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The Food and Land Use Coalition

2019 Report of the FABLE Consortium

Pathways to Sustainable Land-Use and Food Systems

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2019 Report of the FABLE Consortium

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

Mexico

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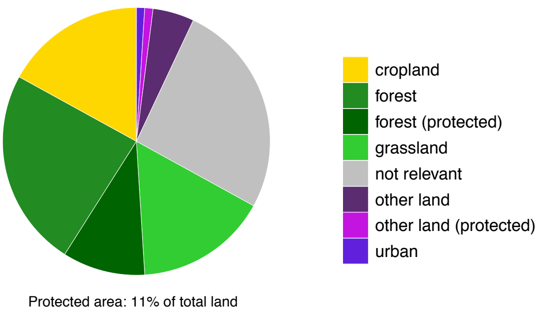
Land and food systems at a glance

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

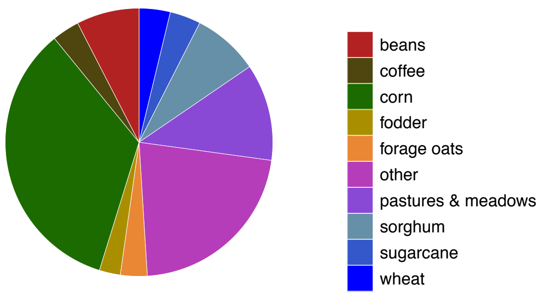
Land & Biodiversity

Fig. 1 | Area by land cover class in 2015



Source: INEGI (2015)

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



Source: SIAP (2017)

Annual deforestation in the period 2011-2014: 251.2kha per year^{-1} = 0.3% of total forest area

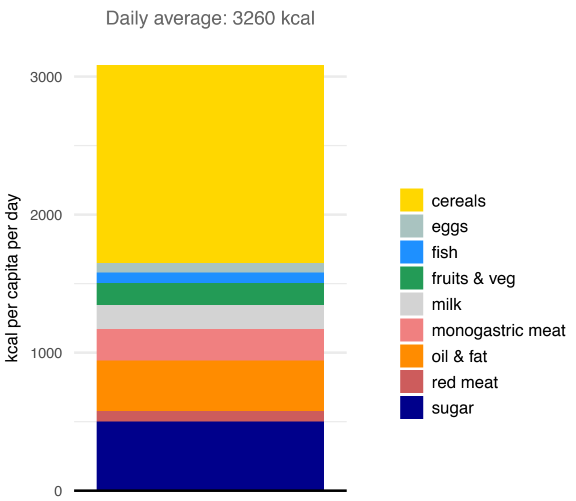
(INECC, 2018)

Endangered species in 2016: 2,606

(CONABIO, 2019)

Food & Nutrition

Fig. 3 | Daily average intake per capita at the national level in 2012



Source: SADER (2012)

Share of undernourished in 2015:

4%

(World Bank, 2019)

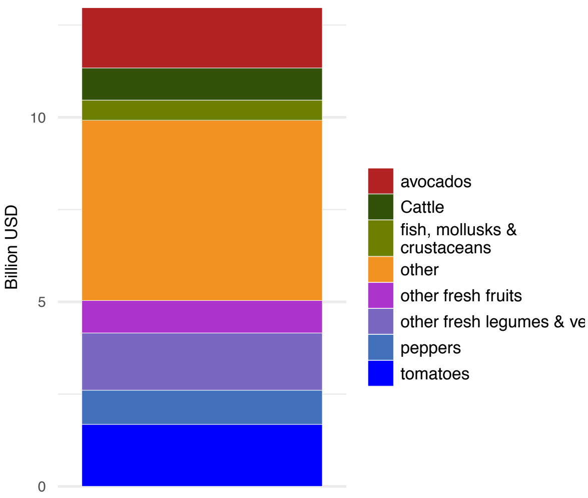
Share of obese in 2015:

32.4%

(OECD, 2017)

