ブラジルのアマゾンにおける農業と森林破壊
－今後の農業開発の課題と展望－

Agriculture and Deforestation in the Brazilian Amazon: Challenges and Prospects for Future Agricultural Development

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要　約

From 2004 to 2012, Brazil achieved successful declines in rates of deforestation in the Amazon. However, from 2012 deforestation rates gradually increased and reached high levels in the triennial of 2019 /2021. In this paper, the author examines the expansion of agriculture and cattle raising in the Legal Amazon states and also makes an analysis of land use and land transitions in the Amazon Biome.

キーワード：**Amazon deforestation, agriculture, cattle raising, spatial data, land use.**

1. Introduction

Brazil was a traditional agricultural country, characterized by monoculture agriculture, livestock production based on extensive pastures and exports of tropical commodities such as coffee and sugar for a long time. This trend however, started to change from the 1970s with the introduction of new agricultural technologies brought by the so-called “Green Revolution”. It was characterized by capital-intensive agriculture, introduction of new agricultural techniques and innovations, massive investments on research and development, among others. Structural changes introduced in the Brazilian agriculture transformed the country from a net importer of food in the 1970s to an important agricultural producer. The country was able to attend to the domestic market demand for agricultural products, reduce food prices and also respond to the increasing demand from international markets.

Despite all technological advancements in agriculture, the world still faces profound food security problems in many developing countries, especially in Africa and Asia. In addition, higher levels of income in very populated countries, such as China and Asian countries also exacerbated international demand for food. As a result, Brazil became an important food supplier in the international arena in the past decades, supplying agricultural commodities and livestock to many countries in the world.

The expansion of agriculture and cattle in Brazil, however, also raised concerns about their impact on deforestation and consequently on the environment and climate change. The expansion of agriculture into the Amazon, associated with the increasing soybean cultivation and cattle raising have brought many concerns about their impact on the Amazon’s environment

and biodiversity (Fearnside,2000) and on overall social and economic implications for the people living in the Amazon region.

In trying to reconcile environmental protection and agricultural development and comply with the commitments agreed in international forums in reducing carbon emissions, the Brazilian government implemented important policies and legal frameworks towards the reduction of deforestation and preservation of the environment.

From 2004 to 2012, Brazil achieved successful declines in rates of deforestation in the Amazon. However, from 2012 deforestation rates gradually increased and reached high levels in the triennial of 2019 /2021, which coincides with president Bolsonaro's government. Due to its multifaceted causes, it is very complex to evaluate and measure the impact of various concomitant policies and initiatives towards reduction of deforestation in the Amazon. In this paper, the author examines the expansion of agriculture and cattle raising in the Legal Amazon[i] states and also makes an analysis of land use and land transitions in the Amazon Biome. The author attempts to answer the following research question: how the expansion of agriculture and cattle raising in the Legal Amazon States affected the Amazon Forest? In other words, to what extent is deforestation related to the expansion of agriculture and cattle raising in the Legal Amazon states in the past decades? This paper will be divided into four parts with this being the first one. The second part summarizes the main environmental and agricultural policies implemented in Brazil in trying to tackle deforestation. In the third section, the author presents the evolution of grain production and cattle raising in Brazil and in the Legal Amazon States. In the fourth part, based on spatial data of the platform MAPBIOMAS[ii], an analysis of land use and land transition in the Brazilian Amazon Biome is presented. The last part addresses the conclusions and future research.

2. Main Environmental and Agricultural Policies, Legal Frameworks and Private Sectors' Initiatives related to Deforestation and Agricultural Development

In terms of environmental policies, the fight against deforestation in Brazil gained a new impetus in the 2000's as deforestation reached its highest levels in 2004, when 2,777,200 hectares of forest were cleared (Figure 1). A series of measures were implemented by the government such as satellite monitoring through the "Program for Amazon Deforestation Monitoring" (in Portuguese, Projeto de Monitoramento do Desmatamento na Amazônia Legal por Satélite-PRODES) developed by the National Institute of Space Research (in Portuguese, Instituto Nacional de Pesquisas Espaciais - INPE). In 2004, the "Plan for the Protection and Control of Deforestation in the Amazon (PPCDAm)" was another policy implemented to curb illegal deforestation, logging and land grabbing. It included not only control of the deforestation but also established incentives for the sustainable management of the forest in the Legal Amazon (Mello et al., 2017). As a result of this command-control policy, "from 2004 to

2011, nearly 650 sting operations were carried out, resulting in the imprisonment of more than 600 government officials and non-government individuals, and the issuing of BRL7.2 billion in fines. Most of these fines were never paid" (Nepstad et. al, 2014). In 2008, as part of the PPCDAm a "Critical Counties" list (Municípios Críticos) was created, where the Ministry of Environment in collaboration with the Central Bank suspended the access to credit in 36 counties with the highest levels of deforestation.

In order to guarantee international markets, especially in European countries where consumers are highly concerned about deforestation-free products, agribusiness-related companies and private organizations also established commitments on non-commer-cialization of products originating from deforested areas. Private organizations such as the Brazilian Association of Vegetable Oil (ABIOVE) and the National Grain Exporters Association (ANEC), in conjunction with the Brazilian government and the civil society signed in July, 2006 the "Soy Moratorium", a trade agreement whose objective was to "ensure that the soy produced in the Amazon Biome and traded by its signatories is free from deforestation occurring after 22nd July 2008" (ABIOVE, 2021). Rural properties with soy crops started to be monitored through satellites within areas deforested after July 22, 2008 (reference date established by the New Forest Code). Another initiative taken by the private sector was a voluntary agreement that was "signed by the main meat producers and supermarket chains to no longer slaughter and sell meat of animals from illegally deforested areas of the Amazon" (Buainain et. al., 2019). This initiative was induced by a Greenpeace report which linked the giant meat company Bertin to deforestation and slave labor, leading to demands on more transparency on traceability of cattle and their by-products (Nepstad et. al, 2014).

After long negotiations among *ruralistas* (Brazilian powerful agricultural lobby group), environmental organizations and civil society, another important legal framework was approved in Brazil: the new Forest Code of 2012 (Law No. 12.651/2012). It defined important mechanisms for monitoring and controlling deforestation and also defined sanctions in case of a lack of obedience of the rules. With exception to small farmers with up to four tax modules, the law established areas of permanent protection (APPs) close to rivers and legal reserve areas within the property. Legal reserves are portions of the property that must be preserved with its natural vegetation and it varies from 20% in the Cerrado to 80% in the Amazon. And an important mechanism to ensure the enforcement of the new Forest Code was the creation of the "Environmental Rural Registration" (Cadastro Ambiental Rural – CAR). The CAR is a monitoring system that checks if properties are in accordance with the rules established by the Forest Code in terms of areas of permanent protection (APPs), legal reserves, remaining natural forest and consolidated areas.

