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A GLOBAL INITIATIVE FOR THE UNITED NATIONS

The Food and Land Use Coalition

2019 Report of the FABLE Consortium

Pathways to Sustainable Land-Use and Food Systems

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2019 Report of the FABLE Consortium

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

Brazil

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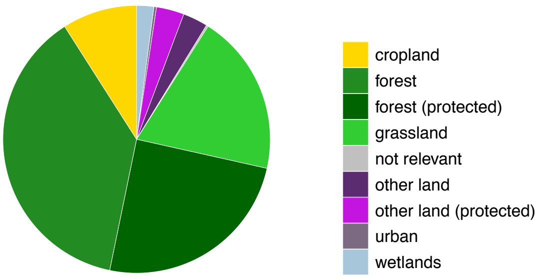
Land and food systems at a glance

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

Land & Biodiversity

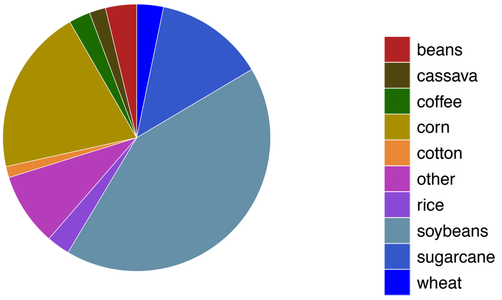
Fig. 1 | Area by land cover class in 2015



Protected area: 28% of total land

Source: MapBiomas

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



Source: Municipal Crop Production survey (PAM/IBGE)

Annual deforestation in the Amazon Biome (2015):
0.62 Mha = 0.12% of total forest area

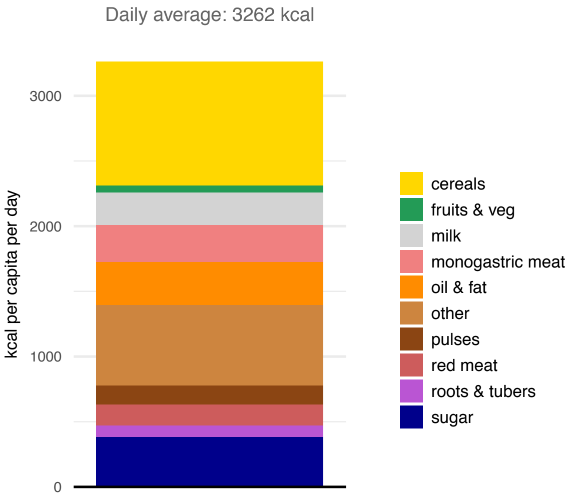
(PRODES/INPE, 2019)

Endangered species in 2018: 1,173 (448 vulnerable, 406 endangered, 318 critically endangered, and 1 extinct in the wild)

(ICMBio, 2018)

Food & Nutrition

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



Source: FAOSTAT

Share of undernourished in 2015:
2.5%

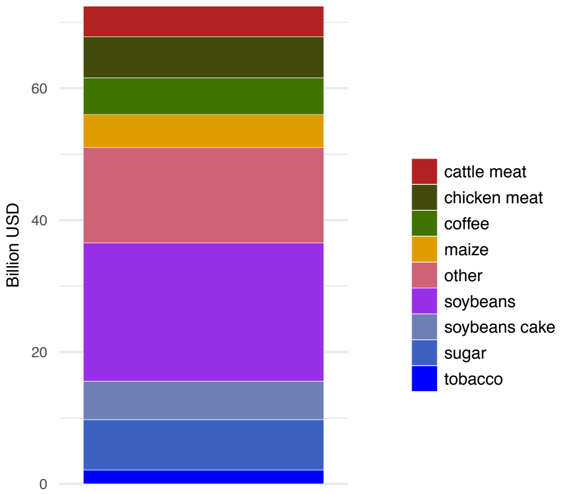
(World Bank, 2019)

Share of obese in 2015:
18.9%

(Ministério da Saúde, 2015)