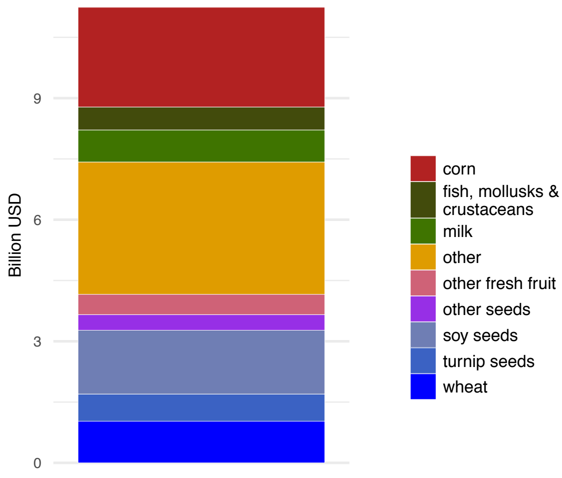
Trade

Fig. 4 | Main agricultural exports by value in 2015



Source: Bank of Mexico (2015)

Fig. 5 | Main agricultural imports by value in 2015



Source: Bank of Mexico (2015)

Surplus in agricultural trade balance in 2015: USD 1.7 bln

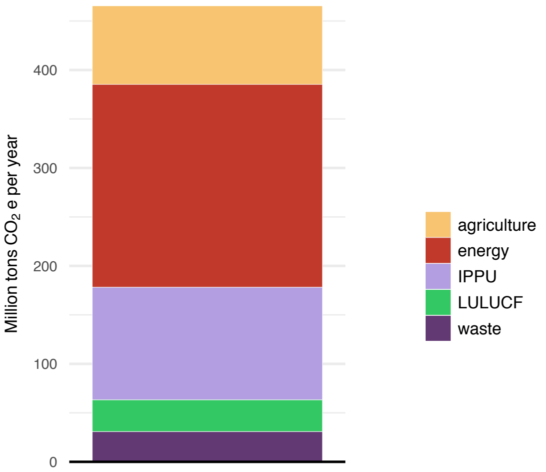
(Bank of Mexico, 2015)

11th most important exporter and 13th most important importer in the world in 2015

(Central Intelligence Agency, 2017)

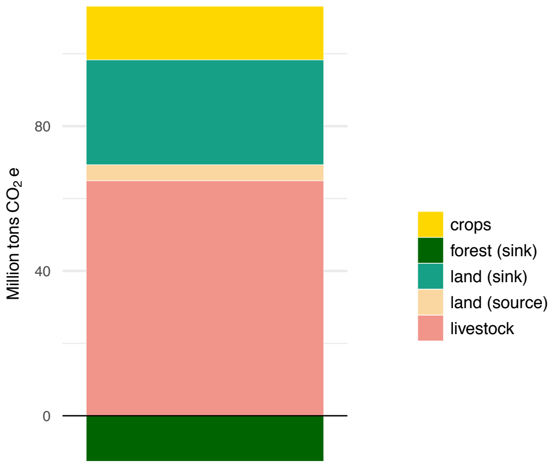
GHG Emissions

Fig. 6 | GHG emissions by sector in 2015



Source: INECC (2015)

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



Source: INECC (2015)

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 21.6% from USD 9,611 in 2015 to USD 23,044 in 2050 (SSP2 scenario selected).	The population is expected to increase by 4% annually between 2015-2050, from 125 mln in 2015 to 145 mln in 2050 (UN low growth scenario selected).
Scenario justification	Based on Mexico GDP growth forecast 2018 – 2020 and up to 2060. According to IMF estimates, Mexican GDP will reach USD 3.2 tln by 2050 or USD 21,567 per capita using our population projections. The SSP2 scenario most closely reflects these estimates (OECD, 2018).	According to projections of the National Population Council (CONAPO, 2018), the population will grow at a decreasing rate, with low mortality and fertility. The CONAPO projects that by 2050 the population will reach 148 mln, which roughly matches the chosen scenario.

