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A GLOBAL INITIATIVE FOR THE UNITED NATIONS

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 China by 2050

China

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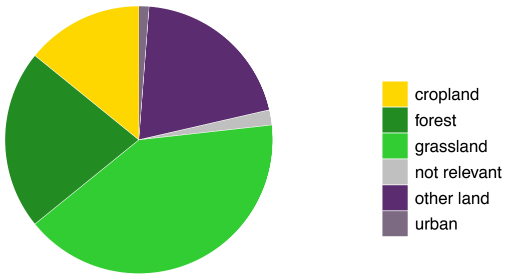
Land and food systems at a glance

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

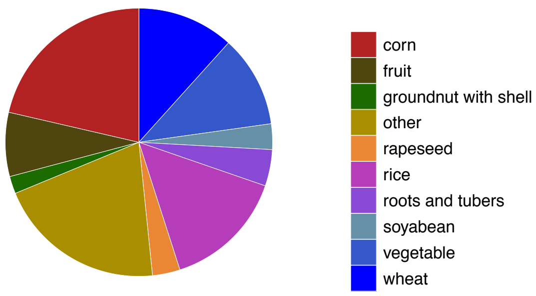
Land & Biodiversity

Fig. 1 | Area by land cover class in 2015



Source: FAOSTAT, ESA

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



Source: FAOSTAT

Annual afforestation in 2015:
1.5Mha = 0.74% of total forest area

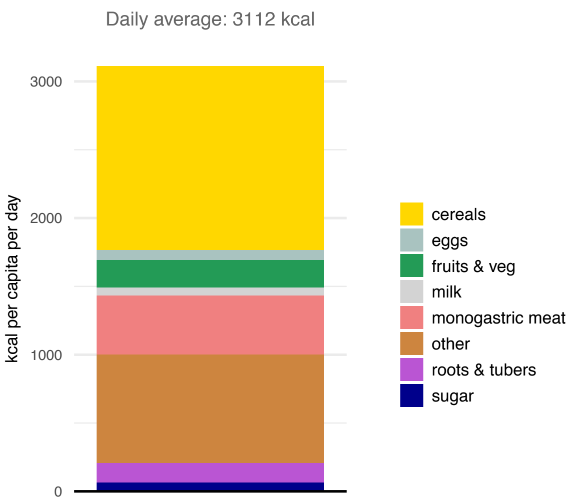
(FAOSTAT, 2019)

Endangered species: 795

(World Bank, 2019)

Food & Nutrition

Fig. 3 | Daily average intake per capita at the national level in 2013



Source: FAOSTAT

Share of undernourished in 2015:

8.8%

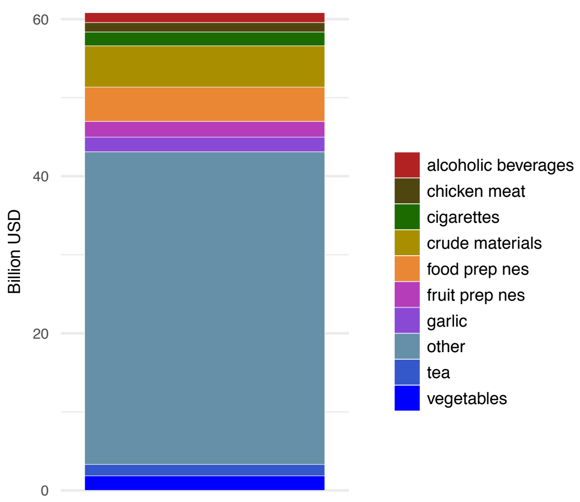
(FAOSTAT, 2019)

Share of obese in 2015:
11.9% of adults over the age of 18
6.4% of children and teenagers between the ages of 6 and 17

(National Health and Family Planning Commission, 2015)

