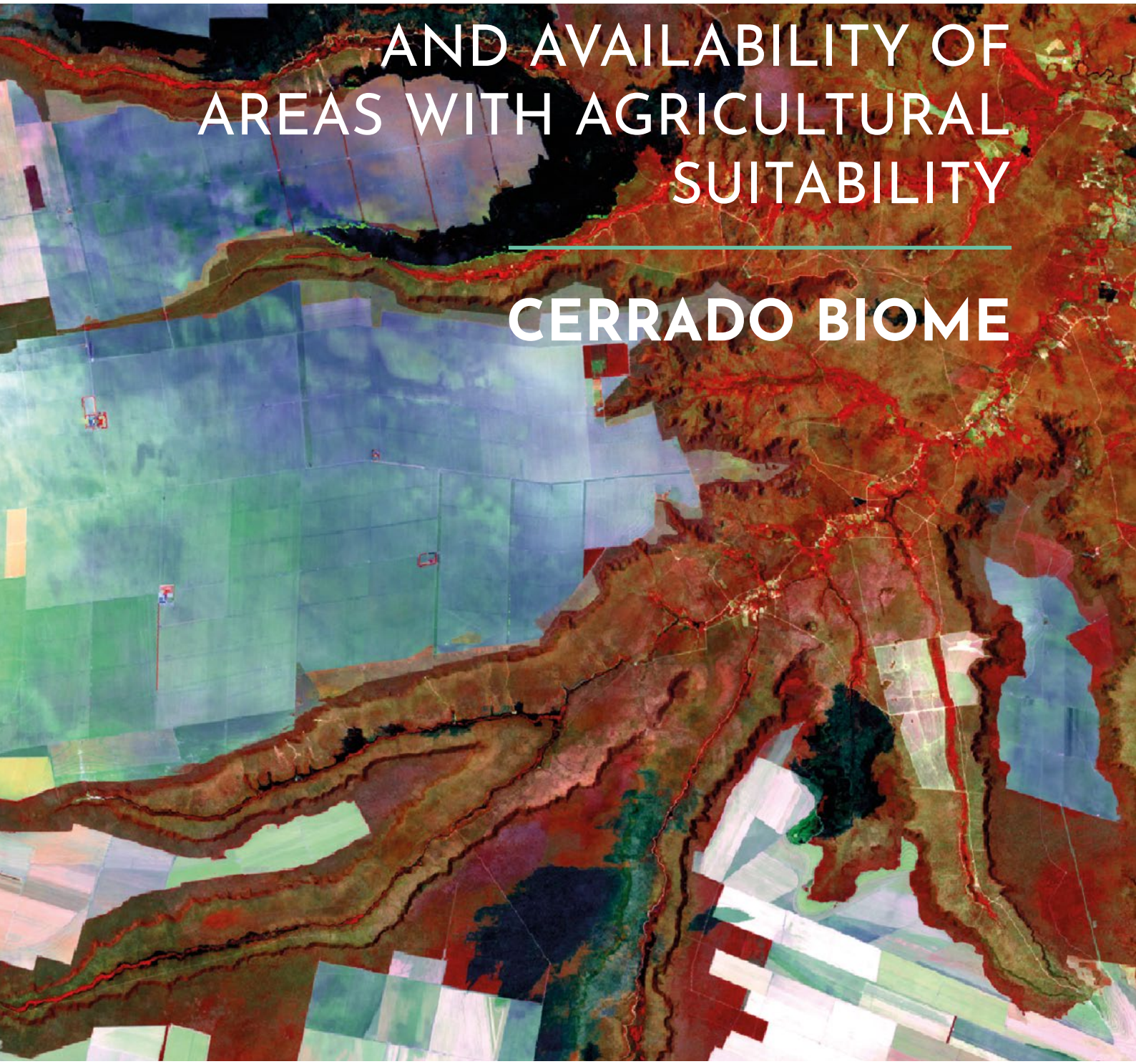
SOY EXPANSION DYNAMICS FROM 2014 TO 2023

AND AVAILABILITY OF AREAS WITH AGRICULTURAL SUITABILITY

CERRADO BIOME



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Executive Summary

This study was divided into two parts of analyses. The first one presents the soy area in the Cerrado Biome in crop year 2022/23, which follows on from a series of mappings carried out to analyse the land use and land cover changes associated to soy expansion, with and without deforestation. For this purpose, three periods of three-years each were chosen to assess the dynamic trend of soy expansion from crop year 2013/14 to crop year 2022/23, with emphasis on: (a) the agricultural frontier region known as MATOPIBA, and (b) the more consolidated region that includes the remaining states in this Biome (Other States).

The second part of this study is an update, to the year 2022, of the potential stocks of land with agricultural suitability for soy expansion in the Biome, on areas that were already anthropized as well as on areas covered with native vegetation.

PART I - SOY EXPANSION DYNAMICS FROM 2014 TO 2023

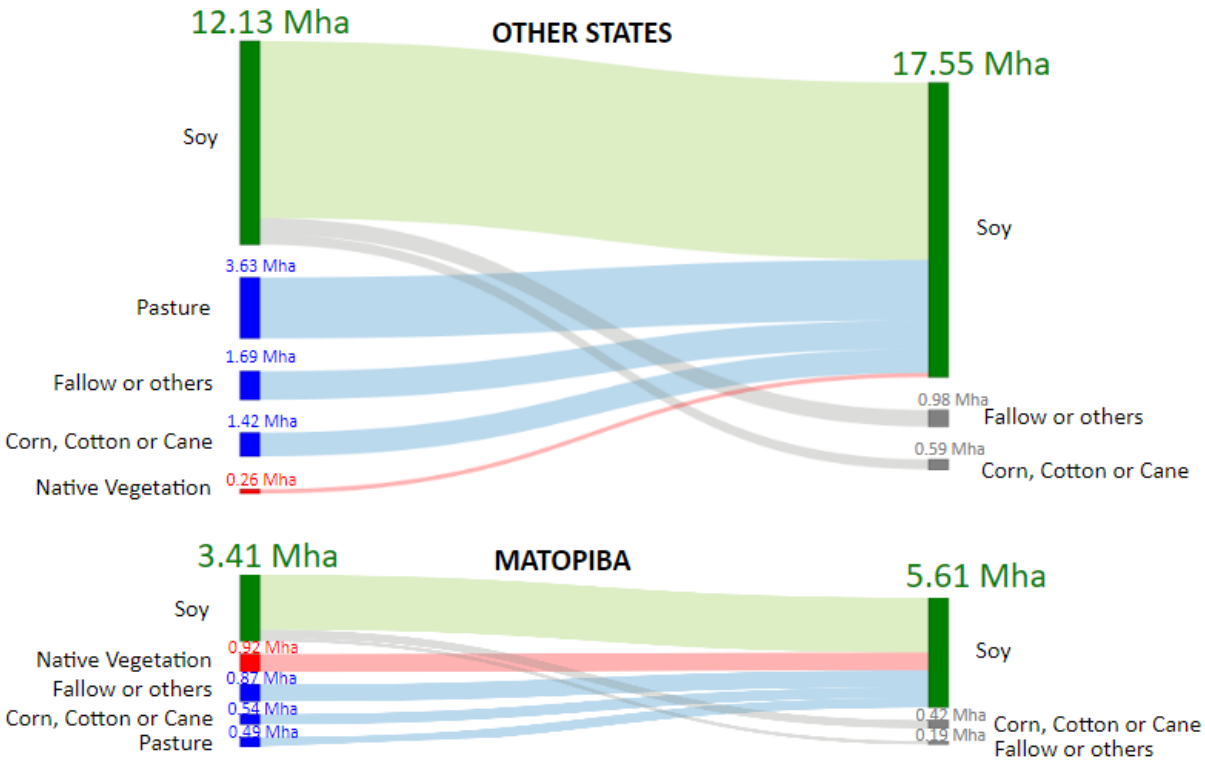
In the last ten years, the soy area in the Cerrado Biome has increased by 49.0%, going from 15.54 million hectares in crop year 2013/14 to 23.15 million hectares in crop year 2022/23, equivalent to 11.7% of the Biome area and 50.1% of the Brazilian soy area, according to the Agrosatélite survey using satellite images (46.17 million hectares). This expansion has significantly accelerated over the last three crop years, from 1.172 million hectares in 2020/21, to 1.470 million hectares in 2021/22 and a record 1.721 million hectares in 2022/23, a total expansion of 4.36 million hectares. In the MATOPIBA region, soy expanded by 1.29 million hectares over the last three years, surpassing the increase of 1.1 million hectares that had been estimated for the region by 2030 (MAPA, 2020)[1].

