The Food and Land Use Coalition

Environmental and agricultural impacts of dietary shifts at global and national scales

FABLE Policy Brief
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The Food, Agriculture, Biodiversity, Land-Use, and Energy (FABLE) Consortium

Contents

Headlines

- Integrated pathways can highlight system-wide implications of dietary shifts and help countries prepare for this transition.
- We use the FABLE modelling framework that connects 20 countries' national food and land use system models and 6 rest-of-the-world regions through international trade.
- Shifts towards healthier diets could cut global green-house gas (GHG) emissions from Agriculture, Forestry and Other Land Use (AFOLU) by half and reduce forest loss by 20% over the period 2030-2050 compared to Current Trends.
- Using country examples, we show contrasted potential impacts of transition towards healthier diets on agricultural trade balance and agricultural production by 2050.
- During this transition, impacts of higher production of nuts, fruits and vegetables on local water use should be carefully monitored.
- Long-term planning is necessary to ensure a feasible, fair, and acceptable transition, especially for the livestock sector in northern and meat exporting countries.

About FABLE

The Food, Agriculture, Biodiversity, Land-Use, and Energy (FABLE) Consortium is a collaborative initiative to support the development of mid-century national food and land-use pathways consistent at the global level that could inform policies towards greater sustainability. FABLE is convened as part of the Food and Land Use Coalition (FOLU). The Consortium brings together teams of researchers from 20 countries and international partners from the Sustainable Development Solutions Network (SDSN), the International Institute for Applied Systems Analysis (IIASA), the Alliance Bioversity-CIAT, and PIK. FABLE has published two reports in 2019 and 2020 which further describe the approach, tools, and resulting national and global pathways of the food and land-use systems.

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1. Diets at the center of the food and land-use systems

Food production uses more than one third of the world's ice and desert-free land.

Diets are a major determinant for human and planetary health. In the last 60 years, world population has more than doubled. Meeting the food demand for this growing population has been a tremendous achievement in many countries but this came at a high environmental cost. The agricultural system covers almost 43% of the world's ice- and desert-free land[1], out of which around 87% is for food[2]. Between a quarter and a third of the global anthropogenic GHG emissions are generated by the food system[2,3].

The global burden of diet related non-communicable diseases has been continuously growing over the last decades. In 2017, 22% of deaths among adults were attributable to dietary risk factors globally, with cardiovascular diseases, cancers, and diabetes as the leading cause. A high intake of sodium, and low consumption of whole grains and fruits accounted for over half of diet-related deaths; while a high consumption of red meat, processed meat, sugar-sweetened beverages, and trans fatty acids were attributable to the other half[4].

We compute three alternative mid-century pathways of the food and land systems for 20 countries and 6 rest-of-the world regions.

A transition towards healthier diets could deeply transform our food systems and help achieve the Paris Climate Agreement[5,6]. This transition, however, needs to be well prepared as diet shifts can have major effects for land use, food value chains, trade patterns, and livelihoods of rural and farming communities. Integrated pathways of the food and land-use systems can highlight some of these system-wide implications.

This brief presents results from the Food, Agriculture, Biodiversity, Land-Use, and Energy (FABLE) Consortium. Pathways by 2050 have been computed for 20 countries and six rest-of-the-world regions[7]. To assess the role of dietary shifts, we compare our results across three pathways:

- *Current Trends (CT)* depicts the lower boundary of feasible action towards environmental sustainability with a future based on current policy and historical trends.

- *Sustainable* corresponds to a high boundary of feasible action towards environmental sustainability. It includes the adoption of Healthier Diets in 15 countries[a] and in 6 rest of the world regions, increases in crop and livestock productivity, decreases in food loss and waste, changes in land regulations, among other measures.

- *Healthy Diets* only applies the shift towards healthier diets that is assumed in the Sustainable pathway to the Current Trends pathway to isolate the impact of healthier diets from the influence of the other levers.

[a] Australia, Brazil, Canada, China, Colombia, Germany, Finland, the UK, India, Mexico, Norway, Rwanda, Sweden, the USA, and South Africa have applied shifts towards healthier diets in the Sustainable pathway. Argentina, Ethiopia, Indonesia, Russia, and Malaysia did not apply shifts towards healthier diets in their Sustainable pathways.

2. Current diets, healthy diets, future diets

Current diets

Compared to nutritional recommendations, most of the current diets fall short in fruits and vegetables, nuts, and pulses consumption.

We can distinguish three broad groups of countries and regions based on similar shares of calorie intake from cereals and animal-sourced foods[b] in 2015 (Figure 1, Annex 2):

Group 1: The average national calorie intake is above 3,000 kcal/cap/day, and the average diet is characterized by a low share of cereals (about one quarter of total calories), high share of animal-sourced foods (almost a third), and high sugar and fat consumption. On average, fruits and vegetables barely make up for 6% of daily calorie intake. This group includes Argentina, Australia, Brazil, Canada, Germany, Finland, Norway, Sweden, the UK, United States, and the Rest of European Union region (EU27).

Group 2: The average national calorie intake is slightly below 3,000 kcal/cap/day. Almost half comes from cereals and about 20% from animal-sourced foods. Similar to Group 1, fruits and vegetables barely represent 6% of the daily calorie intake. This group includes China, Colombia, Malaysia, Mexico, Russia, South Africa, and the regions Rest of Europe (non EU27), and Rest of Central and South America. Colombia has a much higher consumption of sugar and a lower consumption of cereals compared to the rest of the group. China also consumes less fats and sugar compared to the group average.

