École Polytechnique Fédérale de Lausanne

Economic growth and sustainability - HUM-470

Impacts of cattle production on sustainability in Brazil and the possible solutions

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1 Introduction

The number of vegetarians and vegans has increased in recent years, which is illustrated by the growing number of specialized restaurants.[1] Indeed, people have started to realize the impact of meat production on sustainability (both environmental and socio-economic) have chosen to change their consumption habits to mitigate their impact.

The majority of the animal proteins produced in the world come from Brazil.[2] The increase in Brazil's total population (from about 51 million in 1950 to more than 200 million in 2020) has resulted in the country to create and improve a complex agribusiness sector. [3]

However, although the agribusiness sector, and in particular the production of beef, benefits the Brazilian economy and feeds a large part of the world's population, it does so at the expense of the environment and the well-being of local communities. The ecosystem and balance of the Amazon rainforest has been particularly affected by the growth of the agricultural sector and the indigenous communities have been suffering from the predatory practices of the agribusiness sector. This situation may raise the following question:

What are the impacts of the Brazilian cattle production on sustainability and what are the possible solutions ?

In this report we will firstly analyze and point out the underlying causes for the lack of sustainability of cattle ranching in Brazil. Then, we will explain the solutions that have already been taken and will propose a number of additional solutions.

In order to properly understand the problem, it is necessary to first verify the context that led to the current situation, which includes the particularities of beef production in Brazil. Once the context is established, we will analyze some of the socio-economic and environmental impacts of cattle ranching in Brazil. In regards to the environmental impacts, we will mostly focus on deforestation. Then, some of the solutions that have already been adopted and their limitations will be presented. We will also analyze further measures that could be implement and their benefits and drawbacks. Finally we will present technical solution to change the meat production in order to reduce its environmental impact.

2 Context

To better understand how cattle ranching and meat production are far from sustainable today, and the importance of leading the way to sustainable production, it is necessary to understand the context.

2.1 Beef production

Beef is the third most consumed meat in the world, after pork and chicken.

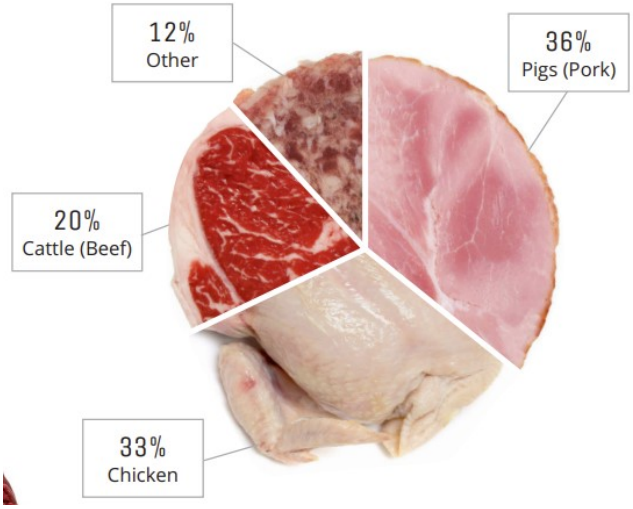


Figure 1: Global Meat Production (based on metric tons)[4, 5]

The products of beef production are meat, but also fat and leather. The average annual world production of beef is 65 million metric tons with a production value of $308 billion.[4]
The demand for beef has increased and is expected to increase in the coming decades due to rising global income and population growth, but also due to urbanization and westernization of diets in developing countries. [6, 7]
Beef production begins with a breeder keeping a herd of breeding cows. Because beef cows (and their calves) graze on rangeland and pasture, this stage requires little to no grain intake. Calves are weaned and moved from their ranch or farm of origin when they are six to twelve months old. They may be sold at an auction, sent to a feedlot (if they are younger or lighter and need more grazing time), or sent directly to a feedlot.
If animals are raised in a feedlot, they are fed a grain-based diet. The time cattle spend in a feedlot is sometimes called the "finishing phase". Some producers, however, choose to finish cattle on pasture, and the beef from these animals is said to be "grass-finished" (also called "grass-fed"). When the cattle reach market weight, they are transported to a processing plant where they are harvested.[5]

2.2 Brazil

Brazil is the largest country in South America and Latin America in terms of both area and population.
The country is considered a regional power and an international middle power, as well as an emerging power [8]. Moreover it is also acknowledged as an advanced emerging economy (twelfth largest GDP in the world in nominal terms, and eighth largest in purchasing power parity terms, the largest in Latin America).[9] This implies that Brazil carries diplomatic weight on the international stage, which means that it has the power to influence international political and economic decisions, especially those that are not in favor of the country. Despite all of this, the country has significant corruption, crime and social inequality.[10]
It is important to note that about 60% of the Amazon rainforest is in Brazil, which represents a huge resource of unused land for the economy, but not without some compromising behavior.[11]

2.2.1 Agriculture and meat production in the Brazilian Economy

Agriculture and related sectors account for 4.9% of Brazil's GDP in 2019.[12] Brazil is one of the largest producers of animal proteins in the world, i.e. chicken, pork, beef, eggs and milk. The distribution of Brazilian

agricultural exports is illustrated in the fig. 2. Meat and edible offal represent 7.42% of Brazil's total exports in 2020, and add up to a value of US$15.9 billion.[2]

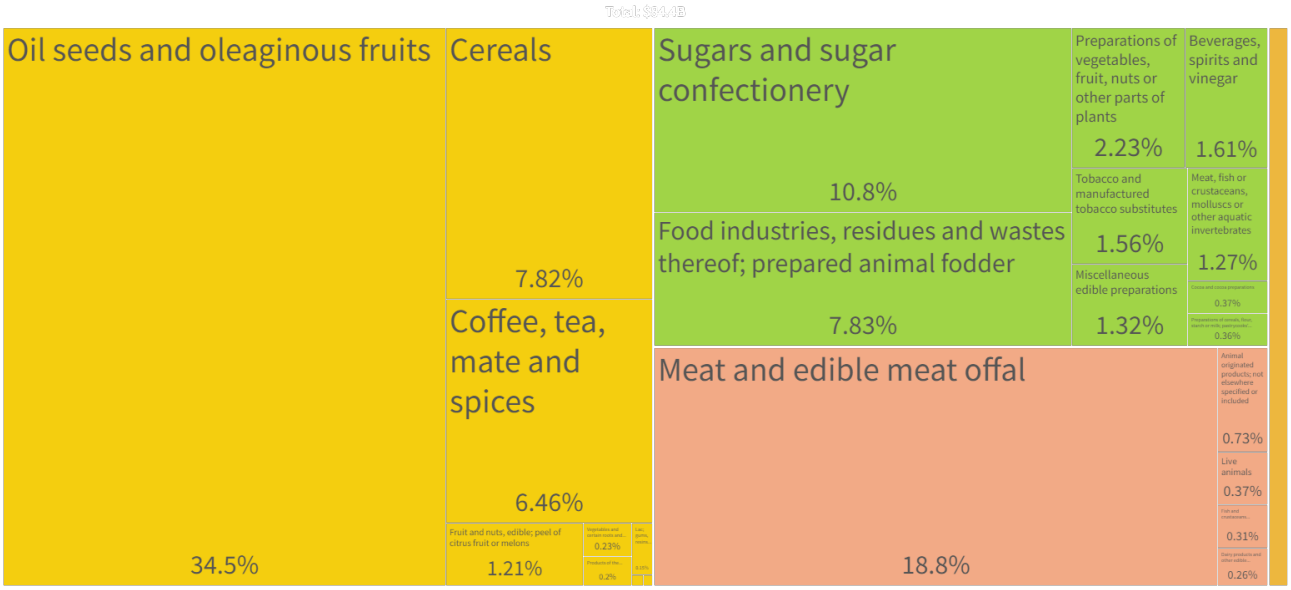


Figure 2: Brazilian agriculture export distribution in 2020 [2]
Legend: Yellow: vegetable products; Green: foodstuffs; Beige: Animal Products; Orange: Animal Hides

2.2.2 Beef production

One of the main agricultural products produced in Brazil, is beef. In 2019, Brazil had the second largest cattle herd in the world (232 million heads) and was the world's largest exporter of beef with 527,000 metric tons of carcass weight equivalent, providing nearly 20% of total world beef exports. Moreover, most projections indicate that Brazilian beef exports will continue to increase in the coming decades.[13, 14]
In the fig. 3, it is possible to see the main countries and regions of Brazilian beef imports in 2019.

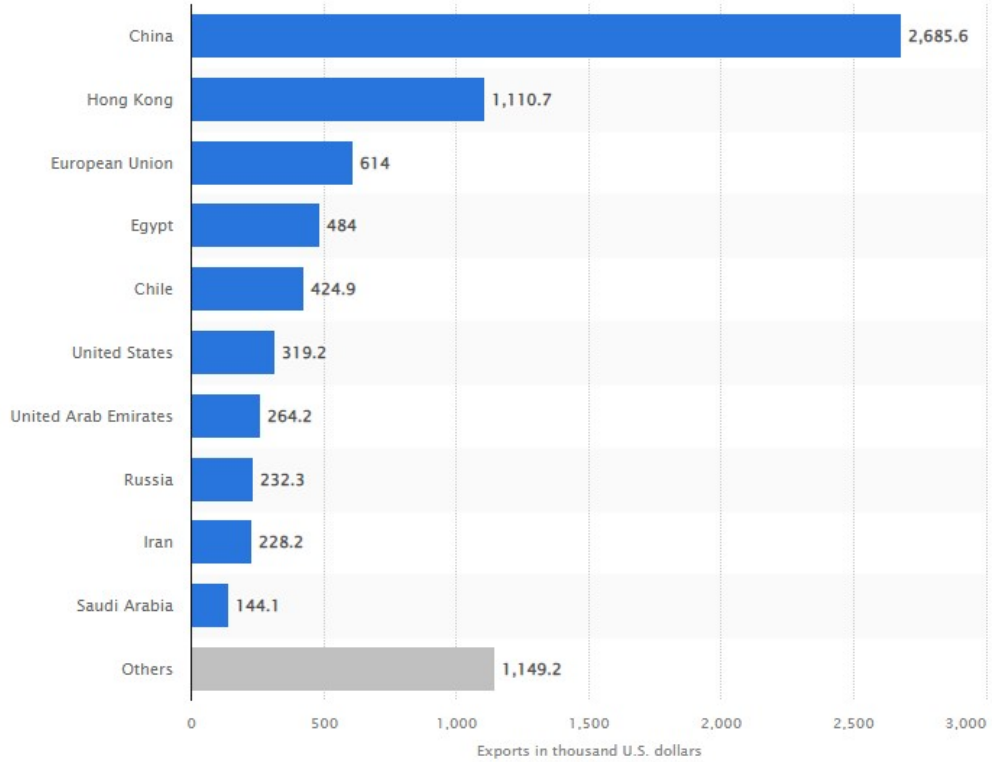


Figure 3: Exports of beef from Brazil in 2019, by destination [15]