The annual deforestation rates in the Cerrado Biome over the last nine years (2014 to 2022) peaked in 2015, with 1.113 million hectares, and then fell to 632,000 hectares in 2019. Since then, a new increase in rates was observed in the 2022 monitoring process, reaching 1.069 million hectares, with emphasis on the MATOPIBA region that, although representing just 36% of the Biome, was responsible for 71% of the deforestation in that year.

1. MAPA, 2020. Projeções do Agronegócio: Brasil 2019/20 a 2029/30 projeções de longo prazo / Ministério da Agricultura, Pecuária e Abastecimento. Secretaria de Política Agrícola. Brasil, Brasília, 2020.

A detailed analysis of the dynamics of the land use and land cover changes associated with the soy expansion of 7.62 million hectares from 2013/14 to 2022/23 shows that the main causes are the incorporation of new areas resulting from the conversion of native vegetation or the intensification of land use through conversion of pastures, as well as the agricultural management practice of rotating agricultural crops with fallow land. In the Other States region, 3.63 million hectares expanded onto pastures (intensification) and 0.26 million hectares onto deforested lands, while in MATOPIBA only 0.49 million hectares expanded onto pastures and 0.92 million hectares onto deforested lands. It should be noted that a significant 2.55 million hectares of this expansion were onto crop areas that were fallow in the 2013/14 crop year, of which 1.69 million hectares were in Other States and 0.86 million hectares were in MATOPIBA.

The analysis split into three equal periods revealed a significant increase in the conversion of native vegetation into soy in the most recent period (2019/20 to 2022/23), compared to the two prior periods (2013/14 to 2016/17, and 2016/17 to 2019/20), both in MATOPIBA and in Other States. This suggests that the soy producer's motivation to clear new areas weighed more heavily than the market's efforts to reduce the soy footprint in recent deforestations, due to the commodity's favourable price.



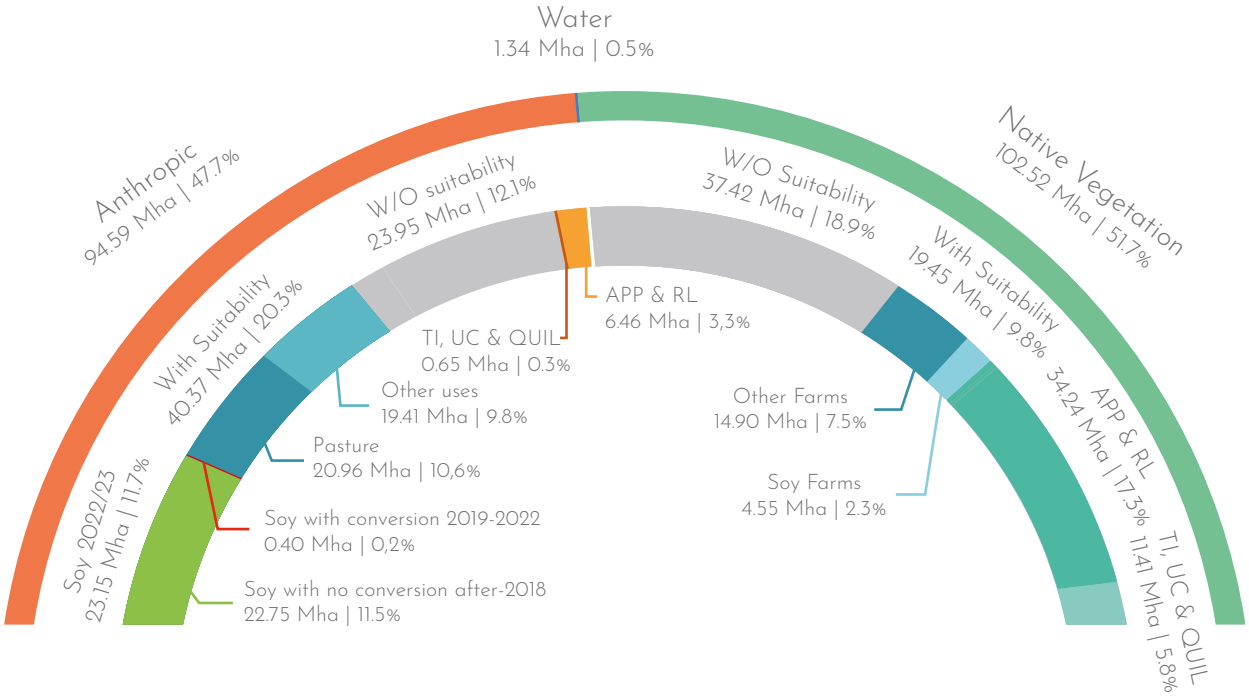
PART II – AVAILABILITY OF AREAS WITH AGRICULTURAL SUITABILITY

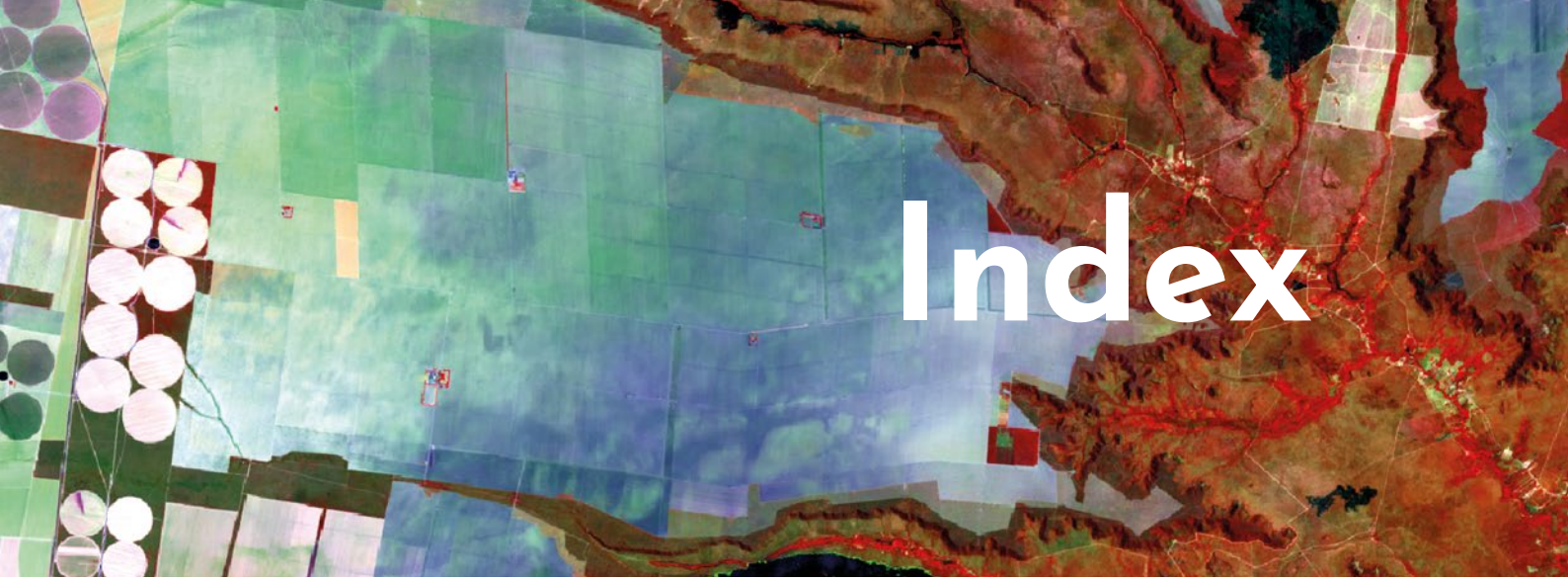
Since the 1970s, soybean farming has found a favourable production environmental in the Cerrado Biome, and currently occupy 11.7% of the Biome with diverse impacts on the land use and land cover transitions. This study's objective is to assess the stocks of areas with agricultural suitability that have the potential for soy expansion in the Biome. In 2019, Agrosatélite made a similar study, with ABIOVE's support, giving the sector groundbreaking data. However, since then, several significant alterations that impact the soy sector have been observed in the Cerrado and justify this update. Among the main alterations that have occurred since 2019 are: (1) new Cerrado Biome boundaries, which resulted in 20.06 million hectares ceasing to be part of the Biome and another 14.51 million hectares being incorporated into the Biome; (2) an increase in the soy area of 5.01 million hectares; (3) the loss of 3.34 million hectares of native vegetation; and (4) an increase of 29.1% in the number of properties registered with the Rural Environmental Registry (CAR).