Group 3: The average calorie intake is below 2,500 kcal/cap/day with more than half coming from cereals. Animal-sourced foods only represent about 10% of the total calorie intake. This group has the highest share of calorie intake from roots and tubers, and pulses (15%). It includes Ethiopia, Rwanda, India, Indonesia, and the regions Rest of Asia and Pacific, Rest of North Africa, Middle East and Central Asia, and Rest of Sub-Saharan Africa. The share of cereals tends to be higher in drier regions, and the share of roots and tubers is significantly higher in tropical humid zones in Africa and Asia. In Rwanda, for instance, roots and tubers account for almost a third of the total calorie intake.

Healthy Diets

In 2016, 83 countries had published national dietary guidelines[8]. Among them, 20 recommend reducing or limiting meat intake, and four considered environmental sustainability as a criterion.

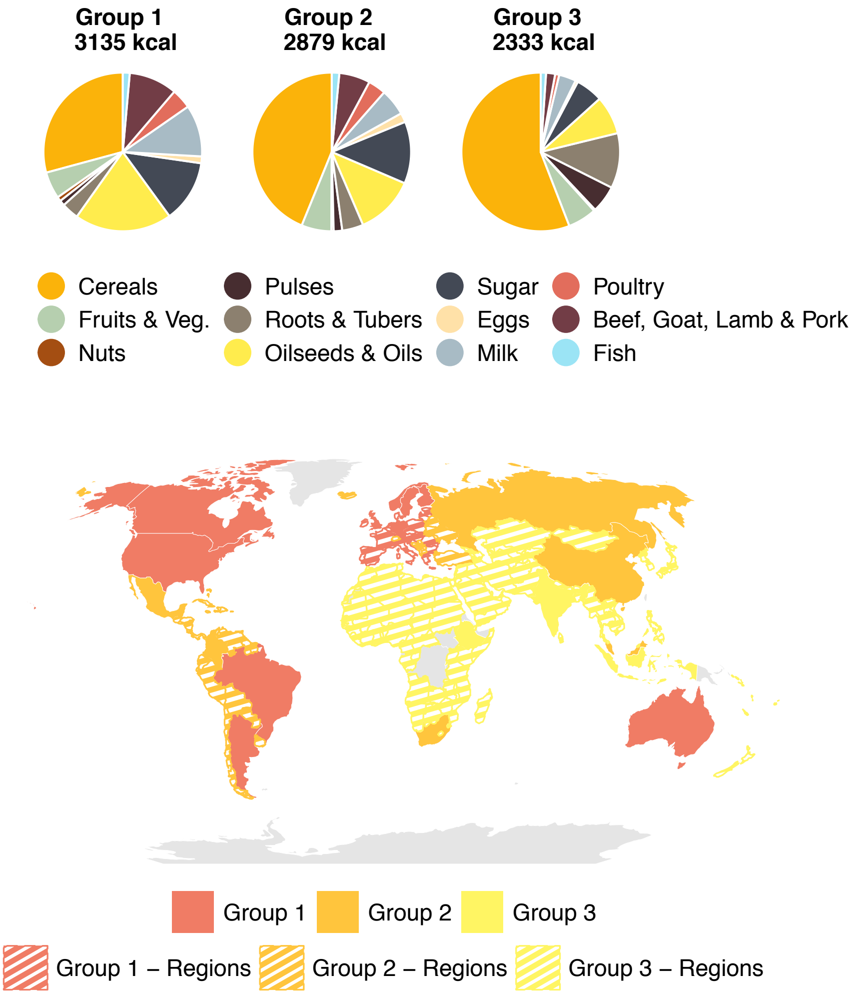
Based on the World Health Organization (WHO) recommendations, almost all countries should increase their consumption of fruits and vegetables, nuts, and pulses, and most countries from Groups 1 and 2 should reduce their consumption of sugar and fats (Figure 1, Annex 2).

The EAT-*Lancet* Commission has recommended a diet which is healthy and environmentally sustainable[9].This results in a maximum of 14% of total calories intake sourced from animals. Based on this threshold, most countries from Groups 1 and 2 overconsume animal-sourced foods while countries from Group 3 under consume them.

[b] In this brief, we use the term "animal-sourced foods" for pork, beef, mutton, goat, poultry meat, milk, and eggs. Fish is not included, unless it is explicitly mentioned.

The current share of cereals in the daily calorie consumption per capita varies from about a quarter to more than a half across countries.

Figure 1. Average diet by group of countries and regions with similar contribution of cereals and animal-sourced foods in the total calorie intake in 2015