In terms of agricultural policies, the approval of the Agriculture Policy Law of 1991 represented a change in the agricultural development in Brazil. Some of the

objectives of this law aimed at protecting the environment and establishing sustainable use and recovery of natural resources. In addition, agroecological zones were established where the adoption of recommended production systems became one of the conditions for agricultural credit support (Buainain, 2019). In 2009, during the United Nations Climate Change Conference in Copenhagen, Brazil voluntary announced a commitment to reduce from 36% to 39% of its carbon emissions by 2020 by reducing deforestation rates in the Amazon by 80% and by 40% in Cerrado (MAPA, 2012). In 2009, the Brazilian National Climate Change Policy was institutionalized by the Art. 12 of the Law No. 12.187/2009 and the "Plan for Adaptation and Low Carbon Emission in Agriculture" was established with the purpose of elaborating a sectorial plan, along with various representatives of the agriculture sector. As a result, in 2010, the ABC Plan was launched and consisted of the following 7 projects: 1)recovery of 15 million degraded pastures, 2) increase of 4 million hectares of Integration of Crop-Livestock-Forest (ILPF) systems and Agroforest Systems, 3) amplification of the use of biological nitrogen fixation, 4) introduction of no-till system in 8 million hectares, 5) promotion of reforestation initiatives 6) increase in the use of technologies for animal waste treatment 7) adaptation of measures for climate change. The plan had a national coverage and was set up to end in 2020 (MAPA, 2012). In 2021, it was relaunched as "ABC+ Plan" aiming at mitigating the effects of climate change and carbon emissions in agricultural production for the period 2021 -2030 (MAPA, 2021).

As observed, various governmental policies and legal frameworks as well as initiatives by private organizations and companies were implemented to curb deforestation in the 2000s. Deforestation in the Legal Amazon decreased substantially from 2004 and it reached its lowest level in 2012 as can be seen in Figure 1. The severe implementation of legal instruments through monitoring, control and application of penalties demonstrated to be effective in reducing deforestation rates in the period 2003-2011 (Nepstad et. al, 2014). These policies, implemented during the Lula government contributed effectively in the reduction of deforestation. The establishment of sectoral agreements and the implementation of the Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm), were effective in decreasing deforestation rates in 2012 (Coelho-Junior et. al., 2022). "The implementation of the PPCDAm has brought significant results to control the deforestation in the Brazilian Amazon, but improvements aimed at attaining the objectives of the promotion of sustainable activities in the region are still needed. (Mello & Artaxo, 2017).

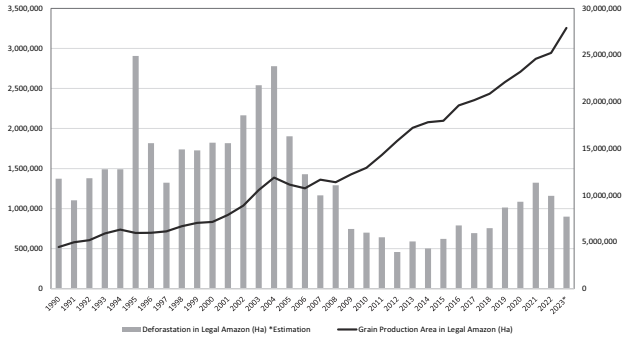


Figure 1: Deforestation (Ha) and Grain Production Area (Ha) in the Legal Amazon
Source: National Institute of Space Reseach (INPE,) Terra Brasilis Platform.

From 2013, deforestation rates started to increase gradually showing that Dilma and Temer governances were not efficient in keeping the deforestation measures taken by their predecessor. And in the triennial of 2019 /2021, which coincides with president Bolsonaro's government, deforestation in the Amazon reached high levels. According to the Amazon Environment Research Institute (IPAM, in Portuguese), deforestation in the Amazon reached a new scale between 2019 and 2021 with forestry losses of more than 10 thousand km^2 compared to previous years, 56.6% higher than the annual average of the previous triennial 2016 /2018. The Institute compared deforestation rates in the triennial 2016 /2018 and 2019 /2021 and found out that 51% of deforestation occurred in public land, among them 83% belonging to the federal domain. In addition, higher rates of deforestation were identified in indigenous land (153%) and conservation units (80%). In the triennial 2019 /2021, the States of Pará concentrated 43% of the deforestation in Amazon Biome, followed by Amazonas (18%), Mato Grosso (16%) and Rondônia(13%). Deforestation also increased by 34% in private rural properties (Alencar et. al. 2022). These illegal deforestation was the result of the dismantling of institutions by the federal government. "Besides shutting down PPCDAm in 2019, the government has significantly reduced environmental agencies budgets and changed the procedures for ensuring liability and assigning responsibilities to offenders" (Coelho-Junior et. al., 2022). The increase of illegal deforestation raises questions about the expansion of agriculture on illegally deforested areas. According to Ferrante & Fernside (2022), in case of Mato Grosso, cattle ranchers have been selling pastures for higher prices to soybean growers and buying cheap land in Amazon, deforesting them to be used as pastures. Rajão et.al. (2020), analyzed the interlinkages between illegal deforestation in Cerrado and Amazon Biome and founded that "although most of Brazil's agricultural output is deforestation free, 2% of properties in the Amazon and Cerrado are responsible for 62% of all potentially illegal deforestation and that roughly 20% of soy exports and at least 17% of beef exports from both biomes to the EU may be contaminated with illegal deforestation" (Rajão et.al, 2020).

In light of the above, in order to better understand the relationship between deforestation and the dynamics of the agriculture in the Legal Amazon States[iii], the author presents, in the next section, an overview of grain (especially soybeans and corn) and cattle production in Brazil and in Legal Amazon States. Export figures are also presented. As can be observed in Figure 1, grain production in the Legal Amazon States increased constantly even during the period of declining deforestation rates in 2004-2012 period.

3. Overview of Grain Production and Bovine Cattle in Brazil and in the Legal Amazon States

According to the National Food Supply Company (in Portuguese, "Companhia Nacional de Abastecimento – CONAB"), apart from fruits, vegetables, sugar cane and coffee, Brazil also produces many grains such as peanuts, rice, oat, canola, rye, barley, "feijão" beans, sun-

flowers, castor beans, soybeans, maize, sorghum, wheat and triticale as shown in Figure 2. Among these grains, soybean and maize production were the ones that presented dramatic increases in the past decades and they will be the focus of analysis in the next subsection.

