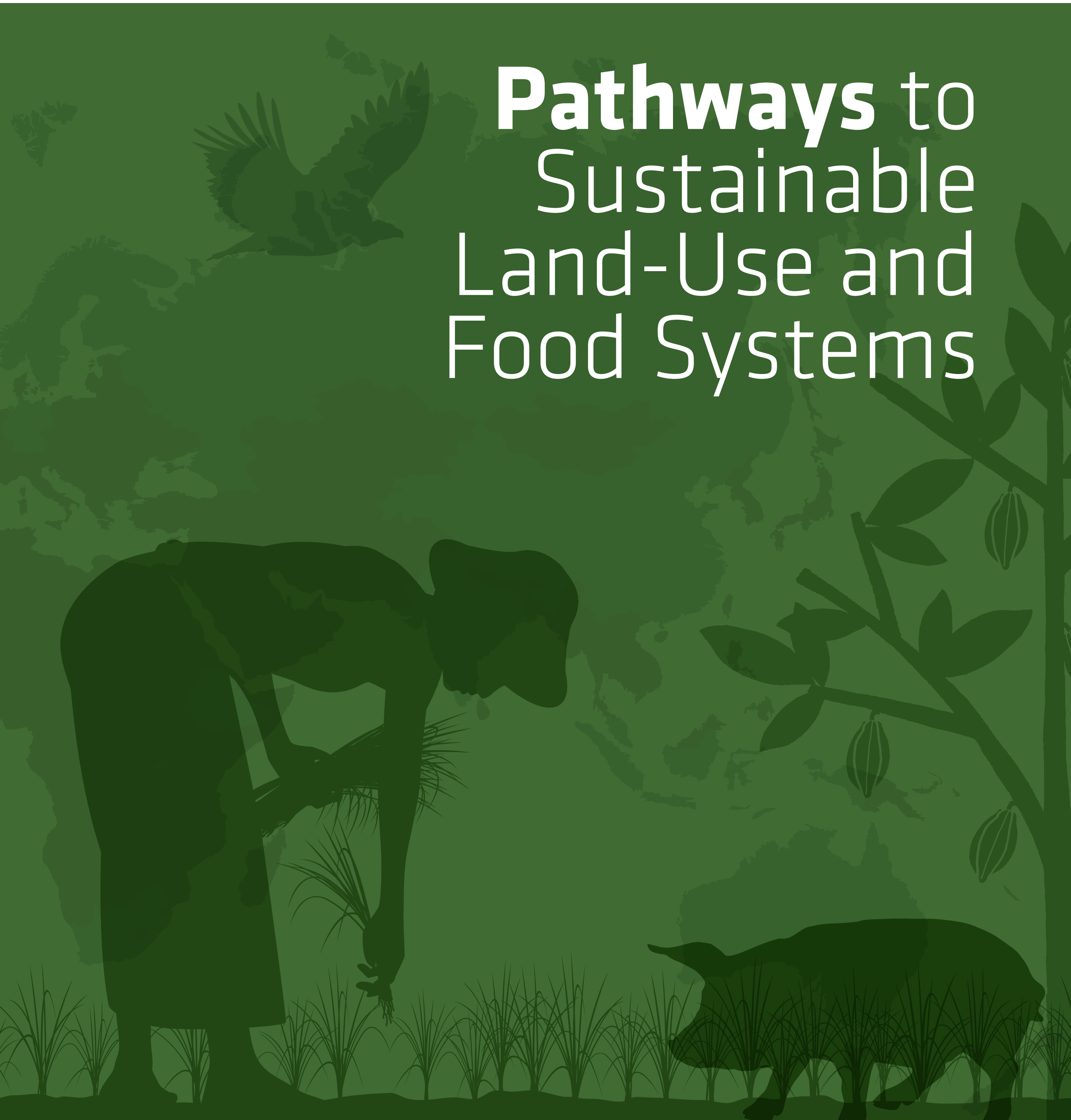
International Institute for Applied Systems Analysis
IIASA www.iiasa.ac.at

Sustainable Development Solutions Network
A Global Initiative for the United Nations

The Food and Land Use Coalition

2020 Report of the FABLE Consortium

Pathways to Sustainable Land-Use and Food Systems



Published by International Institute for Applied Systems Analysis (IIASA) and the Sustainable Development Solutions Network (SDSN) 2020

The full report is available at www.foodandlandusecoalition.org/fable.
For questions please write to info.fable@unsdsn.org

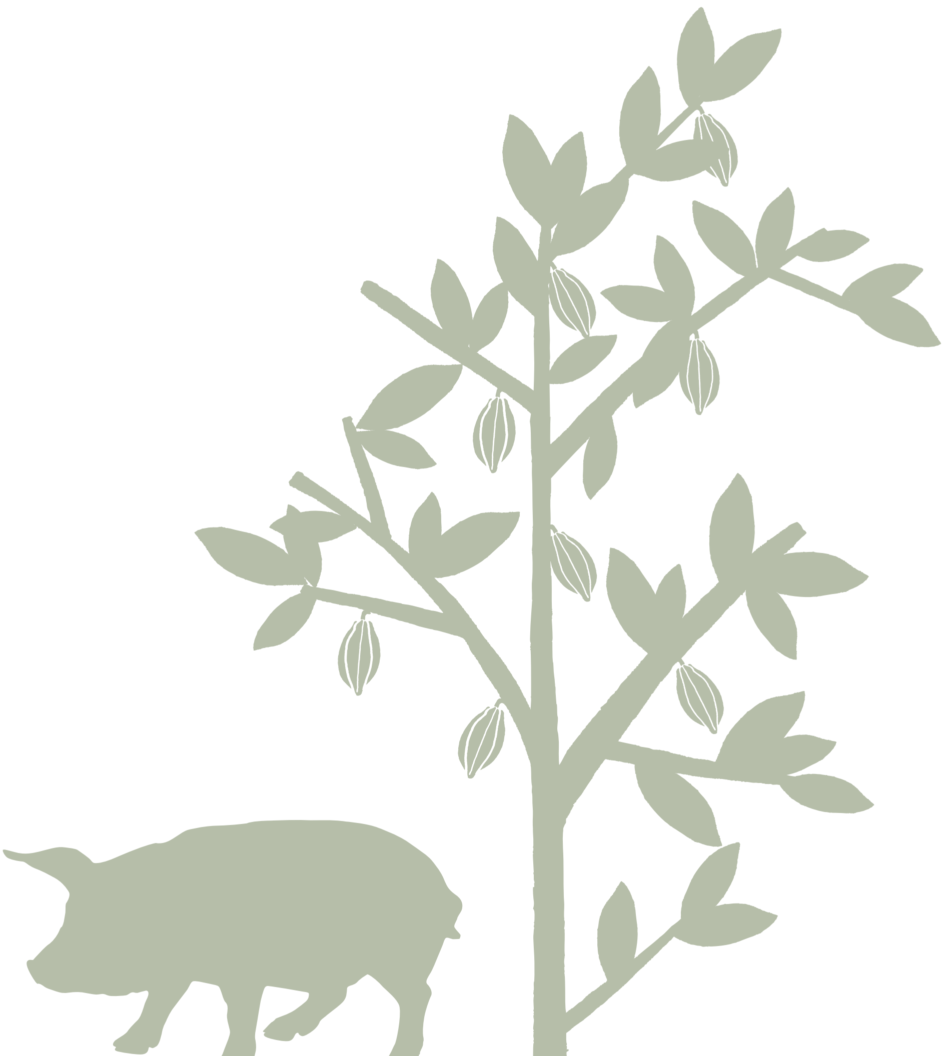
Disclaimer
The 2020 FABLE Report was written by a group of independent experts acting in their personal capacities. Any views expressed in this report do not necessarily reflect the views of any government or organization, agency, or programme of the United Nations (UN). The country chapters use maps prepared solely by the national teams. The boundaries, colors, denominations, and other information shown on any map in this work do not imply any judgment on the part of SDSN or IIASA concerning the legal status of any territory or the endorsement or acceptance of such boundaries.

Recommended citation: Jin X., Bai Z., Zhao H., Wang X., Chang J., Hua F. and Ma L. (2020), "Pathways to Sustainable Land-Use and Food Systems in China by 2050" In: FABLE 2020, *Pathways to Sustainable Land-Use and Food Systems,* 2020 Report of the FABLE Consortium. Laxenburg and Paris: International Institute for Applied Systems Analysis (IIASA) and Sustainable Development Solutions Network (SDSN), pp. 195-229. https://doi.org/10.22022/ESM/12-2020.16896

Design, layout and production by Phoenix Design Aid A/S, a CO2 neutral company accredited in the fields of quality (ISO 9001), environment (ISO 14001) and CSR (DS 49001) and approved provider of FSC™ certified products. Printed on environmentally friendly paper without chlorine and with vegetable-based inks. The printed matter is recyclable.

2020 Report of the FABLE Consortium

Pathways to Sustainable Land-Use and Food Systems in China by 2050



China

Xinpeng Jin[1], Zhaohai Bai[1*], Hao Zhao[1], Xiaoxi Wang[2,3], Jinfeng Chang[4], Fangyuan Hua[5], Lin Ma[1*]

[1]Center for Agricultural Resources Research, Institute of Genetic and Developmental Biology, Chinese Academy of Sciences, Shijiazhuang, China. [2]China Academy for Rural Development, Zhejiang University, Hangzhou, China. [3]Potsdam Institute for Climate Impact Research, Telegrafenberg, Potsdam, Germany. [4]College of Environmental and Resource Sciences, Zhejiang University, Hangzhou, China. [5]Peking University, Beijing, China.
*Corresponding authors: baizh1986@126.com, malin1979@sjziam.ac.cn

This chapter of the 2020 Report of the FABLE Consortium *Pathways to Sustainable Land-Use and Food Systems* outlines how sustainable food and land-use systems can contribute to raising climate ambition, aligning climate mitigation and biodiversity protection policies, and achieving other sustainable development priorities in China. It presents two pathways for food and land-use systems for the period 2020-2050: Current Trends and Sustainable. These pathways examine the trade-offs between achieving the FABLE Targets under limited land availability and constraints to balance supply and demand at national and global levels. We developed these pathways in consultation with national stakeholders and experts and modeled them with the FABLE Calculator (Mosnier, Penescu, Thomson, and Perez-Guzman, 2019). See Annex 1 for more details on the adaptation of the model to the national context.

Climate and Biodiversity Strategies and Current Commitments

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

Table 1 summarizes how China's NDC treat the FABLE domains. According to the NDC, China has committed to reducing its GHG emissions intensity by 60-65% by 2030 compared to 2005 (National Development and Reform Commission of China, 2015). This includes emission reduction efforts from agriculture, forestry, and other land use (AFOLU). Envisaged mitigation measures from agriculture and land-use change include conserving farmland, improving the potential of soil to store carbon, maintaining a balance between forage and livestock, enhancing afforestation, and protecting and restoring wetlands. Under its current commitments to the UNFCCC, China mentions biodiversity conservation (National Development and Reform Commission of China, 2015). China's President Xi Jinping also pledged that China will achieve carbon neutrality by 2060. Though agricultural was not listed as a key sector to achieve this pledge, proper agricultural land-use management to save more land for nature and afforestation could significantly contribute to China's 2060 carbon neutrality pledge.

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

	Total GHG Mitigation					Mitigation Measures Related to AFOLU (Y/N)	Mention of Biodiversity (Y/N)	Inclusion of Actionable Maps for Land-Use Planning[1] (Y/N)	Links to Other FABLE Targets
	Baseline		Mitigation target		Sectors included				
	Year	GHG emissions (Mt CO_2e/yr)	Year	Target					
NDC (2017)	2005	7,466 (without LULUCF) 7,045 (with LULUCF)	2030	60-65% carbon intensity reduction	Energy, Industrial processes, agriculture, waste, LULUCF	Y	Y	N	Food, water, deforestation

Note: "Total GHG Mitigation" and "Mitigation Measures Related to AFOLU" columns are adapted from IGES NDC Database (Hattori, 2019), except for the GHG emissions baseline, which comes from UNFCCC (2005).
Source: UNFCCC (2005)

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

Table 2 provides an overview of the targets listed in the National Biodiversity Strategies and Action Plan (NBSAP) from 2010, as listed on the CBD website (CBD, 2020), which are related to at least one of the FABLE Targets. In comparison with the FABLE Targets, NBSAP targets are a little outdated, but provided a benchmark against which to assess China's performance on climate change mitigation and biodiversity protection when preparing our scenarios.