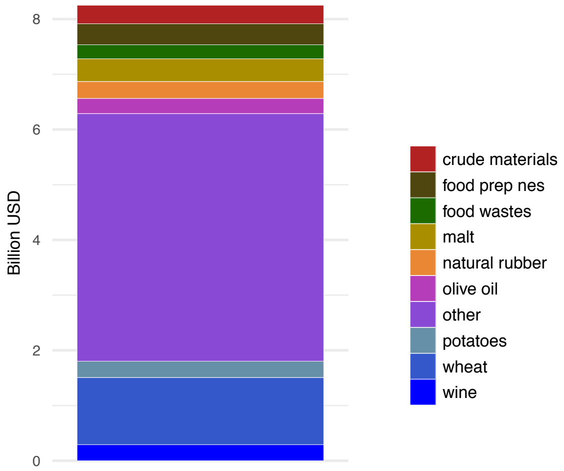
Trade

Fig. 4 | Main agricultural exports by value in 2015



Source: FAOSTAT

Fig. 5 | Main agricultural imports by value in 2015



Source: FAOSTAT

Surplus in agricultural trade balance in 2015: USD 75 bln

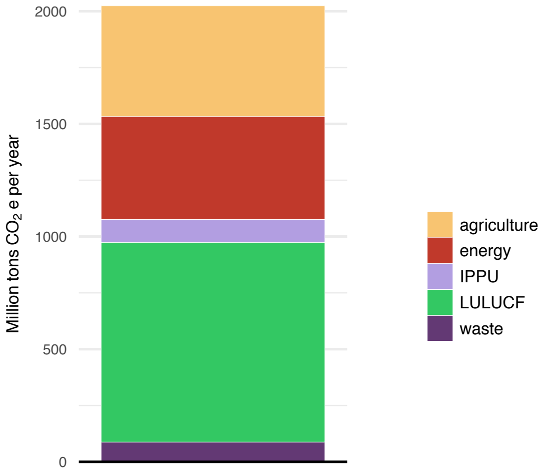
(MAPA, 2019)

The largest soybean exporter in the world in 2015

(FAOSTAT, 2019)

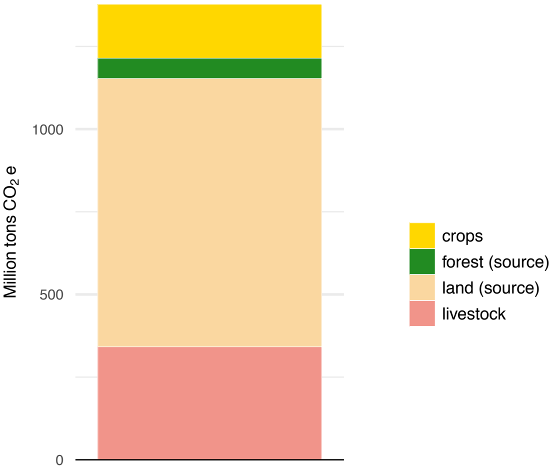
GHG Emissions

Fig. 6 | GHG emissions by sector in 2015



Source: SEEG Brasil

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



Source: SEEG Brasil

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 109% from USD 11,313 in 2015 to USD 23,697 in 2050 (SSP2 scenario selected).	The population is expected to increase by 14.5% between 2015 and 2050 from 206 mln to 236 mln (SSP2 scenario selected).
Scenario justification	According to OECD (2019), GDP will reach 5.78 tln by 2050 which would be equal to USD 24,807 per capita using population projections from the Brazilian Institute of Geography and Statistics (IBGE, 2019), of which the closest scenario is SSP2.	Brazil's population will peak around 233 mln by 2050, according to data from IBGE (2019).

TRADE

	Imports =	**Exports** ↗
Scenario definition	The share of total consumption which is imported is assumed constant at 2010 level.	The exported quantity increases: - from 57 Mt in 2015 to 133 Mt in 2050 for soybean, - from 1.6 Mt in 2015 to 2.3 Mt in 2050 for beef, - from 17 Mt in 2015 to 36 Mt in 2050 for corn.
Scenario justification	Brazilian wheat imports in 2028 do not differ much from 2018 numbers (-2.1%), according to projections from MAPA (2018). Hence, we choose a scenario that reflects that trend.	The following projections are from the MAPA report (2018): soybean exports increase from 70 Mt in 2017/18 to 96.5 Mt in 2027/28 (assuming the same growth rate, it is expected to be 148 Mt in 2050).

Scenario signs = no change → small change ↗ large change

LAND

	Land conversion	Afforestation ↗
Scenario definition	We assume that deforestation will be halted by 2030.	We assume total afforested/reforested area to reach 12 Mha by 2030.
Scenario justification	In line with Brazil's NDC (Brazil, 2018) which commits to strengthen its policies and measures with a view to achieve zero illegal deforestation in the Brazilian Amazonia by 2030. This target goes beyond the Brazil's NDC which assumes zero illegal deforestation. This target also goes beyond the 2012 Brazil's Forest Code (FC). The FC is not a zero deforestation law and it allows deforestation according to the levels of protections defined in the legal reserve requirements (e.g. 20% of private properties in the Amazon biome can be legally deforested while 80% must be preserved).	In 2015, the Government of Brazil pledged to reforest 12 Mha by 2030 under its NDC. Restoring 12 Mha of deforested land is also a commitment Brazil made for the Bonn Challenge (Bonn Challenge, 2014; Brazil, 2018).

BIODIVERSITY

	Protected areas =
Scenario definition	The protected areas remain constant at 243 Mha between 2015 and 2050.
Scenario justification	Brazil has 243 Mha of protected areas including federal, state, and municipal conservation units and indigenous land. The Amazon biome holds the highest percentage of protected areas, as it concentrates more than 80% of the total area, followed by the Cerrado (approximately 10%) (MMA, 2019a; FUNAI, 2019).