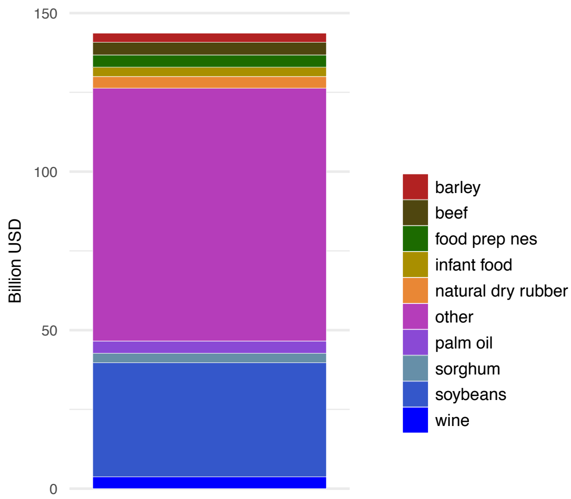
Trade

Fig. 4 | Main agricultural exports by value in 2015



Source: FAOSTAT

Fig. 5 | Main agricultural imports by value in 2015



Source: FAOSTAT

Deficit in agricultural trade balance in 2015: USD 83 bln

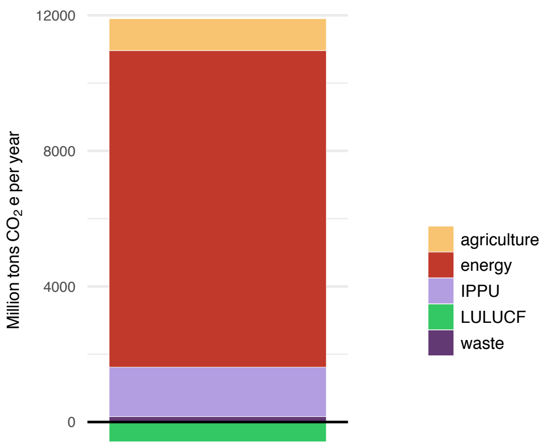
(FAOSTAT, 2019)

#1 soybean importer in the world in 2015

(FAOSTAT, 2019)

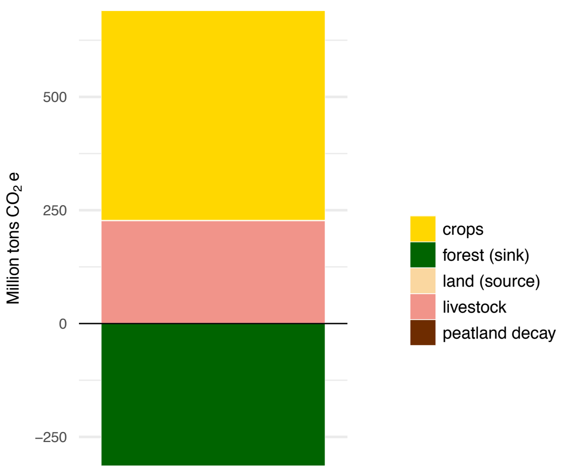
GHG Emissions

Fig. 6 | GHG emissions by sector in 2012



Source: National Leadership Group on Climate Response, Energy Conservation & Emissions Reduction (2016)

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



Source: FAOSTAT

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 by 260% from USD 6,378 in 2015 to USD 21,063 in 2050 (SSP1 scenario selected).	Population is expected to decrease by 2% between 2015 and 2050 from 1.39 bln to 1.36 bln (Family Planning scenario selected).
Scenario justification	This is based on 2050 being close to the 100th Anniversary of the Founding of the People's Republic of China when, according to our national objective, China will be a great modern socialist country. By 2050, China would reach the third quartile of a middle and high income country, therefore economic growth should be kept around 3.4% from 2017-2050, which is close to SSP1 (Center for China in the World Economy, 2017; O'Neill et al., 2014).	Based on China's two child policy, the birth rate will increase in short term, and total population will increase first and peak during 2025-2030 (Jing et al., 2018; Qi et al., 2016).

TRADE

	Imports	Exports
Scenario definition	The share of total consumption which is imported increases: - from 2% in 2015 to 10% in 2050 for pork, - from 5% in 2015 to 10% in 2050 for beef, - from 4% in 2015 to 10% in 2050 for poultry meat, - from 3% in 2015 to 10% in 2050 for mutton, - from12% in 2015 to 20% in 2050 for milk. The share of total consumption which is imported remains constant at 2010 levels for the other commodities.	The exported quantity remains constant at 2010 levels for all products.
Scenario justification	Based on China's current food security policy, as well as trends in recent years for imports of agricultural products, which requires that the self-sufficiency rate of staple foods, such as rice, wheat, and maize, remain above 90%. Meanwhile, the central government would like to increase imports of animal products, but maintain the current self-sufficiency rate for soybean and palm oil (Ma et al., 2019).	Based on China's lack of land available for agricultural production, it is reasonable to reduce or maintain current levels of food exports (Ma et al., 2019).