Table 2 | Overview of the NBSAP targets in relation to FABLE targets

NBSAP Target	Global FABLE Target
By 2015, forest coverage rate will increase to 21.66% and forest reserves will increase by 600 Mm^3 compared to 2010.	**DEFORESTATION:** Zero net deforestation from 2030 onwards
By 2020, national forest holdings will exceed 2.33 Mkm^2, an increase of 223,000 km^2 compared to 2010; and national forest reserves will increase to 15 billion m^3, an increase of about 1.2 billion m^3 compared to 2010.	**DEFORESTATION:** Zero net deforestation from 2030 onwards
By 2020, forest areas and net forest reserves will increase by 52,000 km^2 and by 1.1 Mkm^2 compared to 2010, respectively.	**DEFORESTATION:** Zero net deforestation from 2030 onwards
By 2020, grassland degradation will be nearly contained and the ecological environment of grasslands will be considerably improved.	**BIODIVERSITY:** No net loss by 2030 and an increase of at least 20% by 2050 in the area of land where natural processes predominate
By 2020, the total areas of degraded grasslands will exceed 1.65 Mkm^2, with grassland habitats restored and grassland productivity significantly enhanced.	**BIODIVERSITY:** No net loss by 2030 and an increase of at least 20% by 2050 in the area of land where natural processes predominate
By 2020, a system of nature reserves with reasonable layouts and comprehensive functions will be established, with functions of national-level nature reserves stable, and main targets of protection effectively protected.	**BIODIVERSITY:** At least 30% of global terrestrial area protected by 2030
By 2015, the total area of terrestrial nature reserves will be maintained at around 15% of China's land area, protecting 90% of national key protected species and typical ecosystem types.	**BIODIVERSITY:** At least 30% of global terrestrial area protected by 2030
By 2020, energy consumption and CO_2 emission per unit of GDP will decrease significantly, with the total amount of main pollutants considerably reduced.	**GHG EMISSIONS:** Zero or negative global GHG emissions from LULUCF by 2050
By 2020, forest carbon sinks will increase by 416 Mt compared to 2010.	**GHG EMISSIONS:** Zero or negative global GHG emissions from LULUCF by 2050

Brief Description of National Pathways

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

Our Current Trends Pathway corresponds to the lower boundary of feasible action. It is characterized by a moderate population decrease (from 1.41 billion in 2020 to 1.29 billion in 2050), no constraints on agricultural expansion, a high afforestation target, medium productivity increases in the agricultural sector, an evolution towards higher consumption of animal products, and low livestock productivity increases (see Annex 2). This corresponds to a future based on current policy and historical trends that would also see considerable progress with regards to the ongoing trends of rapid urbanization and increasing incomes. Moreover, as with all FABLE country teams, we embed this Current Trends Pathway in a global GHG concentration trajectory that would lead to a radiative forcing level of 6 W/m2 (RCP 6.0), or a global mean warming increase likely between 2°C and 3°C above pre-industrial temperatures, by 2100. Our model includes the corresponding climate change impacts on crop yields by 2050 for corn, rice, wheat, and soybean (see Annex 2).

Our Sustainable Pathway represents a future in which significant efforts are made to adopt sustainable policies and practices and corresponds to a high boundary of feasible action. Compared to the Current Trends Pathway, we assume that this future would lead to larger increases in crop and livestock productivity and reduced caloric intake (see Annex 2). This corresponds to a future based on the adoption and implementation of more ambitious policies. It would also see considerable progress with regards to the continuous investment in new technologies in crop and livestock production, which will substantially increase agricultural productivity, increases in production on managed grasslands, which will save more grassland for natural protection, and slight reductions in caloric intake due to healthier diets, although not those suggested by EAT LANCET (Ministry of Agriculture of China, 2016; National Development and Reform Commission of China, 2020; Xi, 2017). With the other FABLE country teams, we embed this Sustainable Pathway in a global GHG concentration trajectory that would lead to a lower radiative forcing level of 2.6 W/m^2 by 2100 (RCP 2.6), in line with limiting warming to 2°C.

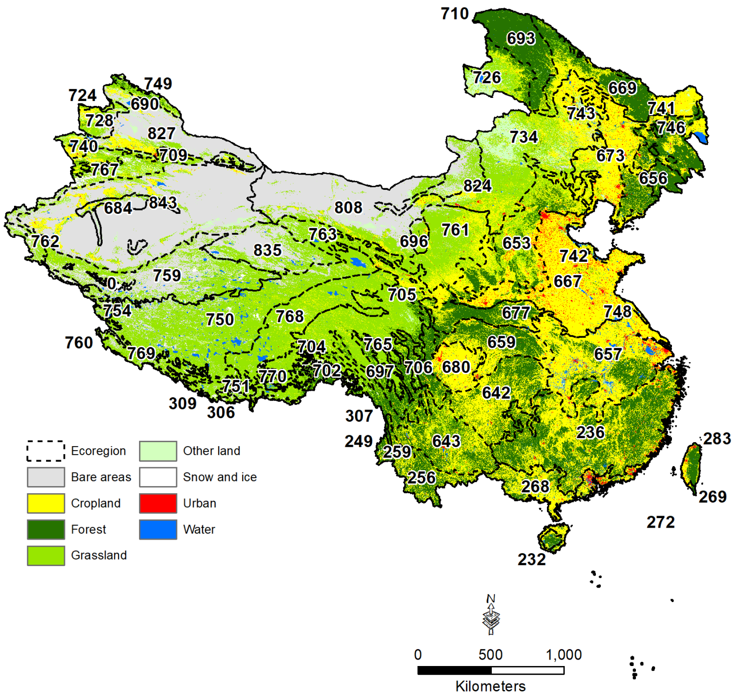
Land and Biodiversity

Current State

In 2010, China's land area consisted of 13% cropland, 41% grassland, 22% forest, less than 1% urban, and 23% other natural land (ESA, 2014; FAO, 2020). Most of agricultural area is located in Northern China and Middle-Lower Yangtze Plain, while forest and other natural land can be mostly found in the northeast and southwest (Map 1). While many threats to biodiversity remain, including habitat destruction and direct exploitation of wild plants and animals, the government has implemented a large system of pro-environment policies under the broad remit of "Ecological Civilization", which has brought about profound changes – many of them positive – to land use and its ecological implications in China (Bryan et al., 2018; Ministry of Ecology and Environment of China, 2010).

We estimate that land where natural processes predominate[2] accounted for 45% of China's terrestrial land area in 2010 (Map 2). The 306-Eastern Himalayan broadleaf forests hold the greatest share of land where natural processes predominate, followed by 307-Northern Triangle temperate forests and 760-Northwestern Himalayan alpine shrub and meadows (Annex 4). Across the country, while 120 Mha of land is under formal protection, falling short of the 30% zero-draft CBD post-2020 target, only 20% of land where natural processes predominate is formally protected (IUCN, 2016; Jacobson et al., 2019; Potapov et al., 2017). This indicates that future land-based protection efforts should particularly target land where natural processes predominate, and land in regions where formal protection is currently not as strong – notably east of the Heihe-Tengchong Line.

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

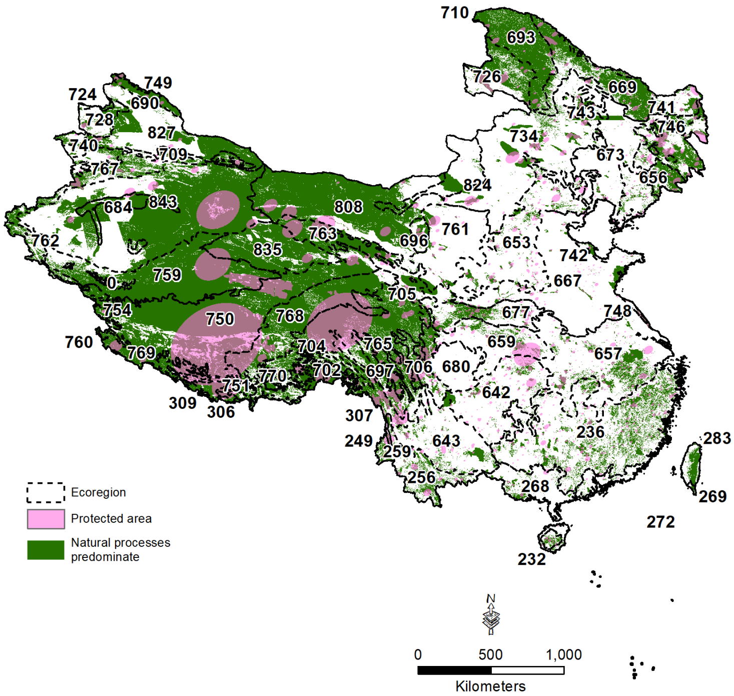


Notes. Correspondence between original ESA CCI land cover classes and aggregated land cover classes displayed on the map can be found in Annex 3.
Sources. countries - GADM v3.6; ecoregions – Dinerstein et al. (2017); land cover – ESA CCI land cover 2015 (ESA, 2017)

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

Approximately 34% of China's cropland was in landscapes with at least 10% natural vegetation in 2010 (Map 2). These relatively biodiversity-friendly croplands are most widespread in 760-Northwestern Himalayan alpine shrub and meadows, 309-Eastern Himalayan subalpine conifer forests, and 249-Mizoram-Manipur-Kachin rain forests (Jacobson et al., 2019; Potapov et al., 2017; IUCN, 2016). The regional differences in extent of biodiversity-friendly cropland can be explained by regional production practices.

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



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

The Food and Land Use Coalition
FABLE Consortium

Pathways and Results

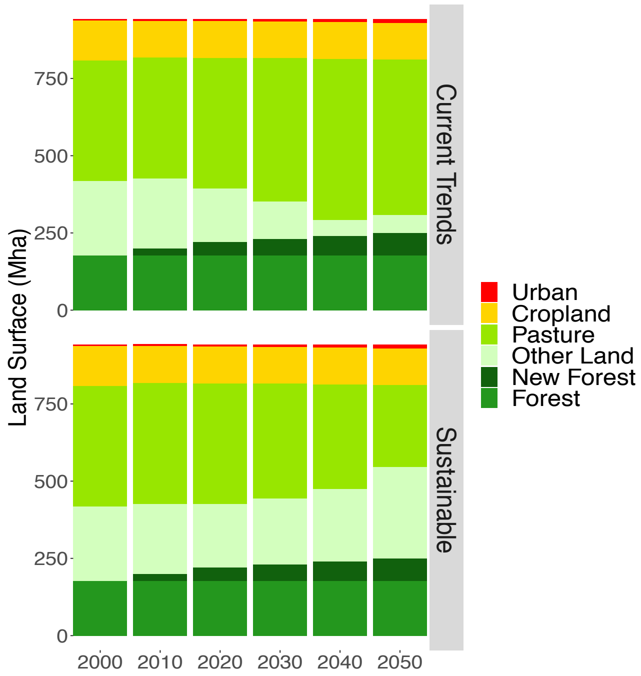
Projected land use in the Current Trends Pathway is based on several assumptions, including no constraints on land conversion beyond protected areas and 72.6 Mha of reforestation or afforestation by 2050 (see Annex 2).

By 2030, we estimate that the main changes in land cover in the Current Trends Pathway will result from an increase in pasture area and a decrease in other land area. This trend remains stable over the period 2030-2050: pasture area further increases and other land area further decreases (Figure 1). Pasture expansion is mainly driven by the rapid increase in domestic consumption of milk, beef and mutton, despite livestock productivity per head increasing slowly and grassland productivity per hectare remaining constant over the period 2020-2030. Between 2030-2050, pasture area first increases before decreasing slightly after 2045. This is explained by initial, rapid increases in milk, beef, and mutton consumption per person followed by declines in the rate of population growth.

This results in a reduction of land where natural processes predominate by 3% by 2030 and an increase by 4% by 2050 compared to 2010, respectively.