Brazil, however, only exports about one-fifth (19.1% in 2017) of its beef production, with the rest used for domestic consumption. [16] The Brazilian livestock sector is dominated by huge meat packing export companies that serve both domestic and foreign markets.[17]
Brazilian beef production is mainly grass-fed.[18, 14] This implies that a massive and growing amount of grassland (linked to increasing demand) is needed to feed the cattle herd, and that the easiest way to find this land is to illegally seize and deforest it. [14]

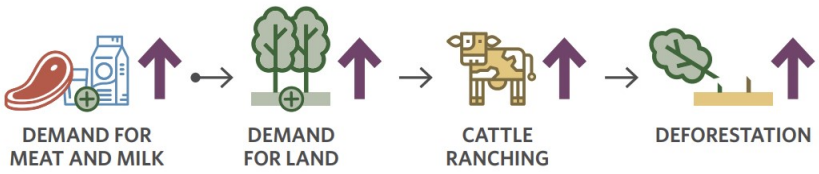


Figure 4: Illustration of the link between the demand for meat and milk and deforestation [14]

Cattle ranching is at the root of many political problems in Brazil, such as uncertain land rights, violence and corruption.[19, 20] This situation has led public authorities to take action and create policies; however, the lack of strict policies, such as property rights, is also responsible for the increase in cattle production, and thus economic development.

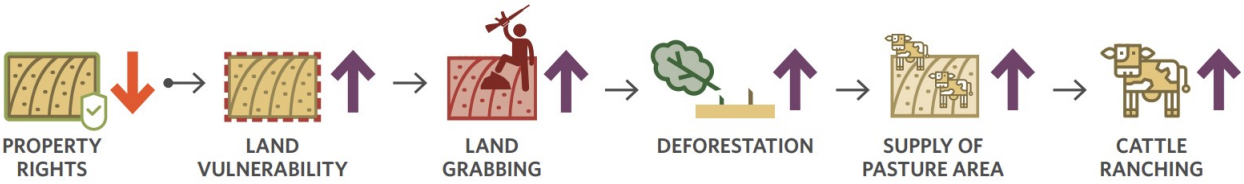


Figure 5: Illustration of the link between the property rights and deforestation and cattle ranching [14]

The Brazilian government is therefore trying to find the right balance between restrictive policies that could lead to a slowdown in economic development, and protecting the land from deforestation.

2.2.3 Soy production

Brazil has eclipsed the U.S. as the world's largest soybean producer in 2019, having surpassed the former leader with expected soybean production of about 134 million metric tons for the 2020/2021 crop year. According to projections, soybean production in Brazil will continue to rise over the following decade, reaching more than 140 million tons by 2029. The importance of this product is at least partially due to its variety in consumption. Soy may be used as an alternate protein source in plant-based diets and as a foundation for processed goods such as soymilk, which is possibly its most well-known application. Meanwhile, soybeans are still used primarily as high-protein soybean meal, making soybeans a protein crop, not an oil crop, used to feed livestock. [21, 22]

Domestic consumption accounts for around 23% of the Brazilian soy harvest. In 2018/19, soymeal for animal feed accounted for 17%, food usage of soybean oil accounted for 3%, and biodiesel accounted for 3%. This means that more than 73% of Brazilian soy consumption is used to feed animals, of which 50% is for chickens, 25% for pigs, and 12% for cattle and dairy cows. [23, 24]
The remaining 77% was exported, with China and the EU being the primary destinations. Where the soybean is also mainly used to feed animals for cattle farming and meat production. [24, 25] The fig. 6 illustrates the Brazilian soy supply chain.

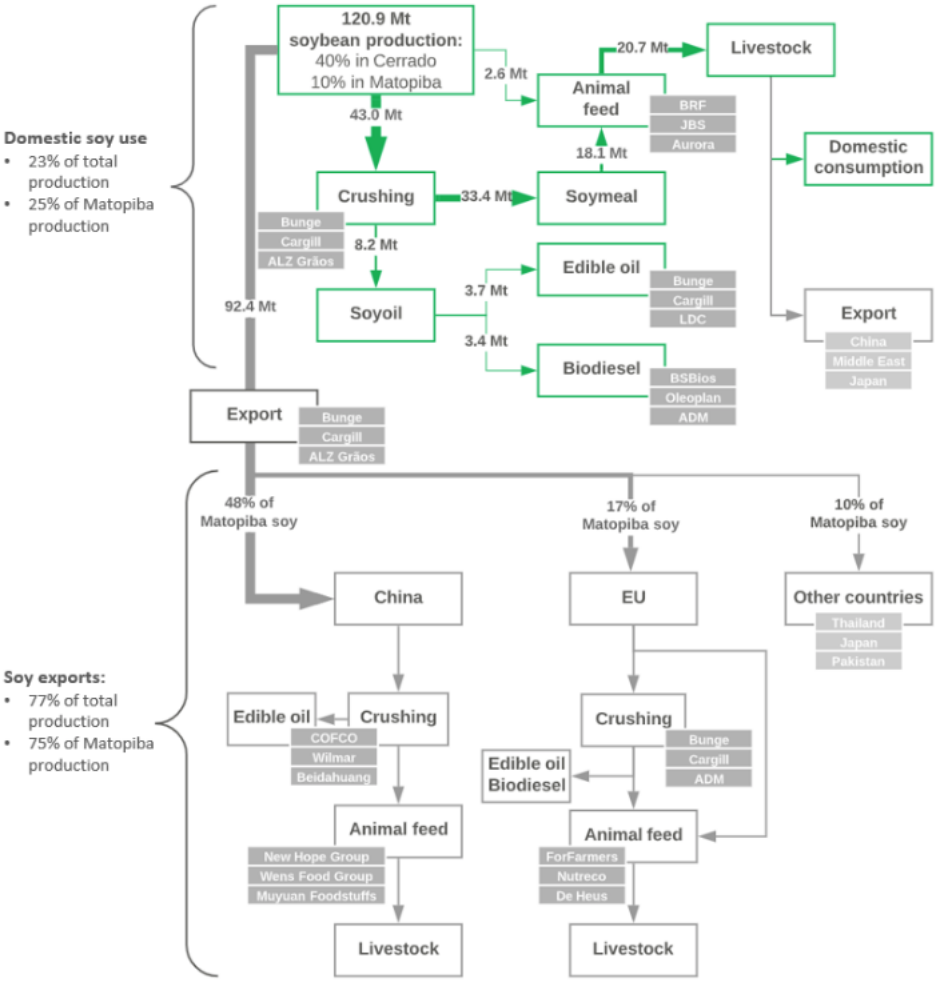


Figure 6: Brazilian soy supply chain (values from 2018/19) [24]

Cropland, particularly soy and sugar cane, has increased significantly in recent decades, with the majority of this growth occurring into grassland previously used as pasture for cattle, which has then spread into forest. Because of this complicated dynamic, the relative significance of cropland and pasture growth in driving vegetation loss in Brazil is now being researched and debated. [16, 26]

3 Sustainability issues

3.1 Socio-economic impacts

Cattle ranching has a considerable impact on the overall socio-economic structure of Brazil. This impact has been growing in recent years mainly due to the growth of the sector despite the economic recession that Brazil has been going through since 2015. The overall dependency of the Brazilian economy on the agricultural sector has resulted in landowners having a considerable amount of political power, which is mainly exerted through the so-called "ruralist caucus", which controls a significant portion of the National Congress of Brazil. The extent of the political influence held by the landowners has considerably increased ever since Jair Bolsonaro became the president of Brazil in 2019. Landowners currently benefit from a considerable deal of protection from the federal government, which allows them to partake in illegal activities, such as the usage of slave labor and illegal land occupations, with relative impunity.

In this section, we will analyze the extent of the influence of the cattle ranching sector in the Brazilian economy and the main factors that have led to their growing influence in the Brazilian society. We will then go over some examples of illegal activities partaken by cattle ranching sector and analyze their impact on local and indigenous communities.

3.1.1 Brazil economic dependency

At first sight, the overall impact of the agricultural sector on the Brazilian economy seems relatively marginal. According to the Brazilian Institute of Geography and Statistics (IBGE), the agricultural sector only accounted for 4.9% of the Brazilian GDP in 2019, as seen in figure 7 [12].