Scenario signs = no change → small change ↗ large change

FOOD

	Diet →	**Food waste** ↗
Scenario definition	Between 2015 and 2050, the average daily calorie consumption per capita increases from 2,735 kcal to 2,831 kcal. Per capita consumption: - increases by 47.3% for fruits and vegetables, - decreases by 7.5% for roots, - increases by 1.5% for cereals, - decreases by 10% for pulses, - for the other food groups, there is no large shift in consumption. We assumed a middle level of activity of the population to compute the MDER.	Between 2015 and 2050, the share of final household consumption which is wasted decreases from 10% to 5%.
Scenario justification	The scenario for diets follows FAO projections at the horizon of 2050 (Ministério da Saúde, 2014; FAO, 2018).	There is little research on food waste in Brazil. According to FAOSTAT (2019), the Brazilian food waste in 2000 was approximately 12.6% of the total production. We assume the share of waste in final household consumption decreases from 10% in 2015 to 5% in 2050 in order to follow the sustainable pathway scenario.

PRODUCTIVITY

	Crop productivity ↗	**Livestock productivity** →	**Pasture stocking rate** ↗
Scenario definition	We assumed the same productivity growth as over 2000-2010. Between 2015 and 2050, crop productivity increases: - from 2.98 t/ha to 3.99 t/ha for soybeans, - from 4.45 t/ha to 7.88 t/ha for corn.	Between 2015 and 2050, the productivity per head: - remains stable at 100 kg/TLU for cattle meat, - increases from 1.9 t/TLU to 2.5 t/TLU for cattle milk.	The average cattle ranching stocking density increases from 0.71 TLU/ha to 1.04 TLU/ha pasture between 2015 and 2050.
Scenario justification	This is based on the following projections from the MAPA (2018) report: soybean increases from 3.33 t/ha in 2017/18 to 3.45 t/ha in 2027/28 (assuming the same productivity improvement rate, then it is expected to be 3.72 t/ha in 2050), and corn increases from 5.35 t/ha in 2017/18 to 6.38 t/ha in 2027/28 (assuming the same productivity improvement rate, then it is expected to be 9.08 t/ha in 2050).	The "Plano Mais Pecuária" aims to increase the cattle meat production by 40% and productivity by 100% up to 2024 (EMBRAPA, 2014; MAPA, 2014).	Cattle ranching in Brazil is commonly referred to as a driver of deforestation. The sustainable intensification of beef production serves as a conservation tool (Cohn et al., 2014; Strassburg et al., 2014). Cattle ranching intensification should spare land for cropland expansion and decrease the deforestation (Soterroni et al., 2018). Therefore, there should be a stocking rate increase from the current amount to follow any sustainable pathway scenario.

Scenario signs = no change → small change ↗ large change

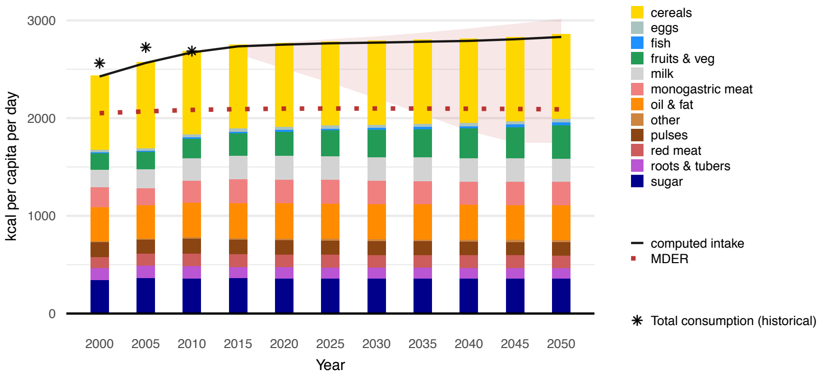
Results against the FABLE targets

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.



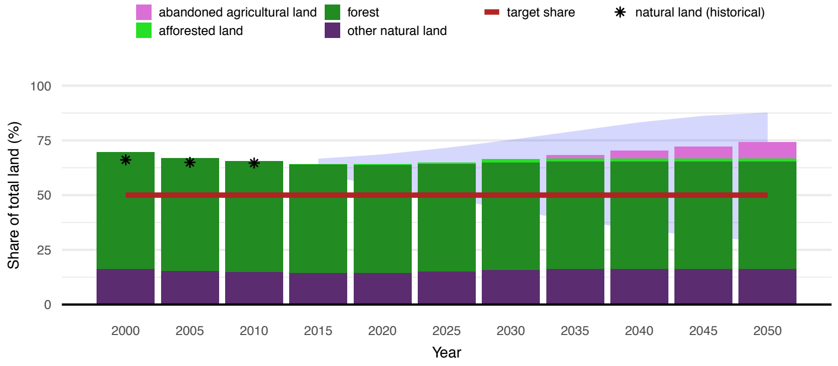
Historical data source: FAOSTAT

Our results show average daily energy intake per capita increases from 2,426 to 2,735 kilocalories between 2000-2015. The value in 2015 is 18.1% lower than the value from FAO for 2013 (FAOSTAT, 2019) because we are not taking into account some products in our calculations. Over the last decade, 31% of the food intake came from cereals. Calorie intake reaches 2,782 over the period 2031-2035 and 2,8301 over the period 2046-2050. In terms of recommended diet, our results show higher consumption of fruits and vegetables. The computed average calorie intake is 35.5% higher MDER at the national level in 2050.