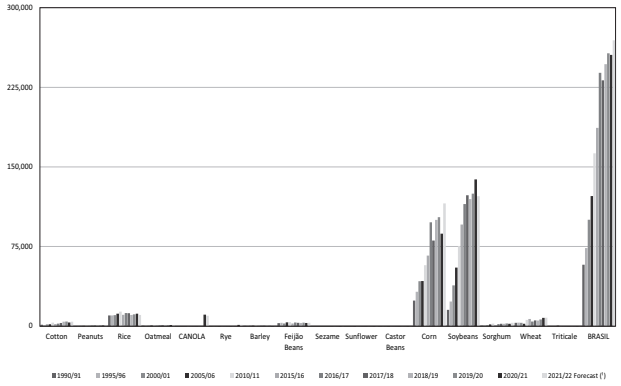


Figure 2:Grain Production in Brazil (1,000 Tonnes)
Source: National Food Supply Company (CONAB)

3.1 Soybean Production and Exports: Brazil and Legal Amazon States

The Legal Amazon (Figure 3) is formed by Acre (AC), Amapá (AP), Amazonas (AM), Pará (PA), Rondônia (RO), Roraima (RR), Tocantins (TO) and Mato Grosso (MT) States and by municipalities of the State of Maranhão (MA). It is also important to note that part of Mato Grosso State also belongs to the Cerrado Biome as well as Maranhão and Tocantins States.

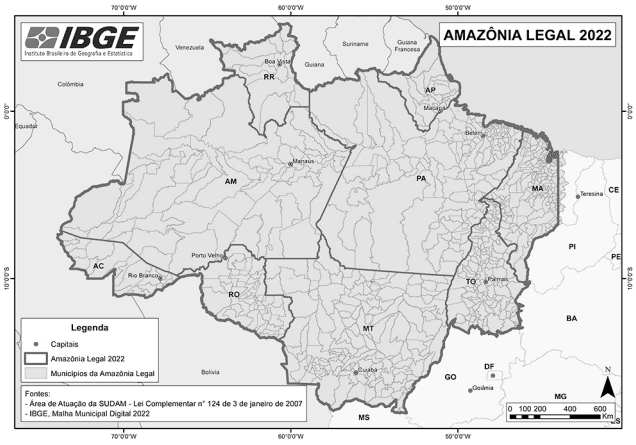


Figure 3: Legal Amazon States
Source: Brazilian Institute of Geography and Statistics - IBGE

Table 1 shows the production of soybeans in the Legal Amazon States and also in other regions of Brazil. Brazil's soybean production increased dramatically in the past two decades. Whereas in 2000/2001 period soybean production was only 38,432,000 tonnes, in 2022/2023 harvest, it reached the amount of 154,610,000 tonnes, representing a 4-fold increase. Mato Grosso State is the leading producer of soybeans in Brazil and although a part of the State belongs to the Cerrado Biome, a significant portion of soybean production is also located in the Amazon Biome. In the 2022/2023 harvest, Mato Grosso soybean

Table 1: Soybean Production – Legal Amazon States and other Regions of Brazil
Source: National Food Supply Company (CONAB)

State/Region	2000/01	2005/06	2010/11	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23
Roraima	-	28	10	79	90	118	108	152	210	285	344
Rondônia	77	283	425	765	930	1,095	1,109	1,294	1,375	1,669	2,037
Acre	-	-	-	-	-	1	4	12	16	20	46
Amazonas	-	6	-	-	-	3	5	5	13	14	20
Amapá	-	-	-	-	54	58	58	59	13	17	20
Pará	2	238	314	1,288	1,635	1,597	1,709	1,859	2,231	2,498	2,878
Tocantins	139	700	1,227	1,687	2,826	3,140	3,154	3,581	3,526	3,877	4,809
Mato Grosso	9,641	16,700	20,412	26,278	30,709	33,201	32,959	35,885	36,522	41,490	45,601
Maranhão	483	1,025	1,600	1,250	2,473	3,026	2,992	3,130	3,286	3,574	3,910
LEGAL AMAZON STATES	10,340	18,981	23,989	31,347	38,719	42,239	42,098	45,917	47,191	53,444	59,664
CENTER-WESTS STATES(*)	7,361	11,124	13,527	17,722	19,933	22,198	22,099	24,813	28,275	26,636	32,108
NORTHEAST STATES (**)	1,810	3,791	6,629	7,676	12,708	14,890	14,190	15,591	9,567	10,303	11,303
SOUTHERN STATES	2,874	4,137	4,622	7,591	8,152	9,157	8,614	10,131	11,321	11,767	13,268
SOUTH STATES	16,264	18,249	28,535	35,181	41,051	40,788	38,864	35,295	43,032	23,400	38,277
BRAZIL	38,432	55,027	75,324	95,698	115,027	123,259	119,718	124,845	139,985	125,550	154,610

(*) Does not include Mato Grosso State
(**) Does not include Maranhão State
Source: CONAB (Elaboration by the author based on CONAB's data)

production represented 77% of Legal Amazon States production and around 30% of Brazil's total production of soybeans.

Apart from Mato Grosso State, production of soybeans in the Amazon has increased especially in Pará and Rondônia States. In the case of Pará State, soybean production increased from 2,000 tonnes in the 2000-2001 harvest to 2,878,000 tonnes in the 2022-2023 harvest. And in the case of Rondônia State, soybean production increased from 77,000 tonnes in the 2000-2001 harvest to 2,037,000 tonnes in the 2022-2023 harvest. The Legal Amazon States has become a new frontier for grain production and as mentioned in the previous section, the growing soybean cultivation towards the Amazon raises concerns about deforestation (either legal or illegal ones) and its impact on the environment, climate, biodiversity, among many others.