Scenario signs = no change → small change ↗ large change

LAND

	Land conversion	Afforestation
Scenario definition	We assume that arable land should be higher or equal to 2010 extent i.e. 120 Mha, over the whole period of simulation.	Total afforested area is expected to reach 72.6 Mha by 2050.
Scenario justification	Based on China's determination to "hold the rice bowl in our own hands" i.e. to guarantee grain self-sufficiency (State Council of China, 2017).	Based on the central government's regular emphasis of the importance of afforestation and our national territorial plan, which clearly states that the forest cover rate should reach 24% by 2030. Therfore, we assume the forest cover rate could reach 26% in 2050 (State Council of China, 2017).

BIODIVERSITY

	Protected areas
Scenario definition	Protected areas remain at their 2010 level, representing 14.8% of total land area.
Scenario justification	This does not take into account the plan to expand protected areas to 25% of China's total land area according to the Ecological Conservation Redline (Ministry of Ecology and Environment, 2016; Gao, 2019).

FOOD

	Diet	Food waste
Scenario definition	The share of total consumption which is imported increases: - from 2% in 2015 to 10% in 2050 for pork, - from 5% in 2015 to 10% in 2050 for beef, - from 4% in 2015 to 10% in 2050 for poultry meat, - from 3% in 2015 to 10% in 2050 for mutton, - from 12% in 2015 to 20% in 2050 for milk. The share of total consumption which is imported remains constant at 2010 levels for the other commodities.	Between 2015 and 2050, the share of final household consumption which is wasted decreases from 13.5% to 11.8%.
Scenario justification	While there is no policy in China that forces people to change their diet, we assume that Chinese people will tend to follow a healthier lifestyle in the future (Chinese Nutrition Society, 2016).	Based on recent government policies that show the feasibility and positive impacts of reducing food waste through, for example, the clean the plate campaign in Chinese universities (Ma et al., 2019).

Scenario signs no change small change large change

PRODUCTIVITY

	Crop productivity	Livestock productivity	Pasture stocking rate
Scenario definition	Between 2015 and 2050, crop productivity per year increases: - from 6.7 t/ha to 7.3 t/ha for wheat, - from 6.1 t/ha to 6.8 t/ha for rice, - from 7.7 t/ha to 8.2 t/ha for corn.	Between 2015 and 2050, the average productivity per year remains constant: - at 44.4 kg/head for beef, - at 95.6 kg/head for pork, at 3.3 t/head for cow milk.	The average livestock stocking density remains constant at 0.32 TLU/ha of pasture land between 2015 and 2050.
Scenario justification	An average of 11% increase in crop yield was achieved between 2005 and 2015 for millions of small household farms in China due to the implementation of better nutrient management practices. Chen et al (2014) also show that the productivity of wheat, rice, and corn could be increased by 45%, 17%, and 69%, respectively, compared to 2010 levels through integrated soil and crop nutrient management, extension services, and closing the yield gap. Therefore, we assume China could achieve 9.6%, 16%, and 7.3% yield increases for wheat, rice, and corn between 2015 and 2050 (Cui et al., 2018; Chen et al., 2014).	This is a conservative estimate made to avoid a sharp decline in pasture area by 2050.	Based on one of the core missions of land-use planning in China, which includes controlling the degradation of grassland (State Council of China, 2017).

OTHER

	Crop harvesting Intensity
Scenario definition	Between 2015 and 2050, average crop harvesting intensity per hectare per year remains constant at 1.4, this is a conservative estimation due to future climate change. However, we assumed there will be constant havesting index if the increase in temperature stays below 1.5 degrees.
Scenario justification	

Scenario signs no change small change large change

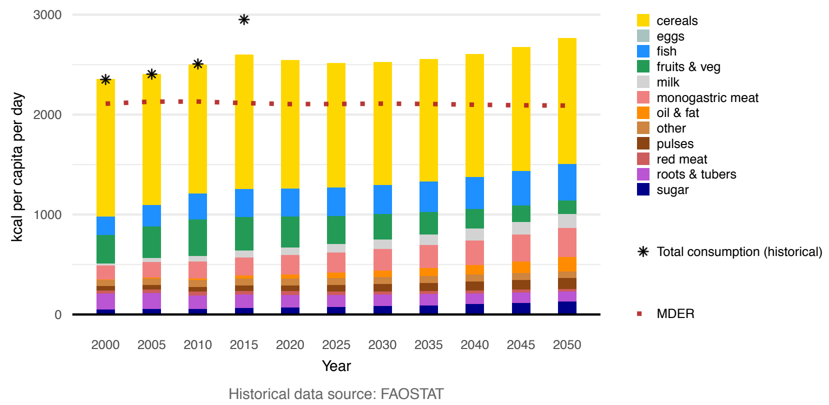
Results against the FABLE targets

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

Food security

Fig. 8 | Computed daily 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.