TRADE

	Imports	Exports
Scenario definition	The share of total consumption which is imported increases: - from 20% in 2010 to 40% in 2050 for milk, - from 9% in 2010 to 18% in 2050 for beef, and - from 26% in 2010 to 53% in 2050 for corn. The share of total consumption which is imported is fixed at 2010 levels for all other products.	The export quantity increases from 2010 to 2050: - from 1.4 Mt to 2.1 Mt for tomatoes, - from 5 kt to 7 kt for peppers, and - from 1 Mt to 1.5 Mt for fruits. The exported quantity remains constant at 2010 levels for the other commodities.
Scenario justification	Mexican imports have been increasing since 1994, hence we chose a scenario that reflects this trend. We selected imports that require more agricultural expansion (milk, beef, and corn for animal feed) (OEC, 2018a).	Mexican exports have been increasing since 2000, hence we chose a scenario that reflects this trend. We selected pepper, tomatoes, and fruits since their export has increased since 2000 (OEC, 2018b).

Scenario signs no change small change large change

LAND

	Land conversion	Afforestation
Scenario definition	We assume no expansion of agricultural land beyond 2015 agricultural area levels.	We assume total afforested area will reach 8.47 Mha by 2050.
Scenario justification	Based on the Agricultural National Plan 2017-2030 (SAGARPA, 2017), which states that Mexico will not expand its agricultural area beyond the 2016 extent. This assumption is also supported by (Armenteras et al., 2017; García-Barrios et al., 2009; Ibarrola-Rivas and Granados-Ramírez, 2017; Mas et al., 2004). Under the Nationally Determined Contributions (NDCs) Mexico has also committed to reach zero deforestation by 2030 (INECC, 2018).	Based on Mexico's 2014 commitment to reforest 8.47 Mha by 2020 as part of the Bonn Challenge (Bonn Challenge, 2014; INECC, 2018). While there is no reforestation target beyond 2020, afforestation would occur in some of the most deforested states in Mexico, paying particular attention to tropical and subtropical moist forest and tropical dry and temperate forests.

FOOD

	Diet	Food waste
Scenario definition	Between 2015 and 2050, the average daily calorie consumption per capita increases from 2,512 kcal to 2,717 kcal. Per capita consumption: - increases by 27% for ruminant meat, - increases by 25% for vegetable oils, - increases by 34% for sugar, - increases by 9% for fruits and vegetables, - increases by 10% for pulses, - increases by 90% for other, including nuts, and - remains constant for cereals and milk.	Between 2010 and 2050, the share of final household consumption which is wasted decreases from 10% to 5%.
Scenario justification	Dietary changes across populations are difficult to achieve, Mexican health authorities have been advancing on addressing the unhealthy food habits that had caused a nutritional epidemic. The Mexican Health Department recommends a more active lifestyle and reduced consumption of processed foods and sugars. It also recommends lower consumption of animal protein among middle and high urban income homes; increased consumption is recommended for low urban and rural homes where animal protein intake is below the dietary recommendations. The recommendations of middle-of-the-range physical activity levels has a strong focus on whole grains and cereals (Barquera et al., 2013; Bonvecchio-Arenas et al., 2013; Ibarrola-Rivas and Granados-Ramírez, 2017; Rivera et al., 2004; Stevens et al., 2008). Dietary changes across populations are difficult to achieve, Mexican health authorities have been advancing on addressing the unhealthy food habits that had caused a nutritional epidemic. The diet that we have created should be accomplished with a minimum amount of processed foods. Despite these recommendations there are not specific measures to implement these recommendations.	While we were unable to identify research or data on food waste in Mexico to justify this scenario, preliminary data suggest that food waste in Mexico might be higher than 10%. We aimed for large reductions as it is beneficial in our view to pursue maximum efforts to reduce food waste.

Scenario signs no change small change large change

BIODIVERSITY

	Protected areas (=)
Scenario definition	Protected areas remain constant between 2015 and 2050.
Scenario justification	In 2018, Mexico had 16% of its total area to conservation under protection (Protected Areas) which includes natural parks, biosphere reserves and, more recently, private lands voluntarily set aside for conservation. Other instruments of protection, where we do not know the full amount of area covered, include payment for environmental services, units for environmental management and sustainable forest management (CONANP-SEMARNAT, 2017; Pisanty et al., 2016). These other instruments of protection work by increasing the selected area's conservation value by protecting and maintaining its biodiversity and ecological functions. We assume that instead of creating additional protected areas, Mexico will work to sustainably manage and promote activities that increase the conservation value of its land.