The results show that there was a significant reduction of the available pasture area with suitability for soy, going from 26.14 million hectares in 2018 to 20.96 million hectares in 2022, of which just 3.95 million hectares are within soy farms. Presumably, the remaining 17.01 million hectares of suitable pastures for soy were mostly allocated to livestock farms. Given that only in the last three crop years the soy area has expanded by 4.36 million hectares, the remaining pastures in soy-producing farms represent a limited stock for deforestation-free soy expansion in the short and medium term. The largest stocks of pastures with suitability for soy are found in the states of Mato Grosso do Sul (5.95 million hectares), Goiás (5,84 million hectares), Minas Gerais (3.72 million hectares) and Mato Grosso (2.38 million hectares). In the MATOPIBA region, the 2.71 million hectares of suitable pastures are concentrated in the state of Tocantins (2.26 million hectares, 83.2%), with the remaining 0.37 million hectares (13.8%) in the state of Maranhão, 72,300 hectares (2.7%) in Bahia, and 8,000 hectares (0.3%) in Piauí. However, the latter three states have reasonable stocks of surplus native vegetation with suitability for soy: Maranhão with 2.85 million hectares, Bahia with 1.48 million hectares and Piauí with 0.93 million hectares.

In the Cerrado Biome, native vegetation is preserved on 102.52 million hectares (51.7%), of which 19.45 million hectares are surplus native vegetation with agricultural suitability for soy. Soy farms with surplus native vegetation in crop year 2022/23 had 4.55 million hectares. Of the 94.59 million hectares (47.7%) of anthropized land, 23.15 million hectares grow soy and 40.37 million hectares have agricultural suitability for soy. Of this latter number, 20.96 million hectares are with pasture and 19.41 million hectares are used for sugarcane, cotton, fallow land, and other crops.

Cerrado Biome





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PART I

SOY EXPANSION DYNAMICS FROM 2014 TO 2023

1. INTRODUCTION

Since the 1980s, soy farming has become so relevant in the Cerrado Biome that, for the last two decades, it has accounted for about 50% of Brazil's soy area[2]. In crop year 2022/23, 23.15 million hectares were planted with soy, an increase of 49.0% (7.61 million hectares) over the last nine crop years. The soy area occupies 11.7% of the 198.45 million hectares of the Biome, whose native vegetation is preserved in about 50% of its territory.

Objective information extracted from satellite images makes it possible to map the spatial distribution of soy fields, in addition to providing data on the land use changes associated with soy expansion, with and without conversion of native vegetation. Knowledge of the stocks of land suitable for soy production provides key elements for achieving a balance between environmental preservation and increase of soy production. In this regard, the images reveal what occurred in the Biome as a result of soy expansion, in addition to providing territorial intelligence for the proper planning of sustainable agribusiness development in the Cerrado Biome.

Two regions of the Cerrado Biome (Figure 1) deserve to be highlighted for their importance in the process of land use changes associated with the dynamics of soy expansion: (1) the MATOPIBA region[3], as it is an important agricultural frontier in the process of consolidation, where conversion of native vegetation into soy is still significant due to the ample stocks of land with agricultural suitability still covered with native vegetation; and (2) the Other States region, more consolidated, where there are large stocks of cleared land with agricultural suitability for soy, allowing for soy expansion through land use intensification (Figure 1). In crop year 2022/23, 5.61 million hectares (24%) were cultivated in the MATOPIBA region and 17.54 million hectares (76%) in the Other States region.

2. IBGE: https://sidra.ibge.gov.br/tabela/1612 e CONAB - Companhia Nacional de Abastecimento. Acompanhamento da safra brasileira de grãos, Brasília, v.10– Safra 2022/23, n.10 - Décimo levantamento, p. 1-110, julho 2023. ISSN 2318 6852.
3. MATOPIBA is a region formed by the states of Maranhão (MA), Tocantins (TO), Piauí (PI) and Bahia (BA), in those areas of these states that lie within the Cerrado Biome and in the transition areas with the Amazon Biome, where an intense transformation of the landscape has been caused by the annual high-technology agricultural expansion. The small portion of MATOPIBA that lies within the Amazon Biome is not part of this study.

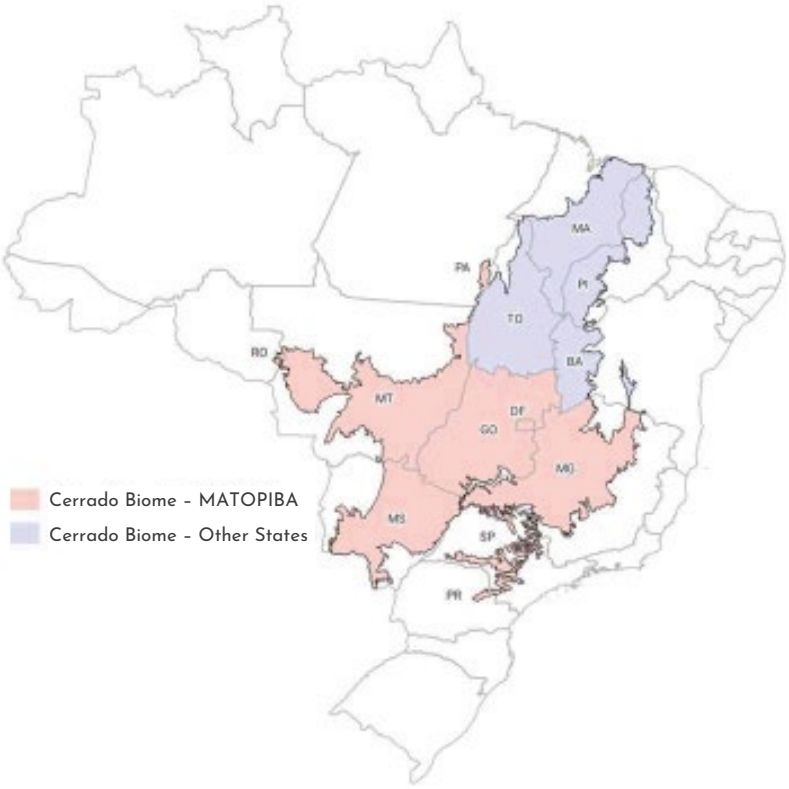


Figure 1. Highlight of the "Other States" and "MATOBIPA" regions in the Cerrado Biome.

1.1 EVOLUTION OF THE SOY AREA

Based on a detailed analysis of satellite images[4], it was possible to assess the gradual increase in the Cerrado's soy area and to detail the land use transitions that occurred in the period from 2013/14 to 2022/23, and of its fractionating into three periods of three years each.