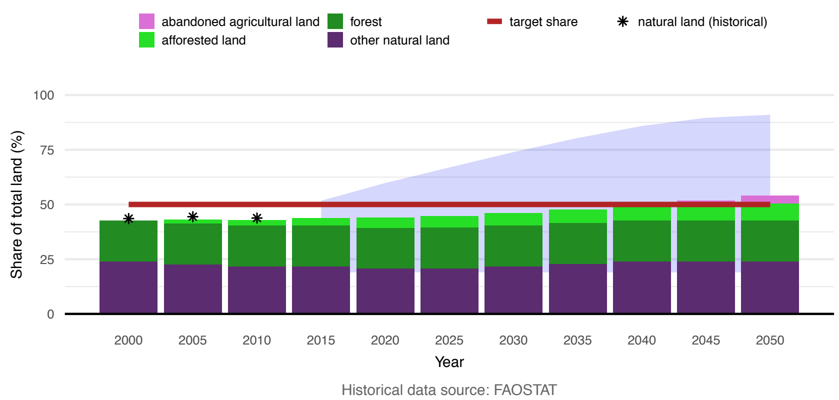


Our results show average daily energy intake per capita increases from 2,355 and 2,617 kcal/cap/day between 2000-2015. Over the last decade, 50% of the food intake came from cereals. Calorie intake reaches 2,617 over the period 2031-2035 and 2,950 kcal/cap/day over the period 2046-2050. In terms of recommended diet, our results show lower consumption of meat, while other food consumption increases for other animal products and pulses. The computed average calorie intake is 41% higher than the Minimum Dietary Energy Requirement (MDER) at the national level in 2050.

Our results suggest that meeting national food security objectives of having zero huger by 2030 will be attainable.

Biodiversity

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

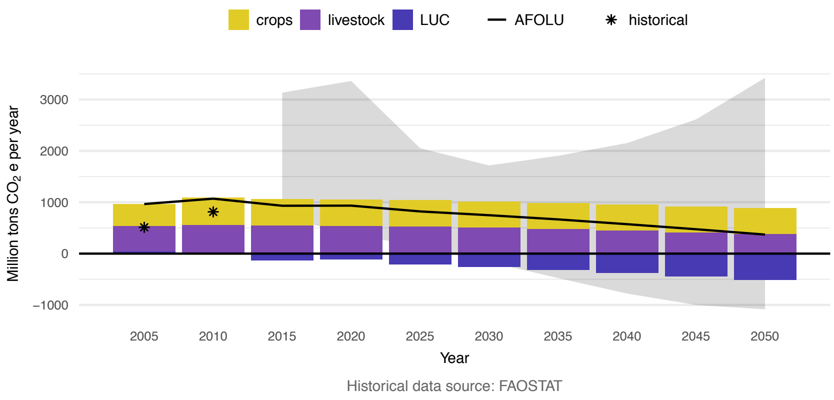


Our results show that the Share of Land which could support Biodiversity conservation (SLB) increased between 2000-2015 from 42.9% to 43.9%. This number is close to historical levels based on FAO land-cover statistics. The lowest SLB is computed for the period 2005-2010 at 43.2 % of total land. This is mostly driven by other non-managed land conversion to pasture. SLB reaches 53.6 % over the last period of simulation, 2046-2050. The difference is explained by high afforestation and the reduction of pasture area where we assume natural vegetation regrowth.

Compared to the global target of having at least 50% SLB by 2050, our results are above the target.