PRODUCTIVITY

	Crop productivity (large change)	Livestock productivity (large change)	Pasture stocking rate (large change)
Scenario definition	Crop productivity increases: - from 2.5 t/ha in 2000 to 7.4 t/ha in 2050 for corn, and - from 0.6 t/ha in 2000 to 1.2 t/ha in 2050 for beans.	Between 2015 and 2050, the productivity per head increases: - from 55 kg/head to 86 kg/head for beef, - from 1 kg/head to 1.2 kg/head for chicken, - from 1.6 kg/head to 1.9 kg/head for eggs, - from 5.4 t/head to 8.44 t/head for cow milk, and - from 75 kg/head to 126 kg/head for pork meat.	The average livestock stocking density increases from 0.32 TLU/ha to 0.46 TLU/ha between 2015 and 2050.
Scenario justification	Based on the Agricultural National Plan 2017-2030 (SAGARPA, 2017), one of the main goals of which is to increase corn and bean productivity without increasing the production area. Compared to 2015, corn production could potentially increase by between 2.3% and 4% by 2030 depending on the type of corn. Combined, it could reach a national average of 6.2 t/ha. In the case of beans, yields could potentially double by 2050 from 0.7 t/ha to 1.4 t/ha.	Based on the Agricultural National Plan 2017-2030 (SAGARPA, 2017), one of the main goals of which is to increase livestock productivity without increasing the area of productive land (Monterroso Rivas and Gomez Diaz, 2003; SAGARPA and FAO, 2012).	In Mexico, one of the objectives regarding livestock has been to increase production by promoting feed lots for beef production. While there is very little information on the pasture stocking rate for Mexico, cattle ranching has risen due to beef demand so we assume that the density of cattle per hectare has also grown as result of government incentives to improve productivity (Monterroso Rivas and Gomez Diaz, 2003; SAGARPA and FAO, 2012).

Scenario signs (=) no change (→) small change (↗) large change

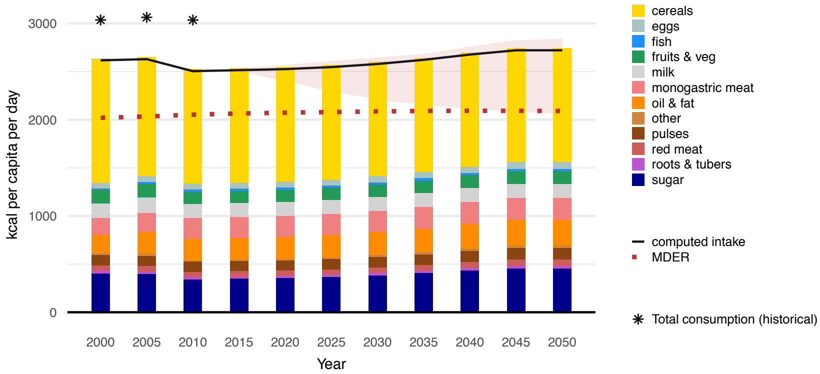
Results against the FABLE targets

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.



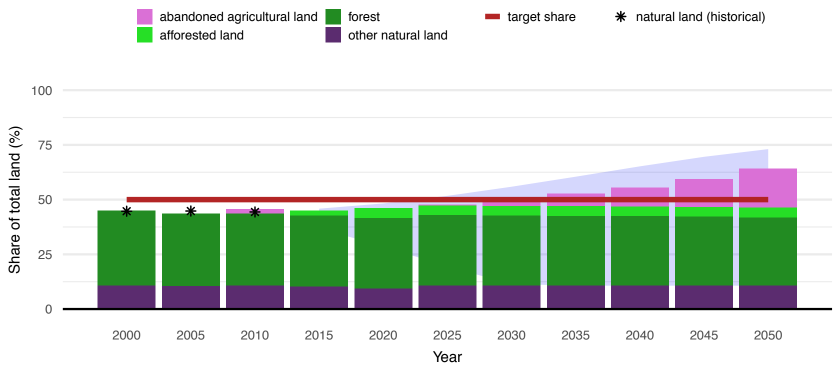
Historical data source: FAOSTAT

Our results show an increase in average daily energy intake per capita from 2,536 in 2015 to 2,777 kcal/cap/day in 2050. The computed average calorie intake is 35% higher than the Minimum Dietary Energy Requirement (MDER) at the national level in 2050 and is a direct result of the middle physical activity lifestyle selected.