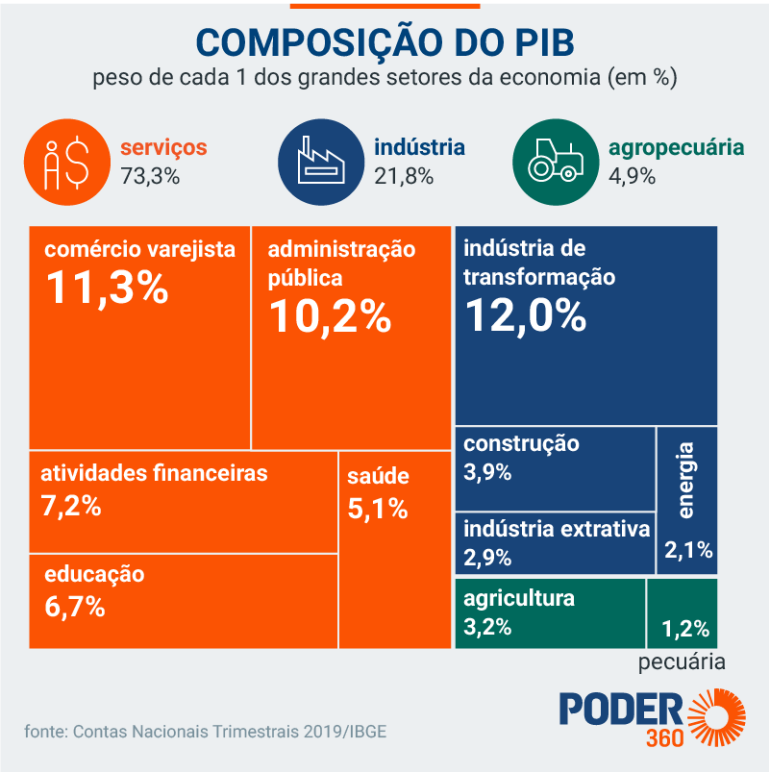


Figure 7: Breakdown of the Brazilian GDP in 2019 by economic sector [12]

Despite this marginal influence over the Brazilian GDP, the agricultural goods constitute a considerable portion of the total Brazilian exports. According to The Observatory of Economic Complexity (OEC), agricultural goods accounted for around 38% of all Brazilian exports in 2020. In particular, meat and edible meat offal products accounted for 7.42% of all Brazilian exports and soybeans accounted for 13.4%. [27]. A full breakdown of Brazilian exports in 2020 can be seen in figure. 8

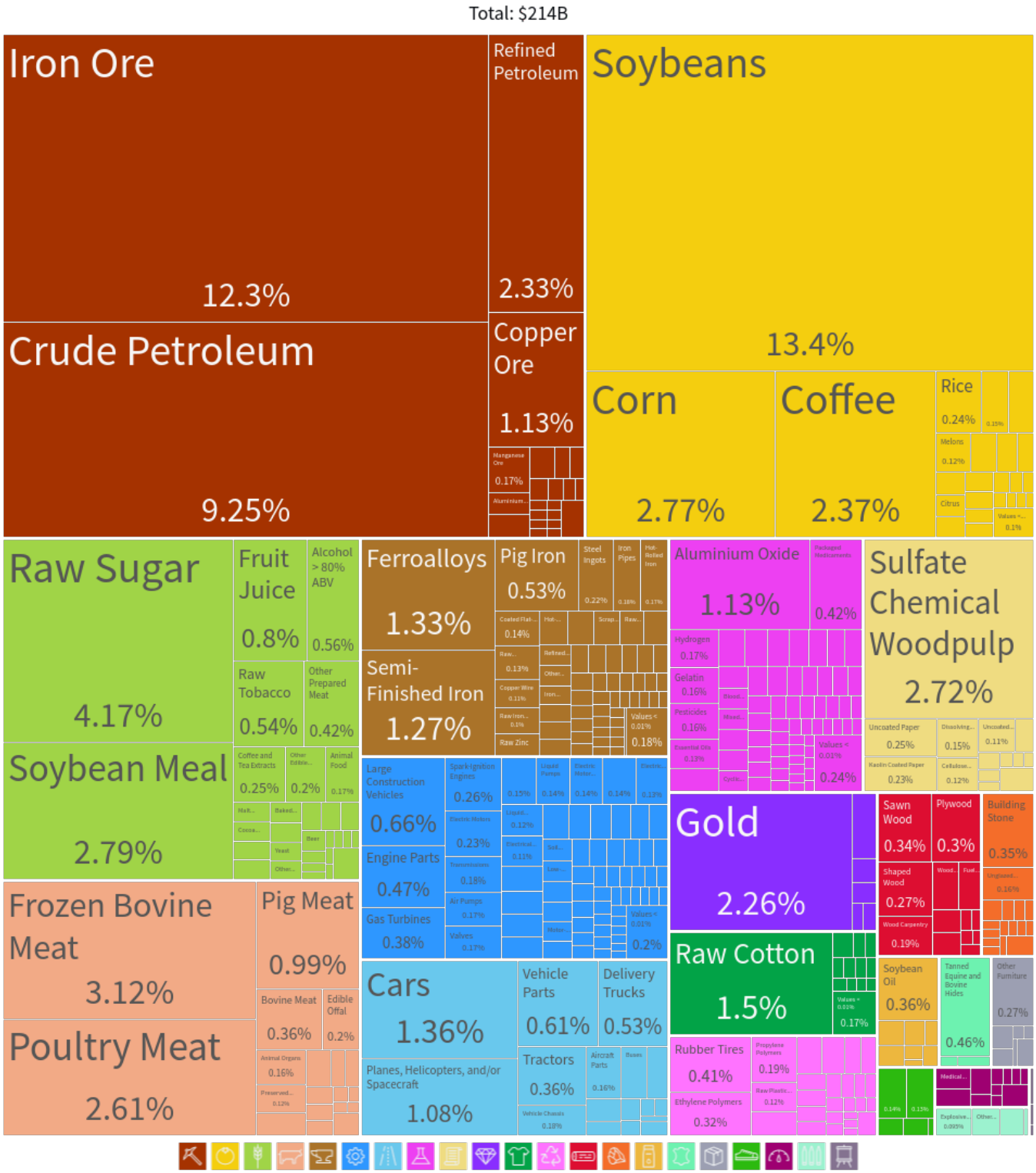


Figure 8: Breakdown of Brazilian exports in 2020 [27]

Ever since the start of the economic recession in Brazil in 2015, the agricultural sector has been the only major economic sector of the Brazilian economy that had an increase in its GDP in 2020. As a result of that, the share contribution of the agricultural sector in the overall Brazilian GDP increased from 5.1% to 6.1% in 2020. In addition, there was a considerable increase in the production and exportation of meat despite the impacts of the COVID-19 pandemic in Brazil. [28]. This economic growth can also be observed in the overall breakdown of Brazilian exports reported by the OEC, which shows that agricultural products, such as soybeans and frozen bovine meat, constitute the type of exports that have experienced the highest amount of growth, as seen in

figure 9.

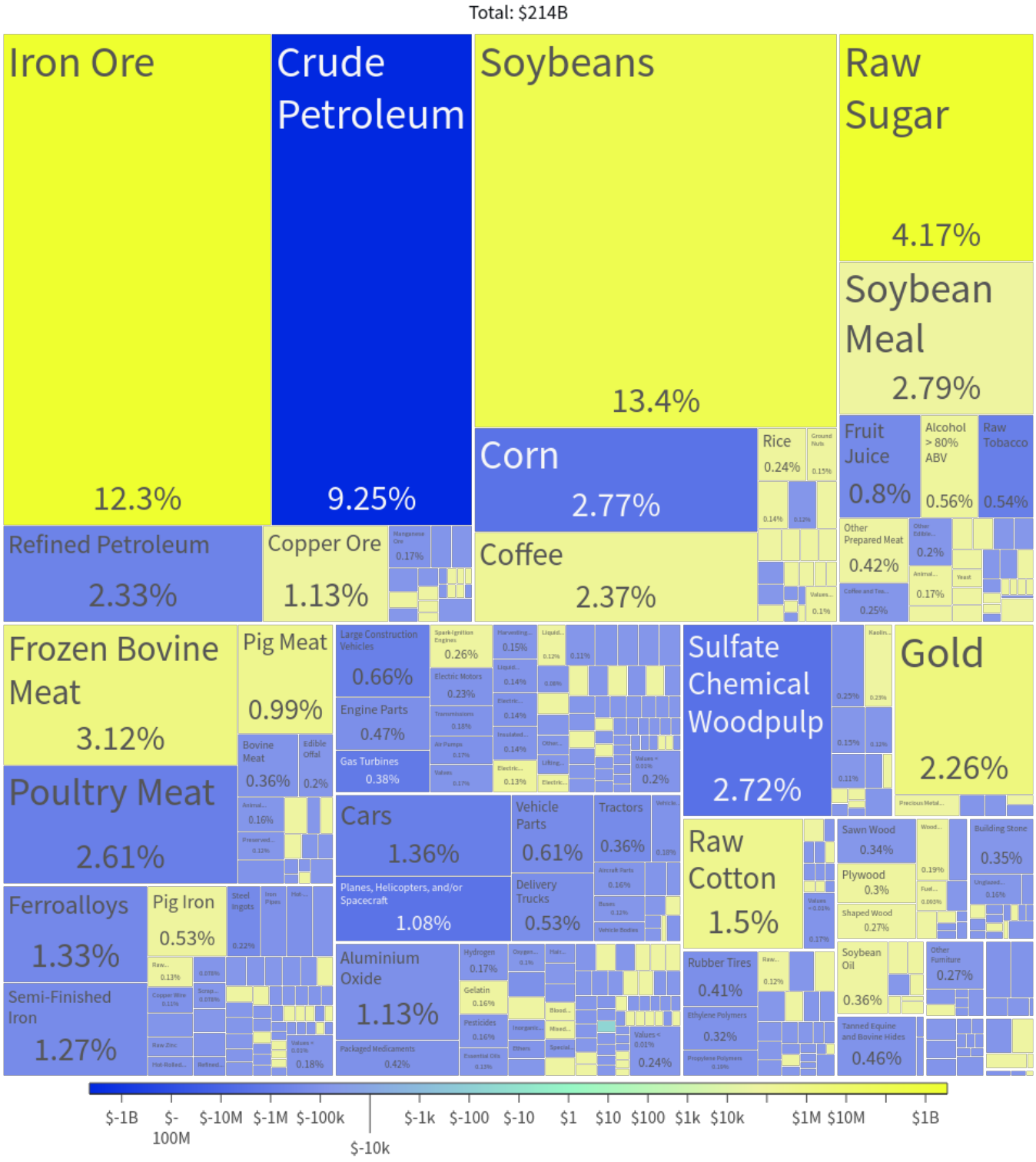


Figure 9: Breakdown of the growth of Brazilian exports in 2020[27]

This increasing in influence of the agricultural sector on the Brazilian economy can be traced back to the mid 2000s. During the government of Luiz Inácio Lula da Silva, Brazil experience a great deal of economic growth that was driven in part by a world-wide increase in the prices of commodities. The price of a kilogram of bovine meat, for example, increased from US$1.93 in 2000 to US$4.07 in 2013. This phenomenon became known as the *boom of the commodities* and resulted in a considerable increase in agricultural production in Brazil. Between

2000 and 2013, total meat production in Brazil increased by 101% and the soybean production increased by 197.6%. There was also a considerable increase in capital inflow into the meat industry in Brazil during that period, which resulted in Brazilian company JBS becoming the largest meat processing company in the world [29, 30].