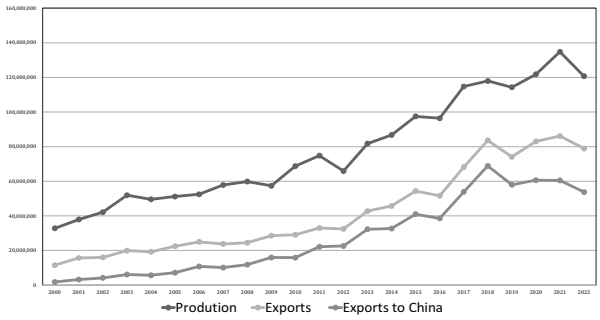


Figure 4: Brazil Soybean Production and Exports (Tonnes) 2000/2022
Source: FAOSTAT

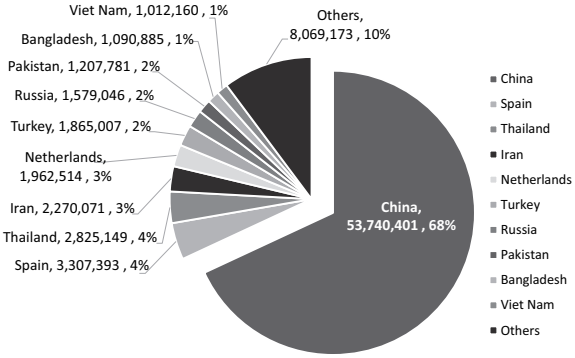


Figure 5: Brazil's Soybean Exports – 2022 (Country,Tonnes,%)
Source: FAOSTAT

Figure 4 shows Brazilian production of soybeans[iv], exports to the world and exports to China from 2000 to 2022. In this period, soybean production increased substantially and foreign countries became an important destination for Brazilian soybeans. Whereas in 2000, exports represented only 35% of total soybean production, in 2022, exports represented 65% of total production. It is also very important to note that exports of soybean to China skyrocketed in the past two decades. Whereas in 2000, exports to China represented only 15% of total exports, in 2022, exports to that country represented 68% of total exports. As can be observed, production of soybeans has been driven by increasing exports to China.

Figure 5 shows soybean's main export destinations in 2022. As observed, 68% of Brazilian total soybean were exported to China. Apart from China, Brazilian soybean exports destinations are very diverse, ranging from European countries to other developing countries in Asia.

3.2 Corn Production and Exports: Brazil and Legal Amazon States

Table 2 shows corn production in the Legal Amazon states and in other regions of Brazil. Corn production in Brazil increased from 42,290 tonnes in the harvest year of 1990/91 to 131,946 tonnes in the 2022/2023 period. Mato Grosso was the leading corn producer in the Legal Amazon,

and as in the case of soybeans there has also been a great increase in corn production in Pará and Rondônia States. In the case of Pará State, corn production increased from 510 tonnes in the 2000-2001 harvest to 1,486 tonnes in the 2022-2023 harvest. And in the case of Rondônia State, corn production increased from 206 tonnes in the 2000-2001 harvest to 1,572 tonnes in the 2022-2023 harvest. Crop rotation became a common practice in Brazilian agriculture and corn is frequently planted in rotation with soybeans. This is an important practice as it does require opening new areas for the cultivation of corn and it also improves the productivity of both cultures.

Table 2: Total Corn Production(1st, 2nd & 3rd Harvest) – Legal Amazon and Other Regions (1,000 tonnes)
Source: National Food Supply Company (CONAB)

State/Region	2000/01	2005/06	2010/11	2015/16	2016/17	2017/18	2018/19	2019/20	2021/22	2022/23
Roraima	17	24	13	14	46	47	78	90	90	61
Rondônia	206	286	351	654	795	742	928	1,004	1,325	1,572
Acre	46	53	84	97	82	81	83	80	158	139
Amazonas	16	23	35	14	31	21	28	28	24	17
Amapá	1	1	3	2	2	2	1	1	2	3
Pará	510	573	545	647	845	787	765	835	1,182	1,486
Tocantins	121	168	385	540	902	768	1,194	1,480	1,880	2,050
Mato Grosso	1,844	4,028	7,620	15,272	28,867	26,401	31,307	34,955	41,620	51,241
Maranhão	310	424	880	874	1,952	1,884	1,793	2,196	2,906	3,144
LEGAL AMAZON STATES	3,070	5,582	9,915	18,113	33,521	30,731	36,176	40,670	49,187	59,712
CENTER-WEST STATES(*)	6,391	5,564	9,696	12,973	20,007	15,051	21,519	21,882	22,590	26,129
NORTHEAST STATES (**)	2,595	3,947	6,664	4,528	7,432	7,008	7,961	10,127	7,831	8,601
SOUTHERN STATES	8,592	9,652	10,952	9,794	12,448	11,129	12,153	11,764	12,055	12,716
SOUTH STATES	22,559	18,899	21,596	23,090	27,138	19,237	25,310	21,663	21,468	24,788
BRAZIL	42,290	42,515	57,407	66,531	97,843	80,710	100,043	102,586	113,130	131,946

(*) Does not include Mato Grosso
(**) Does not include Maranhão State
Source: CONAB (Elaboration by the author based on CONAB's data)

Figure 6 shows Brazilian corn production and corn exports to the world from 2000 to 2022[v]. Corn production presented some oscillations and the same trend occurred with its exports. In 2000, corn export figures were still very low. However, as corn production also increased substantially, in 2022 exports accounted for 40% of total production.

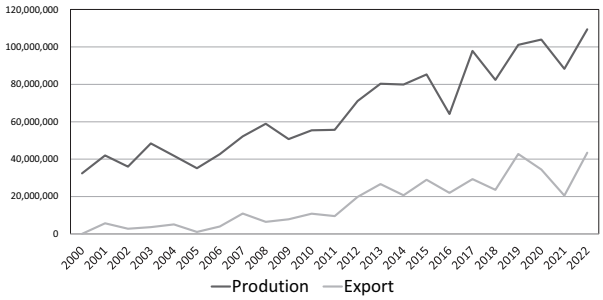


Figure 6: Brazil's Corn Production and Exports (Tonnes) 2000/2022
Source: FAOSTAT

Figure 7 shows Brazil's main export destinations for corn in 2022. Differently from soybeans, corn export destinations are more diversified and have many developing countries as destination. Iran is an important export destination and accounted for 15% of total corn exports. Spain and Japan are the second and third largest destination for Brazilian corn exports and each one accounted for 11% of total corn exports in 2022.