In terms of recommended diet, our results suggest that continuing current trends might lead to a significant deviation compared to the national food security objective of reducing obesity thanks to an increase in physical activity, a reduction in sugars, oils, and dairy (Behrens et al., 2017) (Barquera et al., 2013). However, recommendations should not be made across all population equally. Rural and urban low income populations do not consume enough animal protein while middle to high income urban populations exceed the healthy recommendation (Rivera et al. 2014).

Biodiversity

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



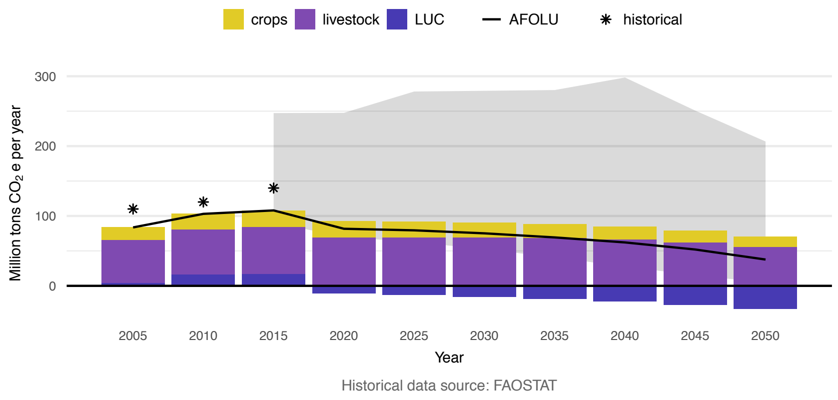
Historical data source: FAOSTAT

The Share of terrestrial Land that could support Biodiversity (SLB) remains constant over 2010-2015 at 45%. This is slightly below Gonzalez-Abraham et al. (2015), who estimate that 56% of the terrestrial area with vegetation cover is in a reasonably good environmental condition. The SLB increases after 2020 due to afforestation and abandonment of agricultural land.

Compared to the global target of having at least 50% of SLB by 2050, our results are above the target. Specifically, Mexico would reach the target in 2035 and reach 65% SLB in 2050.

GHG emissions

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



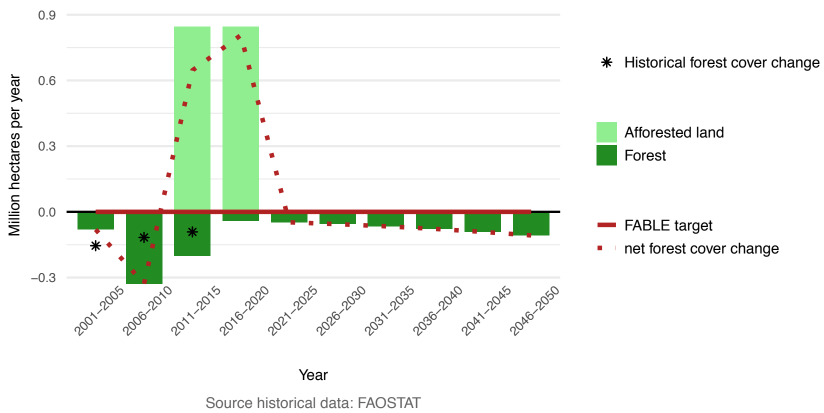
Note: AFOLU (Agriculture, Forestry and Other Land Use) is the sum of computed GHG emissions from crops, livestock and Land Use Change (LUC), emissions and sequestration from forestry are not included. Historical emissions include crops and livestock.