In the current study, made with ABIOVE's support, the analyses were based on the soy mapping for crop year 2022/23 and on the soy mappings of prior studies made by Agrosatélite in crop year 2013/14, supported by GBMF (Gordon and Betty Moore Foundation), and in crop year 2016/17, supported by GTC (Cerrado Working Group) in conjunction with TNC (The Nature Conservancy), as well as in crop years 2018/19, 2019/20, 2020/21 and 2021/22,

4. This study used images acquired by the Landsat and Sentinel-2 series of satellites, in the visible, near-infrared and mid-infrared wavelengths of the electromagnetic spectrum, with spatial resolution between 10 and 30 metres (~100 to 10 pixels per hectare). The joint operation of these satellites made it possible to revisit the same location at intervals of two to five days, enabling the acquisition of cloud-free images during the period favourable for the identification of soy crops. About 3,000 images were used to accurately identify soy fields in the Cerrado Biome in crop year 2022/23 through visual image interpretation techniques. The starting point was the soy map for crop year 2021/22. The following RGB-colour compositions were used: 4-5-3 bands for the OLI/Landsat sensor, and 8a-11-4 bands for the Sentinel-2 MSI sensor. The visual interpretation procedure also considered the analysis of the temporal series of images acquired by the MODIS sensor, transformed into the Enhanced Vegetation Index (EVI) in the form of 16-day temporal compositions made available by EMBRAPA's SatVeg Project (www.satveg.cnptia.embrapa.br). It should be noted that the soy map for the 2016/17 crop year, prepared by Agrosatélite, was validated by a third party (University of Maryland), based on data obtained in the field, and found to have an overall mapping accuracy of 98.4%.

supported by ABIOVE (Associação Brasileira das Indústrias de Óleos Vegetais)[5]. Based on the soy fields' spatial distribution, it was possible to obtain the planted soy area, from the levels of the farms, municipalities, and states to the Biome as a whole[6]. The objective of this historical mapping sequence analysis is to broaden understanding of the recent soy expansion dynamics in the Cerrado Biome, and in the regions of MATOPIBA and Other States.

Figures 2 to 8 illustrate the seven soy maps available for the Cerrado Biome. In each, four sections of the less consolidated regions are highlighted, where soy crops are becoming relevant. Section I shows the municipality of Paranatinga in Mato Grosso state, where the soy area lying within the Cerrado Biome has almost doubled in ten years, going from 138,697 hectares in 2013/14 to 261,489 hectares in 2022/23. The regions around Balsas in the state of Maranhão and around Baixa Grande do Ribeiro in Piauí state (both in Section II), as well as those around Barreiras in the state of Bahia (Section III) and around Porto Nacional in Tocantins state (Section IV) are also highlighted because of the intense expansion of soy crops, whose areas have grown significantly over the last ten years. All these areas are located in MATOPIBA.

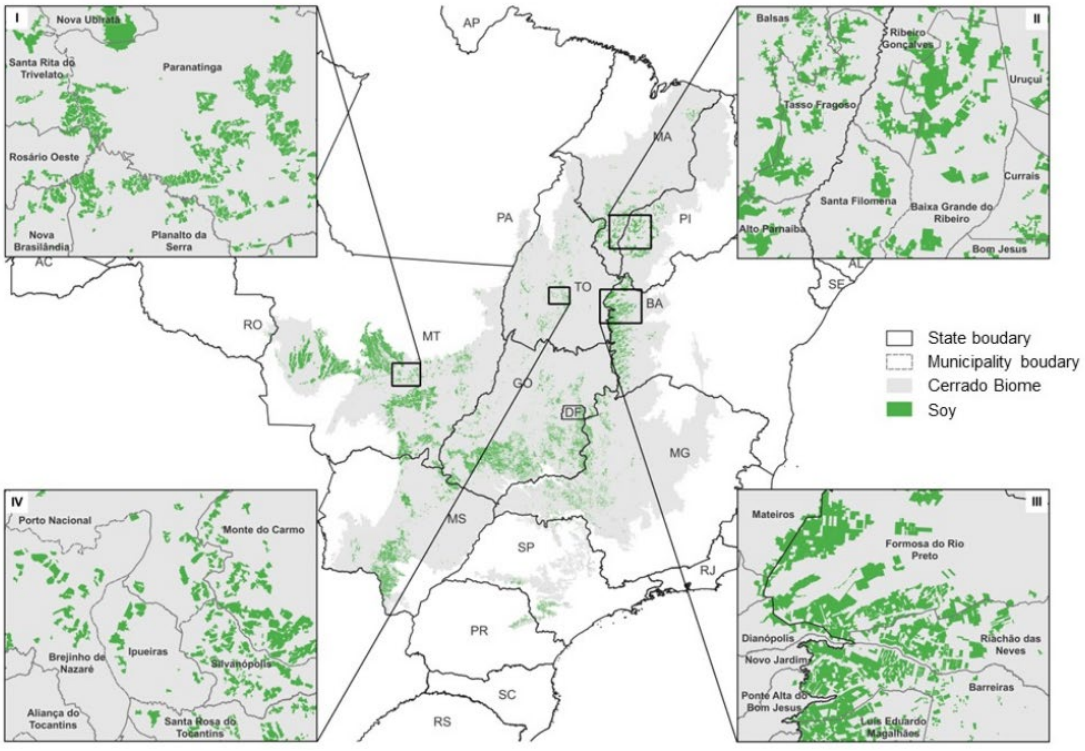


Figure 2. Soybean map in the Cerrado Biome in crop year 2013/14, highlighting the regions that have seen significant soy expansion.

5. Reports available for public consultation on https://agrosatelite.com.br/cases/#expansao-agricola.
6. The Cerrado Biome boundaries used in this study are those defined by the IBGE in 2019, on a 1:250,000 scale (https://www.ibge.gov.br/geociencias/cartas-e-mapas/informacoes-ambientais/15842-biomas.html?edicao=25799&t=acesso-ao-produto).

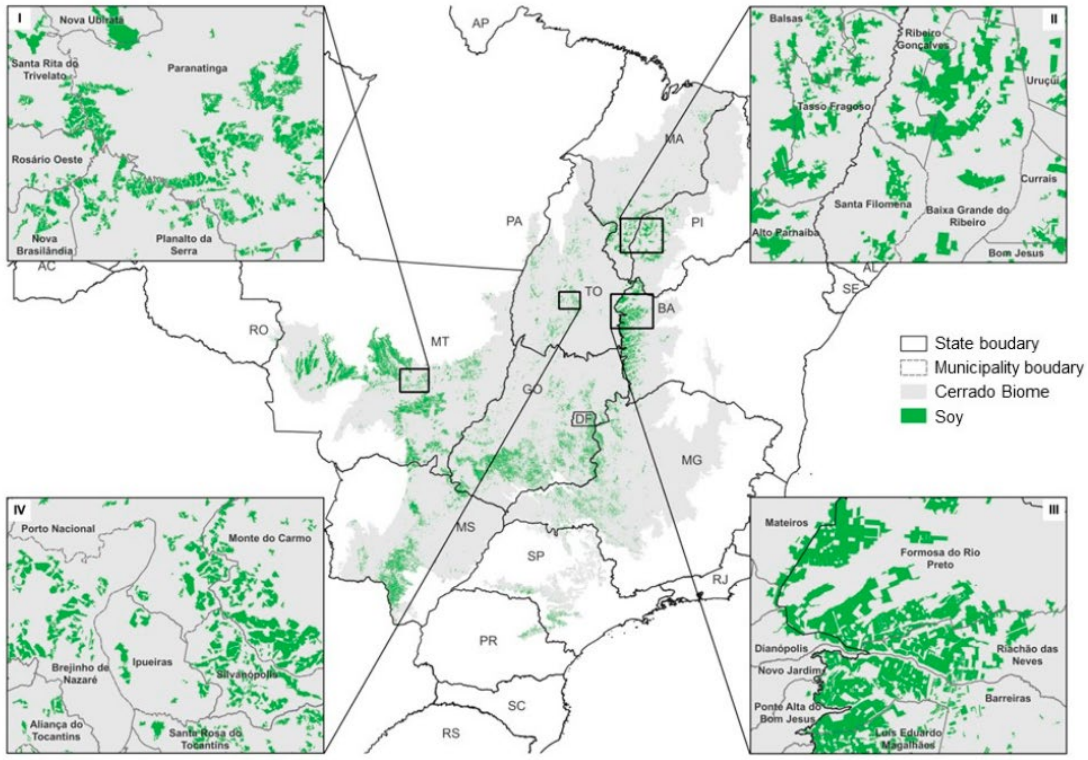


Figure 3. Soybean map in the Cerrado Biome in crop year 2016/17, highlighting the regions that have seen significant soy expansion.