Our results show that national food security objective of having 2,000 kcal/capita/day is reached during the whole simulation period.

Biodiversity

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



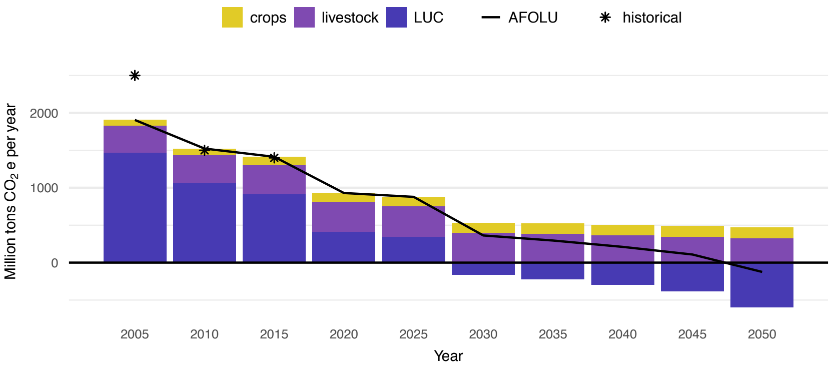
Historical data source: FAOSTAT

Our results show that the Share of total Land which could support Biodiversity conservation (SLB) decreased between 2000-2015 from 72.1% to 65.7%. The lowest SLB is computed for the period 2010-2015 at 65.7% of total land. This is mostly driven by deforestation and the conversion of other non-managed land to cropland and pastureland. SLB reaches 74.1% over the last period of simulation, 2046-2050. The difference is explained by a higher conversion of other land.

Compared to the global target of having at least 50% SLB by 2050, our results are above the target. Our results are not consistent with national CBD biodiversity commitments by 2020: the rate of loss of all natural habitats, including forests, should be at least halved and where feasible brought close to zero, and degradation and fragmentation should be significantly reduced.

GHG emissions

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



Historical data source: SEEG Brasil

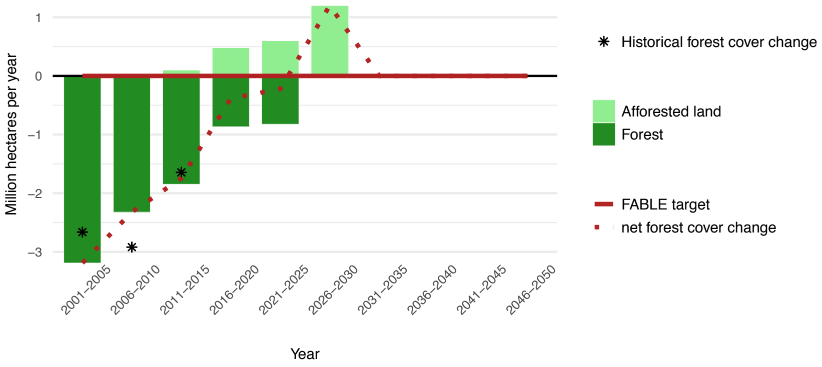
Note: AFOLU (Agriculture, Forestry and Other Land Use) is the sum of computed GHG emissions from crops, livestock and Land Use Change (LUC), emissions and sequestration from forestry are not included. Historical data only include positive emissions from crops, livestock, land use change.

Our results show annual GHG emissions from the AFOLU sector decreasing from 1.9 Gt CO2e to 1.4 Gt CO_2e during the period 2005-2015. Although our values are lower than the estimates from SEEG (2019) in 2005 (2.5 Gt CO_2e/year), they capture a decreasing trend and the estimates for the year 2015 are equal. The emissions from the AFOLU sector reach -124 Mt CO_2e over the period 2046-2050: 472 from agriculture and -596 from LUC. Negative emissions from LUC by 2050 are mainly explained by passive restoration as a result of pasture and cropland areas abandonment.

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

Forests

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



Source historical data: IBGE (2000), PRODES, SOS Mata Atlantica

Our results show accumulated deforestation of 36.79 Mha between 2001 and 2015. This amount is lower compared to PRODES Amazon and PRODES Cerrado which estimate an average of 44.95 Mha over the same period. Deforestation peak is computed for the period 2001-2005 at 15.9 Mha. Zero deforestation is reached over the period 2025-2030 because we assume no deforestation by 2030 in our sustainable scenario, which leads to a positive net forest cover change over the same period.

Compared to the FABLE target of having zero or positive net forest change after 2030, our results are above the target. Our results meet the national objectives of having 12 Mha of forest reforestation until 2030 as defined in Brazil's Bonn Challenge commitment, and the Brazil's NDC.