GHG emissions

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



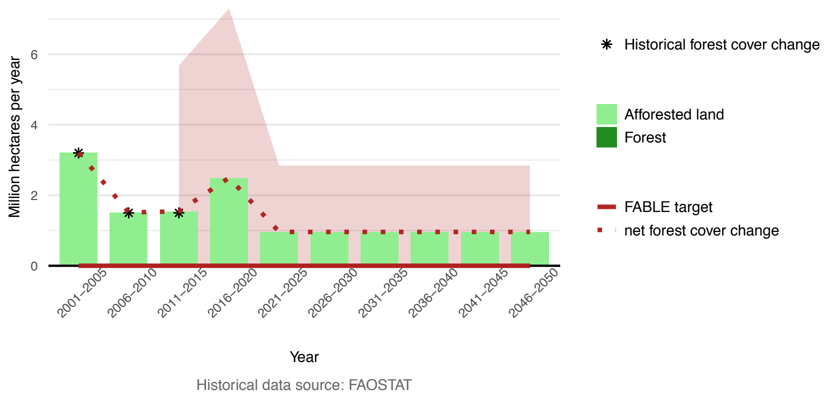
Note: AFOLU (Agriculture, Forestry and Other Land Use) is the sum of computed GHG emissions from crops, livestock and Land Use Change (LUC), emissions and sequestration from forestry are not included. Historical emissions include crops and livestock.

Our results show annual GHG emissions between 807 $MtCO_2e$/yr and 932 $MtCO_2e$/yr over 2000-2015 that increased and then decreased over time, whereas FAO estimates a maximum of 813 $MtCO_2e$/yr over the same period. This is mainly due to different GHG emission parameters used in the FABLE Calculator and FAO GHG emission database. For example, the FAO database does not include GHG emissions by energy use of agricultural machinery. Also, the FABLE Calculator calculated GHG emissions based on the average GHG emissions per head of livestock category, whereas FAO GHG emissions from livestock production includes enteric fermentation, manure management, and manure applied to soil and pastures. Peak AFOLU GHG emissions are computed for the period 2005-2010 at 1,070 $MtCO_2e$/yr. This is mostly driven by GHG emissions from livestock. AFOLU GHG emissions reach 370 $MtCO_2e$ over the period 2046-2050: +883 from agriculture and -513 from LULUCF. Positive net emissions from LULUCF by 2050 are mainly explained by higher agricultural emissions than afforestation can reduce.

GHG emissions per unit of gross domestic product: Compared to the global target of reaching zero or negative GHG emissions from LULUCF by 2050, our results meet the target. The central government of China has committed that average GHG emissions per GDP in 2020 will be 40-45% lower compared to 2005 levels. Our results show that AFOLU could reduce the average GHG emissions per agricultural GDP by 44%, which is in the range of the national target (Ministry of Foreign Affairs, 2011).

Forests

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



Our results show high afforestation from 2001-2005 at about 3.2 Mha/year, which then stabilizes between 2006-2015 at 1.5 Mha/year. This trend is consistent with FAO statistics. Peak afforestation is computed for the period 2016-2020 at 2.5 Mha/year and reaches 950 kha/year over the period 2031-2050. We assume no deforestation between 2000-2050, which leads to a positive net-forest cover change of 72.6 Mha.

Compared to the global target of having zero or positive net forest change after 2030, our results are above the target with 0.96 Mha/year net forest cover increase by 2030.

Other relevant results for national objectives

Table 1 | Other Results

Variable	Unit	2000	2005	2010	2015	2020	2030	2040	2050
Rice									
Production (historical)	Mt	126.6	121.4	131.5					
Production (calculated)	Mt	125.1	119.8	130.5	138.1	136.1	132.3	129.0	125.9
Imports (calculated)	Mt	0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Wheat									
Production (historical)	Mt	99.6	97.4	115.2					
Production (calculated)	Mt	97.9	96.4	116.9	117.1	115.2	111.8	108.8	105.9
Imports (calculated)	Mt	2.1	4.3	2.3	2.3	2.3	2.1	1.9	1.7
Beef									
Production (historical)	Mt	5.0	5.7	6.6					
Production (calculated)	Mt	4.9	5.6	6.4	6.3	6.2	5.6	4.9	4.1
Imports (calculated)	Mt	0.1	0.1	0.3	0.3	0.4	0.4	0.5	0.5
Milk									
Production (historical)	Mt	12.4	32.0	41.1					
Production (calculated)	Mt	12.1	31.4	40.2	46.3	52.8	63.5	70.9	74.9
Imports (calculated)	Mt	1.5	1.6	4.6	6.0	7.6	11.3	15.1	18.8
Soyabean									
Production (historical)	Mt	15.4	16.4	15.1					
Production (calculated)	Mt	15.7	18.0	17.0	12.1	11.7	11.1	10.5	10.0
Imports (calculated)	Mt	12.7	31.8	67.5	65.9	64.5	59.0	51.6	43.4

Source of historical data: FAOSTAT for production, CEH LCM for land cover

Our results show small changes for rice production over the period 2000 to 2010. According to Dietary Guidelines for Chinese Residents 2016, the consumption of rice will continue to decrease between 2015-2050, so the production quantity will also go down. Our government highly values cereals production, and is determined to ensure self sufficiency, so rice imports will remain low in the future, our results show the net import rate close to 0% during the whole period.