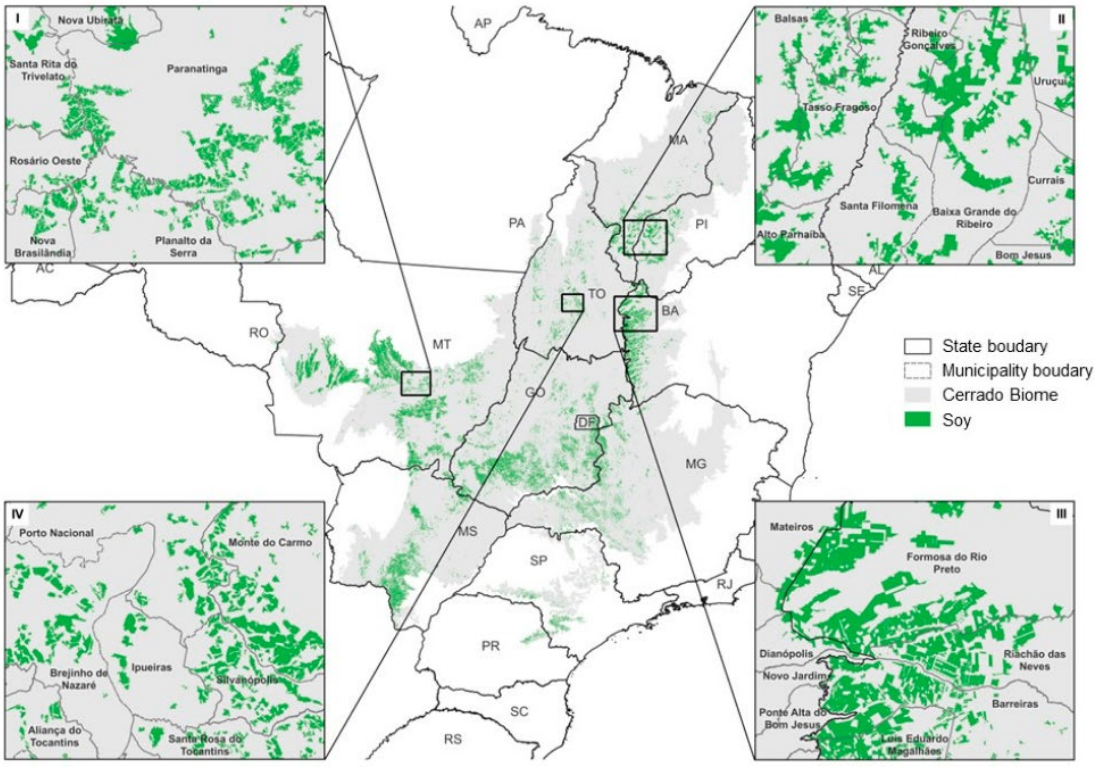


Figure 4. Soybean map in the Cerrado Biome in crop year 2018/19, highlighting the regions that have seen significant soy expansion.

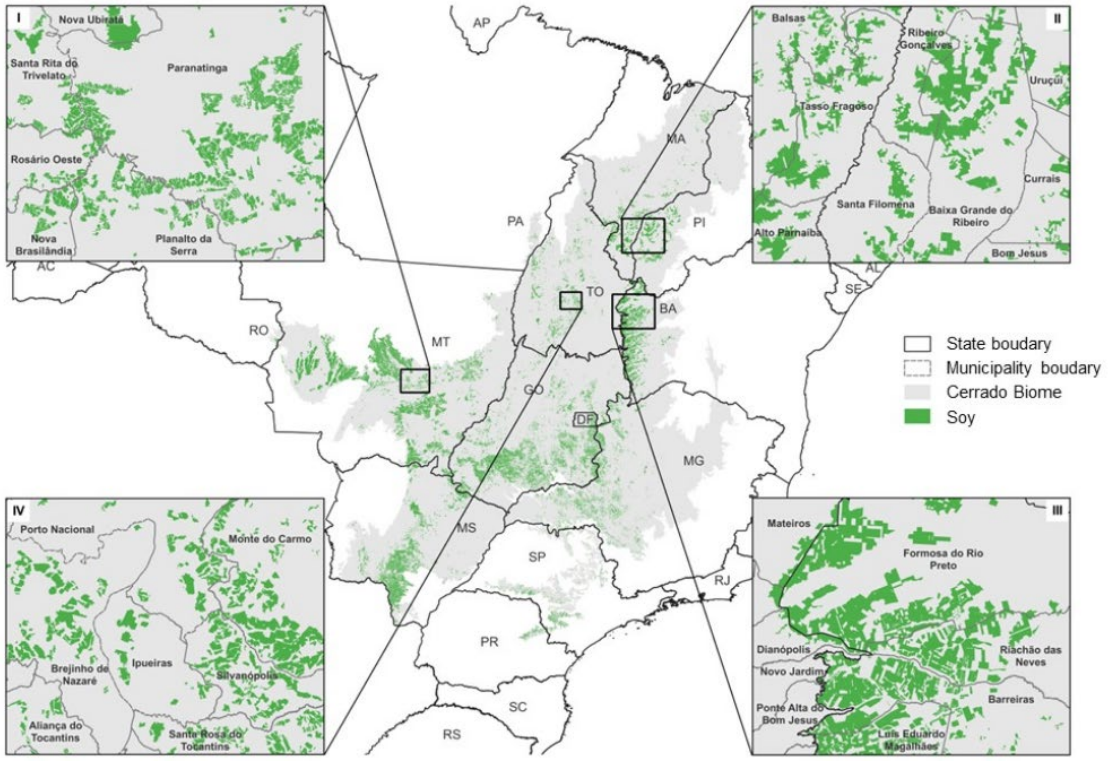


Figure 5. Soybean map in the Cerrado Biome in crop year 2019/20, highlighting the regions that have seen significant soy expansion.