Other relevant results for national objectives

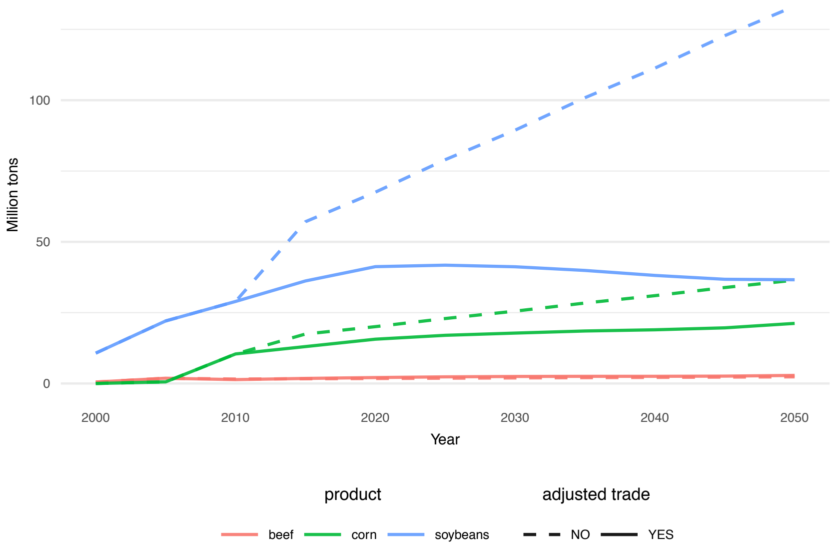
Table 1 | Other Results

Variable	Unit	2000	2005	2010	2015	2020	2030	2040	2050
Cropland	Mha	48.1	62.6	63.6	75.6	79.6	84.2	83.5	78.9
Pasture	Mha	200.1	208.2	223.1	221.8	214.1	190.4	159.4	128.1
Urban	Mha	5.4	6.6	8.0	9.7	11.7	17.2	25.2	30.0
Forest	Mha	461.7	445.8	434.2	425.0	420.6	416.5	416.5	416.5
Afforested land	Mha	0.0	0.0	0.0	0.5	2.9	11.9	11.9	11.9
OtherLand	Mha	141.3	133.4	127.8	124.0	127.6	136.4	160.0	191.1

In summary, there is no deforestation in Brazil after 2030. Pasture areas decrease by 32.7% and croplands also decrease by 6.2% between 2030 and 2050. On the other hand, other natural land is increasing by 40% during the same period.

Impacts of trade adjustment to ensure global trade balance

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



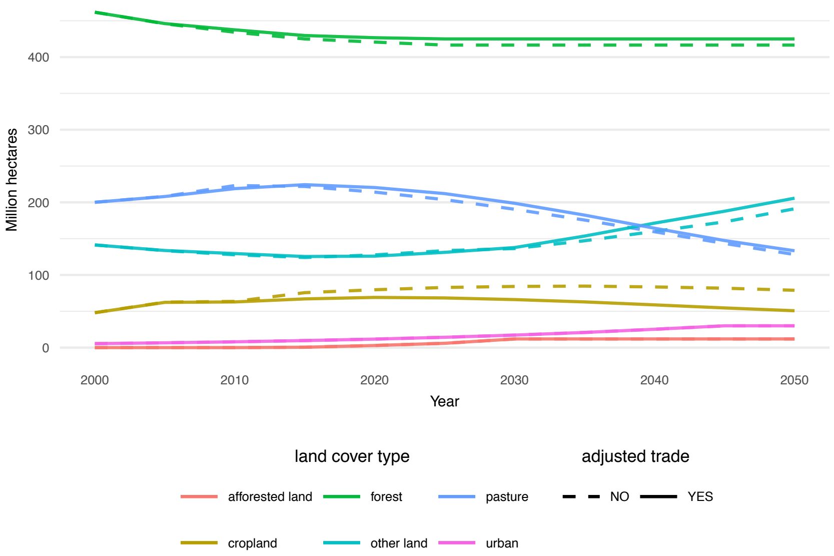
With the trade adjustment, soybean export quantities, started to change by 2015 with a reduction of 37% and a peak of 73% reduction in 2050 compared to no trade adjustment.

For corn export quantities, the results computed with the trade adjustment started to change by 2015 with a reduction of 25%, with a peak of 42% reduction in 2045 compared to no trade adjustment.

For beef export quantities, the results with the trade adjustment started to change by 2010 with a reduction of 13%. From 2020, the exports started to increase compared to no trade adjustment.

It is important to note that the main Brazilian imports are not affected by the trade adjustment.

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



Comparing the evolution of land use with and without trade adjustment, differences in pasture, cropland and other land classes can be observed from 2030 onwards. The cropland area is the land use class with the highest change when compared to the no trade adjustment, with a reduction of 36% by 2050.