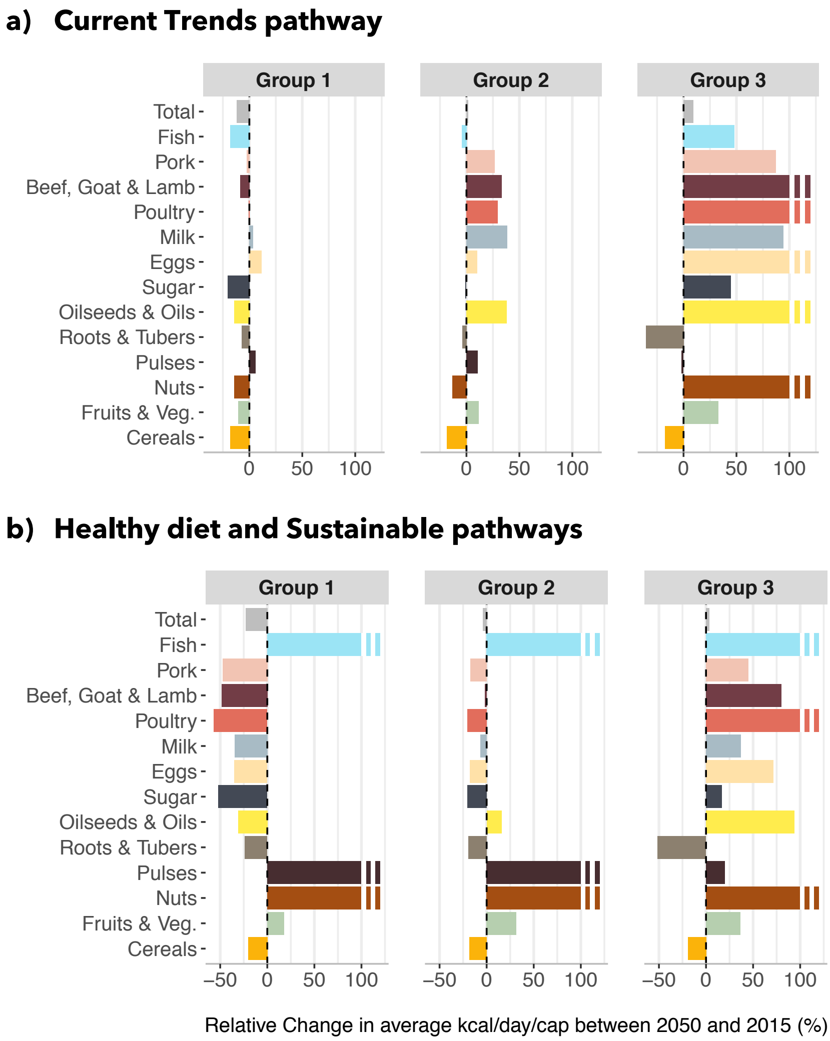


Source: Authors' calculations based on FAOSTAT [10] (cf. Annex 2)

Modelled dietary changes

Each FABLE country team has designed the healthy diet scenario according to the sustainability targets and their national context. National dietary recommendations have been used by the US team (USDA Healthy US style eating pattern[11]) and the UK team (the Eatwell diet[12]). The Norway, Sweden, and Finland teams have based their scenarios from reports from the Norwegian Institute of Bioeconomy Research, the Nordic Council of Ministers[13], and the Finland Government Research Publication Series[14] respectively. The Germany, Mexico, China, India, and Rwanda teams have used a combination of estimates from experts, and national and international recommendations. Australia, Brazil, and Canada have assumed the most drastic changes with the full adoption of the EAT-*Lancet* diet by 2050. The average EAT-*Lancet* diet has been also implemented in Colombia, South Africa, and in the rest-of-the-world regions, only partially, i.e., the 2050 diet is a mix of current diet and the EAT-*Lancet* diet.

Figure 2. Modelled changes in the average daily per capita consumption by food group by 2050 for the Current Trends and Healthy Diets pathways, compared to 2015



Source: Authors' calculations, based on FAO for 2015 [15] and own assumptions for 2050. We compute the average dietary changes in each pathway compared to historical consumption (2015) using simple average by group of FABLE countries and rest of the world regions assumptions.

For Group 1, we assume a quite stable diet compared to the historical diet under Current Trends. For the Healthy Diet scenario, we assume large reductions in the intake of meat, dairy, eggs, sugar, and oil and fat, and a large increase in the consumption of fish, nuts, and pulses (Figure 2).

For Group 2, the main difference between the two pathways is that we assume a shift from higher consumption of meat and dairy in Current Trends (+30%) to a lower consumption in the Healthy diet pathway (-12%). However, if we considered fish[c], overall animal calorie consumption would not be reduced in the Healthy Diet pathway (Annex 2).

For Group 3, we assume an increase in the average calorie consumption per capita in the two pathways. We estimate an increase of meat and dairy

[c] In this analysis, we do not compute fisheries production.

per capita calorie consumption by 120% in 2050 compared to 2015 in Current Trends, and a 75% increase in the Healthy Diet pathway (Figure 2; Annex 2).

When summed up to the global level, these contrasted assumptions per country and regions result in an increase of the average calorie consumption per capita by 6% in the Current Trends pathway and a reduction by 3% in the Healthy Diet pathway in 2050 compared to 2015 level. For animal-sourced foods (excluding fish), the global average per capita consumption would increase by 46% in the Current Trends pathway[d] and reduce by 3% in the Healthy Diet pathway compared to 2015.

3. Contribution of dietary changes to global environmental sustainability

Global GHG emissions from agriculture and land use change

Shifts towards healthier diets could reduce GHG emissions from AFOLU by half compared to Current Trends by 2050.

Integrated Assessment Models have estimated ranges of global GHG emissions from Agriculture, Forestry and Other Land Use (AFOLU) compatible with keeping the rise in average global temperatures to below 1.5°C [17]. Based on these estimates and similar to Searchinger et al. (2018), we use a maximum threshold of 4 $GtCO_2e$ per year from AFOLU by 2050: 4 $GtCO_2e$ from agriculture (including on farm energy use), and zero or net negative emissions for Land Use Change (LUC)[e].