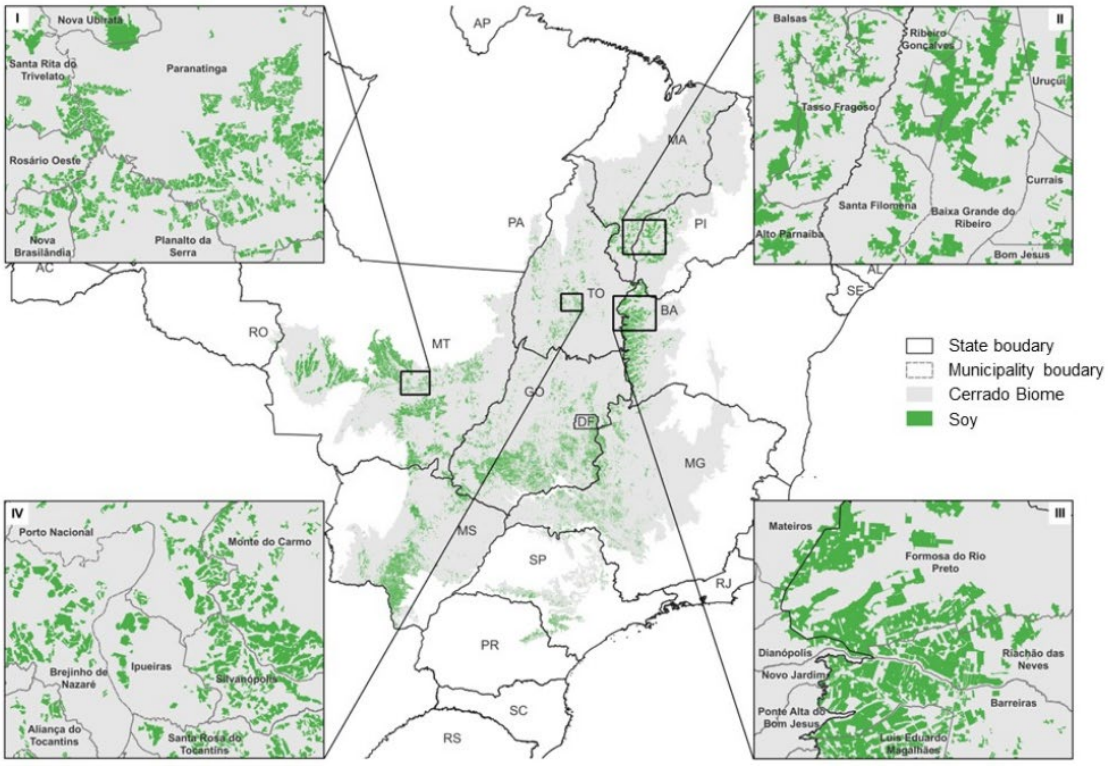


Figure 6. Soybean map in the Cerrado Biome in crop year 2020/21, highlighting the regions that have seen significant soy expansion.

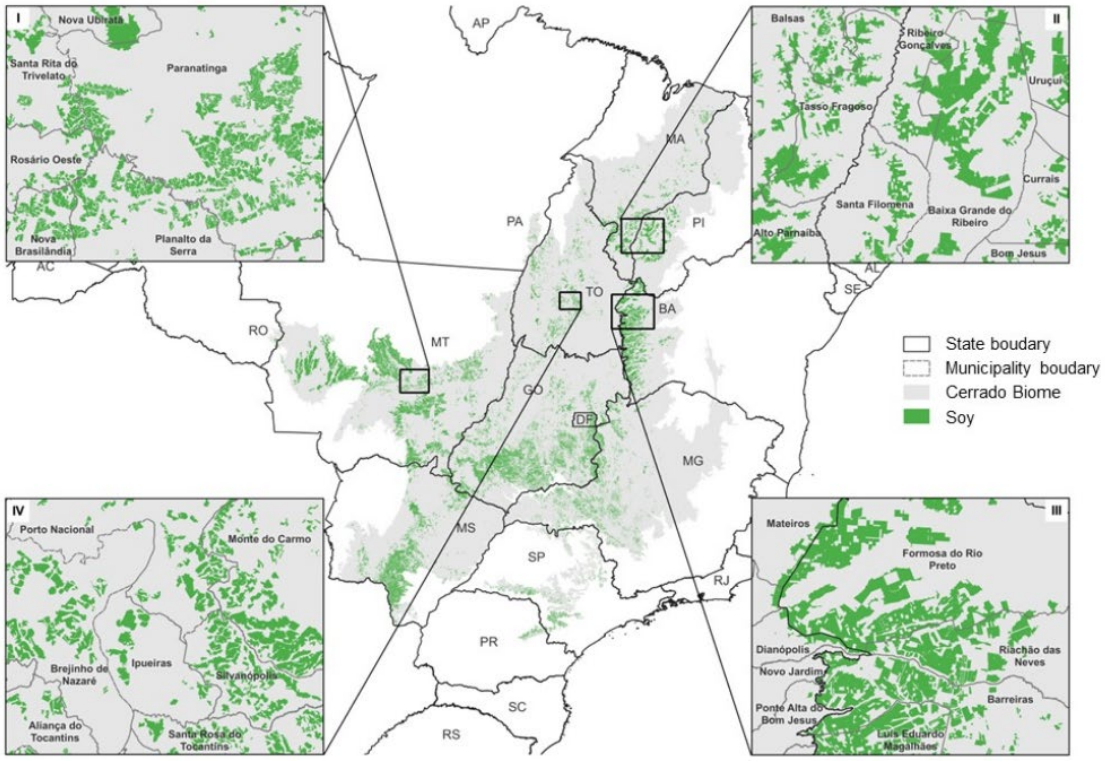


Figure 7. Soybean map in the Cerrado Biome in crop year 2021/22, highlighting the regions that have seen significant soy expansion.

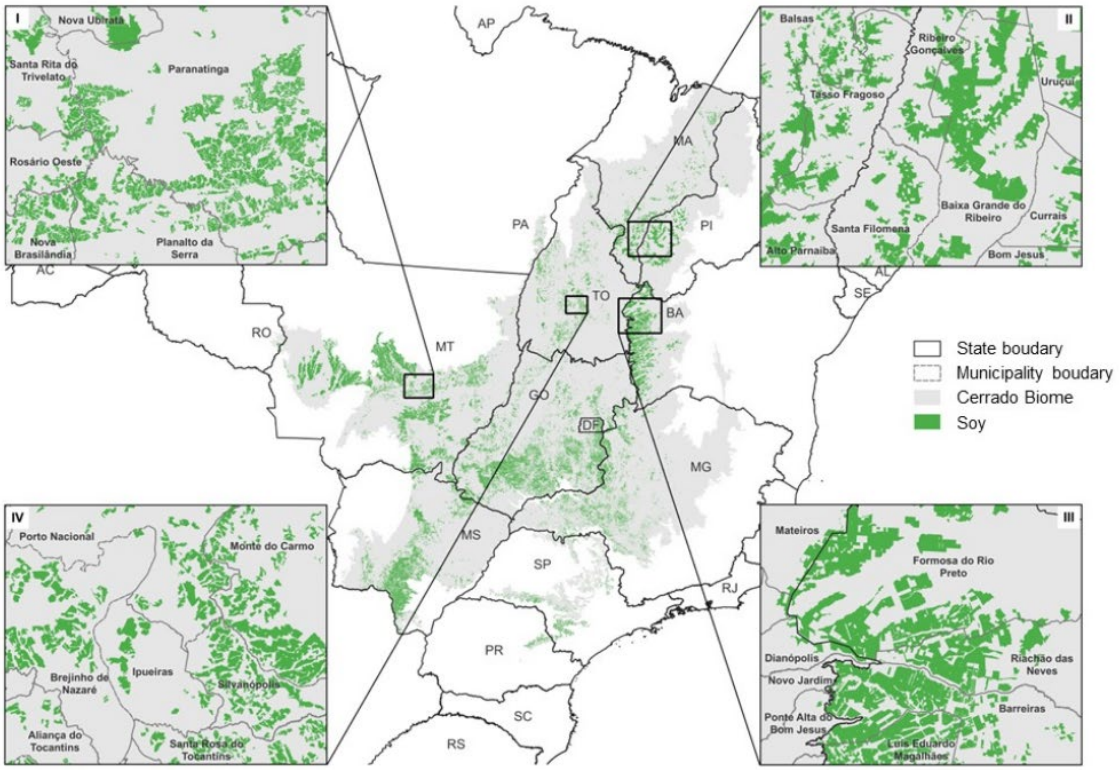


Figure 8. Soybean map in the Cerrado Biome in crop year 2022/23, highlighting the regions that have seen significant soy expansion.

Table 1 shows the results of soy mapping in the Cerrado Biome, by state, and for the Other States and MATOPIBA regions, obtained from satellite images for the same seven years shown in Figures 2 to 8.