Discussion and next steps

Brazil is one of the 17 megadiverse countries in the world with 45,678 plant species, 720 mammals, 1,024 amphibians, 1,924 birds, 761 reptiles, 4,538 species of freshwater fish, and 105,881 species of invertebrates. Within this set, 1,173 animal species and 2,113 plant species are under threat of extinction largely due to habitat loss from agriculture expansion (MMA, 2019b, 2019c). Two-thirds of the Amazon rainforest are located in the Brazilian territory with 48% having some kind of protection including conservation units and indigenous lands. Between 2004 and 2012, Brazil made great progress on protecting natural resources – the deforestation in the Brazilian Amazon decreased by 83% during this period. This sharp reduction was possible thanks to a combination of factors including the expansion of the protected areas network, improvements on national satellite monitoring systems, the implementation of supply chain agreements, the implementation of credit restrictions to farms located in municipalities with high levels of deforestation, among others. Nevertheless, Brazil remains one of the countries with the highest deforestation rates in the world (Weisse and Goldman, 2019).

Since 2012, the area deforested in the Brazilian Amazon has been increasing reaching 7,900 km^2 in 2018, the worst annual deforestation figures in a decade (PRODES/INPE, 2019). The rates of deforestation in the Cerrado – the richest savanna formation on earth and a biodiversity hotspot – have exceeded those of the Amazon over several years in the last decade (Carneiro-Filho and Costa, 2016). It is estimated that less than 20% of the Cerrado biome remains undisturbed (Strassburg et al., 2017). On the other hand, Brazil is a top producer and exporter of several commodities including soybeans and beef, which are well-known drivers of tropical deforestation. These commodities are produced to meet both internal consumption and global demand, which are poised to increase in the next decades (Alexandratos and Bruinsma, 2012; Lapola et al., 2013; Lambin et al., 2013). In 2015, approximately 60% of Brazilian soybean exports went to China and another 17% arrived in the European Union (TRASE, 2015).

Even with these two conflicting interests of increasing food production and preserving the environment, Brazil's COP21 pledge was to cut its GHG emissions by 37% below 2005 levels by 2025 and to reach a 43% reduction by 2030 (Brazil, 2018). The largest source of emissions in Brazil is by far from the land-use change and the forestry (LUCF) sector. In 2017, emissions from agriculture and LUCF sectors (AFOLU) accounted for almost 70% of the country's emissions. Since 50% of forests and native vegetation in Brazil are located in private properties (Soares-Filho et al., 2014), regulating land-use change in those areas is key for the country to achieve its emissions reduction goals. The most important environmental law that regulates land use and environmental management on private properties in Brazil is the Forest Code, which dates from 1965 and underwent a major revision in 2012. The Forest Code sets a minimum percentage of native vegetation to be preserved or restored on each property. It is not a coincidence that among the key measures of Brazil's NDC the enforcement of the Forest Code and the control of illegal deforestation in the Amazon biome are listed. The restoration of 12 million hectares of forests and native vegetation is also an important commitment to increase the land that can support biodiversity as well as contribute to negative emissions through carbon uptake of young forests.

In this study, the scenario implemented in the FABLE Calculator assumes a series of targets to promote a sustainable food and land-use system. Since the transformation towards a sustainable future in Brazil is mainly connected to strategies for managing land-use, the most important goals are the crop and livestock productivities increase, food waste reduction, zero deforestation after 2030, and 12 million hectares of forest restoration. In summary, the FABLE Calculator projects, between 2015 and 2050, a decrease in pasture areas, a slight increase in croplands, and a forest increase due to forest regrowth on abandoned pasture. Although the soybean area in 2025 is very close to OECD-FAO projections (only 1.4% smaller), the FABLE Calculator projects a higher area of rice by 35% and a lower area of sugarcane by 13% when compared to OECD-FAO outlook numbers (OECD-FAO, 2018). This might happen because of different assumptions on crop productivity over time that will need to be reviewed in the future. In addition, the calculation does not include bioenergy demand for products such as sugarcane ethanol, of which demand is expected to increase in Brazil (Empresa de Pesquisa Energética, 2018) with a direct impact on sugarcane area expansion. These refinements might be the next steps for improving the FABLE Calculator results for Brazil.

In terms of emissions, between 2046 and 2050, the average emissions from the AFOLU sector are projected to reach -25 $MtCO_2e$ per year at the national level. According to the Calculator, in the next 35 years the emissions from cropland are projected to increase by 28% (from 22 $MtCO_2e$ per year in 2015 to 28.2 $MtCO_2e$ per year in 2050) while the emissions from livestock decrease by 16% (from 78.9 $MtCO_2e$ per year in 2015 to 66 $MtCO_2e$ per year in 2050), and the emissions from land-use change and forest (LUFC) sector decrease by 169% (from 182.2 $MtCO_2e$ per year in 2015 to -125 $MtCO_2e$ per year in 2050). This negative emissions value is achieved largely due to the ban on deforestation combined with carbon uptake from natural vegetation regrowth and afforestation.