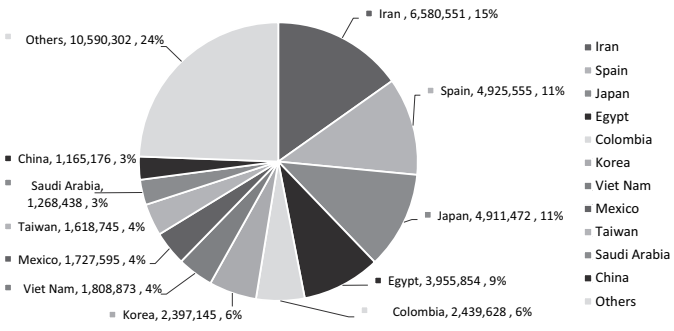
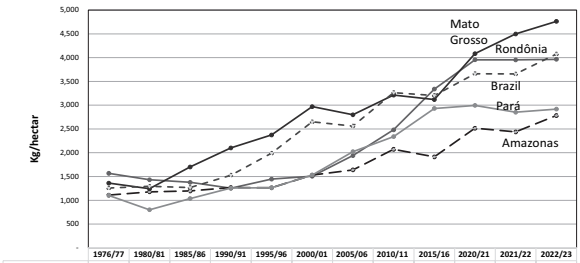


Figure 7: Brazil's Corn Exports – 2022 (Country,Tonnes,%)
Source: FAOSTAT

3.3 Grains' Productivity in Legal Amazon States and in Brazil

The increase in grain production in Brazil in the past decades relied on the expansion of the agricultural frontiers. However, increase in grain production was not only a result of expansion in cultivated area. Increasing productivity gains due to technological improvements have also been an important factor in output increase as can be seen in Figure 8. In four decades, Brazilian grain's productivity increased more than 3-fold, ranging from 1,26 kg per hectare in 1976/1977 to 4,07 kg per hectare in the 2022/2023 harvest. In Mato Grosso State, productivity gains were even higher than Brazil's average productivity. Rondônia State have also presented increasing productivity gains, and from 2015, the state surpassed the national level. In the case of Pará State, productivity gains increased substantially but it still lags behind Brazilian levels. The expansion to new agriculture frontiers in Legal Amazon States, especially in the States of Pará and Rondônia raises concerns about the impact of agriculture on Amazon deforestation and the use of the land. In addition, as mentioned before, high levels of deforestation also raise concerns if agriculture expansion to new frontiers in the Amazon are linked to illegal deforestation.



	1976/77	1980/81	1985/86	1990/91	1995/96	2000/01	2005/06	2010/11	2015/16	2020/21	2021/22	2022/23
RONDONIA	1,568	1,433	1,377	1,254	1,446	1,506	1,940	2,481	3,338	3,953	3,951	3,965
AMAZONAS	1,108	1,179	1,197	1,268	1,264	1,530	1,639	2,073	1,912	2,516	2,439	2,783
PARÁ	1,105	800	1,037	1,256	1,264	1,531	2,022	2,338	2,931	2,995	2,851	2,916
MATO GROSSO	1,361	1,242	1,702	2,102	2,374	2,969	2,799	3,211	3,119	4,081	4,496	4,761
BRAZIL	1,258	1,293	1,268	1,528	1,990	2,649	2,560	3,264	3,203	3,662	3,656	4,073

Figure 8: Grains' Productivity and Selected Legal Amazon States (Kg/Ha)
Source: National Food Supply Company (CONAB)

3.4 Bovine Cattle Herd, Meat Production and Exports

Figure 9 shows the evolution of Brazilian bovine cattle herd from 1974 to 2022. In the past four decades, bovine cattle in Brazil increased dramatically, from 92,495,364 bovine heads in 1974 to 234,352,649 bovine heads in 2022.

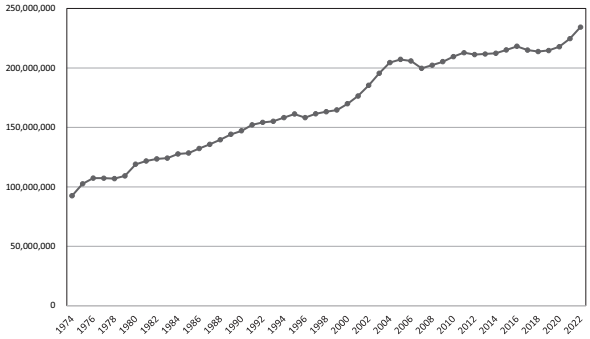


Figure 9: Brazil's Bovine Cattle Herd – 1974 to 2022 (Heads)
Source: Brazilian Institute of Geography and Statistics (IBGE)

Extensive pasture has been a common practice in Brazil. As a result, the increase of the bovine herd also implicated in the opening of new areas for pasture in the past decades. Figures 10 and 11 show the distribution of bovine cattle in each Brazilian State in 1974 and 2022. Brazilian States that belong to the Legal Amazon are in the Central-West and North regions. Central West is formed by Mato Grosso, Mato Grosso do Sul, Goiás States and the Federal District. And the north region is formed by Acre, Amapá, Amazonas, Roraima, Rondônia and Tocantins States. Mato Grosso do Sul State was separated

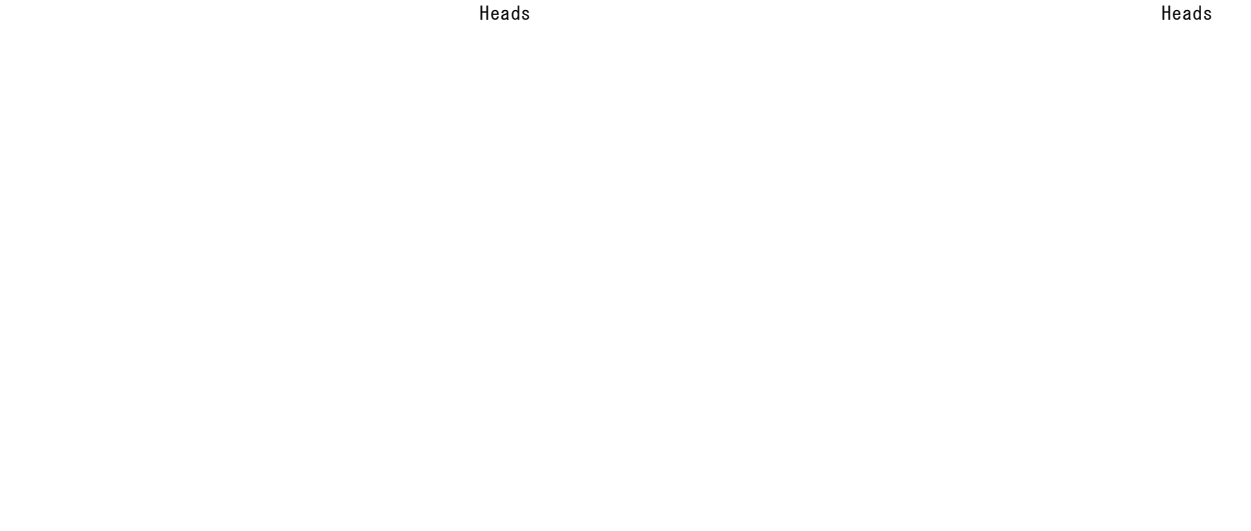


Figure 10: Bovine Herd in Brazil (Heads):1974 Figure 11: Bovine Herd in Brazil (Heads):2022

Source: Brazilian Institute of Geography and Statistics(IBGE)

from Mato Grosso in 1977 and Tocantins State was emancipated from Goiás State in 1989. From these figures it is possible to observe that compared to the 1970s, bovine cattle has moved towards the north part of Brazil, incorporating new pasture areas in states that belong to the Legal Amazon States such as Mato Grosso, Pará, Rondônia and Acre leading to concerns of the impact on deforestation.