States	2000/01	2006/07	2013/14	2016/17	2018/19	2019/20	2020/21	2021/22	2022/23
	ha	ha	ha	ha	ha	ha	ha	ha	ha
DF	39,727	54,956	80,002	88,351	93,245	85,447	84,867	101,636	102,860
GO	1,737,618	2,369,355	3,522,707	3,690,694	4,012,149	4,162,932	4,445,196	4,958,919	5,390,252
MG	593,000	779,797	1,198,138	1,460,482	1,703,974	1,718,523	1,867,793	2,014,220	2,318,198
MS	836,773	1,221,143	1,675,896	1,995,603	2,218,406	2,409,115	2,582,202	2,678,239	2,929,638
MT	3,000,481	3,837,277	5,272,195	5,385,347	5,377,462	5,505,054	5,599,613	5,898,078	6,045,772
PR	52,544	62,731	68,841	76,218	89,581	89,892	91,147	87,777	90,567
SP	196,207	158,679	283,971	338,175	418,894	447,693	502,472	539,119	579,924
RO	13,121	21,124	24,748	22,926	23,432	23,472	23,301	23,435	24,632
PA	481	2,302	5,518	18,192	21,203	28,143	33,493	46,574	62,947
Other States	**6,469,953**	**8,507,365**	**12,132,015**	**13,075,988**	**13,958,346**	**14,470,270**	**15,230,085**	**16,347,996**	**17,544,790**
MA	220,838	437,129	682,536	750,764	818,397	833,834	904,794	1,006,071	1,130,406
TO	77,279	258,419	675,573	916,883	1,020,581	1,089,378	1,171,838	1,284,372	1,424,778
PI	59,385	226,330	629,328	671,529	741,964	732,856	819,459	867,573	970,406
BA	607,305	765,005	1,419,428	1,606,627	1,609,218	1,665,150	1,837,307	1,927,707	2,084,096
MATOPIBA	**964,806**	**1,686,883**	**3,406,864**	**3,945,804**	**4,190,160**	**4,321,218**	**4,733,398**	**5,085,723**	**5,609,685**
TOTAL	**7,434,759**	**10,194,248**	**15,538,879**	**17,021,791**	**18,148,506**	**18,791,487**	**19,963,483**	**21,433,719**	**23,154,475**

Table 1. Evolution of the soy area in the Cerrado Biome, in hectares, by state and for the Other States and MATOPIBA regions

Over the last ten years, the soy area in the Cerrado Biome went from 15.54 million hectares in 2013/14 to 23.15 million hectares in 2022/23, an increase of 49.0% (7.61 million hectares). In the MATOPIBA region, the soy area grew by 64.6% (2.20 million hectares) in the same period, going from 3.41 million hectares to 5.61 million hectares, representing 24% of the Cerrado soy area, while in Other States, the increase was 44.6% (5.41 million hectares), going from 12.13 million hectares to 17.54 million hectares, representing 76% of the Biome's soy area (Table 1, Figure 9).

The average annual growth rate of the soy area in these ten years was 846,000 hectares/year (601,000 hectares/year in Other States and 245,000 hectares/year in MATOPIBA). The history of favourable soy prices has led to an accelerated production over the last three years, causing an increase in planted area of 1.172 million hectares in 2020/21, 1.470 million hectares in 2021/22 and a record 1.721 million hectares in 2022/23 – more than twice the average annual rate for the last ten years. It should be noted that this recent expansion (4.37 million hectares) corresponds to 57.3% of the expansion observed in the period analysed.

Figure 9 graphically illustrates the soy areas for Other States and for MATOPIBA (Table 1), including the annual expansion rates in each of the presented periods.

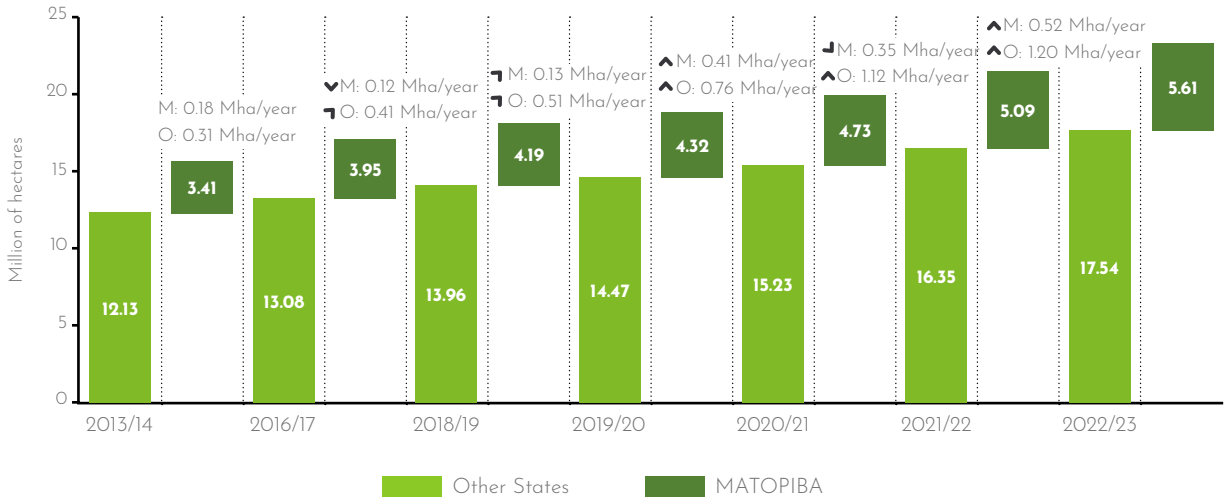


Figure 9. Evolution of the soy area from crop year 2013/14 to crop year 2022/23 in Other States and in MATOPIBA, and the annual rates of soy expansion in the six periods analysed: (1) 2013/14 to 2016/17; (2) 2016/17 to 2018/19; (3) 2018/19 to 2019/20; (4) 2019/20 to 2020/21; (5) 2020/21 to 2021/22; and (6) 2021/22 to 2022/23.

Table 2 shows the percentage change in the soy area in crop year 2022/23, compared to the previous crop year.

States	2021/22 (a)	2022/23 (b)	Var. % (b*100/a)-100
DF	101,636	102,860	1.2
GO	4,958,919	5,390,252	8.7
MG	2,014,220	2,318,198	15.1
MS	2,678,239	2,929,638	9.4
MT	5,898,078	6,045,772	2.5
PR	87,777	90,567	3.2
SP	539,119	579,924	7.6
RO	23,435	24,632	5.1
PA	46,574	62,947	35.2
Other States	**16,347,996**	**17,544,790**	**7.3**
MA	1,006,071	1,130,406	12.4
TO	1,284,372	1,424,778	10.9
PI	867,573	970,406	11.9
BA	1,927,707	2,084,096	8.1
MATOPIBA	**5,085,723**	**5,609,685**	**10.3**
TOTAL	**21,433,719**	**23,154,475**	**8.0**

Table 2. Change in soy area in the Cerrado Biome, in hectares and as a percentage, by state, and in Other States and in MATOPIBA, for the 2021/22 and 2022/23 crop years.

An analysis based on data from the Rural Environmental Registry (CAR)[7] showed that 96.7% (22.38 million hectares) of crop year 2022/23 was grown on 114,599 farms (an average of 195 hectares of soy per farm)[8]. However, it is worth mentioning that CAR has a large number of overlapping properties, which overestimates the number of soy-producing farms. Another analysis based on data of the rural properties certified by INCRA (SIGEF and SNCI) showed that 82.2% (19.02 million hectares) of crop year 2022/23 was grown on 83,809 farms (an average of 227 hectares of soy per farm)[9]. This second analysis supports the fact that the number of CAR properties with soy is overestimated as a result of the overlapping properties, something that does not happen with the rural properties certified by INCRA. This indicates that the true number of farms with soy crops is probably close to 100,000.