The targets of the sustainable pathway scenario implemented in this study are challenging, especially the zero-deforestation assumption. A more realistic but still challenging scenario is the rigorous enforcement of Brazil's Forest Code, which allows the clear cut of native vegetation surpluses in private properties while completely banning illegal deforestation everywhere in Brazil's six biomes. Under the Forest Code the two conflicting goals of agricultural production growth and environmental protection are likely to be achieved (Soterroni et al., 2018). Recently, the Brazilian Government has abandoned command-and-control policies to stop deforestation and environmental protection measures are being systematically weakened (Rochedo et al., 2018). When the governance is weak, supply chain agreements can play an important role in halting deforestation (Soterroni et al., 2019). However, the risk of leakage to other regions and commodities not covered by this type of sectoral agreement might fail in stopping overall deforestation (Lambin et al., 2018). Ideally, a mix of public-private policy with a focus on halting deforestation is needed for Brazil to become more resilient to political turmoil and for increasing the effectiveness of supply-chain agreements.

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

References

Alexandratos, N., & Bruinsma, J. (2012). *World Agriculture Towards 2030/2050: The 2012 revision* [ESA Working Paper 12-3]. Retrieved from FAO website: http://www.fao.org/3/a-ap106e.pdf

Bonn Challenge. (2014). Bonn Challenge Brazil. Retrieved 28 June 2019, from http://www.bonnchallenge.org/content/brazil

Brazil. (2018). *Intended Nationally Determined Contribution: towards achieving the objective of the United Nations Framework Convention on Climate Change* (p. 10). Retrieved from Ministério do Meio Ambiente website: http://www.mma.gov.br/images/arquivo/80108/BRAZIL iNDC english FINAL.pdf

Carneiro-Filho, A., & Costa, K. (2016). *The expansion of soybean production in the Cerrado*. Retrieved from INPUT, Agroicone website: https://www.inputbrasil.org/wp-content/uploads/2016/11/The-expansion-of-soybean-production-in-the-Cerrado_Agroicone_INPUT.pdf

Cohn, A. S., Mosnier, A., Havlík, P., Valin, H., Herrero, M., Schmid, E., … Obersteiner, M. (2014). Cattle ranching intensification in Brazil can reduce global greenhouse gas emissions by sparing land from deforestation. *Proceedings of the National Academy of Sciences*, 111(20), 7236–7241. https://doi.org/10.1073/pnas.1307163111

EMBRAPA. (2014). *Plano Mais Pecuária - Portal Embrapa*. Retrieved from https://www.embrapa.br/busca-de-solucoes-tecnologicas/-/produto-servico/3705/plano-mais-pecuaria

Empresa de Pesquisa Energética. (2018). *Cenários de Oferta de Etanol e Demanda do Ciclo Otto*. Retrieved from Empresa de Pesquisa Energética website: http://epe.gov.br/pt/publicacoes-dados-abertos/publicacoes/cenarios-oferta-etanol-e-demanda-ciclo-otto

FAO. (2018). *The future of food and agriculture – Alternative pathways to 2050* (No. CC BY-NC-SA 3.0 IGO; p. 224). Retrieved from FAO website: http://www.fao.org/3/I8429EN/i8429en.pdf

FAOSTAT. (2019). *FAOSTAT database*. [Data set]. Retrieved from http://www.fao.org/faostat/en/#data

FUNAI. (2019). *Fundação Nacional do Índio - Terras Indígenas* [Data set]. Retrieved from http://www.funai.gov.br/index.php/indios-no-brasil/terras-indigenas

IBGE. (2019). *IBGE - Projeção da população* [Data set]. Retrieved from https://www.ibge.gov.br/apps/populacao/projecao/

ICMBio. (2018). *Livro vermelho da Fauna Brasileira Ameaçada de Extinção*. Retrieved from http://icmbio.gov.br/portal/images/stories/comunicacao/publicacoes/publicacoes-diversas/livro_vermelho_2018_vol1.pdf

Lambin, E.F., Gibbs, H. K., Ferreira, L., Grau, R., Mayaux, P., Meyfroidt, P., … Munger, J. (2013). Estimating the world's potentially available cropland using a bottom-up approach. *Glob Environ Change*, 23(5), 892–901.

Lambin, Eric F., Gibbs, H. K., Heilmayr, R., Carlson, K. M., Fleck, L. C., Garrett, R. D., … Walker, N. F. (2018). The role of supply-chain initiatives in reducing deforestation. *Nature Climate Change*, 8(2), 109–116. https://doi.org/10.1038/s41558-017-0061-1

Lapola, D. M., Martinelli, L. A., Peres, C. A., Ometto, J. P., Ferreira, M. E., Nobre, C. A., … Vieira, I. C. G. (2013). Pervasive transition of the Brazilian land-use system. *Nat Clim Change*, 4, 27–35.