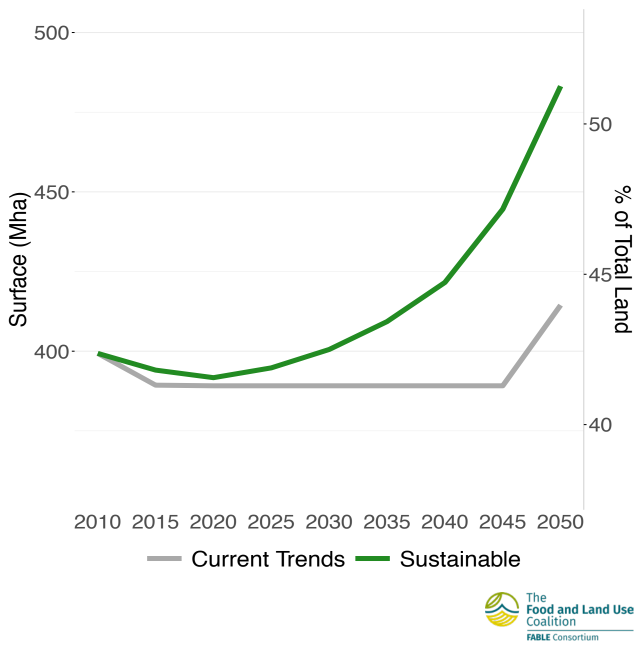
In the Sustainable Pathway, the main assumptions include 72.6 Mha of reforestation or afforestation by 2050 (see Annex 2). Compared to the Current Trends Pathway, we observe the following changes regarding the evolution of land cover in China in the Sustainable Pathway: (i) pasture area decreases steadily, (ii) natural land (the combination of forest, new forest and other land) steadily increases from 2020-2050 due to increases of new forest cover and conversion of pasture for other land use, (iii) cropland area remains stable at 120 Mha due to the strict policy on cropland protection; (iv) changes of forest area are similar to ongoing trends. In addition to the changes in assumptions regarding land-use planning, these changes compared to the Current Trends Pathway are explained by lower milk, beef, and mutton consumption, higher livestock productivity growth, and more food imports. This leads to an increase in the area where natural processes predominate: the area stops declining by 2030 and increases by 21% between 2010 and 2050 (Figure 2). However, the demand for grassland could be further reduced if a share of natural grasslands were converted into managed grasslands. China's grasslands are mostly natural with an average biomass production of 0.75 ton per hectare per year, which is low by international standards. Improving the productivity of managed grassland, which has biomass yields that are more than 10 times higher compared compared with natural grassland, could potentially alleviate some of the pressure on natural grasslands. This requires a significant change in current natural grassland management practices and related livestock production systems.

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



Source. Authors' computation based on FAOSTAT (FAO, 2020) for the area by land cover type for 2000.

Figure 2 | Evolution of the area where natural processes predominate

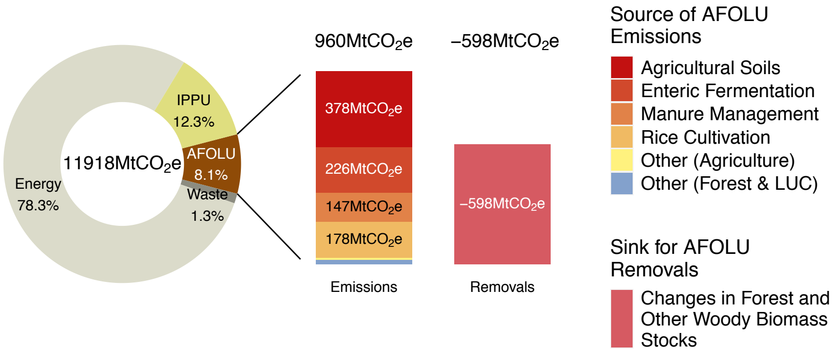


GHG emissions from AFOLU

Current State

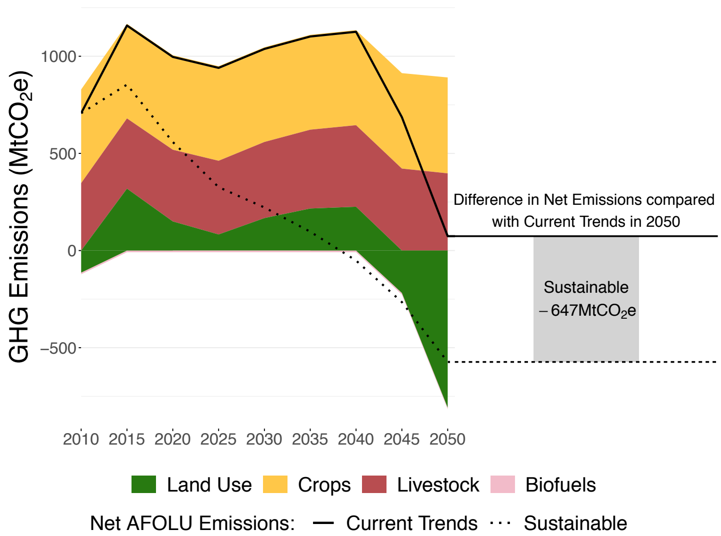
Direct GHG emissions from Agriculture, Forestry, and Other Land Use (AFOLU) accounted for 8.1% of total emissions in 2012 (Figure 3). Agricultural soil is the principle source of AFOLU emissions, followed by enteric fermentation, and rice cultivation (UNFCCC, 2020). China has committed to strengthen global climate governance under the framework of multilateral agreements. For example, China signed the Paris Agreement and pledged to reduce the intensity of its GHG emissions by 60-65% by 2030 compared to 2005. Furthermore, President Xi Jinping announced that China would adopt more effective policies and techniques to reduce CO_2 emission, strive to reach peak emissions by 2030, and achieve carbon neutrality by 2060 (Xi, 2020). However, most of the intended reductions in GHG emissions focus on industry. The agricultural sector is only partially considered, mainly due to the strategic importance of agricultural production for securing food supplies. Hence, we have assumed there will be limited changes in GHG emissions from manure management, enteric fermentation, and rice cultivation in the Sustainable Pathway compare to the Current Trends Pathway. On the other hand, the Chinese government does priorities reforestation. It has undertaken large scale reforestation programs (e.g. "grain for green") and executed them efficiently to control water loss and soil erosion (Bryan et al., 2018). In recent years, the government has launched other projects, such as Ecological Conservation Redlines;

Figure 3 | Historical share of GHG emissions from Agriculture, Forestry, and Other Land Use (AFOLU) to total emissions and removals by source in 2012



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

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



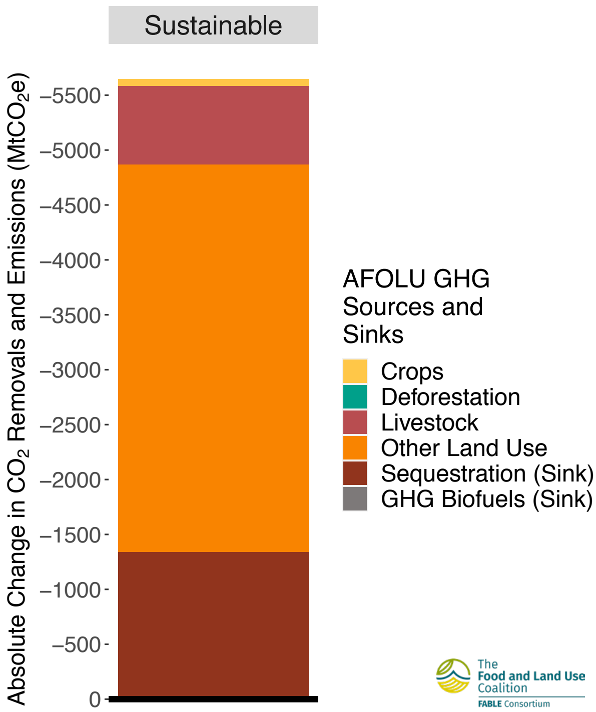
to protect ecosystems, since both the government and general public have realized the importance of the environment for development and human health. This can explain why there is increasing sequestration of carbon in China (Gao, 2019).

Pathways and Results

Under the Current Trends Pathway, annual GHG emissions from AFOLU, increase to 1,038 Mt CO_2e/yr in 2030, before declining to 74 Mt CO_2e/yr in 2050 (Figure 4). In 2050, N_2O from crops is the largest source of emissions (256.1 Mt CO_2e/yr) while sequestration from land use changes acts as a sink (-839.3 Mt CO_2e/yr over the period 2020-2050). The strongest relative increase in GHG emissions is computed for livestock CH_4 (13%) while a reduction is computed for land-use change that does not include deforestation (95%).

In comparison, the Sustainable Pathway leads to a reduction of GHG emissions from AFOLU by 875% by 2050 compared to the Current Trends Pathway (Figure 4). The potential emissions reductions under the Sustainable Pathway is dominated by a reduction in GHG emissions from the land-use change and livestock sectors (Figure 5). Lower beef, milk, and mutton consumption, which reduces the demand for grassland, and reductions in the consumption of corn and wheat, which contributes to lower demand for cropland. and the afforestation of 24.7Mha are the most important drivers of this reduction.

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



Compared to China's commitments under UNFCCC (Table 1), our results show that AFOLU could contribute to the total GHG emissions reduction objective by 2030, though it is difficult to quantify its actual contributions due to the lack of a clear mitigation target for agriculture due to China's food-security-first policy. However, the central government has now pledged to achieve carbon neutrality by 2060 (Wang et al., 2020). The land use sector could contribute greatly to this target. It has been reported that carbon sequestration by terrestrial ecosystems was 1.1 billion tonnes CO_2 annually, which can offset 45% of total emissions. Much of this sequestration came from afforestation, which mainly took place in the northwest and northeast, as well as relevant financial measures. Among the 16 main sustainable land use programs, "Grain-for-Green" and the "Three North" have led to 60.15 Mha in increased forest cover from 1998–2014; the Grain-for-Green increased the vegetation cover of the Loess Plateau significantly, from 31.6% to 59.6% between 1999-2013, and the multi-program afforestation of grasslands in Xinjiang increased forest cover by 68% from 2000–2009 (Bryan et al.,2018). These measures could be particularly important when considering options for NDC enhancement and achieving China's goal of reaching carbon neutrality by 2060.

Food Security

Current State

Undernutrition

6% of the population undernourished in 2012. This share has decreased since 2002 (National Health Commission of China, 2015).

11% of children under 5 stunted and 2% wasted in 2015 (Institute for Health Metrics and Evaluation IHME, 2020).

Micronutrient Deficiency

26.4% of women and 21.4% of children (<5 yr) suffered from anemia in 2016, which can lead to maternal death (WHO, 2020).

14% of the population are deficient in vitamin A (IHME, 2020), which can notably lead to blindness (Sommer, 2001) and child mortality, and/or 16.6% are deficient in iodine, which can lead to developmental abnormalities (Fan et al, 2017).

Overweight/ Obesity

10.2% of the population, and 11.9% of adults, and 5% of children were obese in 2010-2012. These shares have increased since 2002 (National Health Commission of China, 2015).

24.7% of the population, and 30.1% of adults and 8.3% of children, were overweight in 2010-2012. These shares have increased since 2002 (National Health Commission of China, 2015).

Disease Burden due to Dietary Risks

29.9% of deaths are attributable to dietary risks, or 221.5 deaths per year (per 100,000 people) (IHME, 2020).

Dietary risks also lead to/cause 80.3 million disability-adjusted life years (DALYs), or years of healthy life lost due to an inadequate diet (IHME, 2020).

10.9% of the population suffers from diabetes and 21% from cardiovascular diseases, which can be due to or caused by dietary risks (National Center for Cardiovascular Diseases, 2019).