GHG emissions from land-use change first increase until 2015 and then go from being a net source to a net sink of CO_2. Total GHG emissions increase until 2015, when they reach 110 Mt CO_2e per year. This peak concurs with national data. Our results for total AFOLU emissions in 2015 are 110 Mt CO_2e, whereas the national assessment shows 102 Mt CO_2e (INECC, 2018).

Our results show that crop and livestock emissions increase slightly after 2005, peak in 2025 at 90 Mt CO_2e before slowly decreasing until 2050. The most important source of GHG emissions is livestock production, which, despite a decreasing trend starting in 2035, remains a major emitter until 2050. Our projections are fairly consistent with national assessments (INECC, 2018).

Forests

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



The results show a peak in deforestation for the period 2006-2010 with a loss of 0.3 Mha/year. The growth of afforested land due to the Bonn Challenge commitment leads to a positive net forest cover change in 2010-2015 and in 2015-2020. This leads to a net forest cover change between 2000-2015 of 1.2 Mha loss compared to 1.8 Mha according to FAO. National studies show that during the period 2010-2015, deforestation decreased and reached the historically low level of 0.458 Mha (INECC, 2018). We assume no afforestation after 2020, which is in line with Mexico's current commitment.

In Mexico the expansion of agricultural land and cattle ranching are the main drivers of forest loss (Mas et al., 2004; García-Barrios et al., 2009; Armenteras et al., 2017; SEMARNAT, 2015). However, our results show that despite no expansion of productive land, there is still some deforestation in the period 2021-2025 due to urban expansion.

Other relevant results for national objectives

Table 1 | Other Results

Variable	Unit	2000	2005	2010	2015	2020	2030	2040	2050
Trade									
Trade balance	Bln USD	-1.86	-2.32	-0.65	0.14	-0.06	0.38	-0.56	-1.22
Production quantities of selected commodities									
Corn (historical)	Mt	17.56	19.34	23.30					
Corn (calculated)	Mt	17.38	17.29	18.94	20.36	20.55	20.04	18.73	16.81
Beans (historical)	Mt	0.89	0.83	1.16					
Beans (calculated)	Mt	0.88	0.81	1.14	1.33	1.40	1.51	1.59	1.60
Beef (historical)	Mt	1.41	1.56	1.74					
Beef (calculated)	Mt	1.40	1.54	1.72	1.84	1.94	2.13	2.36	2.38
Mutton Goat (historical)	Mt	0.07	0.09	0.10					
Mutton Goat (calculated)	Mt	0.07	0.09	0.09	0.10	0.11	0.12	0.14	0.14
Pork (historical)	Mt	1.03	1.10	1.17					
Pork (calculated)	Mt	1.02	1.09	1.16	1.25	1.31	1.39	1.41	1.40
Chicken (historical)	Mt	1.87	2.48	2.72					
Chicken (calculated)	Mt	1.85	2.46	2.70	2.89	3.04	3.21	3.27	3.25

Source historical data: FAOSTAT

Compared to the Mexican National Institute of Statistics and Geography (INEGI, 2019b), our results do not diverge from recent historical trends in the Mexican trade balance, where a trade deficit in agricultural products is the norm. However, since 2015 this trend has reversed, reaching USD 1.7 bln (INEGI, 2019b). Our results show fluctuations from USD -0.67 bln to a maximum surplus of USD 0.57 bln in 2030. After 2035, our results show a growing deficit until 2050. Mexico does not have a national objective for trade besides the commercial treaties already in place or in negotiation.

