the entire population does not lend itself well to understanding the impacts of ongoing trends in dietary preferences (e.g., vegetarian, flexitarian diets, plant-based meat substitutes). Thus, constructing average diets using a "bottom-up" approach based on percentage of population adopting different diets could help in understanding the sensitivity of emerging or novel dietary choices and products on land-use pathways.

Finally, productivity values for crops and livestock are based on linear extrapolations of historic trends. Future versions of the Calculator or partial equilibrium land-use models should account for the counteracting effects of climate change on productivity.

There are no specific policy targets in the US currently that would increase the level of ambition in the sustainable land-use pathway as a whole. However, several policy proposals that have recently been put forward for debate have the potential to interact with the specific land-use sector targets outlined in this narrative. First, a national clean energy standard (NCES) announced in May 2019 is currently being debated (Morehouse, 2019). A US NCES would create additional competition in the land-use sectors for renewable energy development, which would potentially conflict with food production and healthy diet goals but could reduce greenhouse gas emissions from the energy and industrial sectors substantially. Ambitious policy frameworks such as the Green New Deal could have similar implications. Emerging proposals to increase fossil energy extraction on public lands in the US should also be addressed in future iterations of this Calculator. Likewise, various state-level proposals to increase management or timber removals on public forestland to reduce wildfire risk could have land carbon and biomass supply implications.

Nearly half of the states have joined the US Climate Alliance, which commits member states to reduce greenhouse gas emissions 26-28% below 2005 levels by 2025. Several Climate Alliance states have passed legislation to achieve far more ambitious mid-century targets, including 80-85% GHG reductions below 1990s levels by 2050 (California and New York) and 100% clean and renewable energy targets by 2040-2050 (Hawaii, California, New Mexico, Washington, and New York). Even without an NCES, these regional or state-level commitments could result in a sizable demand for land use to support low-carbon electricity as well as natural and working land climate solutions (e.g., reforestation, increase soil carbon sequestration).

While technologically advanced, the US would benefit from increased investments in agricultural research related to specialty crops (e.g., fruits, vegetables and nuts) that would comprise a higher share of total caloric intake and agricultural area under a healthy diet future. Current agronomic knowledge of these systems in the US context lags scientific knowledge of primary grains and oilseeds produced in the US. If dietary shifts are driven by policy, preference changes, or environmental conditions, new scientific research on non-traditional crops (e.g., pulses) is needed to enhance the resilience of the US food supply system.

One of the key levers for achieving sustainable land use in this pathway is shifting dietary preferences to a healthy US style diet - which effectively requires reversing recent historical trends of increasing red meat, poultry, and dairy consumption per capita. Under current 2015 diet assumptions for the US and "Middle of the Road" GDP and population growth assumptions, the amount of otherland (primarily grass and shrubland) converted to pasture land must increase from 249 Mha to 293 Mha in 2040 and 283 Mha in 2050. With the exception of importing more meat products or feed, no other combination of reasonable pathway levers (e.g., crop productivity, food waste) can achieve a stable or declining trajectory for land under agricultural use. Healthier dietary choices can be encouraged and incentivized through stronger educational campaigns and removing direct and indirect subsidies for the dairy and meat industries so that commodity prices most closely reflect the true cost of production.

Another primary challenge in implementing a sustainable land-use pathway in the US is resistance to regulation on the part of landowners and managers and the political feasibility of ambitious land-use sector policies. It is important to note that while the assumptions developed for this US sustainable land-use pathway are based on information in publicly available reports, databases, and peer reviewed literature, this pathway does not represent current policies or programs being implemented at the US federal level, and are thus hypothetical policy targets. However, the Calculator and its sustainable land-use scenario provide key information on potential trade-offs associated with ambitious land sector policy goals. In the absence of strong policy incentives, private sector leadership and philanthropic contributions can also help advance sustainable land-use goals, so the FABLE Consortium and country-level sustainable land-use pathways can help inform investment strategies for these non-governmental entities.

The analysis for land use policy design should be based on a unified and consistent set of assumptions. For example, consistent definitions of land cover type (pastureland, grassland, forest) across various federal agencies could avoid mis-interpretation of model assumptions on land-cover conversion. Future approaches should also be detailed enough - spatially and in terms of sector representation - to support land use decisions at state or regional levels given that land conservation and natural resource management requires highly spatially explicit planning.

Units

% – percentage
bln – billion

cap – per capita

CO_2 – carbon dioxide

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

GHG – greenhouse gas

Gt – gigatons

ha – hectare

kcal – kilocalories

kg – kilogram

kha – thousand hectares

km^2 – square kilometer

kt – thousand tons

Mha – million hectares

mln – million

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

tln – trillion

USD – United States Dollar

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