Table 3 | Daily average fats, proteins and kilocalories intake under the Current Trends and Sustainable Pathways in 2030 and 2050

	2010	2030		2050	
	Historical Diet (FAO)	Current Trends	Sustainable	Current Trends	Sustainable
Kilocalories (MDER)	2,658 (2,130)	3,015 (2,110)	2,978 (2,110)	3,775 (2,090)	3,583 (2,090)
Fats (g) (recommended range)	87 (59-89)	98 (67-101)	96 (66-99)	120 (84-126)	113 (80-119)
Proteins (g) (recommended range)	84 (66-233)	104 (75-264)	95 (74-261)	144 (94-330)	118 (90-314)

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

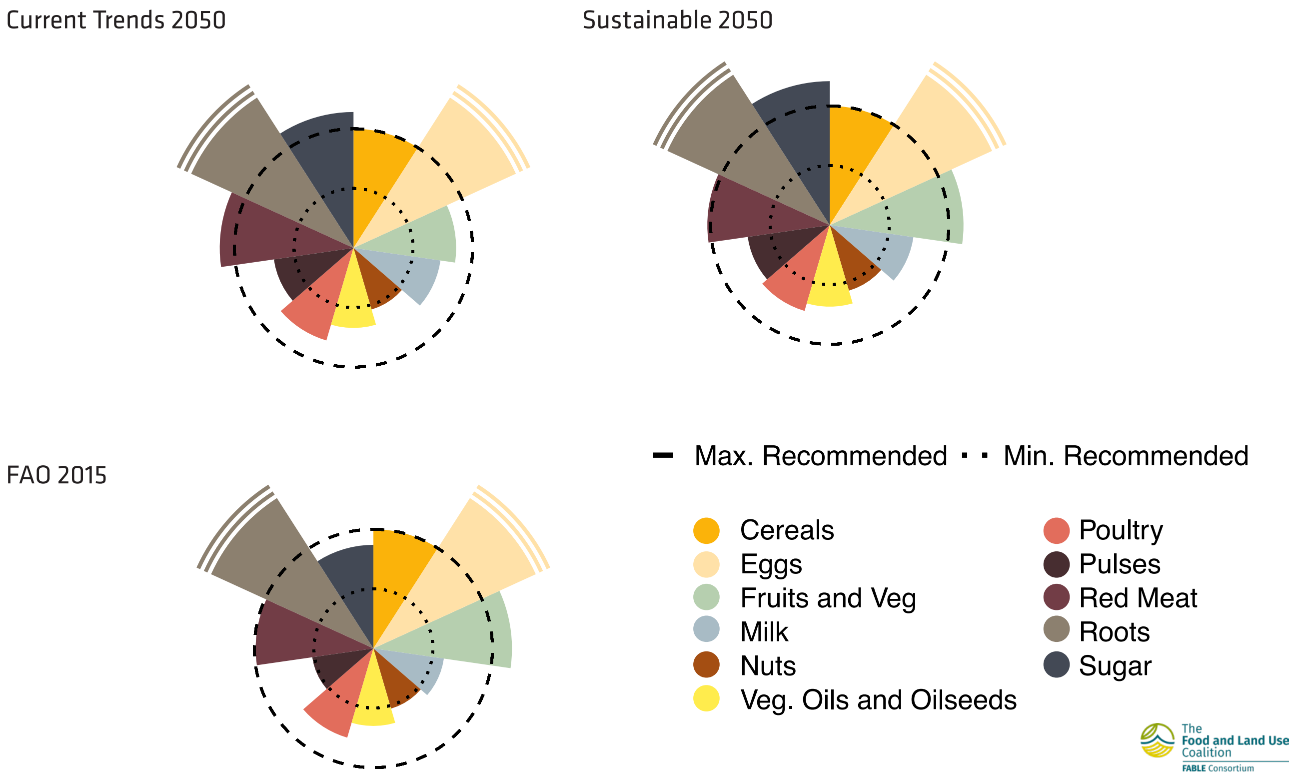
Pathways and Results

Under the Current Trends Pathway, compared to the average Minimum Dietary Energy Requirement (MDER) at the national level, our computed average calorie intake is 43% higher in 2030 and 81% higher in 2050 (Table 3). The current average intake is mostly satisfied by cereals, pork, vegetables and fruits, with animal products representing 23% of the total calorie intake. We assume that the consumption of pulses will increase by 103% between 2020 and 2050. The consumption of milk, sugar, beverages and spices, nuts, and oil seeds and vegetable oils will also increase while the consumption of vegetables and fruits will decrease by 11%. Compared to the EAT-Lancet recommendations (Willett et al., 2019), roots, eggs, and red meat are over-consumed while the consumption of nuts is slightly above the minimum recommended in 2050 (Figure 6). Moreover, fat and protein intake per capita are in line with the dietary reference intake (DRI) in 2030.

Under the Sustainable Pathway, we assume that diets will transition towards lower consumption of animal products and higher consumption of vegetables, fruits, and nuts. The ratio of the computed average intake over the MDER decreases to 41% in 2030 and 71% in 2050. Compared to the EAT-Lancet recommendations, the consumption of red meat is now within the recommended range, though at the upper limit, and the consumption of fruits and vegetables increases to slightly to exceed the upper limit of the recommended range in 2050 (Figure 6). In addition, the fat and protein intake per capita is in line with the dietary reference intake (DRI) in 2030.

Education on healthy diets and curtailing food waste, reducing subsidies for animal products together with higher taxes for high-pollution-livestock-production will be particularly important to promote this shift in diets (Lipinski et al., 2013; Ma et al., 2019).

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



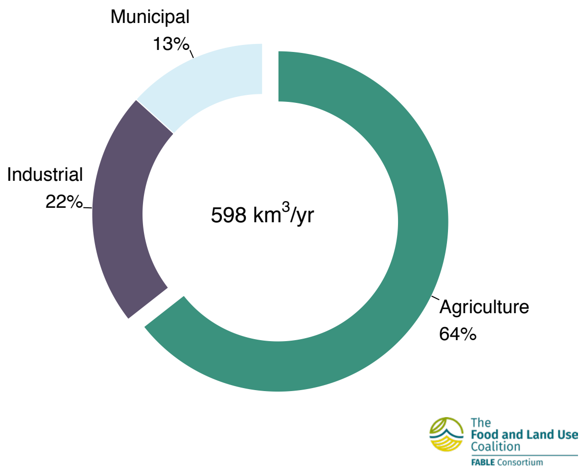
Notes. These figures are computed using the relative distances to the minimum and maximum recommended levels (i.e. the rings), therefore different kilocalorie consumption levels correspond to each circle depending on the food group. The EAT-Lancet Commission does not provide minimum and maximum recommended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

Water

Current State

China is characterized by a monsoon climate and plateau-mountain climate in Tibet with 630 mm average annual precipitation that mostly occurs between May and October (State Council of China, 2005). The agricultural sector represented 64% of total water withdrawals in 2015 (Figure 7). Moreover in 2013, 51% of agricultural land was equipped for irrigation, representing 52% of estimated-irrigation potential (FAO, 2017). The three most important irrigated crops (rice, wheat, and corn), account for 40%, 20%, and 18% of total harvested irrigated area. These crops were mostly used for domestic consumption in 2010 (FAO, 2020). However, China is continuously suffering from water deficits, especially in the North China Plain and in northwest China. The over depletion of ground water, loss of shallow surface wells and rivers in northern China has created many ecological problems. To offset the water deficit, the central government has launched the South-North Water Transfer project, which required significant investment to launch and maintain. The central government also imitated several policies to phase out the high-water-consuming and low-productivity wheat production in the North China Plain to alleviate severe water deficit issues.

Figure 7 | Water withdrawals by sector in 2015

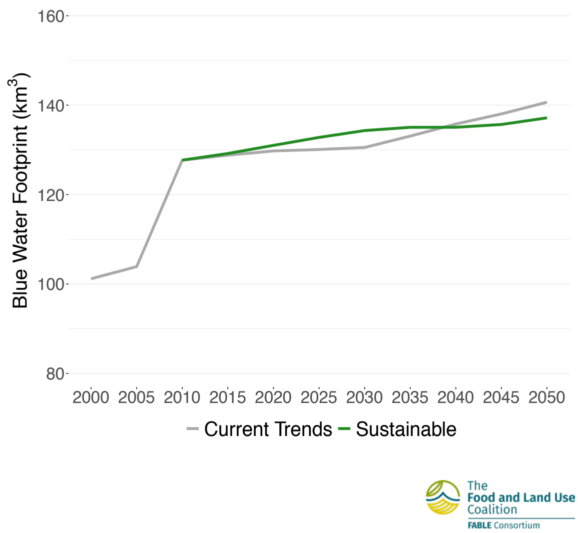


Source. Adapted from AQUASTAT Database (FAO, 2017)

Pathways and Results

Under the Current Trends Pathway, annual blue water use increases between 2000-2015 (101 129 km^3/yr and 129 km^3/yr), before reaching 131 km^3/yr and 141 km^3/yr in 2030 and 2050, respectively (Figure 8), with wheat, rice, and corn accounting for 41%, 32%, and 12% of computed blue water use for agriculture by 2050[3]. In contrast, under the Sustainable Pathway, the blue water footprint in agriculture reaches 134 km^3/yr in 2030 and 137 km^3/yr in 2050, respectively. This is explained by the increase of water use efficiency and more sustainable diets (Annex 2) that have led to changes in the production of corn, wheat, and sweet potato due to the decline in domestic food demand and increases in crop productivity.

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



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

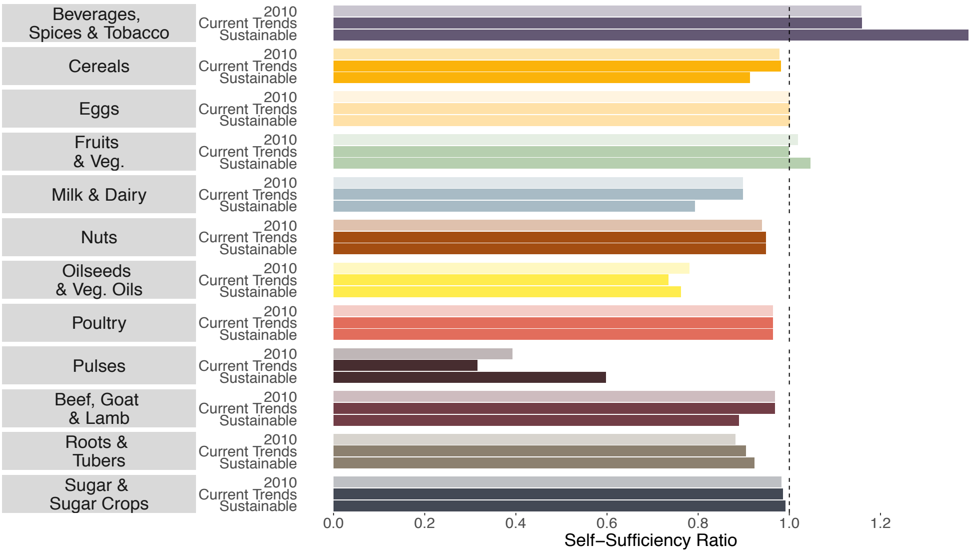
Resilience of the Food and Land-Use System

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

Self-Sufficiency

In 2010, the self-sufficiency of cereals (excluding beer) and fruits were, respectively, around 99.3% and 103% in China. However, the self-sufficiency of vegetable oils and oil crops was only 67.5% and 50.4%, much lower when compared with that of cereals. Self-sufficiency of animal products was relatively high, except for milk products, for which the self-sufficiency stood at 92% due to the outbreak of the melamine scandal in 2008 (National Bureau of Statistics of China, 2020). Under the Current Trends Pathway, we project that China would be self-sufficient in beverages, spices and tobacco, eggs, and fruits and vegetables in 2050, with self-sufficiency by product group remaining relatively constant for the majority of products from 2010 – 2050 (Figure 9). The product groups for which China is most dependent on imports to satisfy domestic consumption are pulses and oil seeds and vegetable oils. This dependency will slightly increase until 2050. By contrast, under the Sustainable Pathway, China would increase imports of the main cereals and animal products, namely decreasing their self-sufficiency to relieve the huge resources over consumption and environmental pressure of food supply. However, China would be more self-sufficient in pulses to support livestock production.

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



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

Diversity

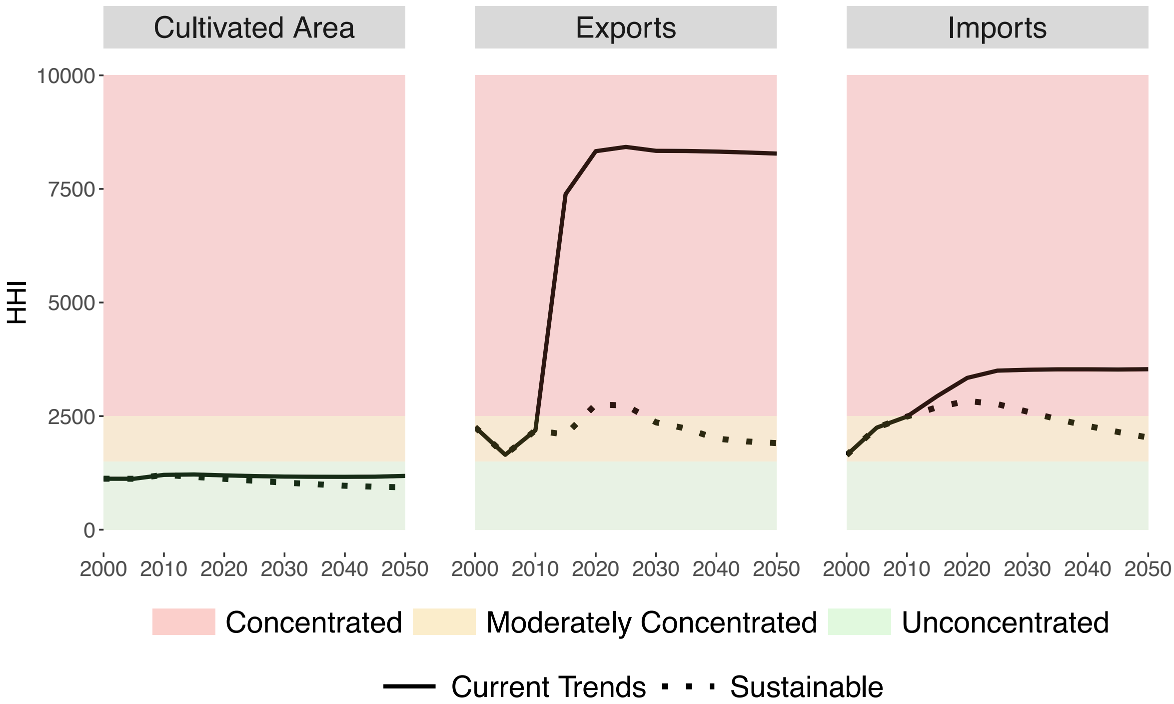
The Herfindahl-Hirschman Index (HHI) measures the degree of market competition using the number of firms and the market shares of each firm in a given market. We apply this index to measure the diversity/concentration of:

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

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

In 2010, four crops represented 66% of the cultivated area with shares of total cropland area varying between 12 and 20%. These are, by order of importance, corn, rice, wheat, and vegetables. Two crops (soybean and cassava), represented 69% of the total volume of imported crops. Finally, fruits and vegetables represented 63% of the total volume of exported crops.