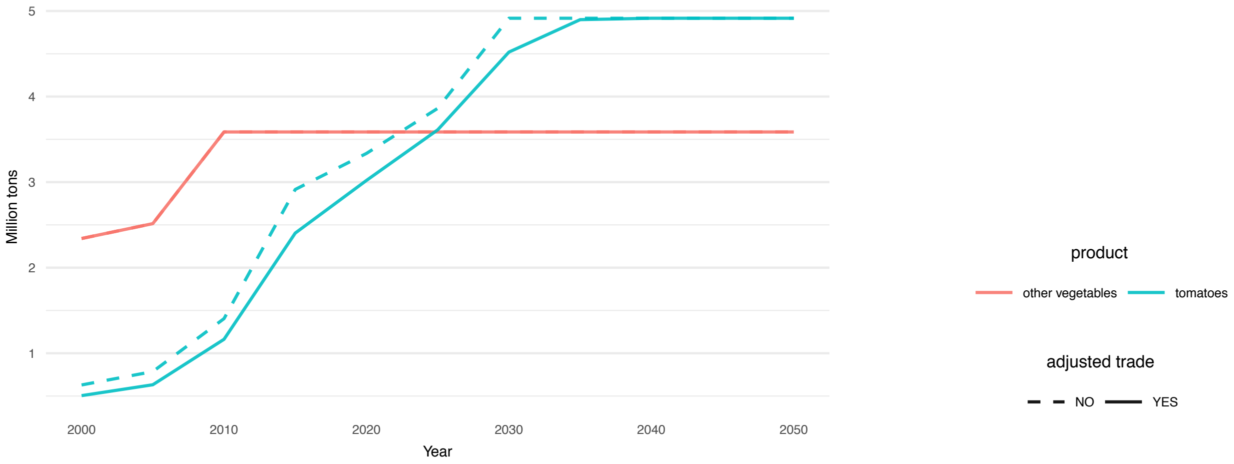
Our results show that corn production increases until 2020 and decreases from 2020-2050. This is based on the assumption that a higher share of internal consumption will be met by imports. The combination of higher imports and higher productivity results in a decline in corn harvested area from 6 Mha in 2015 to 2.3 Mha in 2050. Our results are inconsistent with national projections which show a general reduction in yields due to higher instabilities in production due to climate change (SAGARPA and FAO, 2012).

Our results show that bean production (second most important crop) increases from 2015 until 2050. The assumption of higher productivity results in a decline of harvested area from 1.9 Mha in 2020 to 1.3 Mha in 2050 without compromising its production. Our results are inconsistent with national projections that show production instability and lower yields due to climate change (SAGARPA & FAO, 2012).

Livestock production increases, stabilizes, then falls very slightly for all meat products, including beef, goat, lamb, pork, and chicken. This trend is the result of an increase in animal protein consumption assumed in the selected diet (Rivera et al., 2004). Mexico does not have livestock production projections.

Impacts of trade adjustment to ensure global trade balance

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

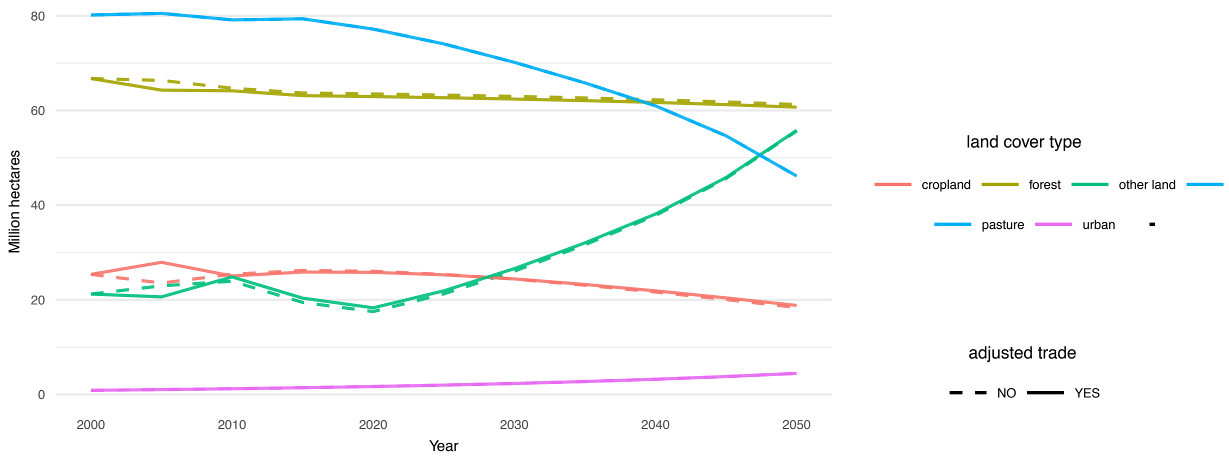


The evolution in exports compared to no trade adjustment for tomatoes and fruits is very slight. With trade adjustment, production decreases by less than 20% between 2015 and 2030. Beginning in 2035, there is no difference between the two scenarios.