This period of economic prosperity, however, came to an end with the start of political and economic crisis that has plagued Brazil since 2015 [31]. In 2016, the Brazilian GDP dropped by 3.6%, marking the worst recession in the history of Brazil. The agricultural sector was initially hit particularly hard, with its GDP dropping by 6.6% in the same year [32]. In 2017, however, the economic situation of Brazil seemed to have slightly improved, with the GDP growing by 1.0%. This small growth was largely driven by the agricultural sector, which had experienced an increase of 13% in its GDP. According to the IBGE, the agricultural sector accounted for 70% of the overall GDP growth in 2017 and, without it, the Brazilian GDP would have only increased by 0.3%. Meanwhile, the GDP of the industrial and services sector was largely stagnant in 2017 [33]. In 2020, with the advent of the COVID-19 pandemic, the Brazilian GDP dropped by 4.8%, with the industrial and services sectors suffering very heavily. The agricultural sector, however, experienced a growth of 2% in its GDP and the quantity of bovine meat exported by Brazil in 2020 was the highest that it has ever been[28].

The overall success of the agricultural sector and, in particular, the meat industry in Brazil in the recent years has largely translated into a substantial increase of the influence of those sectors in both the economic and political sphere. With the agricultural sector being the only economic sector that has experienced any meaningful economic growth since 2016, it can now be argued that the Brazilian economy depends on the success of this sector. Furthermore, since meat production is one of the main components of the Brazilian economy, it can also be argued that meat production is a crucial sector of the Brazilian economy. This allows the meat industry and the landowning elite of Brazil to essentially hold the Brazilian economy hostage and use their economic leverage as a meas to further extend their political power.

3.1.2 Political Implications

The ruralist caucus is the name that is often given to the group of congressmen in both the Chamber of Deputies and the Federal Senate that represent the interests of the landowning elite and the agricultural industry. It was initially organized around the Democratic Association of Ruralists (UDR), which was founded in 1985. The UDR was an influential group in the Brazilian Constituent Assembly of 1988, where it attempted to block any sort of land reform. The ruralist caucus as it is known today was created in 2002 as the Parliamentary Front of Agriculture (FPA) [34].

Although the ruralist caucus has always been influential, it would only come to dominate the Brazilian political scene in 2016, when president Dilma Rousseff was impeached and vice-president Michel Temer took over. One of the first acts of the Temer government was to extinguish a series of programs that were aimed towards the strengthening of family agriculture and the democratization of land access. This was largely pushed by the ruralist caucus, which has had become one of the main support groups of the Temer government [35]. In May 2017, after the CEO of JBS, Joesley Batita, was arrested, a series of audios of a phone call between Batista and Temer were released. In them, Batista discusses his plans to bribe several influential figures in order prevent the charges of corruption against Temer from going forward [36]. These audios resulted in the start of Parliamentary process that could have resulted in Temer being removed from office. In order to prevent that from happening, Temer forgave a series of debts that agricultural producers had with the federal government, which costed the government almost US$ 3 million. In return, he gained the full support of the ruralist caucus, which ensured that he would stay in office [37]. From that point on, the ruralist caucus would become one of the most influential political groups in Brazil and would be become a key actor in the political sphere of the country. Their influence would continue to increase and the ruralist caucus would become even more powerful when Jair Bolsonaro became the President of Brazil in 2019.

The political influence of the ruralist caucus has considerably expanded ever since Bolsonaro became president in 2019. It is estimated that the Parliamentary Front of Agriculture (FPA) is currently composed of 245 deputies out of a total of 513 in the Chamber of Deputies, and 39 out of a total of 81 senators. This almost gives them a majority in both houses of the Brazilian Congress [38]. Bolsonaro himself has demonstrated the extent of the power of the FPA when he stated to a group of congressmen from the group that "this government is yours. [39]" This great deal of power has resulted in the FPA successfully implementing several measures that it has been pushing for years. In February 2022, the Chamber of Deputies approved a law that would decrease regulations on pesticides [40]. Bolsonaro himself has actively promoted measures that have been defended by the ruralist

caucus. One example of such measures is the *marco temporal*, which would effectively invalidate several land claims made by indigenous peoples. When the Supreme Federal Court announced that it would evaluate if the *marco temporal* is valid or not, Bolsonaro stated that he would not respect the decision of the STF if it decides that the *marco temporal* is invalid [41]. These examples clearly demonstrate the deep negative impacts that the political power exerted by the ruralist caucus has on Brazilian society. Furthermore, the overall influence that the ruralist caucus has exerted on the Bolsonaro government has effectively resulted in the lack of accountability for the land owning elite, particularly when it comes to illegal land occupations.

3.1.3 Land occupations

Land grabbing is a common practice in Brazil, particularly in the Amazon. It is estimated that there is approximately 1 million square kilometers of illegally occupied land in the Amazon [42]. This process is mainly constituted by the illegal occupation of indigenous lands or ecological reserves. The occupying party will usually deforest the land with the help of slave labor and sell extracted wood in the black market. This land is then either sold or used for cattle ranching or plantations [43]. This practice is largely driven by the cattle ranching sector as it is an effective manner of further expanding the land used by cattle ranching [42], as illustrated in figure 5.

The Bolsonaro government has attempted to legalize the process of land grabbing. In December 2019, Bolsonaro signed an executive order that would open way for the privatization of land that was illegally occupied up until the end of 2018. This same executive order also suspended the process of demarcation of indigenous land [44]. Ruralists have defended this measure, claiming that would facilitate access to credit to rural producers that currently do not have a land title. According to Raul Valle, one of the directors of WWF-Brasil, this measure effectively encourages deforestation and the use of violence to seize land. He further adds that the landowning elites will be the ones that will benefit from this measure since they are the only ones that have enough money to go through the regularization process of invaded land. He also states that the federal body that manages land ownership, known as Incra, is currently headed by a ruralist and its local bodies are filled with local landowners and land grabbers [45]. These concerns have been proven to be accurate as, in 2021, the total area of illegally occupied land in the Amazon has increased by 56% and the area of illegally occupied indigenous land has increased by 31% [46].

The illegal occupation of indigenous lands often results in violent confrontations between indigenous peoples and landowners. One of the most prominent cases of this occurred in 2016 at an illegally occupied plot of indigenous land in the south of the state of Mato Grosso do Sul. A group of indigenous people was attacked by local landowners when they attempted to retake a plot of land that has been illegally occupied. This resulted in one indigenous person being killed and six others injured [47]. Events like these have become more common ever since Bolsonaro became president. Between January and September of 2019, there were a total of 160 cases of invasion or illegal expropriation in 153 different indigenous reservations. This a considerable increase when compared to 2018, in which there were 111 cases of such invasions throughout the whole year [48].

This overall increase in illegal land occupations is a direct result of the increase in political power exerted by the landowning elite. By being a key component of the Bolsonaro government, they have managed to ensure that they will be protected by the government and that they will suffer no consequences for their illegal land occupations. This practice not only results in the displacement and violence against indigenous communities, but has also resulted in a sharp increase in deforestation, particularly in the Amazon.

3.2 Environmental impacts: deforestation case

Deforestation refers to the cutting, clearing, and removal of natural forests. It generally includes converting natural forests into tree plantations or breeding fields. Forest degradation, instead, consists in a reduction in the density of trees in the area - but without a change in land use. Of all the environmental impacts of meat production in Brazil, we will mainly focus on studying the case of deforestation.[49]

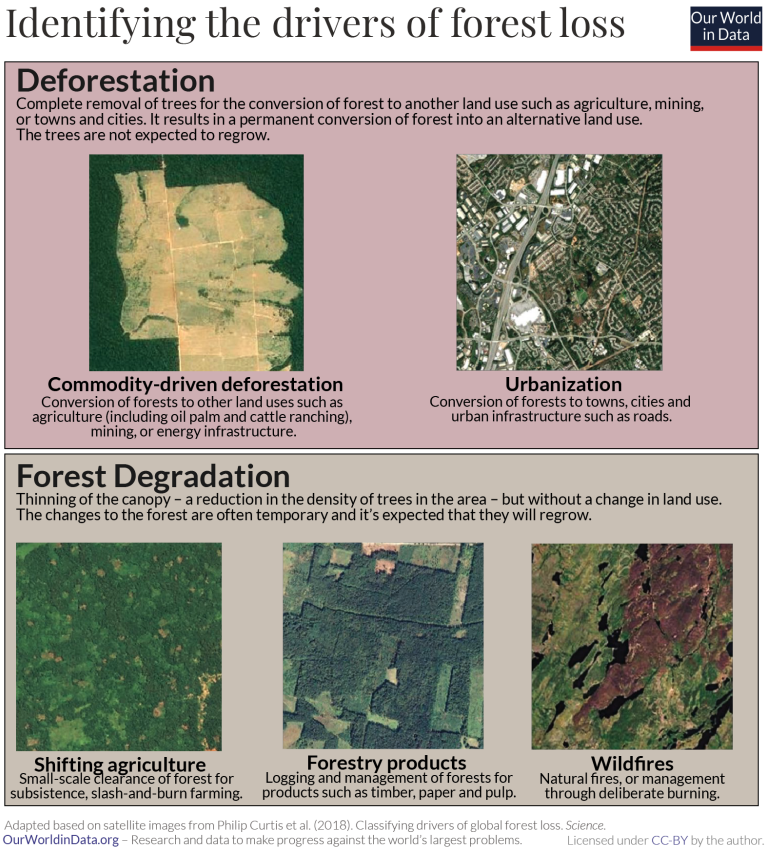


Figure 10: Understanding and seeing the drivers of forest loss, data from OurWorldinData.org [49]

As explained in section 2, Brazil is the largest beef exporter globally, and as a result of that, a massive amount of land to host cattle and the crops meant to feed them. Cattle ranching is indeed the main driver of deforestation in the country [17]. Furthermore, Brazil is also the largest producer of soybeans globally, with the crop primarily being used to feed animals. Such monoculture crops also damage biodiversity and leave ecosystems vulnerable.