Under the Healthy Diets pathway, AFOLU GHG emissions would reach the global target by 2050, representing a cut by half compared to *Current Trends* (Figure 3). In this pathway, GHG emissions from livestock would be reduced by half, and GHG emissions from crops would decrease by 25%, compared to *Current Trends*. This is consistent with other studies which have shown that shifts towards healthier diets could have a large contribution on reducing emissions from agriculture and land use change[19].

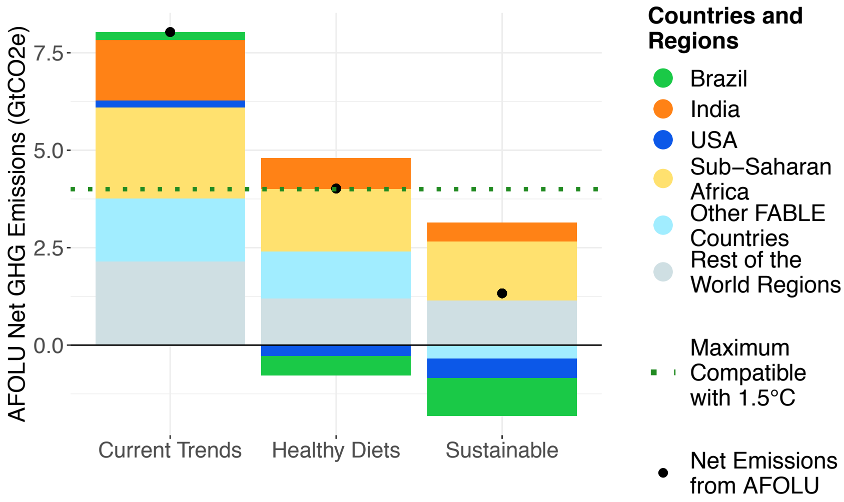
Under the *Healthy Diets* pathway, two thirds of the computed reduction of AFOLU GHG emissions by 2050 are attributed to Brazil, US, India, and the Sub-Saharan Africa region (Figure 3). With a transition to healthier diets, Brazil would shift from net positive emissions in *Current Trends* by 2050 to net negative emissions from AFOLU, due to the high reduction in methane emissions from ruminants and an increase in land carbon sequestration after agricultural abandonment. The US, India, and the Sub-Saharan Africa region also play a major role to reduce global GHG emissions from livestock in our results.

Additional measures implemented in the *Sustainable* Pathway would further

[d] For comparison, our *Current Trends* consumption projections for meat and dairy at the global level are comparable with the OECD-FAO projections for 2030[16] varying between -12% and +6% depending on the animal-sourced products.
[e] This analysis also includes CO_2 emissions from on farm energy use while this is not included in IPCC's AFOLU category.

reduce GHG emissions from agriculture and land use by more than half in 2050 compared to the *Healthy Diets* pathway (Figure 3). Half of this reduction is attributable to Indonesia, Brazil, China, US, and India, due to the implementation of policies strengthening deforestation bans, higher afforestation and reforestation plans, and improvements in livestock productivity in the design of the *Sustainable* pathway.

Figure 3. GHG emissions from agriculture and land use change under each pathway



Source: Authors' calculations.

Deforestation

Dietary shifts reduce deforestation by 20% over 2030-2050, but other measures are needed to reach net zero forest loss by 2030.

The FABLE Consortium uses a zero net forest-cover-loss target by 2030, drawing on the WWF's Living Forest Report [20] [f], the Sustainable Development Goal (SDG) Target 15.3, and the New York Declaration on Forests[21].

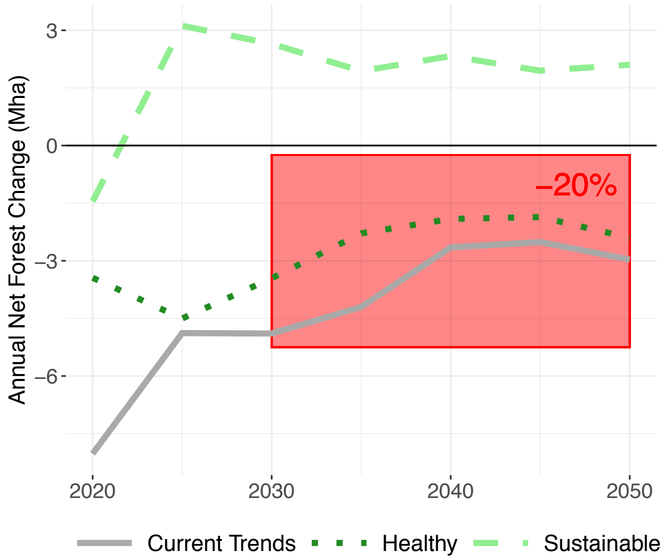
The *Healthy Diets* pathway would lead to a reduction in cumulated forest loss of 20% over the period 2030-2050, compared to *Current Trends* (Figure 4). Global cropland area would begin to decline after 2045 and the pasture area would be in constant decline until 2050. By 2050, pasture area would be 18% lower in the *Healthy Diets* pathway, compared to *Current Trends*.

Country focus: Brazil and Canada would be the biggest contributors to the global decrease in deforestation under the *Healthy Diets* pathway. The large drop in forest loss in Brazil in 2050 would be mostly driven by the decrease in pasture areas used for livestock production with the reduction by half of Brazilian beef exports over the period 2020-2050 compared to *Current Trends* and the fall of Brazil's domestic beef demand.

With additional measures in place, the *Sustainable* Pathway would avoid the destruction of 35Mha of forests mostly in Indonesia and Sub-Saharan Africa.