As a result of a growing number of bovine herd, meat production and exports in Brazil increased substantially in the past two decades. As can be observed in Figure 12, in 1996, Brazil produced 6,187,000 tonnes of meat and exports were only 249,000 tonnes, representing 4% of total production. Imports accounted for 150,000 tonnes, and the overall domestic availability of meat was 6,088,000 tonnes in that year. In the following years, meat production grew substantially and reached its pick in 2006, when 10,185,000 tonnes were produced and 2,195,000 tonnes were exported, which represented 22% of total production. As imports were very low, domestic availability was 8,017,000 tonnes. From 2006, meat production in Brazil had a decreasing trend whereas the export of meat for international markets increased, affecting the availability of meat in the domestic market. In 2022, meat production accounted for 8,674,000 tonnes and exports of 3,018,000 tonnes, representing 35% of total production. Imports were of 81,000 tonnes, and the availability of meat for the domestic market was only 5,736,000 tonnes. As observed, whereas the supply of meat has decreased slightly in recent years, the demand for bovine meat is increasing sharply in foreign markets. This is an important issue to take into account as the opening of new areas in the Amazon may be directly linked to the deforestation. The intensification of bovine cattle, the recovery of degraded pastures and the integration of crop-livestock-forest (ILPF) systems and agroforest systems will be important instruments for the preservation of the Amazon Forest. Figure 13 shows Brazil's meat export destinations in 2022. Brazil exports meat to various developed and developing

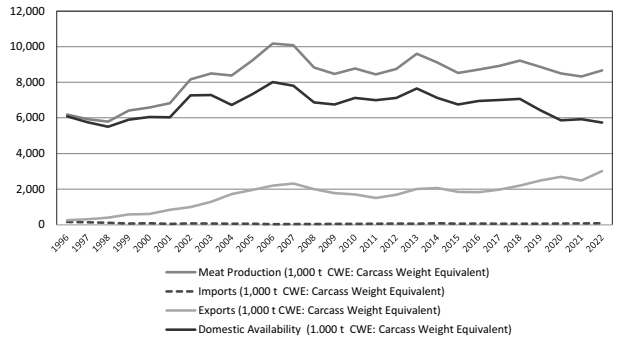


Figure 12: Bovine Meat Production, Exports, Imports and Domestic Availability (1,000 tonnes CWE)
Source: National Food Supply Company (CONAB)

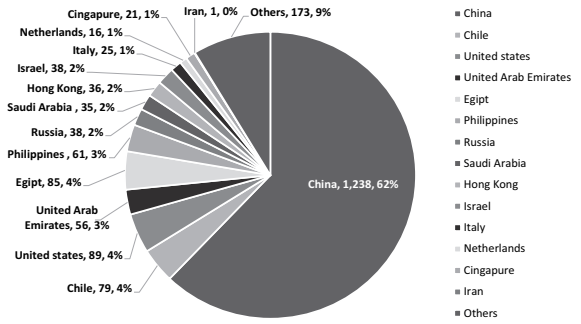


Figure 13: Exports of Bovine Meat (Country, Tonnes,%)
Source: National Food Supply Company (CONAB)

countries. However, in 2022, 62% of meat exports were exported to China.

As observed in this section, grain production, such as soybeans and corn increased dramatically in the past decades. The same trend occurred in the case of bovine cattle raising. In both cases, the Legal Amazon States have become new frontiers for this development. And as a growing percentage of the production is exported to China, it is also important to take into account the possible effects that the growing demand from China plays on the production of grains and meat and if it may be translated into an indirect impact on deforestation.

In order to understand the transformation caused by the expansion of agriculture and cattle raising in the Amazon, in the next section, land coverage, land use and land transition will be analyzed.

4. Land Coverage, Use and Transition in the Amazon Biome

4.1 Land coverage and use in the Amazon Biome

In this subsection, land coverage and use for the Amazon Biome was analyzed, using data extracted from the MapBiomas platform (Collection 8). According to the Brazilian Institute of Geography and Statistics (IBGE), the Amazon Biome occupies around 49% of the Brazilian territory and is formed by the States of Acre, Amazonas, Amapá, Rondônia, Roraima, Pará, and part of the Mato Grosso, Tocantins and Maranhão States as can be seen in Figure 14.

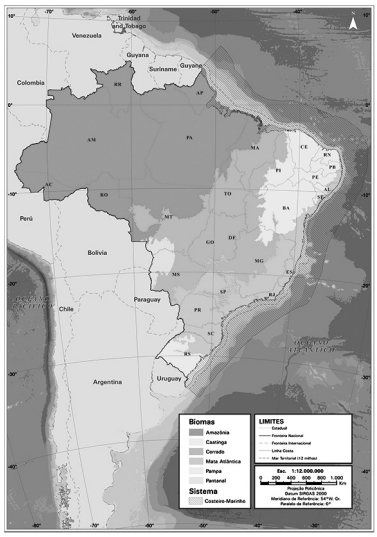


Figure 14. Brazilian Biomes and Costal Marine System
Source: Brazilian Institute of Geography and Statistics – IBGE

Figure 15 presents land coverage and land use in the Amazon Biome from 1985 to 2022 for forest formation, pasture and agriculture. Data on land use for soybeans and sugarcane are also presented. In

terms of forest formation, in 1985 forests occupied 427,225,773 hectares of the Amazon Biome, pastures accounted for 102,977,379 hectares and agriculture for 19,135,396 hectares. Land use in case of soybeans was of 4,402,201 hectares and sugarcane accounted for 2,162,184 hectares. During the period analyzed (1985-2022), forest formation in the Amazon Biome lost about 14% of its vegetation for other uses, accounting for only 369,049,532 hectares in 2022. In the period analyzed, the area occupied by pastures increased substantially, reaching its peak in 2010 when 164,040,424 hectares of land were used for pastures. From 2011, it can be observed that pasture land use remained stable and also had a slight decrease, accounting for 162,477,936 in 2020 and having a slight increase to 164,338,657 hectares in 2022.