Figure fig. 11 shows the tree cover loss in the Amazon rainforest, compared by country from 2001 to 2019. Nearly two-thirds of the Amazon rainforest is located in Brazil, with the latter being one of the main contributors to the region deforestation rate. [50]

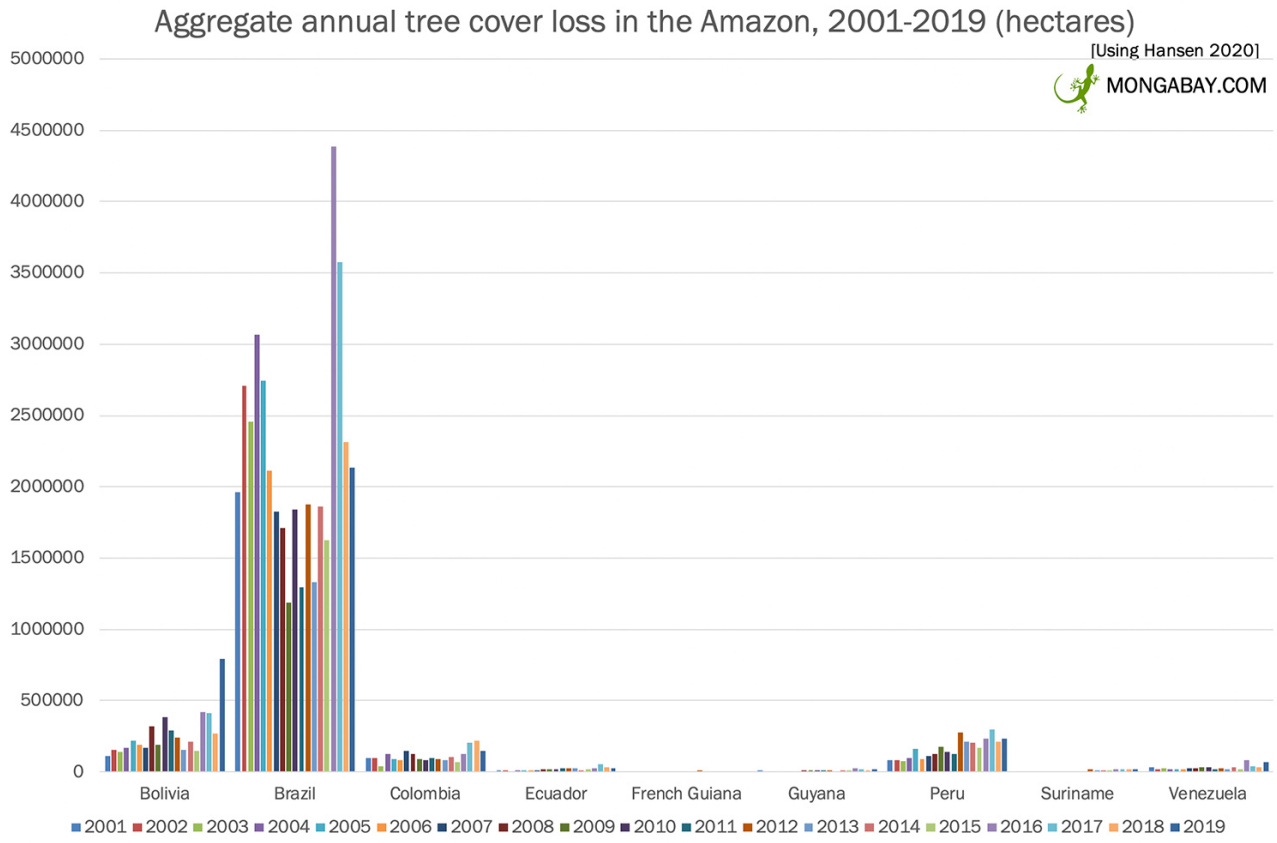


Figure 11: Tree cover loss loss across the Amazon biome, by country, 2001-present, according to data from Matthew Hansen and WRI's Global Forest Watch. [51]

Luckily, the country also has the best systems to track deforestation. The government and Imazon (Amazon Institute of People and the Environment), a national civil society organization, release updates quarterly and monthly using satellite data [52]. This data is primarily gathered using MODIS (Moderate Resolution Imaging Spectroradiometer), a satellite-based sensor, and Landsat, the longest-running enterprise, to acquire satellite imagery of Earth [53] [54]. Through these services, the Brazilian government and Imazon can release accurate data about the actual state of deforestation every year [52].

Impacts can be easily monitored on the web through tools such as Forest Monitoring for Action (FORMA) from the Global Forest Watch, allowing a near-real-time forest covering system that uses the previously mentioned MODIS. From the data provided by the Global Forest Watch, both primary forest loss and tree cover loss have increased since 2016 as a direct consequence that were mentioned in section 3.1.2. Primary forests are forests of native tree species with no visible indications of human activities. [55] Tree cover loss is not the same as deforestation. "Tree cover" refers to trees in plantations and natural forests, and "tree cover loss" is the removal of tree canopy due to human or natural causes, including fire.[56]

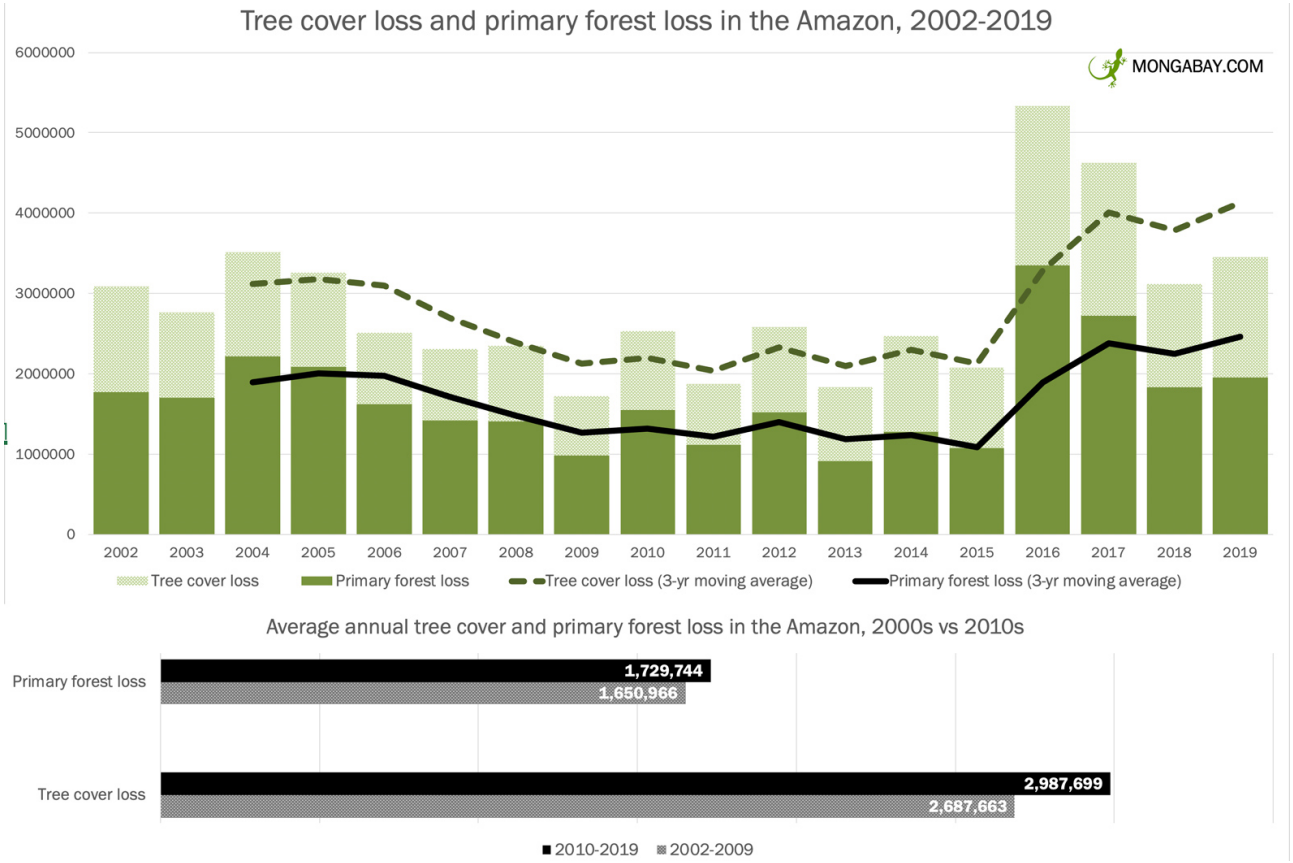


Figure 12: Tree cover loss loss across the Amazon biome, 2002-present, according to data from Matthew Hansen and WRI's Global Forest Watch. [51]

The rate of deforestation has decreased compared to thirty years ago, but since 2018 it has kept increasing, reaching almost the values of 2002.

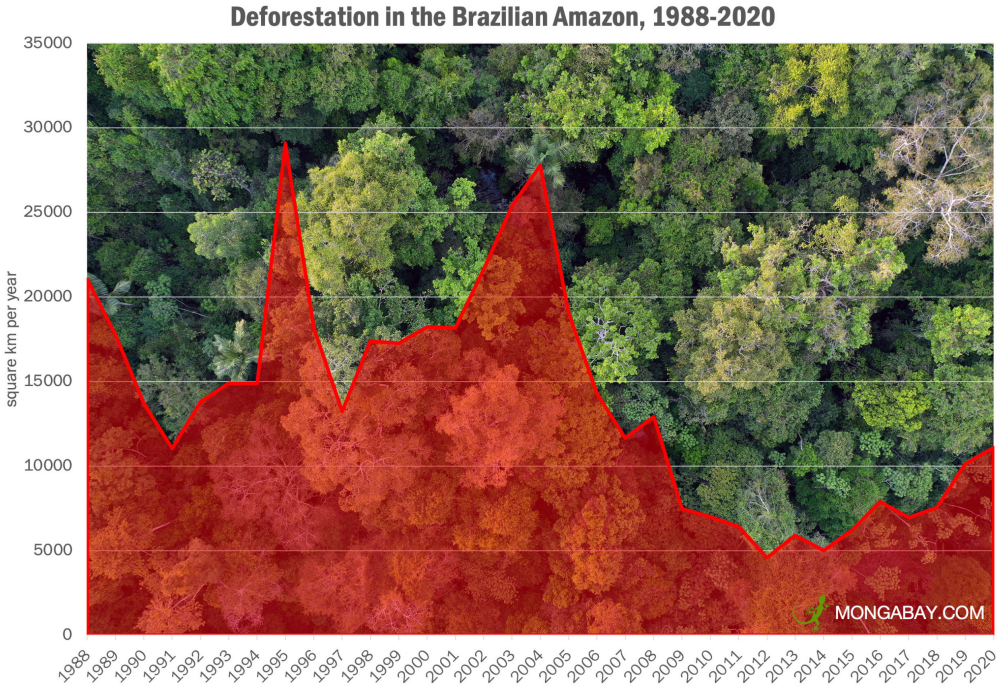
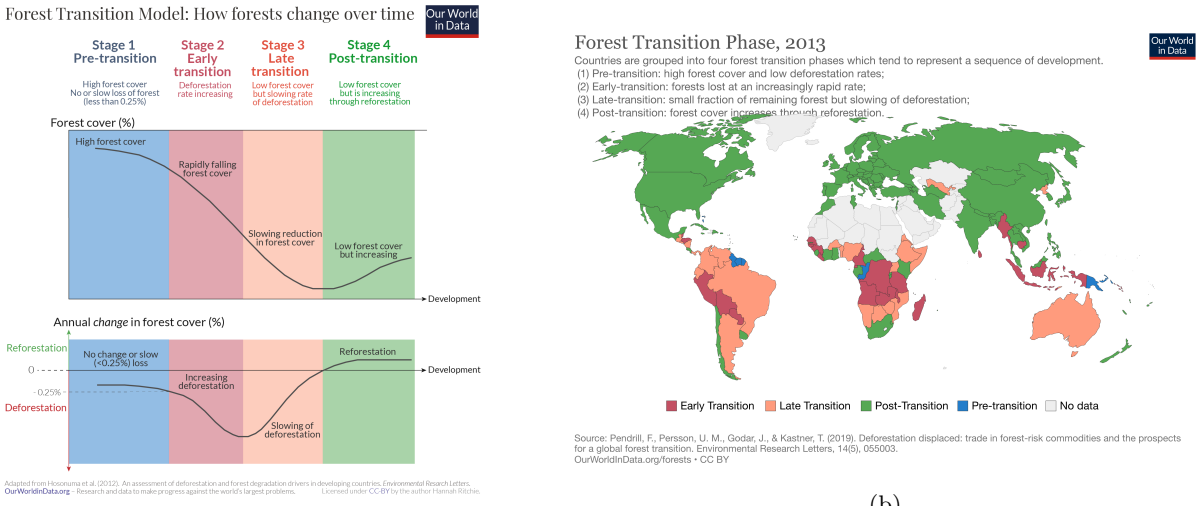