[f] The WWF's Living Forest Report (WWF, 2015) provided additional forest conditions for the definition of forests to ensure the ecological integrity of the target, for example, ruling out fast growing plantations, that are not taken into account in this study.

Figure 4. Evolution of net forest change per year under each pathway



Source: Authors' calculations

4. Implications for countries

Agricultural trade balance

Large exporters of livestock, poultry and animal feed will likely reduce their trade surplus with transition to healthier diets. But new trading opportunities will also arise.

Dietary changes lead to an increase in the consumption of certain products and a reduction in others, resulting in changes in global demand. Our approach ensures global trade consistency, so that country pathways also reflect changes from the rest of the world. Using fixed prices[g], we computed the impact of dietary changes on the trade balance of agricultural products.

Under the *Healthy Diets* pathway, there would be a large reduction in global trade value of animal-sourced foods (-50%), cereals (-20%), and soybeans (-15%), and an increase in global trade of nuts (+235%), and fruits and vegetables (+30%), compared to *Current Trends*.

Country focus: US agricultural trade surplus computed in *Current Trends* would turn into a trade deficit in the *Healthy Diets* pathway (Figure 5)[h]. Its poultry exports would be reduced by more than half in 2050 and the fall in the global consumption of animal-sourced foods would drive a large reduction in the exports of crops for animal feed. This explains the drop by 30% in US corn exports in 2050. US whole soybean exports would be less impacted (-6%) due to the projected sustained global demand for soybean oil. However, the US is also a major nuts exporter. Higher nut exports would then offset part of the reduction in exports.

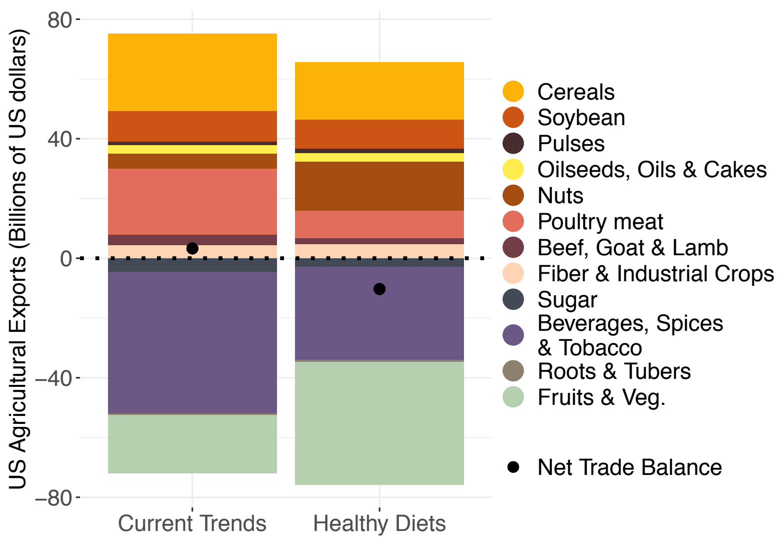
On the other hand, shifts towards healthier diets could generate new

[g] FAO 2014 producer prices are used to compute exports and imports value. For processed products, other sources have been used. Three alternative imputation methods were tested top fill price data gaps (see Annex 1 for more information).
[h] Most of the products are expressed in primary equivalent in our models. That could explain differences between the computed value of the agricultural trade balance and the official one.

trade opportunities for certain countries, even in those where dietary shifts were not projected. The FABLE Ethiopia team did not project a domestic dietary shift by 2050. However, in the *Healthy Diets* pathway, Ethiopia would increase its trade surplus compared to *Current Trends* in 2050. Even though its imports are not impacted[i] in this scenario, its exports are. Pulses and sesame oil exports from Ethiopia would increase in the *Healthy Diets* pathway, driven in part by a higher demand from Europe.

The FABLE Indonesian team did not assume a domestic dietary shift either. Under the *Healthy Diets* pathway, there would not be any changes in Indonesia's imports. Nevertheless, palm oil exports from Indonesia would slightly increase, due to increased demand from countries with a dietary shift that requires higher vegetable oil consumption, particularly India. Indonesia would also benefit from increased nut exports, due to higher global demand.

Figure 5. Impact of domestic and global dietary shifts on the US agricultural trade balance in 2050



Source: Authors' calculations.

Strategic planning will be required to ensure that the large increase in fruits and vegetables and nuts production will not exacerbate water stress.

Cropland composition

We assume that production will follow demand. However, the adjustments required for the agricultural sector following these kinds of dietary shifts might be large and need to be anticipated to ensure agronomic feasibility. These adjustments include new crop rotations due to significant changes in the repartition of crops on cropland, new irrigation infrastructure, as well as reorganization of the food value chains.

Country focus: For instance, domestic dietary change would deeply reshape cropland in Mexico. In the *Healthy Diets* pathway, the share of cereals would drop from 40% to 20% while the share of fruits and vegetables would increase from 24% to almost 40% of total cropland in 2050, compared to

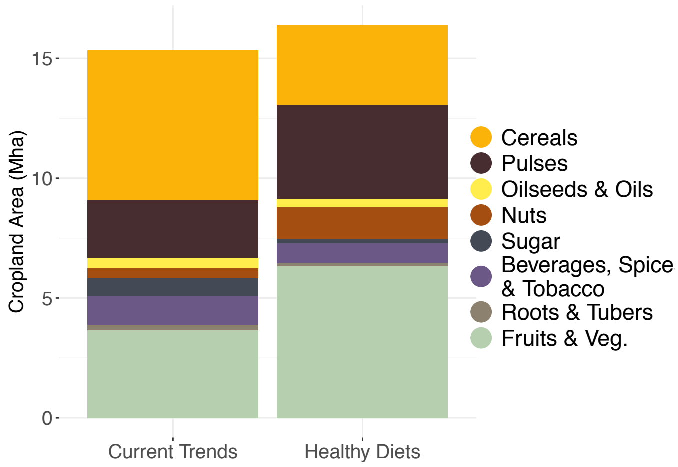
[i] In reality, imports might be affected by dietary shifts in the rest of the world due to price changes, but prices are not included in the FABLE Calculator[22].