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



Under the Current Trends Pathway, we project a high concentration of crop exports and imports and a low concentration in the range of crops planted in 2050. This indicates high levels of diversity across the national agricultural production system and low levels of diversity for food imports and exports. In contrast, under the Sustainable Pathway, we project medium concentration of crop exports and imports, and a low concentration in the range of crops planted in 2050, indicating moderate levels of diversity across the national production system and imports and exports (Figure 10). This is partially due the rapid increase in domestic crop and livestock productivity, which reduces the demand for imported products, mainly soybean. Soybean has accounted for around half of China's agricultural food and feed import in recent years, hence reducing soybean demand will reduce China's concentration of imports. Rapid increases in agricultural productivity will also offset a significant share of cropland for production of products for domestic demand, due to the Cropland Protection Redline. This may increase China's exports for a few agricultural products, which would reduce the concentration of exports (The State Council Information Office of China, 2010, 2019)

Discussion and Recommendations

Increase productivity or adapt to the "Eat Lancet" diet

We found that the reduction of food waste and increases in livestock productivity are two of the most important drivers to move toward a sustainable food and land-use system in China. Dietary patterns also play a role, but, at present, shifting toward diets in line with the Eat-Lancet recommendations seems very difficult. Currently, China's average per capita consumption of beef and milk is only 50% and 20% of the global average (He et al., 2016). These numbers are even lower when compared to developed countries. Moreover, even during the initial wave of Covid-19, the central government imported large quantities of animal products, such as pork and beef, to secure food supplies and decrease the price of meat and the consumer price index(Ministry of Agriculture and Rural Affairs of China, 2020). This helped ensure that quality of life in China did not decline significantly during the pandemic, one of the central government's main objectives. However, there is strong potential to reduce food loss and waste across China's food system and for different foods in particular, as shown in this chapter and in Ma et al. (2019). Recently there is also strong movement by the central government to reduce food wastage, especially in restaurants and schools, after the statement by President Xi to reduce food waste in August 2020 (Central Government of China, 2020).

In addition, China has high potential to improve agricultural productivity, as evidenced by its lower crop and livestock productivity when compared to developed countries (Bai et al., 2018a; Bai et al., 2018b). Over recent decades, China has sought to ensure its food security, which has led to the overuse of groundwater, fertilizers, pesticides and imported feed products. This has significantly contributed to air and water pollution, global land use change, and rising domestic water scarcity (Wu et al.,2016; Xu et al., 2020; Escobar et al.,2020). To address this challenge, multiple technological innovations, such as improved agricultural infrastructure for low-yield fields, high-yielding breeds, and high-water- and nutrient-use efficiency breeds, and precision crop and livestock farming could be implemented to achieve such target. Such improvements will offset many of the negative impacts on the domestic environment, increase agricultural productivity, and prevent land use change in other countries.

Reduce China's reliance on global market

China's demand for meat and dairy products is rising rapidly, outstripping domestic production by large margins. In 2017, China imported 170 Tg of crops and 1.6 Tg of fishmeal, equal to 38 Tg of protein, of which 86% were used as animal feed. Currently, 40% of imported protein feed is dedicated to livestock production in China, including 13 billion chickens and 700 million pigs(FAO, 2020). In 2019, China also imported 20 Tg of livestock products – of which 80% were ruminant-based– to supplement the increasing demand for animal products. Alongside the European Union, North America, India, and other major importers, China's international demand for soft commodities also contributes to deforestation and other environmental damage in major exporters of agricultural and forestry commodities (Escobar et al., 2020). There is growing recognition of the need for sustainable soft commodity supply chains, which may further increase the need for China to reduce its import dependency for animal protein and feed, particularly as China prepares to host the 15th Conference of the Parties under the UN Convention on Biological Diversity in Kunming in 2021(FABLE Consortium, 2020).

China now needs to revolutionize its livestock production system to reduce its reliance on imports to meet50% of its animal meat, dairy, and eggs consumption through domestic production. This will help ensure long-term security, address environmental spillovers, and provide an opportunity to strengthen meat production processes to improve food safety. There are three technically and economically feasible food system revolutions that can greatly reduce China's reliance on imports: (1) a revolution in feed protein supply through organic and non-organic sources based micro-protein feed production(Pikaar et al., 2017); (2) a revolution in grasslands through vegetation greening and fodder production through grassland restoration to replace imported ruminant animal products(Fang et al., 2016); and (3) a revolution in aquaculture through industrial-indoor-fish-plants and sustainable offshore marine production to boost aquatic production(Palma et al., 2019). Together these measures may have profound impacts on the Sustainable Development Goals in China and the countries from which it imports agricultural commodities.

In addition, new technologies in food production could also offer solutions for China, such as high-tech greenhouses for vegetable production to reduce demand for cropland, synthetic beef and meat-production technologies to reduce demand for grassland, and plant-based alternatives to meat made from beans and grain to reduce demand for animal feed. These technologies can help produce more food while limiting agricultural land expansion, reducing GHG emissions and pollution so as to achieve sustainable food production. All of these technologies are too expensive at present but may become more affordable in the future due to breakthroughs in technology and supplies of green energy.

Policies and recommendations

The report of the 19th National Congress of the Communist Party of China states that, "what we now face is the contradiction between unbalanced and inadequate development and the people's ever-growing need for a better life" (Xi, 2017). This is true for food and land-use systems, which face trade-offs between, for example, higher livestock production and the risk of high environmental pollution, or biodiversity loss or grassland degradation domestically and internationally. Since China is facing great pressures in terms of air and water pollution, in recent years, the central government has promoted several large projects to control haze in the North China Plain and the Yangtze River Delta, nonpoint source surface and ground water pollution, over-use of fertilizer and pesticides (Ministry of Agriculture of China, 2015b, 2015a; State Council of China, 2013). Moreover, a series of new policies have been implemented to shut down highly-polluting factories, reduce subsides for fertilizer manufacturing companies, limit transportation, increase the livestock manure recycling rate to substitute for fertilizer, implement the Non Livestock Production Zone, and enhance environmental protection without loosening the protection of cropland. (Ministry of Agriculture of China, 2015a, 2017; State Council of China, 2015) Meanwhile, President Xi has emphasized to the importance to reduce food wastage, with the "Empty the Plate" campaign, and announced that China will achieve Carbon Neutrality in 2060.

Therefore, we have witnessed the improvement of environmental protection, a decrease in fertilizer use, and increases of grain production in China. This indicates that China is on track to solve these tradeoffs, though large uncertainties remain due to climatic change and rapidly increasing demand for animal products.

To continue these advances, and to combat pollution, resources depletion and to achieve the SDGs, we recommend that the first priority for China be to take measures to improve the productivity of crop and livestock production without increasing inputs per unit (Cui et al., 2018; Ma et al., 2019). A series of policies, such as the circulation of rural land and rural land consolidation, are also needed to increase farm size and productivity. (Cui et al., 2018). We also recommend investing in micro-protein production, grassland management, and aquatic production to reduce China's reliance on imported feed protein and animal products, which may significantly reduce the potential negative impacts on other countries. Finally, reducing food waste and encouraging more moderate consumption of meat should also be considered by the central government to achieve the SDGs.

Limitations of the models and next step

At present, the FABLE Calculator is unable to account for the competition between urban land and cropland. Specifically, this means that that urban land only grows by 2% per year but does not impact other land use types. That may lead us to draw the erroneous conclusion that the agricultural redline policy is unnecessary when crop productivity is high, when, in reality, we have not accounted for cropland occupied by cities. However, if we give up the Cropland Protection Redline, we cannot ensure the protection of high productivity cropland that has ensured China's domestic food security. In addition, there was mismatch between our modeled GHG emissions, water use, food consumption with the historical data for China. This may be due to overestimations of the increase in crop and livestock productivity in the Sustainable Pathway, which may lead to lower land-use change when compared to our Current Trends Pathway. In addition, the FABLE Calculator does not account for nutrient management, which has large impacts on China's environment. Finally, biodiversity indexes are mostly based on land area, which does not capture the biodiversity by land use in a country.

Going forward we plan to address these limitations. First, by further calibrating the FABLE Calculator and matching the modeled results with historical changes. Second, by linking the model to nutrient management which enhances the prediction of demand for nitrogen and phosphorus fertilizers, and related environmental pollution. Third, by improving projections on the quality of diets by looking beyond energy intake to proteins, vitamins, and essential amino acids. Fourth and finally, by incorporating the aquaculture sector as it accounts for a great deal of the food produced in China and could contribute to the protection of ecosystems.

Finally, following the announcement of China's ambitious pledge to achieve carbon neutrality by 2060, the FABLE China team, in partnership with the Food and Land Use Coalition Platform in China, will seek to develop a long term pathway specifically focused on decarbonizing China's land sector.

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

- We have created a new scenario to ensure cropland area remains above 120 Mha, which reflect China's Cropland Protection Redline (Standing Committee of the National People's Congress, 2020).
- We have created a new scenario on afforestation to reflect the historical evolution of forest area and China's target to achieve 26% forest cover rate by 2050. (State Council of China, 2017a; National Forestry and Grassland Administration of China, 2016).
- We have collected protected area data, including natural reserves, national scenic areas, national geoparks and national forest park. Unfortunately, provincial-level protected areas are not included in the data, as many provinces did not build a standard geological database. This made it difficult for us to locate and identify their spatial scope (National Specimen Information Infrastructure, 2020).
- We have included the SSP1 and SSP2 crop productivity scenarios from the GLOBIOM model. For the crops that are included in the FABLE Calculator, but not included in GLOBIOM, we further reviewed statistic data and Ma et al. (2019) to complete the crop production scenario setting.
    - We referred to the increase rates in GLOBIOM-China and Ma et al. (2019) but not their absolute value as their data may come from different sources (for example Ma et al. (2019) used some data from National Bureau of Statistics) which may not match the FAO data used in FABLE Calculator.
    - First, we collected the crop productivity data in 2010 from FAOSTAT. Then for crops which are contained in GLOBIOM (wheat, sunflower, barley, cassava, corn, groundnut, millet, potato, and rice), we used the crop productivity increase rates from SSP1 and SSP2, which originated from Zhao et al.(n.d), as the productivity increase rates, respectively, of the Sustainable and Current Trends Pathways. For the crops which are not contained in GLOBIOM (soybean, vegetabless and fruits), we used the productivity increase rates from Ma et al. (2019) and FAO's historical data (2000-2010), as the crop increase rates, respectively, in the Sustainable and Current Trends Pathways. Finally, we multiplied the crop productivity data in 2010 and their increase rates to achieve their productivities in 2050.
- We have included a sustainable scenario on the evolution of imports for key commodities by reviewing annual reports that monitor the trade of agricultural products (Ma et al., 2019; FAO, 2020; Ministry of Agriculture and Rural Affairs of China, 2020).
- We identified the main imported and exported products, and important agricultural products for China to set a sustainable scenario which turns on importing more: soyabean (56%), cassava (68%), palm oil (98%), milk (20%), pork (10%), beef (10%), mutton (10%), corn (20%), and wheat (14%).
- We have used the SSP1 and SSP2 diet scenarios from GLOBIOM. For the food categories which are not covered in GLOBIOM, we have used the *Dietary guidelines for Chinese residents and the fat diet* (Chinese Nutrition Society, 2016).