Between 2010 and 2030, the evolution of exports compared to no trade adjustment for other vegetables is 72% lower by 2030.

There is no significant change in the imports of key commodities when the trade adjustment is applied.

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



Land-Use Change trends are mostly unaffected by the trade adjustment. Cropland area continues to decline and forests, pasture, and urban areas all remain unchanged. Trade adjustment increases the amount of cropland reduction beginning in 2015. Other land is positively affected and increases its area, thus mirroring cropland loss.

Discussion and next steps

Our results are driven to a large extent by the livestock sector and the evolution of cattle and pasture productivity. Livestock is expected to be the main source of greenhouse gas emissions in the Agriculture, Forestry, and Other Land Use sector, while at the same time abandoned pastures, thanks to pasture productivity, increasingly play an important role in carbon sequestration. However, it is difficult to assess the realism of our results as there are large data gaps on the carrying-capacity, density, and spatial distribution of cattle and, even more importantly, on the ecological effects of free-range cattle ranching.

There are several key limitations to the FABLE Calculator that are important to highlight. The Calculator does not currently consider ecosystem degradation and invasive species, which may affect the productive and regenerative capacity of land and food systems in the future. Moreover, climate shocks and climate change are also not considered. Estimates from (Murray-Tortarolo et al., 2018) show that climate change might lead to a 10-30% reduction of the rainfed corn yield by 2050. Future model development should focus on these aspects to avoid overly optimistic results.

It is also important to differentiate corn production for human consumption and corn production for animal feed. The yield difference between the two is significant so in the future it will be important for us to model public policies that affect these two types of corn production.

Finally, Mexico has created a large network of Protected Areas that cover 16% of its terrestrial area. This effort is not reflected in the current Calculator, so we intend to improve it and to also include all other conservation mechanisms that Mexico has under its current Environmental Law (Pisanty et al., 2016).

There are several technologies that could help increase the level of ambition of our pathway. These include: the use of improved seeds to improve yields for our main crops, as well as the inclusion of traits for drought resistance which are important for climate change adaptation of rainfed systems; the adoption of sustainable agricultural practices adapted to the diversity of agroecological regions in Mexico; and an increase in the development and adoption of sustainable forest management.

There are two important challenges that hinder the adoption of these practices and the implementation of this pathway. The first relates to data. Even though the National Institute of Statistics and Geography (INEGI) generates and compiles data with the same criteria for the entire country, it is challenging to maintain the same indicators and monitoring programs for more than one political term (6 years). This generates temporal and spatial data gaps and makes it difficult to assess the success of programs that have been implemented.

There are also important data constraints on free-range livestock (population size and spatial distribution) and food waste. This lack of data generates a gap in any analysis on productivity and the ecological effects of food waste and free-range livestock.

The second relates to the policy-making process. Designing and implementing national-level policies requires the use of monitoring frameworks that use a systems approach to effectively exploit data generated at sub-national scales. Therefore, multiple sectors and types of collaborators (e.g. scientific and policy-making communities) should be jointly involved in the design of more comprehensive scenarios for land and food systems in order to mitigate against climate change. Attention to the environment should cut across all government agencies so that resources and programs coordinate with each other and transcend a change of government.

We see several other areas that would allow Mexico to develop integrated policies to address these challenges. First, public policy development should come from evidence-based research. Second, efforts should be made to improve capacity building within different government agencies in order to promote greater understanding of environmental issues, including the costs of not addressing them. Third, INEGI should improve monitoring instruments to measure the evolution of land and food systems. At the same time, government agencies need to implement independent evaluation systems for the policies they are implementing. Finally, more funding should be made available for research focusing on land and food studies. For example, increased investment in breeding for main crops, including maize (open-pollinated varieties and hybrids) for traits like drought resistance that are important for climate change adaptation.

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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