Current Trends. Higher production of citrus fruits in Mexico is driven by higher exports, but to a lesser extent. In China, the share of cropland area dedicated to fruits and vegetables would also rise from 14% to 20% in 2050. This shift in production has large impacts on water demand: +50% in Mexico and +30% in China in 2050 compared to the *Current Trends* pathway.

In the *Healthy Diets* pathway, average per capita consumption of nuts would reach 4% of the average total calorie consumption globally. We estimate that this would require an increase of planted area for nuts from about 14 million ha currently (FAOSTAT) to 100 million ha in 2050. This would lead to very large increase in planted area for nuts especially in Brazil and Sub-Saharan Africa region to satisfy their own growing demand as well as the increasing global demand.

In Rwanda, cereals would account for 31% of cultivated areas in 2050 under *Current Trends*. In the *Healthy Diets* pathway, the share of cereals would grow and account for 56% in 2050 at the expense of pulses and root crops planted area.

Figure 6. Impact of domestic and global dietary shifts on the Mexican cropland composition in 2050



Source: Authors' calculations.

Land abandonment

In most countries, abandoned agricultural land tends to have a negative societal connotation, and is perceived as a neglection of rural livelihoods. Abandoned land may also be vulnerable to invasive species and fires[23]. Still, it can also bring environmental benefits such as carbon sequestration and the return of biodiversity caused by the regrowth of natural vegetation[j]. Abandoned agricultural land can be targeted for afforestation and land restoration programs as part of climate and biodiversity strategies.

In countries where a reduction in agricultural land is expected, governments could explore alternative uses for the land. Other uses include

[j] In our modelling framework, we assume growing carbon stock from abandoned agricultural land.

diversification of agricultural production, or extensive activities that would use more land per unit produced but have more benefits to the environment, [24] e.g., grass-based livestock with low densities per hectare.

Shifts towards healthier diets will reduce the agricultural land area needed compared to Current Trends. In some countries, this can be an opportunity for natural vegetation regrowth and/or more extensive agricultural practices.

Country focus: With the exception of Norway, all countries and regions from Group 1 would have reduced agricultural land in the *Healthy Diets* pathway, compared to *Current Trends*. In Australia, one of the top five exporters of mutton, beef, and milk, domestic meat consumption is among the highest in the world, significantly above the OECD average. As a result of the uptake of a healthier diet, animal-sourced foods represent less than 20% of total Australian calorie intake instead of more than one quarter in *Current Trends*. Mutton exports are also cut by half in 2050. This leads to the most dramatic computed reduction of agricultural land in the *Healthy Diets* pathway compared to the *Current Trends* pathway for Australia[k].

Similarly, the UK experiences a reduction of its agricultural land by 20% over 2020-2050 in the *Healthy Diets* pathway: 10% reduction in cropland area and about 30% reduction in pasture area. The UK is a net importer of milk, beef, and mutton, so the pasture reduction is driven by domestic dietary shifts following national dietary guidelines. Cropland abandonment is driven by a reduction in rapeseed and sugar beet area due to lower oil and sugar food consumption.

Overall, the abandonment of cropland area due to healthier diets is more limited than pasture abandonment. The most significant increase in cropland abandonment takes place in Argentina: cropland area drops by almost 30% between 2020 and 2050 because of lower soybean exports.

Our results show lower agricultural land abandonment for countries and regions from Group 2 and 3. The agricultural land would even slightly increase in some countries with healthier diets, e.g., Colombia, Rwanda, Malaysia.

5. Conclusion

Our results support previous findings that show the large positive impacts of healthier diets on forest ecosystems and climate change mitigation. But as the *Sustainable* pathway shows, additional levers are necessary to realize the required transformation of the food and land systems, such as regulation of forest conversion, productivity gains, and active afforestation and reforestation plans. With large co-benefits across sectors, the adoption of healthier diets should nevertheless be considered as a critical lever to achieve this transformation. As such, diets should be reflected in

[k] In fact, the impact of the adoption of healthier diets on Australian exports might be less pronounced. In this study, we apply a proportional reduction of exports following the drop in global imports while in reality countries that are less competitive than Australia might be the first to lose export markets. Australian meat exports are also concentrates in a few countries in the Asian region where the adoption of healthier diets might lead to less variation in meat consumption.

climate and biodiversity strategies and commitments towards the UN Food Systems Summit, United Nations Framework Convention on Climate Change, and the Convention on Biological Diversity.

The dietary shifts modelled in this study require a high number of levers to come into effect on the consumption side that are out of the scope of this study. This analysis focused on the agricultural production and trade impacts. If not anticipated, these changes might be delayed, and it could compromise the affordability and accessibility of healthier diets for all socio-economic groups.

Farmers and agri-food industries would need to reorganize, e.g., start new agricultural products while reducing or phasing out others and implement new crop rotations. That might also be an opportunity to diversify cropping systems and integrate nature conservation approaches into agricultural production through land sharing. For instance, agroforestry practices could increase the share of fruits and nuts on current cropland.