MAPA. (2014). *Plano Mais Pecuária*. Retrieved from MAPA website: http://www.agricultura.gov.br/assuntos/camaras-setoriais-tematicas/documentos/camaras-setoriais/leite-e-derivados/anos-anteriores/plano-mais-pecuaria.pdf

MAPA. (2018). *Projeções do Agronegócio: Brasil 2017/18 a 2027/28 projeções de longo prazo* (p. 112) [Report]. Retrieved from Ministério da Agricultura, Pecuária e Abastecimento website: http://www.agricultura.gov.br/assuntos/politica-agricola/todas-publicacoes-de-politica-agricola/projecoes-do-agronegocio/banner_site-03-03-1.png/view

MAPA. (2019). *MAPA Indicadores* [Data set]. Retrieved from http://indicadores.agricultura.gov.br/index.htm

MapBiomas. (2019). *MapBiomas* [Data set]. Retrieved from http://mapbiomas.org/map#coverage

Ministério da Saúde. (2014). *Guia alimentar para a população brasileira*. Retrieved from http://bvsms.saude.gov.br/bvs/publicacoes/guia_alimentar_populacao_brasileira_2ed.pdf

Ministério da Saúde. (2015). *Vigitel Brasil 2015: vigilância de fatores de risco e proteção para doenças crônicas por inquérito telefônico : estimativas sobre frequência e distribuição sociodemográfica de de fatores de risco e proteção para doenças crônicas nas capitais dos 26 estados brasileiros e no Distrito Federal em 2015* (p. 162) [Report]. Retrieved from Ministério da Saúde website: http://portalarquivos2.saude.gov.br/images/pdf/2018/marco/02/vigitel-brasil-2016.pdf

MMA. (2019a). *Ministério do Meio Ambiente - Áreas Protegidas* [Data set]. Retrieved from http://www.mma.gov.br/publicacoes/areas-protegidas.html

MMA. (2019b). Ministério do Meio Ambiente - Biodiversidade - Fauna. Retrieved 28 June 2019, from http://www.mma.gov.br/mma-em-numeros/biodiversidade

MMA. (2019c). Ministério do Meio Ambiente - Biodiversidade - Flora. Retrieved 28 June 2019, from http://www.mma.gov.br/mma-em-numeros/biodiversidade-flora

OECD. (2019). *Real GDP long-term forecast (indicator)* [Data set]. https://doi.org/doi: 10.1787/d927bc18-en

OECD-FAO. (2018). *Agricultural Outlook 2018-2027* [Data set]. Retrieved from https://stats.oecd.org/viewhtml.aspx?QueryId=84949&vh=0000&vf=0&l&il=&lang=en

PAM/IBGE. (2019). *Sistema IBGE de Recuperação Automática - SIDRA* [Data set]. Retrieved from https://sidra.ibge.gov.br/home/pmc/brasil

PRODES/INPE. (2019). *Taxas anuais de desmatamento na Amazônia Legal Brasileira (AMZ)* [Data set]. Retrieved from http://www.obt.inpe.br/prodes/dashboard/prodes-rates.html

Rochedo, P. R. R., Soares-Filho, B., Schaeffer, R., Viola, E., Szklo, A., Lucena, A. F. P., … Rathmann, R. (2018). The threat of political bargaining to climate mitigation in Brazil. *Nature Climate Change*, (8), 695–698. https://doi.org/10.1038/s41558-018-0213-y

SEEG. (2019). *Sistema de estimativa de emissões de gases de efeito estufa, Brasil* [Data set]. Retrieved from http://seeg.eco.br/

Soares-Filho, B. S., Rajão, R., Macedo, M., Carneiro, A., Costa, W., Coe, M., … Alencar, A. (2014). Cracking Brazil's Forest Code. *Science*, 344(6182), 363–364.

Soterroni, A.C., Ramos, F. M., Mosnier, A., Fargione, J., Andrade, P. R., Baumgarten, L., … Polasky, S. (2019). Expanding the Soy Moratorium to Brazil's Cerrado. *Science Advances,* 5(7). https://doi.org/10.1126/sciadv.aav7336

Soterroni, Aline C., Mosnier, A., Carvalho, A. X., Câmara, G., Obersteiner, M., Andrade, P. R., … Kraxner, F. (2018). Future environmental and agricultural impacts of Brazil's Forest Code. *Environmental Research Letters*, 13(7), 074021. https://doi.org/10.1088/1748-9326/aaccbb

Strassburg, B. B. N., Brooks, T., Feltran-Barbieri, R., Iribarrem, A., Crouzeilles, R., Loyola, R., ... Balmford, A. (2017). Moment of truth for the Cerrado hotspot. *Nature Ecology and Evolution*, 1(0099). https://doi.org/doi.org/10.1038/s41559-017-0099

Strassburg, Bernardo B. N., Latawiec, A. E., Barioni, L. G., Nobre, C. A., Silva, V. P. da, Valentim, J. F., ... Assad, E. D. (2014). When enough should be enough: Improving the use of current agricultural lands could meet production demands and spare natural habitats in Brazil. *Global Environmental Change*, 28, 84–97. https://doi.org/10.1016/j.gloenvcha.2014.06.001

TRASE. (2015). *Transparent supply chains for sustainable economies* [Data set]. Retrieved from https://trase.earth/data?lang=en

Weisse, M., & Goldman, E. D. (2019).The World Lost a Belgium-sized Area of Primary Rainforests Last Year. Retrieved from https://www.wri.org/blog/2019/04/world-lost-belgium-sized-area-primary-rainforests-last-year

World Bank. (2019). *Prevalence of undernourishment (% of population)* [Data set]. Retrieved from https://data.worldbank.org/indicator/SN.ITK.DEFC.ZS?