Our results show that the production of wheat increased by 15% between 2000 and 2010. Similarly to rice, the consumption of wheat will decline by around 40% between 2010 and 2050. Net imports of wheat are low and remain within the lower bound. The reduction of wheat production and harvested area could contribute to the objective for reducing groundwater depletion.

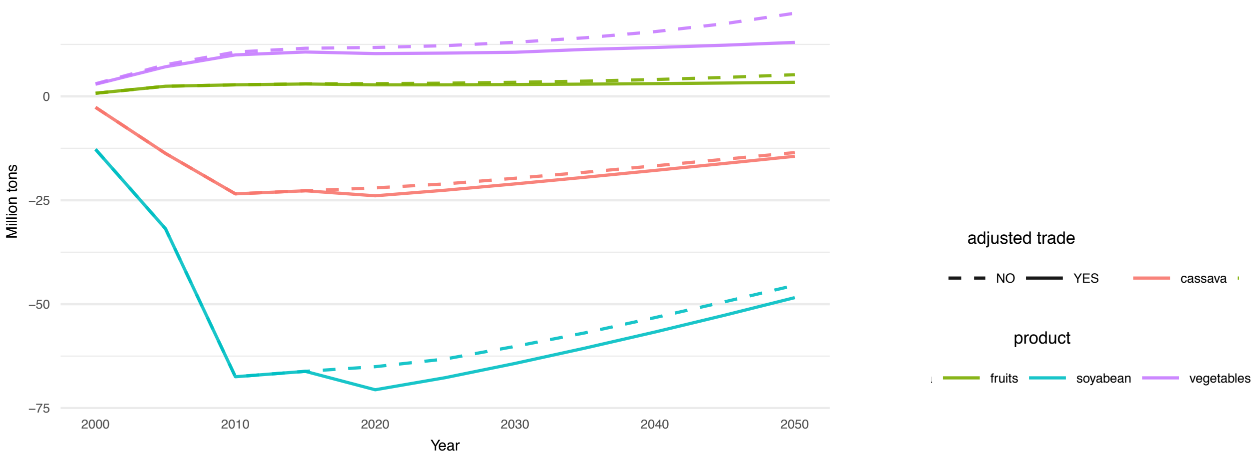
Our results show that the production of beef increased by 31% from 2000 to 2010. The targeted production quantity is projected to decline due to future dietarty shifts, reaching 4.1 Mt in 2050, which is much lower than the level in 2000. Net imports of beef will remain constant at around 450 kt, which will account for 10% of production in 2050.

Our results show that the production of milk increased by more than a factor of 2 between 2000 to 2010. The targeted production quantity is projected to further increase by 30% between 2010 and 2050, due to dietary changes. Meanwhile, milk imports will also increase, reaching 22 Mt in 2050 or 25% of total production. There is a national plan to increase milk consumption, especially for students and the central government would like to increase the self-sufficiency rate of milk in the future (Bai et al., 2013; General Office of the State Council of China, 2018).

Our results show that the production of soybean remains stable between 2000 to 2010. The targeted production quantity is projected to decline, reaching 7.9 Mt in 2050 which is much lower than the level in 2000. Soybean imports will steadily decrease between 2010 to 2050. A decline in soybean production does not align with current policy, which seeks to increase soybean production. The harvest area of soybean will reach 10 Mha in 2022 and may continue to increase in the future (Ministry of Agricultural and Rural Affairs, 2019).