Both our *Current Trends* and *Healthy Diets* pathways recognize that in most low-income countries, the challenge is to increase the calorie intake by 2050, including from animal proteins. More work would be needed to better define healthy diets in these contexts, depending on cultural preferences and availability. For instance, reducing the intake of roots and tubers to the recommended level of the EAT-*Lancet* Commission might not be optimal for humid tropical countries where roots and tubers grow easily and are very diverse.

We project that the transition towards healthier diets would reduce the extent of agricultural land in countries where the consumption of animal-sourced foods is currently very high or where a large share of the cropland is used for animal feed production. The impacts of animal production on the environment depends on the ecoregion and the practices. In some ecosystems, grazing animals contribute positively to biodiversity and landscape. In other areas, the transition can offer opportunities to restore natural ecosystems or invest in other income-generation activities such as renewable energy production. This would require in each country a mapping of areas where land abandonment is the more likely and/or where better alternative land uses are possible.

This study highlights that if countries promote a transition towards healthier diets, farmers and rural communities need support to use their land in new ways which would be both economically and environmentally sustainable.

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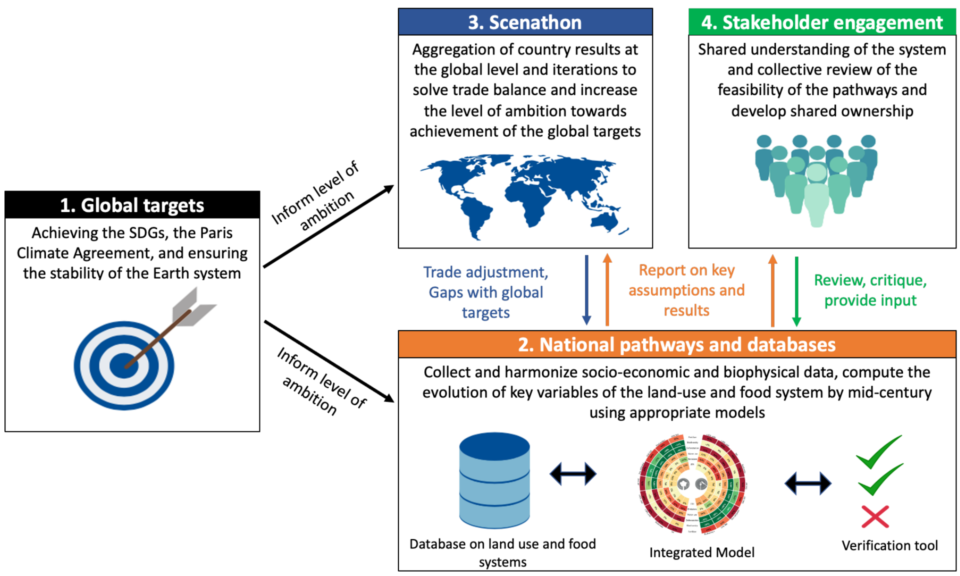
Annex 1: Methods

Overview of the FABLE methodology

We have developed four steps for coordinating bottom-up national pathways to address national priorities, collectively achieve global sustainability objectives, and balance international trade in agricultural commodities (Figure 7):

1. **Global Targets** – the country teams jointly decide on global targets to be achieved collectively, and each country team applies them to its country context.
2. **National pathways and databases** – each FABLE country team integrates national data from many different sources and develops mid-century pathways towards sustainable land-use and food systems.
3. **Scenathon** – key parameters and results from the FABLE country pathways are aggregated to determine if the sum of national pathways meets the FABLE targets and to check for consistency in assumptions regarding imports and exports of agricultural commodities. Discrepancies are addressed through iterative refinements of national FABLE pathways.
4. **Stakeholder engagement** – throughout, FABLE country teams consult stakeholders to test and refine assumptions, support a shared understanding of land-use and food systems, and develop shared ownership of the results.

Figure 7: Step-by-step FABLE methodology



Source: FABLE 2020

Models

For the Scenathon 2020, two models have been used: the FABLE Calculator for 19 countries and the rest of the world regions, and MAgPIE for India.

- The FABLE Calculator is an Excel accounting tool[I] used to study the potential evolution of food and land-use systems over the period 2000-2050 for each five-year time step. It includes 76 raw and processed agricultural products from the crop and livestock sectors and relies extensively on the FAOSTAT (2020)

[I] The FABLE Calculator has a very similar structure as the GLOBAGRI[25] and TYFA models[24].

database for input data. All details are provided in the model documentation[22] and the FABLE Calculator can be downloaded here. It focuses on agriculture as the main driver of land-use change and tests the impact of different policies and changes in the drivers of these systems through the combination of a large number of scenarios [22].

- MAgPIE is a recursive dynamic cost-minimization model of global land systems developed at PIK. The model simulates crop production, land-use patterns, water use for irrigation, and carbon stock changes at a spatial resolution of 0.5° × 0.5°[26]. Associated with the REMIND energy-economy model, it is used in global integrated assessments to support the IPCC.

Each pathway is defined by a combination of scenarios that allow for variation across key parameters of the models. Each of our country teams could select different values for the following parameters: affecting demand (GDP, diets, biofuel use), trade, food loss and waste, productivity, land use restrictions, afforestation, and climate change. In the MAgPIE model, carbon tax is an additional scenario.