Annex 2. Underlying assumptions and justification for each pathway

POPULATION Population projection (million inhabitants)

Current Trends Pathway	Sustainable Pathway
The population is expected to reach 1,286 million by 2050 (SSP2). China implemented the "Two Child" policy in 2016, which has increased the annual birth rate in a short period. But we expect this will not change the long-term projections by UN towards to 2050, unless other policies are implemented. Based on National Bureau of Statistics of China (2020), Qi, Dai, & Zheng (2016) Jing, Wang, & Sun (2018) (SSP2 scenario selected)	The population is expected to reach 1,251 million by 2050 (SSP1). This is of high uncertainty in the future, as the central government has no such plan. However, when there is a continuous increase in education and income levels, the annual birth rate slightly decreases. Based on Brueckner & Schwandt (2015), Handa (2000) (SSP1 scenario selected)

LAND Constraints on agricultural expansion

Current Trends Pathway	Sustainable Pathway
We assume that there will be no constraint on the expansion of agricultural land beyond existing protected areas and under the total land boundary and that cropland will always remain higher than 120 Mha. Implementing the national policy of "cherish and use land rationally as well as give a true protection to the cultivated land" means that cultivated land should be more than 120 Mha.	Same as Current Trends

LAND Afforestation or reforestation target (1,000 ha)

Current Trends Pathway	Sustainable Pathway
We assume total afforested/reforested area will reach 249.6 Mha by 2050. 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. In addition, according to National forest management plan, the forest cover rate could reach 26% in 2050. Based on State Council of China (2017a) and National Forestry and Grassland Administration of China (2016)	Same as Current Trends

BIODIVERSITY Protected areas (1,000 ha or % of total land)

Current Trends Pathway	Sustainable Pathway
We used the by-default assumption in the FABLE Calculator which is that in the ecoregions where current level of protection is between 5% and 17%, the natural land area under protection increases up to 17% of the ecoregion total natural land area by 2050.	We used the by-default assumption in the FABLE Calculator which is that in the ecoregions where current level of protection is between 5% and 17%, the natural land area under protection increases up to 17% of the ecoregion total natural land area by 2050.

PRODUCTION Crop productivity for the key crops in the country (in t/ha), here we show the productivity with the influence of RCP

Current Trends Pathway	Sustainable Pathway
By 2050, crop productivity (with the impacts of climate change) reaches: • 6.1 tonnes per ha for rice • 7.9 tonnes per ha for wheat • 7.8 tonnes per ha for corn We used the SSP2 crop productivity data from the GLOBIOM model. For several crops which are not included in GLOBIOM, we used historical productivity growth rates. Based on Zhao et al. (n.d.) and National Bureau of Statistics of China (2020)	By 2050, crop productivity (with the impacts of climate change) reaches: • 6.6 tonnes per ha for rice • 7.6 tonnes per ha for wheat • 9.1 tonnes per ha for corn We used the SSP1 crop productivity data from GLOBIOM model. For several crops which are not included in GLOBIOM, we used MA et al. (2019). Based on Zhao et al. (n.d.)
PRODUCTION Livestock productivity for the key livestock products in the country (in t/head of animal unit)	
By 2050, livestock productivity reaches: • 110 kg per head for pig • 54 kg per head for beef cattle • 12 kg per head for sheep and goats These numbers are very close to the average animal productivity yearly growth rate in 2011-2018, according to Chinese statistics. Based on National Bureau of Statistics of China (2020)	By 2050, livestock productivity reaches: • 134 kg per head for pig • 78 kg per head for beef cattle • 15 kg per head for sheep and goats Taking the United States as the reference point, there are still large gaps in livestock productivity. Pig and poultry productivity are expected to increase by 20% compared to 2010. For beef cattle, dairy, sheep, goat and layer, the increase rate is assumed to be 40%. Based on Ma et al. (2019)
PRODUCTION Pasture stocking rate (in animal units/ha pasture)	
By 2050, the average ruminant livestock stocking density is 0.37 TLU/ha per ha. As 2019 is almost the end of 13th five-year plan, the targets are almost achieved, so we believe the trend will also be the same as the Sustainable Pathway. Based on National Development and Reform Commission of China (2015, 2016)	By 2050, the average ruminant livestock stocking density is 0.35 TLU/ha per ha. Pasture-livestock balance is a long-term goal of animal production development and the government encourages rest grazing, rotational grazing, and high ambitious targets, which are set in "The 13th five-year plan for grassland protection, construction and utilization in China" Based on National Development and Reform Commission of China (2016) and National Bureau of Statistics of China (2020)
PRODUCTION Post-harvest losses	
Remains constant. At present, there is no clear policy to address this issue.	By 2050, the share of production and imports lost during storage and transportation reduced by 20%. According to Ma et al. (2019), food loss and food waste would be reduced by 20% through a combination of new technologies, improved facilities, and education.

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

Current Trends Pathway	Sustainable Pathway
By 2050, the share of total consumption which is imported is: • 1% by 2050 for pork • 4% by 2050 for beef • 10% by 2050 for milk • 80% by 2050 for soybean In this pathway, we still regard food security as an important target, the priority is self-sufficient, so the import is stable and export share keep constant. Based on The State Council Information Office of China (2019)	By 2050, the share of total consumption which is imported is: • 10% by 2050 for pork • 10% by 2050 for beef • 21% by 2050 for milk • 56% by 2050 for soybean Freer trade between China and other countries, agricultural product which is not the staple food and has low comparative effectiveness for China can depend more on other countries (i.e. milk and palm oil). As for soybean, we assumed imports would be 30% lower since, according to the FABLE Calculator's results, when we keep cropland higher than 120 Mha, we are able to plant more crops to increase China's self-sufficiency for soybean. Based on Ma et al. (2019)

TRADE Evolution of exports for key exported products (1,000 tons)

Current Trends Pathway	Sustainable Pathway
E4 for export By 2050, the volume of exports is: • 261 tonnes by 2050 for tea • 158 tonnes by 2050 for tobacco • 343 tonnes by 2050 for orange • 584 tonnes by 2050 for onion • 6078 tonnes by 2050 for vegetable_other Food security is a major governmental objective, so the self-sufficiency is prioritized. Therefore, exports remain constant, meaning that China's agricultural product trade deficit remains large. Based on The State Council Information Office of China (2010, 2019)	**E1 for export** By 2050, the volume of exports is: • 967 tonnes by 2050 for tea • 474 tonnes by 2050 for tobacco • 1030 tonnes by 2050 for orange • 1752 tonnes by 2050 for onion • 18233 tonnes by 2050 for vegetable_other Developing comparative advantages to further export agricultural products (e.g. tea, vegetables, and water products) can not only help to achieve sustainable goals in global level, but also to decrease China's trade deficit in agricultural products. Based on Ministry of Agriculture and Rural Affairs of China, (2020) and Thow & Nisbett (2019)

FOOD Average dietary composition (daily kcal per commodity group)

Current Trends Pathway	Sustainable Pathway
By 2030, the average daily calorie consumption per capita is 2,855 kcal and is: • 1196 kcal for cereals • 368 kcal for pork • 53 kcal for other red meat • 80 kcal for milk • 230 kcal for vegetable and fruit Using the SSP2 diet scenario from the GLOBIOM model. For the categories which are not included in GLOBIOM, we used the FABLE Calculator's scenario transitioning to a Western-style diet. Based on Zhao et al. (n.d.)	By 2030, the average daily calorie consumption per capita is 2,789 kcal and is: • 1185 kcal for cereals • 356 kcal for pork • 50 kcal for other red meat • 75 kcal for milk • 256 kcal for vegetable and fruit Using the SSP1 diet scenario from the GLOBIOM model. For the categories which are not included in GLOBIOM, we used the FABLE Calculator's scenario transitioning to a Western-style diet. Based on Zhao et al. (n.d.) and Chinese Nutrition Society (2016)

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

Current Trends Pathway	Sustainable Pathway
By 2030, the share of final household consumption which is wasted at the household level remains constant. At present, there is no clear policy to address this issue.	By 2030, the share of final household consumption which is wasted at the household level decreases by 20%. According to Ma et al. (2019), food loss and food waste would be decrease by 20% through a combination of new technologies, improved facilities, and education.

BIOFUELS Targets on biofuel and/or other bioenergy use

Current Trends Pathway

By 2050, biofuel production accounts for:

- 15.4 Mt of corn production
- 2.8 Mt of wheat production

At present, biofuel policy in China is not clear

Sustainable Pathway

Same as Current Trends

CLIMATE CHANGE Crop model and climate change scenario

Current Trends Pathway

RCP 6.0
By 2100, global GHG concentration leads to a radiative forcing level of 6 W/m^2 (RCP 6.0). Impacts of climate change on crop yields are computed by the crop model GEPIC using climate projections from the climate model HadGEM2-E without CO_2 fertilization effect

	Yield shift between 2000-2050	
	Yield shifter (irrigation)	Yield shifter (rainfed)
Corn	0.93	0.89
Rice	0.9	0.9
Soyabean	0.92	0.91
Wheat	1	1.02

Based on NOAA (2020)

Sustainable Pathway

RCP 2.6
By 2100, global GHG concentration leads to a radiative forcing level of 2.6 W/m^2 (RCP 2.6). Impacts of climate change on crop yields are computed by the crop model GEPIC using climate projections from the climate model HadGEM2-E without CO_2 fertilization effect

	Yield shift between 2000-2050	
	Yield shifter (irrigation)	Yield shifter (rainfed)
Corn	1	1.01
Rice	0.95	0.95
Soyabean	0.99	0.97
Wheat	1.02	1.07

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

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

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

	Ecoregion	Area (1,000 ha)	Protected Area (%)	Share of Land where Natural Processes Predominate (%)	Share of Land where Natural Processes Predominate that is Protected (%)	Share of Land where Natural Processes Predominate that is Unprotected (%)	Cropland (1,000 ha)	Share of Cropland with at > 10% natural vegetation within 1km²(%)
0	Rock and Ice	5,662.07	20.30	71.80	24.40	75.60	15.48	99.40
232	Hainan Island monsoon rain forests	1,557.01	10.60	40.50	21.40	78.60	273.10	50.40
236	Jian Nan subtropical evergreen forests	66,407.70	5.50	22.60	8.30	91.70	21,901.72	51.40
249	Mizoram-Manipur-Kachin rain forests	1.55	-	68.00	-	-	0.01	100.00
256	Northern Indochina subtropical forests	14,730.88	7.20	31.60	9.20	90.80	2,393.34	72.80
259	Northern Triangle subtropical forests	4.76	-	88.60	-	-	-	
268	South China-Vietnam subtropical evergreen forests	18,461.27	2.70	9.80	9.20	90.80	9,697.20	34.60
306	Eastern Himalayan broadleaf forests	1.26	-	100.00	-	-	-	
307	Northern Triangle temperate forests	0.06	-	100.00	-	-	-	
309	Eastern Himalayan subalpine conifer forests	71.17	-	89.40	-	-	1.12	100.00
642	Guizhou Plateau broadleaf and mixed forests	27,013.86	10.90	8.60	31.20	68.80	13,054.51	51.90
643	Yunnan Plateau subtropical evergreen forests	24,087.38	4.00	12.70	6.30	93.70	5,169.23	69.10
653	Central China Loess Plateau mixed forests	36,043.46	6.80	9.60	18.60	81.40	14,055.21	46.70
656	Changbai Mountains mixed forests	4,612.25	13.70	70.40	16.00	84.00	489.80	56.80
657	Changjiang Plain evergreen forests	43,870.74	5.80	15.20	16.60	83.40	28,964.30	15.30
659	Daba Mountains evergreen forests	16,867.79	16.10	16.70	28.40	71.60	6,890.10	41.20

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

China

	Ecoregion	Area (1,000 ha)	Protected Area (%)	Share of Land where Natural Processes Predominate (%)	Share of Land where Natural Processes Predominate that is Protected (%)	Share of Land where Natural Processes Predominate that is Unprotected (%)	Cropland (1,000 ha)	Share of Cropland with at > 10% natural vegetation within 1km²(%)
667	Huang He Plain mixed forests	43,457.09	2.60	4.40	13.90	86.10	35,860.66	5.80
669	Manchurian mixed forests	35,701.55	10.00	51.90	13.50	86.50	9,709.24	39.10
673	Northeast China Plain deciduous forests	23,190.93	3.80	6.40	16.20	83.80	17,325.62	17.40
677	Qin Ling Mountains deciduous forests	12,360.19	10.10	30.90	18.20	81.80	3,275.00	48.40
680	Sichuan Basin evergreen broadleaf forests	9,833.61	2.00	0.70	15.70	84.30	8,383.45	15.10
684	Tarim Basin deciduous forests and steppe	5,459.54	2.40	68.20	1.90	98.10	359.62	28.00
690	Altai montane forest and forest steppe	1,699.32	10.60	88.10	11.10	88.90	71.80	45.30
693	Da Hinggan-Dzhagdy Mountains conifer forests	15,146.50	6.30	91.70	6.40	93.60	264.87	76.80
696	Helanshan montane conifer forests	2,474.11	13.70	49.30	18.80	81.20	386.54	38.60
697	Hengduan Mountains subalpine conifer forests	9,964.12	19.90	56.30	23.10	76.90	610.98	78.40
702	Northeast Himalayan subalpine conifer forests	4,096.27	30.10	86.60	33.10	66.90	62.24	97.70
704	Nujiang Langcang Gorge alpine conifer and mixed forests	7,842.75	38.50	60.00	41.20	58.80	473.47	88.50
705	Qilian Mountains conifer forests	1,668.98	22.70	70.60	25.10	74.90	149.36	91.70
706	Qionglai-Minshan conifer forests	8,039.45	20.90	58.10	26.40	73.60	938.61	77.30
709	Tian Shan montane conifer forests	1,282.45	6.80	30.20	14.90	85.10	228.16	51.80
710	East Siberian taiga	32.37	-	92.30	-	-	-	