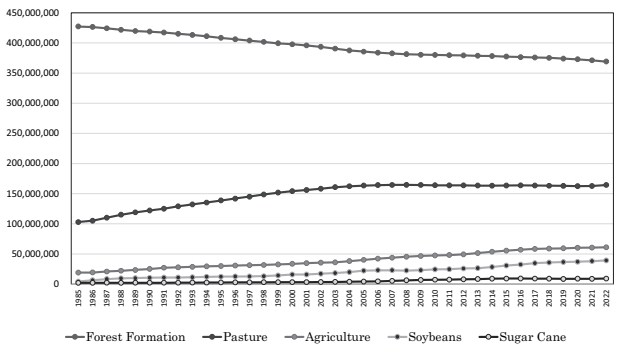


Figure 15: Land Coverage and Land Use in the Amazon Biome (1985-2022) Hectars
Source: MAPBIOMAS Collection 8

In the case of agriculture, land usage changed from 19,135,396 hectares in 1985 to 61,041,001 hectares in 2022, representing a 3-fold increase in the land use for agriculture in the Amazon Biome. Within these figures, soybean cultivation became one of the dominant crops, increasing from 4,402,201 hectares in 1985 to 39,373,028 hectares in 2022. The expansion of soybean cultivation into the Amazon Biome raises concerns about relationship between soybean cultivation and deforestation. Is soybean cultivation occurring in former forest areas? Or in pasture land? These will be the objectives of further studies in the next subsection.

In the case of sugarcane, increasing cultivation of sugarcane in the Amazon Biome was verified, changing from 2,162,184 hectares in 1985 to 9,210,509 hectares in 2022. It is important to note that many other crops such as rice and cotton are harvested as temporary crops in the Amazon Biome. In addition, cultivation of coffee, citrus and palm tree “Dendê” (used for the fabrication of Dende Oil) and many other fruits and crops are cultivated and they are very important for the Amazon’s family agriculture and Amazonian people. However, the dramatic expansion of soybeans into the Amazon, associated with the increase of sugarcane cultivation is of great concern, especially due to the continuous threat towards to the environment and deforestation. Whereas in 1985, soybean and sugarcane together occupied only 34% of total agriculture land use, in 2022, 80% of land used for agriculture in the Amazon Biome were occupied by soybeans (65%) and sugarcane (15%). In the next sub-section, land transitions will be analyzed in order to identify how the use of land has changed in the past decades in the Amazon Biome.

4.2 Land transitions in the Amazon Biome

This subsection aims at analyzing land transitions in the Amazon Biome from the year 1985 to the year 2022. Table 3

shows the land transitions (changes in land use) in the Amazon Biome. The data utilized was extracted from MapBiomas (Collection 8).

As mentioned in the previous subsection, in terms of forest formation, in 1985 forests occupied 427,225,773 hectares of the Amazon Biome and it has lost around 14% for other uses. Observing the row "Forest formation (1985) in Table 3, it can be observed that there was a substantial land transition to "Pasture (2022)" and "Agriculture (2022)", meaning that from 1985 to 2022, a total of 45,337,886 hectares of forests were converted into pasture areas and 5,338,519 hectares of forests were used for agriculture. Within the agriculture sector, more than 80% were used for soybean and sugarcane cultures in 2022. As observed in the previous section, agriculture and cattle raising is increasing substantially in the Amazon states, and from this data it can also be observed that there has been a large portion coming from forests. Observing the column "1.1 Forest Formation (2022)", it is interesting to notice that it acquired back 1,763,331 hectares from "Pasture", 10,429 hectares from "Agriculture" and 9,720 hectares from "Perennial crop". An interesting aspect is that "Pasture (1985)" row contribution to "Forest Formation (2022)" is quite high, and this may be related to the natural regeneration of the pasture after its abandonment. According to MapBiomas (2022), in Brazil, "66.3% of native vegetation does not necessarily correspond to preserved areas. A part of this native vegetation is already degraded or has already been deforested and is in regeneration...".

Table 3: Land Transitions in the Amazon Biome (1985-2022) in Hectars

	1. Forest (2022)	1.1. . Forest Formation (2022)	1.2 Other Forest Formation	2. Non Forest Natural Formation	3. Farming (2022)	3.1. Pasture(2022)	3.2. Agriculture (2022)	3.2.1. Temporary Crop (2022)	3.2.1.1. Soybean (2022)	3.2.1.2. Sugar cane (2022)	3.2.1.5. Other Temporary Crops (2022)	3.2.2. Perennial Crop (2022)	3.3. Forest Plantation (2022)	3.4. Mosaic of Uses (2022)	4. Non vegetated area (2022)	5. Water (2022)	6. Not Observed (2022)	Total (2022)
1. Forest (1985)	326,340,037			394,085	51,854,779										310,910	836,967	4	379,736,783
1.1. . Forest Formation (1985)		306,267,473	16,309			45,337,886	5,338,519	5,221,920	4,401,225	14,630	801,622	116,599	178,147	1			2	368,896,101
1.2 Other Forest Formation		6,104	20,050,152	0	0	899,246	96,557	89,174	79,164	1,128	8,765	7,383	4,424	0	0	0	3	21,710,835
2. Non Forest Natural Formation (1985)	788,182		0	13,421,833	1,612,498										90,723	1,370,060	5	17,283,301
3. Farming (1985)	1,942,069		0	52,613	11,652,372										113,619	58,172		13,818,845
3.1. Pasture (1985)		1,763,331	166,762			10,142,817	1,361,158	1,317,236	1,027,879	52,013	235,917	43,922	75,698					16,455,336
3.2. Agriculture (1985)		10,429	1,546			15,599	52,434						177					81,335
3.2.1. Temporary Crop (1985)		709	163			6,295		48,167				1	167					56,397
3.2.1.1. Soybean (1985)		7	0			118			1,306	3	46							1,482
3.2.1.2. Sugar cane (1985)		0				58			4	89	41							193
3.2.1.5. Other Temporary Crops (1985)		703	163			6,119			40,080	109	6,472		167					54,722
3.2.2. Perennial Crop (1985)		9,720	1,383			9,304		49				4,217	10					24,938
3.3. Forest Plantation (1985)		1	0			1	1,229	25	21		4	1,203	3,252					6,940
3.4. Mosaic of Uses (1985)		0	0			4	1	1	1					3				8
4. Non vegetated area (1985)	1,177		0	464	1,308										147,798	2,050		152,797
5. Water (1985)	388,567		0	558,315	13,797										6,172	9,581,895	5	10,548,751
6. Not Observed (1985)	207	153	54	24	286	283	1	1	1	1			1		70	1,343	1,801	5,664
Total (1985)	329,460,239	308,356,397	21,127,793	14,427,335	65,135,040	57,650,294	7,163,345	6,983,557	5,771,452	87,681	1,117,718	179,788	352,952	3	669,293	11,850,487	1,831	857,471,109