Impacts of trade adjustment to ensure global trade balance

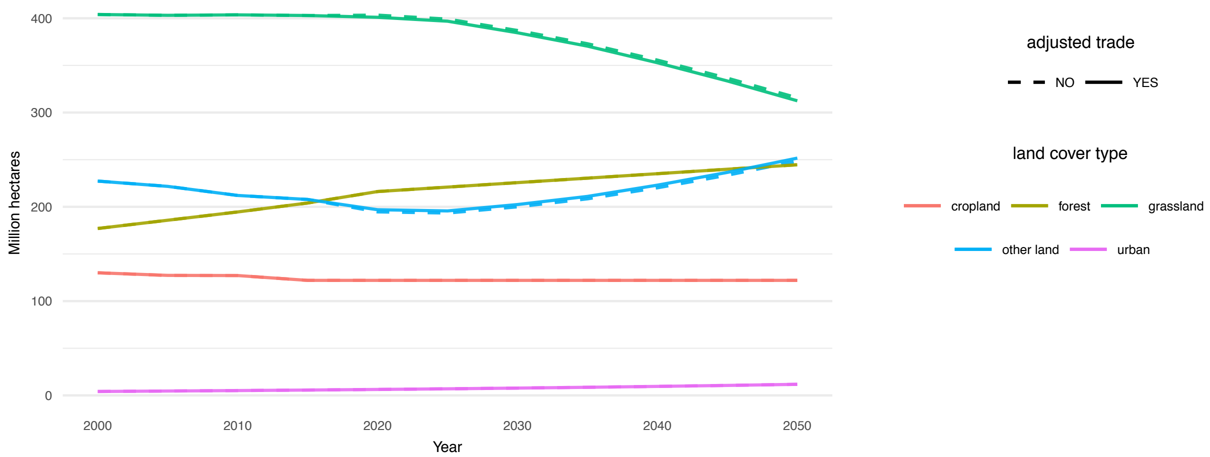
Fig. 12 | Impact of global trade harmonization on main exported/imported commodities over 2000-2050



For fruits, the change is apparent starting in 2020. Exports first increase, then decrease starting in 2015, before increasing again after 2025, and finally peaking at 3,400 kt in 2050. When trade is not adjusted, exports increase, first quickly, before slowing down and picking back up starting in 2030, and finally peak at about 3,700 kt in 2050. For vegetables, the change is apparent starting in 2005 and follows a similar trend to fruits with and without the trade adjustment, peaking at 13,000 kt and 14,000 kt in 2050, respectively. Lower exports after the trade adjustment may be due to other countries exporting more than we had anticipated and/or importing countries importing less than anticipated.

Soybean and cassava are two of the most important imports for China. They have the same trend before and after the trade adjustment. When trade is adjusted, they first increase between 2000-2010, then decrease between 2010-2015, then increase and peak in 2020, before falling until 2050. Imports peak in 2020 at 24,000 kt for cassava and 71,000 kt for soybean, respectively. When trade is not adjusted, both products peak in 2010 (23,500 kt for cassava and 67,000 kt for soybean), after which imports steadily decline. Similar to the case of exports, China will need more imports in the future based on our assumption that the population will peak between 2020-2030.

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



There is no significant impact of trade adjustment on land cover which is explained by the fact that trade still represents 10% maximum of total consumption for most of the agricultural commodities and the impact of trade adjustment on Chinese traded commodities is relatively small.

Discussion and next steps

Under this pathway, China achieves zero hunger, no deforestation and the increase of land for biodiversity, however total GHG emissions from AFOLU remain positive in 2050. The main underlying assumptions for this sustainable pathway are shifts towards healthier diets and reductions in food waste, as well as strict afforestation policies and increasing imports of agricultural products from abroad. These two strategies greatly contributed to achieving sustainable agricultural production.

According to recommendations made by the Chinese Nutrition Society on healthy diets, average consumption per capita should decrease by 22% for cereals, 59% for pork and poultry, and increase by 89% and 68% for milk and pulses, respectively. Overall, average daily calorie consumption per capita increases from 2,617 to 2,950 kilocalories per capita per day between 2015 and 2050. This is a relatively optimistic estimate, since average meat consumption per capita in China is already relatively low compared to other developing countries (FAOSTAT, 2019). In 2050, we assume a relatively high increase in GDP per capita, which would mean a continuous reduction in the consumption of animal protein with an increasing GDP per capita between 2015 and 2050. This will require a joint effort from scientists, government, consumers, producers, and retailers to develop healthly and nutritious food, linking nutrition, diet, food waste, and behavioral subsidies, building clear information and sound extension services, incentives for vegetarian food production, taxes on meat consumption, acceptance of healthly diets, and training for environment protection, etc. (Ma et al., 2019). Meanwhile, reducing food waste could also supplement decreasing demand for agricultural products. Here we aimed to reduce food waste from 13.5% to 11.8%. This is a relatively conservative estimate and could be achieved in the near future.