Figure 13: Annual deforestation in the Brazilian portion of the Amazon since 1988. [51]



(a) (b)

Figure 14: The Forest Transition Model and an illustration by country. [49]

As illustrated in fig. 14a, accordingly to the "Forest Transition Model" [57], Brazil is in the late transition phase, which means the forest cover is low and that the deforestation rate has generally decreased over time, as shown in fig. 13. Therefore, considering Brazil's environmental losses, it is evident how much the country needs to enter the post-transition phase; only then the very low forest cover will be able to increase through reforestation programs.

In an attempt to account for the services that the forest provides, TEEB (The Economics of Ecosystems and Biodiversity) [58], and The Cost of Policy Inaction [59] have estimated that in a business-as-usual scenario, with deforestation continuing at present rates, global human welfare losses range between $2 trillion and $4.5 trillion of natural capital lost each year. The global deforestation is 10,15 million hectares per year, and Brazil accounts for 1,7 million hectares per year (~17%); however, Ergo, the estimated cost of deforestation for Brazil only ranges from $34 billion and $76 billion every year.

"Not all that is very useful commands high value (water, for example) and not everything that has a high value is very useful (such as a diamond)."
Pavan Sukhdev, The Economics of Ecosystems and Biodiversity, An Interim Report, 2008 [58]

As a result, climate (carbon sequestration, CO2 emissions), wildlife (biodiversity loss, phylogenetic), water (freshwater, water cycle), and people (indigenous land, education) are suffering a tremendous impact. The implications of deforestation on water and climate will be briefly explored in the following two paragraphs.

3.2.1 Water

The Amazon rainforest has a complex water cycle consisting of evaporation, transpiration, and absorption; it releases 20 billion tonnes of moisture into the atmosphere every day [60]. The rainforests are so warm and moist that they create as much as 75% of their own rainfall through evaporation and transpiration. In fact, More than 50% of the precipitation that falls on rainforests is returned to the atmosphere through evapotranspiration. [61]

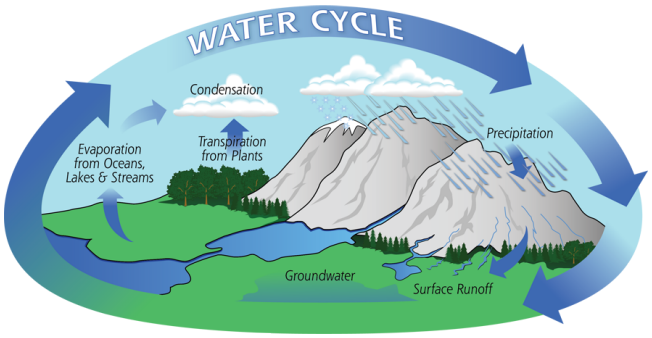


Figure 15: Water Cycle diagram [62]

The current rate of deforestation is deeply affecting this functionality, endangering in the first place freshwater and the well-being of the natural ecosystem [63].

3.2.2 Climate

Forest loss plays a significant part in climate change. Tropical forests have the highest carbon density of all forest types due to their ability for vast carbon sequestration. They contribute to more than 12% of absorption of all CO2 emissions. [64]
Overall, deforestation of tropical forests accounts for about the same amount of greenhouse gas emissions as every car, truck, bus, plane, ship, and train on the planet combined. [65]

4 Solutions

In this section we will focus on the solutions that have been implemented and could be implemented to reduce the impacts due to meat production in Brazil. However, achieving sustainable meat production is only made possible with the combination of changes in the Brazilian policies, in cattle ranching intensification and in changes in the Brazilian mentality regarding meat consumption. In this regard, we will outline the main bottleneck and possible solutions that have been implemented or could be implemented to pave the way ta sustainable meat production.

4.1 Brazilians policies

Currently, a large number of government interventions aiming to improve the sustainability of cattle ranching and deforestation are being developed by the public and private sectors. These interventions are based on a combination of institutional, incentive, and informational approaches and include national and state forestry policies, agricultural moratorium, payments for environmental service programs, and certification programs [66].
One of the world's leading initiatives that comprehensively certifies cattle ranching production while taking into account social and environmental aspects as well as animal welfare and product quality is the Sustainable Agriculture Network (SAN). The Sustainable Agriculture Network is a certification consortium that develops standards to promote social and environmental sustainability in agricultural supply chains globally by integrating sustainable production with biodiversity conservation, social responsibility and environmental well-being [67]. The Sustainable Agriculture Network cattle certification program in Brazil is probably one of the most comprehensive programs for the sustainability initiative of any government policy or incentive in Brazil [66]. Numerous governance interventions have been developed and implemented by the state, civil society and the private sector in order to improve the sustainability of the supply chain of cattle in Brazil. We are going to describe the main interventions of the various entities involved in achieving this goal.

4.1.1 The Forest Code

The Forest Code is one of the most stringent forest protection legislations in the world (in effect since 2012). Among the many requirements of this code, landowners must maintain a minimum proportion of forest area of their properties as Legal Reserves (RL). In fact, properties located in the Amazon biome of the legal Amazon must maintain 80 percent of their property as a protected area according to RL. In the areas located in the Cerrado biome, 35 percent of the properties must be maintained as protected zones. Finally, in the rest of the country, outside of the legal Amazon, 20 percent of the land must be maintained as protected zones according to RL [68].
The Forest Code encompasses many of the proposed requirements of the SAN program, yet the SAN program goes beyond the Forest Code. In fact, the SAN program requires that there be no legal deforestation even on certified farms [66].

4.1.2 Rural Environmental Register

The Rural Environmental Register is a national tool created by the Forest Code in order to register each rural property in Brazil through the definition of geo-referential boundaries. It aims to be able to monitor, apply and control all registered environmental data (e.g. deforestation). This tool makes it possible to monitor whether the various agricultural entities meet the criteria defined by the Forest Code, and if not, to intervene [69].

4.1.3 Cattle traceability

Knowing the origin of the cattle is a very important issue because the animals come from many farms and during their life cycle they are moved from one farm to another through informal mechanisms, auctions, etc. and the control of their provenance becomes therefore difficult. However, it is of great importance to know if they have been raised on illegally deforested properties. Therefore their tracking is necessary. For this purpose, a mandatory federal government tracking system called Sisbov (Brazilian system of identification and certification of bovine and buffalo origin) has been developed. However, tracking is limited to the last three months of the animal's life and is primarily designed to facilitate the export of beef to more stringent markets [70]. A wider adoption of this program would allow us to know the entire life cycle of the animal and ensure that the origin of the animal is of sustainable origin.

4.1.4 Illegal deforestation monitoring

The monitoring of illegal deforestation carried out by the center of terriotrial intelligence (Núcleo de Inteligência Territorial - NTI), the satellite monitoring system of the Brazilian Amazon (Monitoramento da Floresta Amazônica Brasileira por Satélite - PRODES), the plan for the prevention and control of deforestation (Plano de Prevenção e Controle do Desmatamento na Amazônia - PPCDAm) and the IBAMA embargoed areas are of vital importance and allow the data to be made available to the public [66]. In this way slaughterhouses can use this data to identify producers from which they can buy sustainably raised cattle.

4.1.5 Small scale interventions

Several programs aimed at providing the infrastructure and knowledge needed to assist smallholders to improve grazing and cattle management (e.g. 'Amazon Eyes of Water' and 'Green Municipalities' programs) [66]. Other interventions, however, aim to improve sustainability by limiting market access for unsustainable producers. The main purpose of these interventions is to prevent companies from purchasing cattle from illegally managed properties. In 2009, government ministries imposed a mandatory "Conduct Adjustment Term" (TAC) [71] on slaughterhouses and retailers throughout the Amazon in order to fine those who did not comply with sustainable cattle production (e.g., through illegal deforestation) or did not comply with the forest code. This has led slaughterhouses to carefully select their suppliers by keeping track of the entire cattle production cycle. This has led to a significant decrease in slaughterhouses purchasing cattle from recently deforested properties thereby curbing deforestation [66]. However, these commitments still have gaps to be filled in order to be fully efficient. In fact, checking the provenance of cattle is done only by monitoring the last property the cattle was on before being sent to slaughter. Therefore, the cattle may still have been raised on a property with deforestation and socio-environmental irregularities [71]. An example of a TAC violation is shown in the figures 16. In this regard, a control of the entire supply chain would allow total control over the origin of cattle.