Elaboration by the author based on MapBiomas data.
Source: MAPBIOMAS COLLECTION 8

Source: MAPBIOMAS Collection 8

Observing the row “Pasture (1985)”, it can be noticed that there was a substantial land transition to “Agriculture (2022)”, meaning that from 1985 to 2022, a total of 1,361,158 hectares of pasture were converted into agriculture. Within these figures, 1,027,879 hectares of pasture were converted to soybean and 52,013 hectares to sugarcane production.

Observing the “Soybeans (2022)” column, it can be noticed that in the period analyzed (1985 to 2022) there were substantial incorporations of land from “Forest Formation(1985)” and “Pasture(1985)”. Land transitions from “Forest formation” show that cultivation of soybeans is related to deforestation. However, more detailed analysis is necessary to evaluate if these areas come from legal or illegal deforestation. In addition, in the “Soybeans (2022)” column, a growing transition of land from pasture to soybean cultivation was observed as mentioned before. On one hand, the cultivation of soybeans in recuperated pasture areas may reduce the impact on deforestation. However, on the other hand, it is important to guarantee that pasture areas do not come from illegal deforested areas as mentioned previously. In this case, the cultivation in pasture areas may be indirectly linked to deforestation. The same trend occurs with sugarcane cultivation. Observing the “Sugarcane (2022)” column, it is interesting to observe that although there has been incorporation of areas from “Forest formation (1985), in the period analyzed, a great part (52,013 hectares) was incorporated from “Pasture (1985)”, showing that cultivation of sugarcane was also made in areas already opened.

Based on the “Plan for Adaptation and Low Carbon Emission in Agriculture” there have been efforts to recuperate depredated pasture areas and/or incorporate them into agriculture. The recuperation of depredated pasture areas, the intensification of cattle production and implementation of integration of crop-livestock-forest (ILPF) systems and agroforest systems will be of great importance in reducing the burden on the Amazon Forest and reducing deforestation.

5. Conclusions and future research

In the first part of this paper, it was observed that governmental policies and legal frameworks as well as initiatives by private organizations and companies were successful in curbing deforestation in the period 2004-2012. However, from 2013 deforestation rates started to increase gradually showing that the central government under Dilma, Temer and Bolsonaro governance were not efficient in reducing deforestation.

Brazil has become an important producer of grains and livestock products and also an important supplier of commodities to many countries, especially China. Increasing productivity gains were an important factor for increases in output. However, agriculture expansion towards the Amazon Biome, especially in the States of Pará and Rondônia raises concerns about its impact on deforestation and the possibility of cultivation on illegally deforested areas. Another important fact is that the increase of grain production such as soybeans has been highly motivated by the increased demand from international markets, especially China. To what extent

this “China effect” causes impacts on the Amazon Biome deforestation is a relevant issue for further research.

In section 4, land use and land transitions in the Amazon Biome were analyzed. It was observed that in the Amazon Biome, despite initiatives to curb deforestation, the forest has been losing vegetation for other land uses such as pasture formation and soybeans. In the case of pastures, the area it occupies is extremely high representing a huge impact on forest loss and deforestation. Pasture conversion to soybeans, sugar cane and other temporary crops were observed. On one hand, one of the hypothesis is that pasture holders maybe intensifying their production, recovering depredated pastures and converting them for agricultural use. On the other hand, it is important to guarantee that pasture areas do not come from illegal deforestation and they are not transformed into agricultural areas, resulting in additional impact of agriculture on deforestation.

The utilization of the existing technological resources and the implantation of legal frameworks have proven to be effective in curbing deforestation in Brazil in the time between 2004 and 2012. However, despite all these mechanisms deforestation still remains a central problem in Brazil. In this way, state-level policies towards reduction of deforestation and promotion of sustainable agricultural development are extremely important to curb deforestation rates and will be the focus of further studies. Brazil has important environmental and agricultural policies towards the development of low carbon agriculture. The promotion and implementation of sustainable agricultural policies is extremely important in reducing deforestation rates and the burden on climate change. Curbing deforestation rates in the Amazon is extremely important for the Brazilian agricultural development and to guarantee food security in Brazil and in other countries.

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i "The Legal Amazon corresponds to the area under the responsibility of the Superintendence of the Amazon Development – SUDAM established by Article 2 of Complementary Law no. 124, of 03/01/2007. The region is formed by the states of Acre, Amapá, Amazonas, Pará, Rondônia, Roraima, Tocantins and Mato Grosso, and also by the municipalities of the state of Maranhão located west of the 44th meridian. It has an approximate area of 5,217,423 km², which corresponds to about 61% of the Brazilian territory". Brazilian Institute of Geography and Statistics-IBGE Homepage, available at https://www.ibge.gov.br/en/geosciences/environmental-information/geology/17927-legal-amazon.html.

ii "MapBiomas is a collaborative network formed by NGOs, universities, and technology startups, which reveals the transformations in the Brazilian territory through science, making knowledge about land use accessible to seek conservation and combat changes in climate. It has produced annual land cover and land use mapping and monitors surface water and fire scars monthly with data from 1985. The project also validates and produces reports for each deforestation event detected in Brazil since January 2019 with the product MapBiomas Alert". Available at https://brasil.mapbiomas.org/en/o-projeto/

iii It is worth noting that only some municipalities of Maranhão State belong to Legal Amazon but in the analysis, data for the whole Maranhão State was used.

iv Data on soybean production in Table 1 were obtained from CONAB database and data on production and exports in Figure 4 were obtained from FAOSTAT. Due to the differences in database, production figures have some slight discrepancies, depending on the year.

v Data on corn production in Table 2 were obtained from CONAB database and data on production and exports in Figure 6 were obtained from FAOSTAT. Due to the differences in database, production figures have some slight discrepancies, depending on the year.