	Ecoregion	Area (1,000 ha)	Protected Area (%)	Share of Land where Natural Processes Predominate (%)	Share of Land where Natural Processes Predominate that is Protected (%)	Share of Land where Natural Processes Predominate that is Unprotected (%)	Cropland (1,000 ha)	Share of Cropland with at > 10% natural vegetation within 1km²(%)
724	Altai steppe and semi-desert	219.51	0.10	15.70	0.20	99.80	79.12	41.50
726	Daurian forest steppe	266.36	5.20	42.20	12.30	87.70	6.75	98.70
728	Emin Valley steppe	4,598.05	2.80	27.40	7.20	92.80	786.30	32.80
734	Mongolian-Manchurian grassland	57,820.23	7.20	21.40	20.60	79.40	14,085.58	48.40
740	Tian Shan foothill arid steppe	871.13	-	6.80	0.10	99.90	531.64	20.70
741	Amur meadow steppe	5,292.45	11.00	27.60	22.20	77.80	3,975.65	10.10
742	Bohai Sea saline meadow	1,128.32	6.90	26.50	14.40	85.60	464.30	31.00
743	Nenjiang River grassland	2,325.17	2.60	26.10	5.00	95.00	1,649.06	23.80
746	Suiphun-Khanka meadows and forest meadows	1,822.99	25.60	25.80	41.60	58.40	1,139.38	13.00
748	Yellow Sea saline meadow	529.16	38.90	39.40	95.60	4.40	411.73	3.50
749	Altai alpine meadow and tundra	1,587.39	13.10	87.00	15.00	85.00	96.22	71.60
750	Central Tibetan Plateau alpine steppe	62,979.43	43.40	85.90	42.20	57.80	916.55	92.20
751	Eastern Himalayan alpine shrub and meadows	8,791.06	23.90	72.90	26.50	73.50	108.76	98.10
754	Karakoram-West Tibetan Plateau alpine steppe	2,822.47	3.60	74.10	3.90	96.10	7.70	96.50
759	North Tibetan Plateau-Kunlun Mountains alpine desert	37,525.98	15.00	88.30	16.20	83.80	136.90	90.20
760	Northwestern Himalayan alpine shrub and meadows	90.96	-	93.60	-	-	0.36	100.00
761	Ordos Plateau steppe	21,595.10	4.20	8.30	21.50	78.50	5,389.52	70.00
762	Pamir alpine desert and tundra	3,355.48	-	41.00	-	-	21.89	95.40

China

	Ecoregion	Area (1,000 ha)	Protected Area (%)	Share of Land where Natural Processes Predominate (%)	Share of Land where Natural Processes Predominate that is Protected (%)	Share of Land where Natural Processes Predominate that is Unprotected (%)	Cropland (1,000 ha)	Share of Cropland with at > 10% natural vegetation within 1km²(%)
763	Qilian Mountains subalpine meadows	7,339.41	33.20	89.90	32.30	67.70	190.57	93.30
765	Southeast Tibet shrublands and meadows	46,184.76	31.50	78.30	34.80	65.20	4,304.21	80.30
767	Tian Shan montane steppe and meadows	19,357.17	5.70	46.20	8.00	92.00	2,438.09	48.50
768	Tibetan Plateau alpine shrublands and meadows	27,272.96	27.20	83.60	28.80	71.20	1,340.50	93.70
769	Western Himalayan alpine shrub and meadows	3,521.03	20.40	91.80	19.60	80.40	34.53	94.80
770	Yarlung Zanbo arid steppe	5,958.75	34.60	47.60	39.90	60.10	151.12	90.30
808	Alashan Plateau semi-desert	45,714.08	6.10	75.60	5.40	94.60	1,928.23	50.40
824	Eastern Gobi desert steppe	10,414.71	0.40	23.60	0.80	99.20	292.77	39.20
827	Junggar Basin semi-desert	23,927.79	2.30	41.30	3.00	97.00	2,903.40	17.20
835	Qaidam Basin semi-desert	19,247.18	9.10	87.80	10.00	90.00	89.17	87.50
843	Taklimakan desert	74,353.46	10.10	61.80	13.50	86.50	4,386.31	20.20

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

Units

°C – degree Celsius

% – percentage

/yr – per year

cap – per capita

CO_2 – carbon dioxide

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

g – gram

GHG – greenhouse gas

Gt – gigatons

ha – hectare

kcal – kilocalories

kg – kilogram

kha – thousand hectares

km^2 – square kilometer

km^3 – cubic kilometers

kt – thousand tonnes

m – meter

Mha – million hectares

mm – milimeters

Mm^3 – million cubic meters

Mt – million tons

t – tonne

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

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

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

USD – United States Dollar

W/m^2 – watt per square meter

yr – year

References

Bai, Z., Lee, M. R. F., Ma, L., Ledgard, S., Oenema, O., Velthof, G. L., … Zhang, F. (2018). Global environmental costs of China's thirst for milk. *Global Change Biology, 24*(5), 2198–2211. https://doi.org/10.1111/gcb.14047

Bai, Z., Ma, W., Ma, L., Velthof, G. L., Wei, Z., Havlík, P., … Zhang, F. (2018). China's livestock transition: Driving forces, impacts, and consequences. *Science Advances, 4*(7). https://doi.org/10.1126/sciadv.aar8534

BirdLife International. (2019). Digital boundaries of Important Bird and Biodiversity Areas from the World Database of Key Biodiversity Areas. Retrieved February 8, 2019, from BirdLife International website: http://datazone.birdlife.org/site/requestgis

Brueckner, M., & Schwandt, H. (2015). Income and Population Growth. *The Economic Journal, 125*(589), 1653–1676. https://doi.org/10.1111/ecoj.12152

Bryan, B. A., Gao, L., Ye, Y., Sun, X., Connor, J. D., Crossman, N. D., … Yu, D. (2018). China's response to a national land-system sustainability emergency. *Nature, 559*(7713), 193–204.

Cadena, M., Supples, C., Ervin, J., Marigo, M., Monakhova, M., Raine, P., & Virnig, A. (2019). *Nature is counting on us: Mapping progress to achieve the Aichi Biodiversity Targets*. United Nations Development Programme.

Central Government of China (2020). *Xi Jinping made important instructions to stop food waste*. Retrieved from http://www.gov.cn/xinwen/2020-08/11/content_5534026.htm

Chinese Nutrition Society. (2016). *Dietary Guidelines for Chinese Residents*. Retrieved from https://www.cnsoc.org/bookpublica/9017112075.html

CBD. (2020). China—National Targets. Retrieved May 8, 2020, from Convention on Biological Diversity website: https://www.cbd.int/countries/targets/?country=cn

Cui, Z., Zhang, H., Chen, X., Zhang, C., Ma, W., Huang, C., … Dou, Z. (2018). Pursuing sustainable productivity with millions of smallholder farmers. *Nature, 555*(7696), 363–366. https://doi.org/10.1038/nature25785

Dinerstein, E., Olson, D., Joshi, A., Vynne, C., Burgess, N. D., Wikramanayake, E., … Saleem, M. (2017). An Ecoregion-Based Approach to Protecting Half the Terrestrial Realm. *Bioscience, 67*(6), 534–545. https://doi.org/10.1093/biosci/bix014

ESA. (2014). *ESA database* Data set. Retrieved from https://www.esa-landcover-cci.org/?q=node/158

ESA. (2017). *Land Cover CCI Product User Guide Version 2*. Tech. Rep. Retrieved from maps.elie.ucl.ac.be/CCI/viewer/download/ESACCI-LC-Ph2-PUGv2_2.0.pdf

Escobar, N., Tizado, E. J., zu Ermgassen, E. K., Löfgren, P., Börner, J., & Godar, J. (2020). Spatially-explicit footprints of agricultural commodities: Mapping carbon emissions embodied in Brazil's soy exports. *Global Environmental Change, 62*, 102067.

FABLE Consortium (2020). Sustainability of China's projected trade in agriculture products. Analysis of trade flows with major trading partners. Retrieved from https://docs.google.com/document/d/1CiobbZf7ZCrGFr__zIlwpj9wfAtGKC-cpoTJki6kCQY/edit?usp=sharing

Fan, L., Su, X., Shen, H., Liu, P., Meng, F., Yan, J., … Sun, D. (2017). Iodized salt consumption and iodine deficiency status in China: a cross-sectional study. *Global Health Journal*, 1(2), 23-37. https://doi.org/10.1016/S2414-6447(19)30076-4.

Fang, J. Y., Pan, Q. M., & Gao, S. Q. (2016). Small vs large area'principle: Protecting and restoring a large area of natural grassland by establishing a small area of cultivated pasture. *Pratacultural Science, 33*(10), 1913-1916.

FAO. (2017). *AQUASTAT* Database. Retrieved from http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en

FAO. (2020). *FAOSTAT* Database. Retrieved from http://www.fao.org/faostat/en/#home Food Security Information Network, & Global Network Against Food Crises. (2020). *2020 Global Report on Food Crises*. Retrieved from https://www.wfp.org/publications/2020-global-report-food-crises

GADM. (2020). Global Administrative Areas. Version 3.6. Retrieved from https://gadm.org/data.html.

Gao, J. (2019). How China will protect one-quarter of its land. Nature, 569(7755), 457–458.

Handa, S. (2000). The Impact of Education, Income, and Mortality on Fertility in Jamaica. *World Development, 28*(1), 173–186. https://doi.org/10.1016/S0305-750X(99)00114-X

Hattori, T. (2020). *IGES NDC Database v7.3*. Retrieved from https://www.iges.or.jp/en/pub/iges-indc-ndc-database/en

He, Y., Yang, X., Xia, J., Zhao, L., & Yang, Y. (2016). Consumption of meat and dairy products in China: a review. *Proceedings of the Nutrition Society, 75*(3), 385-391.

Institute for Health Metrics and Evaluation. (2020). Global Burden of Disease results tool Database. Retrieved from http://www.healthdata.org/results/data-visualizations

IUCN. (2016). *World Database of Key Biodiversity Areas* Data set. Retrieved from http://www.keybiodiversityareas.org/site/mapsearch

IUCN. (2017). *World Database on Protected Areas (WDPA)* Data set. Retrieved from https://www.iucn.org/theme/protected-areas/our-work/quality-and-effectiveness/world-database-protected-areas-wdpa

Jacobson, A. P., Riggio, J., M. Tait, A., & E. M. Baillie, J. (2019). Global areas of low human impact ('Low Impact Areas') and fragmentation of the natural world. *Scientific Reports, 9*(1), 14179. https://doi.org/10.1038/s41598-019-50558-6

Jing, Guangzheng, Wang, Ruotong, & Sun, Juhe. (2018). Constructing Population Mathematical Model Based on MATLAB to Study the Influence of the Second Birth Opening on Chinese Population. *Advances in Applied Mathematics, 07*(5), 546–564. https://doi.org/10.12677/AAM.2018.75066

Lipinski, B., Hanson, C., Lomax, J., Kitinoja, L., Waite, R., & Searchinger, T. (2013). *Reducing food loss and waste*. World Resources Institute. Retrieved from WRI website: https://www.wri.org/publication/reducing-food-loss-and-waste

Ma, L., Bai, Z., Ma, W., Guo, M., Jiang, R., Liu, J., … Zhang, F. (2019). Exploring Future Food Provision Scenarios for China. *Environmental Science & Technology, 53*(3), 1385–1393. https://doi.org/10.1021/acs.est.8b04375

Mekonnen, M.M. and Hoekstra, A.Y. (2010a). The green, blue and grey water footprint of crops and derived crop products, Value of Water Research Report Series No. 47, UNESCO-IHE, Delft, the Netherlands. Retrieved from http://www.waterfootprint.org/Reports/Report47-WaterFootprintCrops-Vol1.pdf.