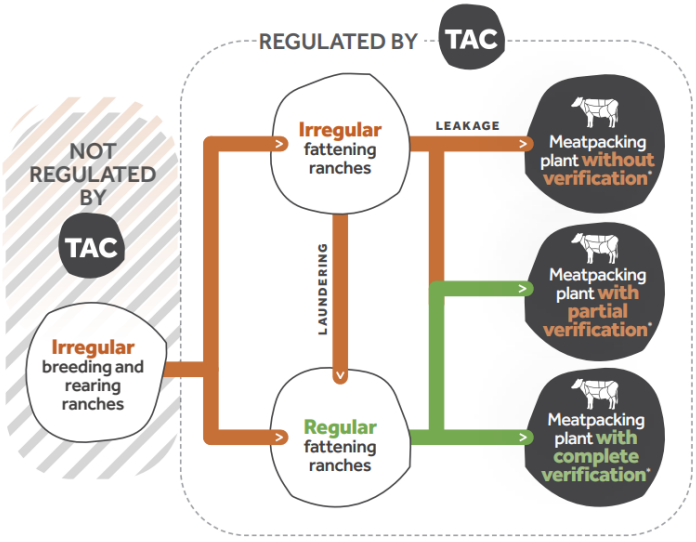


Figure 16: Possible arrangements for violating the TAC and the voluntary agreements that are based only on monitoring the direct meat-packing plant suppliers [71]

4.1.6 Credit lines

There are credit lines that aim to reduce deforestation and encourage sustainable farming (e.g. Low Carbon Agriculture - ABC Credit) [72]. However, access to these credit lines is not always evident for all producers because long documents must be completed in order to access credit. The lack of knowledge of small and medium-sized producers prevents them from accessing these credits. Facilitation in obtaining credits to small and medium-sized producers would allow to further extend these aids and make these producers more sustainable [66].

4.1.7 Non-designated forests

Today, in Brazil there are more than 60 Mha of Amazon forests that are not officially designated by the Brazilian government. This condition has led to the illegal appropriation and occupation of these territories by land grabbers and land speculators through forging land titles or loopholes in Brazilian legislation (see figure 5). These forging land titles are then sold to third parties at low cost creating a favorable condition for land speculators[73].
One possible solution to greatly reduce illegal deforestation and limit land speculation would be to designate and protect these non-designated forests with laws. In addition, the protection of these forests would contribute to the maintenance of the ecosystem and biodiversity also endangered by the deforestation to make room for cattle ranching, soybean cultivation, etc. On the other hand, the preservation of these forests could become a source of attraction for green investors and associations aimed at reducing emissions, deforestation and forest degradation [74].

4.1.8 Private properties forests

In addition to non-designated forests, a considerably large number of private properties can be legally deforested. We are talking about more than 25 Mha of the Amazon rainforest. At least half of these lands could be converted through a market for environmental offsets known as Environmental Reserve Quotas (CRA). The CRA is a mechanism created by the federal government designed to create a market through which owners of land with a Legal Reserves value (owners must maintain native vegetation on at least 20 percent of their total land area) in deficit can meet their legal obligations by purchasing shares of other lands the same size as those in deficit, thereby protecting an area equivalent to that in surplus [75]. However, the implementation of the CRA mechanism proposed during the revision of the Brazilian Forest Code is currently still pending regulation because of the complexity and the missing synergy between different tools needed for its implementation.
Furthermore, for the remaining land, in order to preserve the deforestation of forests, it would be necessary to introduce a regulatory system for payments for environmental services (also known as payments for ecosystem services or PES) to compensate farmers and landowners who have agreed to take certain actions to manage their land to provide an ecological service (in this case forest conservation) [76]. Therefore, the Brazilian government should promote public or private compensation programs to those who preserve the forests, the ecosystem and the biodiversity. Preliminary calculations suggested an opportunity cost of US 77-123 hectare per year to compensate 12 Mha of forest surplus [74]. These revenues can then be used by the farmers themselves to increase the productivity of their herds. Currently, this mechanism is being pursued by the Brazilian Congress [73].

4.2 Changes in meat production

4.2.1 Sustainable intensification

The intensification of production in already deforested lands is certainly one of the key elements to reduce deforestation given also the Brazilian agricultural development goals to be achieved (defined during MAPA 2017). Have been calculated that by increasing beef productivity in the Amazon from 60 kg ha-1yr-1 to 150 kg ha-1yr-1 on just 21 % (11.5 Mha) of existing range lands would free enough land (4 Mha) to meet beef production targets and allow for crop expansion in these areas (MAPA 2017) without any new deforestation [74]. Clearly, increasing production requires significant investments. These investments involve both public and private sectors and should be incentives for increased production. For example, these incentives could be subsidies that promote the use of existing technologies or the implementation of more innovative technologies.
In addition, producers should be encouraged to implement changes in their production in order to meet the requirements of deforestation-free and environmentally-friendly production. However, there are cultural and economic barriers that still prevent ranchers from taking the risk of intensifying production because culturally, land expansion has always been seen as a sign of prosperity and sometimes buying new land is cheaper than investing in production [73].

4.2.2 Technical assistance to smaller farmers

Another important and probably less known point is the impact on deforestation due to small farmers. In fact, small farming families have been forgotten during the modernization of Brazilian agriculture [74]. About two million people occupy the 77 Mha of official settlements in the Amazon – the same areas responsible for 30 % of all Amazon deforestation in recent years [74]. However, their impact is considerable and is mainly due to low income, lack of basic infrastructure, institutional support and little access to technical assistance,

farming technology and markets. This means that land exploitation is scarce and therefore the only alternative to increase their production is to create new spaces through deforestation.
There are still pilot projects aimed at giving technical assistance to small farmers with the aim of decreasing deforestation and increasing their income (IPAM). These projects include: planning of farm interventions together with smallholders; adoption of new technology to increase the productivity, improvements in processing infrastructure to comply with health and sanitary regulations, and increase access to markets [73].

4.3 Change in Brazilian mentality regarding meat consumption

In the graph below (figure 17) we can see the high consumption of beef in Brazil compared to the rest of the world. In fact, Brazil ranks third. If we compare Brazil's per capita beef consumption to the OECD total, we see that Brazil consumes 41 % more of beef annually [77].

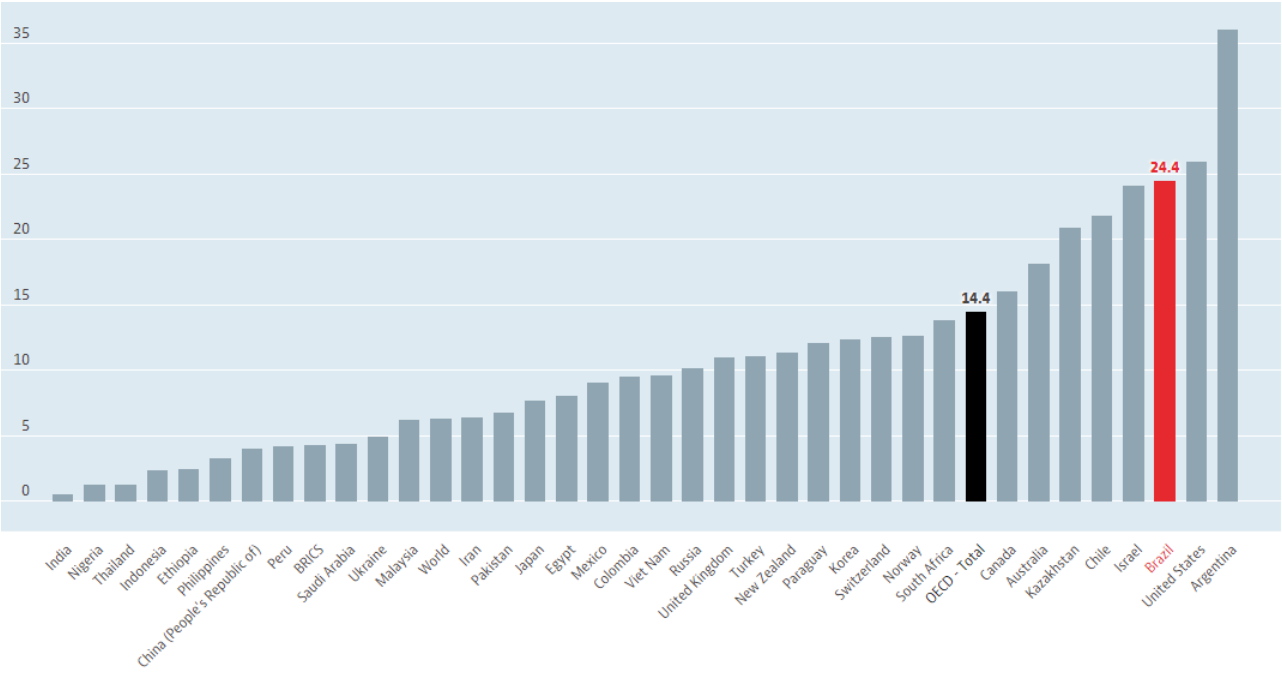


Figure 17: Meat consumption (Beef and veal), kilograms/capita [77]

In this regard, we show the major behavior factors that lead to high meat consumption. The table of figure 18 summarizes the main factors that influence meat-eating behavior. These factors can be divided between: personal factors (knowledge and skills, values and attitudes, emotion and cognitive dissonance, habits and taste, sociodemographic factor and personality traits and perceived behavioral control), socio-cultural factors (culture and religion, social norms, roles and relationship, social identity and lifestyle) and external factors (political and economic factors and food environment). Each of these factors shows barriers to reducing meat consumption. However, these barriers can be turned into opportunities to reduce and change the mentality of excessive meat consumption [78].
The "opportunities" column summarizes the main strategies aimed at improving behaviors that lead to excessive meat consumption. However, we will emphasize through examples what could be strategies that encourage synergistic effects between these factors.

- One example would be to create "positive" messages that amalgamate the concepts of dietary flexibility, personal health, and animal health for specific groups of people (e.g. young people, the elderly, etc.).
- Another would be to broaden the concept of learning in order to reach a wider range of people with different levels of education.
- Several studies suggest that in order to promote changes in dietary behavior (e.g., on nutritional adequacy and preparation of plant-based meals), it is helpful to provide a more emotional and empathetic message, in addition to increasing appropriate knowledge, values, and attitudes, which alone are not sufficient.