Other measures, such as improving crop productivity and land-use planning also support sustainable agricultural production. In 2050, we assume that the crop productivity of wheat, rice, and corn increase by 9.6%, 16%, and 7.3% compared to 2015. This is could be achieved through Integrated Soil-Crop System Management (ISSM) technology (Chen et al., 2014; Cui et al., 2018). Cui et al (2018) showed that an average 11% increase in crop yield was achieved between 2005 and 2015 for millions of small household farms in China due to the implementation of better nutrient management practices. Chen et al (2014) also showed that the productivity of wheat, rice, and corn could be increased by 45%, 17% and 69%, compared to 2010, through integrated soil and crop nutrient management, closing of the yield gap and greater extension services. Therefore, we assume China could increase wheat, rice, and corn yields by 9.6%, 16%, and 7.3%, respectively, between 2015 and 2050. These improvements have already been achieved in field experiments, experimental farms, and millions of small household farms but will require further integration, testing, and up scaling through, for example, the Science and Technology Backyard program, a program where young students and researchers stay in villages and help farmers adopt technologies needed to close the yield gap and improve nutrient management. This requires the joint efforts of policymakers, researchers, extension services, farmers, citizens, industry, and market organizations to fully understand the levers and barriers of each option.

The Integrated Soil-Crop System Management (ISSM) applied in these studies involved agronomic measures such as planting appropriate crop varieties or hybrids at the right sowing dates and densities and applying fertilizer according to crop demands and soil fertility. ISSM redesigns cropping systems using advanced crop and nutrient management to bring yields closer to their biophysical potential, while optimizing various resource inputs (that is nutrient and water) and minimizing environmental costs. Such agronomic improvements represent a huge underutilized potential in China. Even larger technological improvements should be feasible over the longer term and beyond the 2050 period considered here, including genetic crop improvement and, in the future, more mechanized and automated production technologies for precision field management.

Increased imports of food from abroad is also a sound option for China to achieve domestic SDGs. In this study, we assumed imports of animal products will increase substantially between 2015 and 2050. This could largely reduce the need for domestic livestock production, as well as GHG emissions and demand of land. However, China is a leading livestock producer globally and increasing the proportion of meat imports will greatly transfer the burden of domestic agricultural production to other leading exporting countries, such as Brazil and Argentina, although this may be less likely to happen when these countries embark on a pathway towards SDGs.

The main challenge of the current FABLE Calculator is the lack of geographic analysis, which is important for China due to the highly uneven distribution of human population and agricultural production. Currently, the FABLE Calculator covers most of the policies at the national level in China. In the future, improvements could be made so that the impacts of polices at the regional level could be considered which is important because of the high diversity in agricultural production between regions and the highly uneven distribution of production systems. For example, there are increasingly strict water-use policies in the North China Plain, which may greatly impact wheat and maize production (State Council of China, 2012). There is also a strict water protection rule in southern China, which has impacts on total pig production throughout China (State Council of China, 2015). Furthermore, the Ecological Redline also limits the further expansion of agricultural production. The nutrient management and water requirement for agricultural production may need to be further strengthened, mainly due to decoupled crop-livestock production and severe water shortages, which have already contributed to the severe air and water pollution in China (Bai et al., 2018; Du et al., 2014). These factors are not yet well covered by FABLE Calculator.

Additionally, a coherent framework to ensure a sustainable pathway for land and food systems needs to be developed in the future to help with implementation. This framework should include: (1) incentives to adopt improved agronomic practices and technologies, (2) incentives to support land-based animal production and pasture-based livestock systems, so as to improve manure management and meet water quality standards (which is included in the new Environmental Protection Law of China), (3) subsidy reforms to ensure that subsidies reach their target stakeholders, and (4) education and policies that promote a healthy diet and reduced food waste. Implementing such a strategy also commits China to sound monitoring and evaluation for assessing the impacts of action and enables it to adjust the strategy in a proactive, evidence-based manner, taking constraints and barriers into account. In principle, the ambitious targets embedded in China's new agricultural and environmental strategies appear to be achievable through an integrated transformation of the whole food system (Ma et al., 2019).

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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