Result Indicators

GHG emissions from agriculture and land-use*:* GHG emissions from Agriculture include emissions from enteric fermentation, manure management, rice cultivation, agricultural soils, and other sources. For all countries, GHG emissions from LULUCF include carbon stocks changes due to the conversion of forest and other natural land to cropland, grassland and urban area, changes in biomass after grassland and cropland abandonment. GHG emissions from the cultivation of organic soils are included for Finland and Indonesia.

Net forest cover change*:* Net Forest cover change is the sum of forest loss and forest gain by 5 year-time steps. Forest loss is the deforestation associated with agriculture and urban expansion. Forest gain is the land which is taken out of pasture, cropland and/or other natural land to be afforested.

Agricultural trade balance: Each country's agricultural trade balance is computed as the sum of projected export and import quantities for all products multiplied by FAO 2014 producer prices. Producer prices are missing for 29 commodities out of the 76 agricultural products covered by the Calculator. The missing producer prices for coconut oil, palm kernel oil and cake, soybean cake and sugar raw were replaced by the 2014 average monthly price from IndexMundi. The producer price for tomato was used for other missing vegetable products. Another gap in the data is that some products' producer prices are available for only some countries. We used three imputation methods to fill these gaps: 1) the producer price of the main exporter for each product is used, 2) the average price of all the importers is used if there is no price available for the exporting countries, 3) the simple average of producer prices from all the countries that have available data is used.

Cropland composition: A country's cropland composition is computed as the share of projected planted area by crop in the projected total cropland area.

Abandonment of agricultural land: Area that was planted or grazed during the previous period that is not used for agricultural production in the following period. We assume passive natural vegetation regrowth (i.e., without human action) with associated carbon sequestration.

Annex 2. Assumptions on diets under each pathway

		Current (2015)		Current Trends (2050)		Healthy Diet and Sustainable pathways	
	Product group	average kcal/cap/day	[min-max]	average kcal/cap/day	[min-max]	average kcal/cap/day	[min-max]
Group 1	Cereals	911	[740-1096]	745	[553-1107]	725	[584-900]
	Fruits & Veg.	171	[102-205]	153	[112-204]	201	[112-393]
	Nuts	28	[3-52]	24	[2-58]	116	[3-243]
	Pulses	34	[6-134]	36	[4-168]	114	[4-237]
	Roots & Tubers	109	[89-164]	101	[67-168]	83	[32-206]
	Oilseeds & Oils	619	[254-955]	531	[293-808]	427	[130-650]
	Sugar	396	[296-608]	314	[193-495]	190	[59-403]
	Eggs	43	[28-56]	48	[34-56]	28	[15-57]
	Milk	330	[188-494]	341	[273-437]	216	[108-366]
	Poultry	127	[61-215]	126	[46-200]	55	[19-142]
	Beef, Goat & Lamb	124	[35-351]	113	[41-332]	64	[12-332]
	Pork	183	[77-361]	178	[57-366]	96	[12-218]
	Fish	44	[13-106]	36	[9-72]	90	[18-198]
	Livestock	851	[402-1583]	842	[460-1463]	549	[184-1313]
Group 2	Cereals	1243	[875-1527]	1010	[720-1636]	1014	[557-1537]
	Fruits & Veg.	162	[78-351]	181	[107-238]	213	[94-474]
	Nuts	15	[2-46]	13	[0-28]	64	[0-119]
	Pulses	56	[12-100]	62	[16-150]	114	[16-245]
	Roots & Tubers	129	[32-207]	124	[21-247]	104	[21-189]
	Oilseeds & Oils	316	[140-489]	436	[332-618]	366	[264-497]
	Sugar	348	[74-577]	345	[128-657]	276	[48-531]
	Eggs	50	[31-89]	55	[37-86]	41	[21-74]
	Milk	166	[50-280]	230	[71-360]	155	[71-291]
	Poultry	98	[58-163]	127	[64-200]	78	[52-139]
	Beef, Goat & Lamb	60	[26-134]	80	[26-115]	59	[26-107]
	Pork	104	[44-374]	132	[21-390]	86	[25-357]
	Fish	44	[12-103]	42	[15-107]	110	[40-213]
	Livestock	522	[221-1143]	666	[234-1258]	529	[235-1181]
Group 3	Cereals	1315	[409-1830]	1083	[667-1400]	1063	[809-1400]
	Fruits & Veg.	118	[24-455]	157	[66-205]	161	[66-241]
	Nuts	8	[0-12]	21	[0-80]	72	[0-117]
	Pulses	111	[10-338]	109	[51-284]	133	[39-198]
	Roots & Tubers	242	[55-735]	156	[51-304]	118	[24-301]
	Oilseeds & Oils	170	[98-338]	356	[211-420]	329	[222-644]
	Sugar	127	[65-219]	184	[90-280]	148	[90-297]
	Eggs	14	[1-28]	31	[14-50]	24	[10-54]
	Milk	87	[18-203]	169	[60-256]	119	[60-197]
	Poultry	23	[0-45]	84	[52-106]	58	[25-200]
	Beef, Goat & Lamb	20	[5-33]	56	[13-83]	36	[22-50]
	Pork	31	[0-120]	58	[0-130]	45	[0-151]
	Fish	25	[1-74]	37	[8-63]	68	[16-126]
	Livestock	200	[25-503]	435	[147-688]	350	[133-778]

The average kilocalories intake is computed as a simple average of the average consumption at the FABLE countries and rest-of-the-world regions level to avoid that densely populated countries drive too much the group average.