Mekonnen, M.M. and Hoekstra, A.Y. (2010b). The green, blue and grey water footprint of farm animals and animal products, Value of Water Research Report Series No. 48, UNESCO-IHE, Delft, the Netherlands.

Mekonnen, M.M. and Hoekstra, A.Y. (2011) National water footprint accounts: the green, blue and grey water footprint of production and consumption, Value of Water Research Report Series No. 50, UNESCO-IHE, Delft, the Netherlands.

Ministry of Agriculture and Rural Affairs of China. (2020). *Agricultural Product Trade Monitoring database* Database. Retrieved from http://zdscxx.moa.gov.cn:8080/nyb/pc/index.jsp

Ministry of Agriculture of China. (2015a). *Action Plan for Zero Growth of Fertlizer and Pesticides by 2020*. Retrieved from http://jiuban.moa.gov.cn/zwllm/tzgg/tz/201503/t20150318_4444765.htm

Ministry of Agriculture of China. (2015b). *Implement Suggestion on Tough Battle of Agricultural Non-point Sources Pollution*. Retrieved from http://jiuban.moa.gov.cn/zwllm/zwdt/201504/t20150413_4524372.htm

Ministry of Agriculture of China. (2016). *Plan for Glassland Protection, Construction and Utilization in 13th five-year*. Retrieved from http://country.cnr.cn/gundong/20170105/t20170105_523439342.shtml

Ministry of Agriculture of China. (2017). *Action Plan of Organic Fertilizers Substitute for Chemical Fertilizers*. Retrieved from http://jiuban.moa.gov.cn/zwllm/tzgg/tz/201702/t20170210_5472878.htm

Ministry of Ecology and Environment of China. (2010). *China National Biodiversity Conservation Strategy and Action Plan (2011-2030).* Retrieved from https://www.cbd.int/doc/world/cn/cn-nbsap-v2-en.pdf

Ministry of Water Resources of China. (2018). *Water Resources Bulletin (2010-2019).* Retrieved from http://www.mwr.gov.cn/sj/tjgb/szygb/

Mosnier, A., Penescu, L., Thomson, M., Perez-Guzman, K. (2019). Documentation of the FABLE Calculator: SDSN/IIASA. Retrieved from https://www.abstract-landscapes.com/fable-calculator

National Bureau of Statistics of China. (2020). *National Data* Database. Retrieved from http://data.stats.gov.cn/easyquery.htm?cn=C01

National Center for Cardiovascular Disease of China. (2019). Report on cardiovascular disease in China 2018. Retrieved from https://www.nccd.org.cn/Sites/Uploaded/File/2019/8/14-%E4%B8%AD%E5%9B%BD%E5%BF%83%E8%A1%80%E7%AE%A1%E7%97%85%E6%8A%A5%E5%91%8A2018%EF%BC%88%E4%B8%AD%E6%96%87%E7%89%88%EF%BC%89.pdf

National Development and Reform Commission of China. (2015). *Enhanced Actions on Climate Change: China's Intended Nationally Determined Contributions*. Retrieved from https://www4.unfccc.int/sites/submissions/indc/Submission%20Pages/submissions.aspx

National Development and Reform Commission of China. (2016). *The outline of the 13th five-year plan for national economic and social development of the People's Republic of China*. Retrieved from http://www.gov.cn/xinwen/2016-03/17/content_5054992.htm

National Development and Reform Commission of China. (2017). *National Land Renovation Plan (2016-2020).* Retrieved from https://www.ciyew.com/wp-content/uploads/2018/10/8c42c6ff194925313c71.pdf

National Development and Reform Commission of China. (2020). *Index System for the Construction of Beautiful China*. Retrieved from http://www.gov.cn/zhengce/zhengceku/2020-03/07/content_5488275.htm

National Forestry and Grassland Administration of China. (2016). *National Forest Management Plan (2016-2050).* Retrieved from http://www.forestry.gov.cn/uploadfile/sljk/2016-12/file/2016-12-20-af1d97bd5a0b4f2eb14cf909b6012730.pdf

National Health Commission of China. (2015). Report on Nutrition and Chronic Diseases of Chinese Residents 2015. Retrieved from http://www.nhc.gov.cn/jkj/s5879/201506/4505528e65f3460fb88685081ff158a2.shtml

National Specimen Information Infrastructure. (2020). *Protected Area database* Database. Retrieved from http://www.nsii.org.cn/2017/tdb.php?id=node/822

NOAA. (2020). Climate Change: Atmospheric Carbon Dioxide. Retrieved from https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide

Palma, L., Fernandez-Bayo, J., Niemeier, D., Pitesky, M., & VanderGheynst, J. S. (2019). Managing high fiber food waste for the cultivation of black soldier fly larvae. *NPJ science of food, 3*(1), 1-7.

Pikaar, I., Matassa, S., Rabaey, K., Bodirsky, B. L., Popp, A., Herrero, M., & Verstraete, W. (2017). Microbes and the Next Nitrogen Revolution. *Environmental Science & Technology, 51*(13), 7297–7303.

Potapov, P., Hansen, M. C., Laestadius, L., Turubanova, S., Yaroshenko, A., Thies, C., … Esipova, E. (2017). The last frontiers of wilderness: Tracking loss of intact forest landscapes from 2000 to 2013. *Science Advances, 3*(1). https://doi.org/10.1126/SCIADV.1600821

Qi, meidong, Dai, mengyu, & Zheng, yanyan. (2016). Discuss the impact and tendency of the Universal Two-child Policy on China's birth rate fluctuation. *China Population Resources and Environment, 26*(9), 1–10.

Roe, S., Streck, C., Obersteiner, M., Frank, S., Griscom, B., Drouet, L., … Lawrence, D. (2019). Contribution of the land sector to a 1.5 °C world. Nature Climate Change, 9(11), 817–828. https://doi.org/10.1038/s41558-019-0591-9

Sommer, A. (2001). Vitamin A Deficiency. In John Wiley & Sons, Ltd (Ed.), Encyclopedia of Life Sciences (p. a0002106). John Wiley & Sons, Ltd. https://doi.org/10.1038/npg.els.0002106

Standing Committee of the National People's Congress. (2020). *Land Administration Law of the People's Republic of China*. Retrieved from https://duxiaofa.baidu.com/detail?searchType=statute&from=aladdin_28231&originquery=%E5%9C%9F%E5%9C%B0%E7%AE%A1%E7%90%86%E6%B3%95&count=87&cid=108596f96efdf41ee1ef83f7cca2d310_law

State Council of China. (2005). General Condition of China. Retrieved from http://english.www.gov.cn/archive/chinaabc/

State Council of China. (2013). *Action Plan for Air Pollution Prevent and Control*. Retrieved from http://www.gov.cn/zhengce/content/2013-09/13/content_4561.htm

State Council of China. (2015). *Action Plan for Water Pollution*. Retrieved from http://www.gov.cn/xinwen/2015-04/16/content_2847709.htm

State Council of China. (2017a). *National Territorial Planning Outline (2016-2030)*. Retrieved from http://www.gov.cn/zhengce/content/2017-02/04/content_5165309.htm?from=timeline

State Council of China. (2017b). Regulations of the People's Republic of China on Nature Reserves. Retrieved from https://duxiaofa.baidu.com/detail?searchType=statute&from=aladdin_28231&originquery=%E4%B8%AD%E5%8D%8E%E4%BA%BA%E6%B0%91%E5%85%B1%E5%92%8C%E5%9B%BD%E8%87%AA%E7%84%B6%E4%BF%9D%E6%8A%A4%E5%8C%BA%E6%9D%A1%E4%BE%8B&count=44&cid=0c9df0c8abc192654ef02d3ba63a3abb_law

The State Council Information Office of China. (2010). *Outline of the national medium and long-term plan for food security (2008-2020).* Retrieved from http://www.scio.gov.cn/xwfbh/xwbfbh/wqfbh/2011/1206/xgzc/Document/1059447/1059447.htm

The State Council Information Office of China. (2019). *Food Security in China*. Retrieved from http://www.scio.gov.cn/zfbps/32832/Document/1666228/1666228.htm

Thow, A. M., & Nisbett, N. (2019). Trade, nutrition, and sustainable food systems. *The Lancet, 394*(10200), 716–718. https://doi.org/10.1016/S0140-6736(19)31292-9

U. S. Department of Justice, & Federal Trade Commission. (2010). *Horizontal Merger Guidelines*. Retrieved from https://www.justice.gov/atr/horizontal-merger-guidelines-08192010#5c

U.S. Department of Health and Human Services and U.S. Department of Agriculture. (2015). *2015-2020 Dietary Guidelines for Americans, 8th Edition* (p. 144). Retrieved from U.S. Department of Health and Human Services website: http://health.gov/dietaryguidelines/2015/guidelines/.

UN DESA. (2017). *World Population Prospects: The 2017 Revision, Key Findings and Advance Tables* Working Paper. Retrieved from United Nations website: https://esa.un.org/unpd/wpp/Publications/Files/WPP2017_KeyFindings.pdf

UNEP-WCMC, & IUCN. (2020). *Protected Planet: The World Database on Protected Areas (WDPA)*. Retrieved from UNEP-WCMC and IUCN website: www.protectedplanet.net

UNFCCC. (2005). Greenhouse Gas Data. Retrieved from https://unfccc.int/process-and-meetings#:0c4d2d14-7742-48fd-982e-d52b41b85bb0:adad877e-7830-4b8b-981a-5cdd34249c9d:6218053d-e6b9-4bb8-9644-4cc8716237e2

UNFCCC. (2020). *Greenhouse Gas Inventory Data—Flexible Queries Non-Annex I Parties Database*. Retrieved from https://di.unfccc.int/flex_non_annex1

Wang, J., Feng, L., Palmer, P. I., Liu, Y., Fang, S., Bösch, H., ... & Xia, C. (2020). Large Chinese land carbon sink estimated from atmospheric carbon dioxide data. *Nature, 586*(7831), 720-723.

Wanner, N., Cafiero, C., Troubat, N., & Conforti, P. (2014). Refinements to the FAO Methodology for estimating the Prevalence of Undernourishment Indicator. *ESS Working Paper No. 14-05*. Retrieved from http://www.fao.org/3/a-i4046e.pdf

WHO. (2020). *WHO Nutrition Landscape Information System Database*. Retrieved from https://apps.who.int/nutrition/landscape/report.aspx

Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., Garnett, T., Tilman, D., DeClerck, F., Wood, A., Jonell, M., Clark, M., Gordon, L. J., Fanzo, J., Hawkes, C., Zurayk, R., Rivera, J. A., Vries, W. D., Sibanda, L. M., … Murray, C. J. L. (2019). Food in the Anthropocene: The EAT–Lancet Commission on healthy diets from sustainable food systems. *The Lancet, 393*(10170), 447–492. https://doi.org/10.1016/S0140-6736(18)31788-4

Wu, R., Zhang, S., Yu, D. W., Zhao, P., Li, X., Wang, L., … Long, Y. (2011). Effectiveness of China's nature reserves in representing ecological diversity. *Frontiers in Ecology and the Environment, 9*(7), 383–389. https://doi.org/10.1890/100093

Wu, Y., Gu, B., Erisman, J. W., Reis, S., Fang, Y., Lu, X., & Zhang, X. (2016). PM2. 5 pollution is substantially affected by ammonia emissions in China. *Environmental Pollution, 218*, 86-94.

Xi, J. (2017). *Report of 19th CPC National Congress*. Retrieved from http://www.chinadaily.com.cn/interface/flipboard/1142846/2017-11-06/cd_34188086.html

Xi, J. (2020). *Speech at the general debate of the 75th UN General Assembly*. Retrieved from http://www.xinhuanet.com/2020-09/22/c_1126527652.htm.

Xu, Z., Chen, X., Liu, J., Zhang, Y., Chau, S., Bhattarai, N., ... & Li, Y. (2020). Impacts of irrigated agriculture on food–energy–water–CO 2 nexus across metacoupled systems. *Nature Communications, 11*(1), 1-12.

Zhao, H. China's future demand for agricultural products and environmental sustainability: A major challenge for trading partners. (n.d.) Unpublished.

Zhu, Y., Pu, M., Liu, M., Niu, K., & Zhang, L. (2020). The Impact of COVID-19 on China's Food Security and Suggestion for Ensuring Stable Grain Production. *Issues in Agricultural Economy, 04*, 13–22.