Factors	Barriers	Opportunities
Knowledge and skills	Low knowledge of the consequences of high meat consumption and reasons for reduced meat-eating behaviour;	Campaigns based on emotional messages, specific arguments and with particular tools for targeted groups;
	Lack of skills relating to practical issues (such as those related to vegetarian cooking);	Increasing skills that facilitate a plant-based diet;
	Denial mechanisms provided by cognitive dissonance, which block new knowledge	Mechanisms and tools to overcome cognitive dissonance (see below)
Values and attitudes	Low priority of values/attitudes which favour low meat consumption;	Campaigns based on emotional and symbolic messages;
	Denial mechanisms provided by cognitive dissonance and social norms which block the incorporation of ethical food attitudes into behaviour	Mechanisms and tools to overcome cognitive dissonance (see below)
Emotions and cognitive dissonance	Cognitive dissonance blocks new knowledge and adequate values through denial and defence mechanisms	Emotional and symbolic messaging, promotion of new social norms (see below)
		Removing cognitive dissonance by changing behaviour to encourage reduced meat consumption
Habits and taste	Day-to-day food habits as unconscious routine;	Infrastructure supportive of plant-based diet: vegetarian-friendly shopping and dining environments (including canteens and hospitals) support the establishment of new habits
	Taste preferences towards meat;	
	The production and supply system has a major influence on food habits	
Sociodemographic variables and personality traits	Being male, elderly, belonging to a lower social class (in terms of income and/or education);	Strong health argument for men and the elderly;
	Personality traits: being extravert, facing a lack of conscientiousness	Promoting flexitarianism as a new food style
Perceived behaviour control	Low perceived ability to control behaviour reduces the probability of behaving in the desired way	Increasing skills and self-esteem by stressing the role of vegan/vegetarian opinion leaders as role models
Culture and religion	Symbolism attached to meat: desire to express human power in order to dominate the natural world;	Taboos and prohibitions in several religions (e.g. the ahimsa concept);
	Cultural belief that meat provides strength and vigour (in particular to men)	Promotion of new social and cultural norms (see below)
Social identity and lifestyles	Meat consumption as a social marker in the construction of social identities and lifestyles (e.g. as a sign of prosperity or masculinity)	Flexitarianism as a new food style;
		Enhancing social status of plant-based diets
Social norms, roles and relationships	Perceptions of normative behaviour by socially connected peers who favour meat consumption	Promotion of new social norms, e.g. by stressing the role of vegan or vegetarian opinion leaders as role models and community-based social marketing
Political and economic factors	Lack of political will;	Increasing prices (e.g. by eliminating harmful subsidies, internalising external costs and/or imposing taxes on animal production and products)
	Powerful lobbies in agro-industry;	
	High subsidies for the production of animal-based food;	
	Low prices of animal-based products	
Food environment	No broad infrastructure that facilitates a plant-based diet; lack of vegetarian-friendly shopping and dining environments (including canteens, college refectories and hospitals), especially in rural areas	Increase in tasty and affordable vegetarian products in supermarkets, on the menus of restaurants, in hospitals, canteens and college refectories

Figure 18: Summary of the barriers to and opportunities for reducing meat consumption [78]

4.4 Overall framework on reduction of environmental impacts of food production

Lastly, an overview of reducing environmental impact through producers and consumers have been proposed [79] and it is depicted in the figure 19. The big picture includes collaboration among manufacturers, consumers, policy-makers, processors, distributors, and retailers.
The proposition firstly proposes that producers should monitor their impacts through digital tools. The data should then be validated against known ranges for each value and/or independently validated or certified. Second, policy-makers should set environmental indicators and incentivize producers by providing them with credit lines, tax breaks, or reallocation of agricultural subsidies. In addition, policies that encourage sustainable consumption should be promoted by policy-makers. Third, assessment tools, in the form of platforms that would share best production practices from researchers around the world, would provide multiple options for mitigation and increased productivity for producers. Finally, environmental impacts would be communicated

through a supply chain all the way to the consumer. To achieve this, supply chain traceability is essential and communication should be done through environmental labels, taxes or subsidies designed to reflect environmental costs in product prices, broader education on the true cost of food. [79]

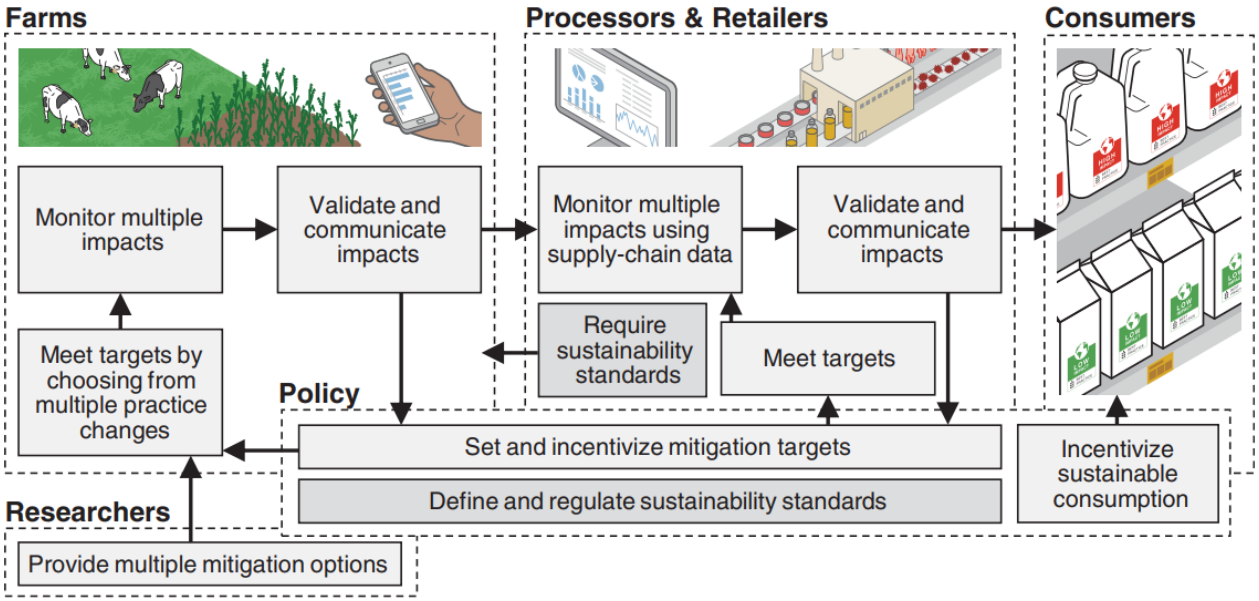


Figure 19: Graphical representation of the mitigation framework [79]

5 Conclusion

Brazil is the largest exporter of beef in the world and most projections show that the country's beef exports will continue to increase in the coming decades. The Brazilian meat production industry is dominated by huge meat packing companies, such as JBS. Brazil is also the largest exporter of soybeans in the world, having overtaken the United States in 2019. The influence of these sectors on the overall Brazilian economy has grown considerably in the last few years, particularly after the 2015 economic crisis.

The prominence of the Agricultural sector in Brazil mostly comes from its influence over the exports of the country and the fact that it has been the only sector in the Brazilian economy that has experienced any meaningful growth since the start of the economic crisis that has been plaguing Brazil since 2015. This has effectively resulted in the landowning elite gaining a considerable amount of political power over the last few years. This power has grown even more since Bolsonaro became president in 2019, resulting in the successful implementation of several measures that largely benefit the agricultural sector, but have a deep negative impact in the local population, particularly indigenous communities. A clear example of such policies is the push towards the legalization of land grabbing, which has resulted in a considerable increase illegal occupations in ecological reserves and indigenous land in the Amazon. This has led to an increasing wave of violence perpetrated by the landowning elites against indigenous communities and a sharp increase in the rate of deforestation in the Amazon.

Nearly two-thirds of the Amazon rainforest is located in Brazil, with the latter being the main contributor to the region's deforestation. As mentioned before, rise in the deforestation of the Amazon has mainly been driven by the growth in meat and soybean production in the country. Although the rate of deforestation is lower than it was thirty years ago, there has been a sharp increase in both primary forest loss and tree cover loss since 2018[55]. As a result of this the climate, wildlife and water supply and the population have been suffering a tremendous impact in recent years. The Amazon has a considerable contribution to the local water supply due to the large amount of water vapor that it releases into the atmosphere. The current rate of deforestation of the rainforest has been deeply affecting this functionality, and as a result of that, the local supply of freshwater is in danger. Furthermore, the Amazon considerably contributes to the absorption of CO_2 emissions in the world, and, as a result of that, the deforestation of the forest has a deep impact on global warming.

In order to address the previously mentioned socio-economic and environmental issues, a number of solutions have been developed. One of them is the Sustainable Agriculture Network (SAN) cattle certification program, which is a certification consortium that develops standard to ensure that cattle production follows a sustainable framework[67]. Several of these frameworks were embraced in the Forest Code, which requires landowners in the Amazon to maintain 80% of their property as a protected area[69]. This, however, still falls short of the goals of the SAN, which requires there be no deforestation even on certified farms [66]. The Forest Code also created the Rural Environment Register, which registers every rural property in Brazil and aims to be able to monitor, apply and control all registered environmental data [69]. The Brazilian government has also created a system illegal deforestation and ensures that this data is available to the public [66]. Furthermore, there have also been several programs aimed towards educating and providing the necessary infrastructure to assist small holders to grazing and cattle management [66]. Although these programs have been somewhat effective, as shown by the reduction of the deforestation rate in Brazil between 2004-2015 [51], these policies have largely been dismantled and boycotted by the federal government since the start of the Bolsonaro administration [80].

To effectively tackle the negative impacts of cattle ranching in Brazil, not only should be previously mentioned policies be reinstated, but a few new measures should be implemented. One of them would be the intensification of production in already deforested lands, which requires significant amount of investment. Furthermore, there must be a nationwide program that ensures widespread access of credit lines and technical assistance to small and medium-sized producers in order to encourage them to be adopt more sustainable factors. Furthremore, these producers should also have access to digital tools that allow them to monitor their overall environmental impact. Finally, there must be a educational campaign in order to change the mentality of the Brazilian people in regards to meat consumption. The adoption of these policies would represent a major step towards the sustainable development of the Brazilian agricultural sector.

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