Table 3 shows the result of the analysis of the soy areas in crop year 2022/23, both within and outside of Special Areas: TI – Indigenous Lands; QUIL – Quilombola Communities; UC_PI – Conservation Units with Full Protection; UC_US – Conservation Units with Sustainable Use, except APAs; Sobrep. TI-QUIL-UC_PI-UC_US – Overlaps involving these specific Special Areas; APP_RL-CAR – Areas of Permanent Preservation and Legal Reserves registered with the Rural Environmental Registry (CAR); UC_APA – Conservation Unit with Sustainable Use of the APA type (Areas of Environmental Protection); ASS – Settlements; Sobrep. ASS-UC_APA – Overlaps exclusively between these Special Areas.

It should be noted that 92.4% of the Biome's soy area is found outside these areas. Deducting the Areas of Environmental Protection (APA)[10] and settlements (ASS), where agricultural activity is permitted, the area outside these Special Areas is 97.7%.

Soy grown in APAs is the most significant, with 584,000 hectares in MATOPIBA and 379,000 hectares in Other States, corresponding to 4.2% of the soy grown in the Cerrado Biome. In second place is the soy grown on Legal Reserves (RL) and in Areas of Permanent Preservation (APP) registered with CAR7, with 463,000 hectares (2.0%) – this is more significant in Other States where the degree of anthropization is greater. Such cases in general are registered as Legal Reserves, most of which still have to be validated by the State Environmental Secretariats so that the Environmental Recovery Plans (PRAs) can be implemented, and the areas recovered or compensated. Soy in settlements is almost entirely in Other States, concentrated in a few areas. In the other Special Areas that make up the protected areas (Indigenous Lands, Quilombola Communities, Conservation Units with Full Protection, Conservation Units with Sustainable Use, except APAs, and the overlaps between them), where the rules for growing soy are restrictive, the soy area is less than 0.4% (61,300 hectares), with 72% of this area concentrated on Indigenous Lands.

7. Data from CAR (Rural Environmental Registry) used in this study were obtained from SICAR (National System for Rural Environmental Registration) on https://www.car.gov.br/publico/imoveis/index, as updated on 11th April 2023.
8. Properties with less than 10 hectares of soy and properties without CAR registration were not included in this study. They respectively represent 0.5% (0.12 million hectares) and 2.8% (0.65 million hectares) of the soy area.
9. INCRA properties with less than 10 hectares of soy represent just 0.32% (0.07 million hectares) of the total soy area.
10. Agricultural crops such as soy are not restricted in the APAs, although these areas are part of SNUC's set of Conservation Units with Sustainable Use. Agricultural activity, however, should follow the precautions and guidelines described in each APA's management plan.

Category		Other States		MATOPIBA		Cerrado Biome	
		ha	%	ha	%	ha	%
SOY OUTSIDE SPECIAL AREAS		16,537,627	94.3	4,858,937	86.6	21,396,565	92.4
SOY INSIDE SPECIAL AREAS	**TI**	51,405	0.3	9,934	0.2	61,339	0.3
	QUIL	3,224	0.0	2,940	0.1	6,164	0.0
	UC_PI	2,522	0.0	4,446	0.1	6,968	0.0
	UC_US	2,202	0.0	8,516	0.2	10,719	0.0
	Sobrep. TI-QUIL-UC_PI-UC_US	0	0.0	0	0.0	0	0.0
	APP_RL-CAR	342,833	2.0	119,909	2.1	462,742	2.0
	UC_APA	378,954	2.2	583,626	10.4	962,581	4.2
	ASS	224,785	1.3	20,115	0.4	244,900	1.1
	Sobrep. ASS-UC_APA	1,237	0.0	1,261	0.0	2,498	0.0
TOTAL		**17,544,790**	**100.0**	**5,609,685**	**100.0**	**23,154,475**	**100.0**

Table 3. Soy area in crop year 2022/23, within and outside the Special Areas*, in Other States, in MATOPIBA and in the Cerrado Biome.

While analysing the remote-sensing satellite images, Agrosatélite's team of analysts had access to an enormous collection of images that enabled a careful analysis to correctly identify and precisely map the soy areas in crop year 2022/23. The soy area estimate extracted from this mapping shows higher values than those published by CONAB. For example, for the states of Goiás and Bahia, whose soy area is practically entirely within the Cerrado Biome, Agrosatélite estimated an area that was respectively 843,000 hectares and 164,000 hectares higher. It should be noted that, during the crop year 2020/21, Agrosatélite carried out field work in Goiás to assess the quality of the mapping and did not find any inconsistencies that would justify a revision. With about 700 samples of land use collected during the field work in Goiás state, the overall mapping accuracy was 98.3%. Therefore, Agrosatélite is confident that the estimates of the soy grown in the Cerrado, as presented in this report, reliably represent the territorial extension occupied by soy. It should be further noted that the map for crop year 2016/17 was validated by a third party (University of Maryland), who indicated an overall mapping accuracy for the entire Cerrado Biome of 98.4%.

2. DEFORESTATION IN THE CERRADO BIOME

Figure 10 shows the deforestation rates for the Cerrado Biome, estimated by PRODES-Cerrado from 2001 to 2022 and segmented into the MATOPIBA and Other States regions. It also shows the annual deforestation for soy in crop year 2022/23.

The annual deforestation rates, which were about 2.8 million hectares/year at the beginning of this millennium, have fallen over the last nine years to an average 774,000 hectares/year. This reduction was mainly in the Other States region, which accounted for about two-thirds of the Biome's deforestation at the beginning of the historical series. The regional situation, however, has been inverted in recent years and the MATOPIBA region now accounts for over two-thirds of the deforestation (Figure 10), even though it represents just one-third of the Cerrado's territory.

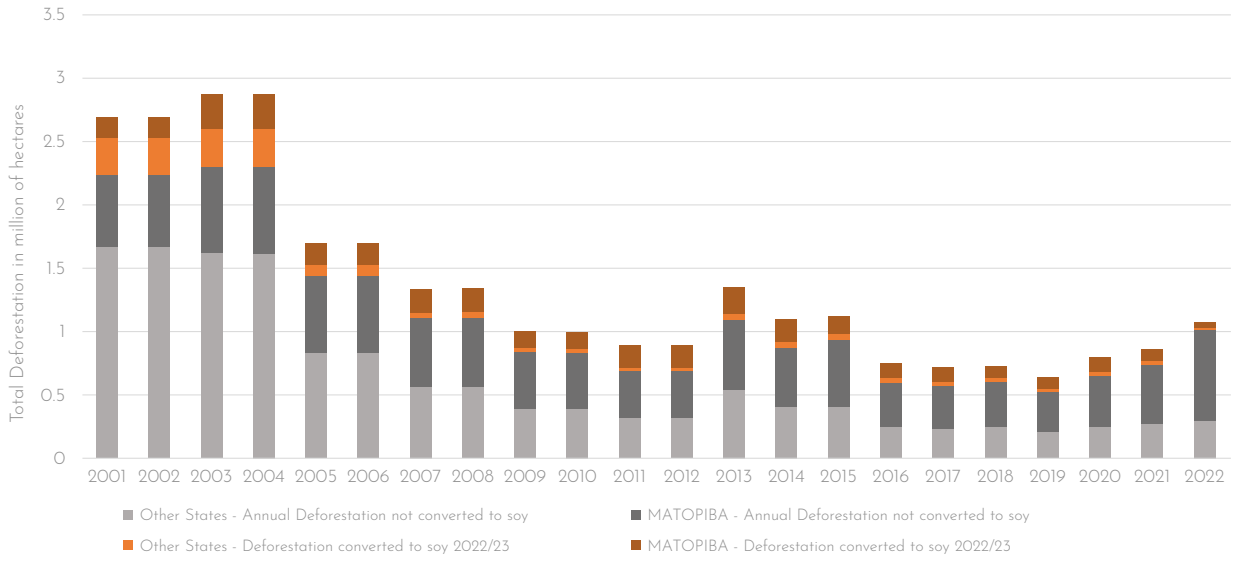


Figure 10. Annual deforestation rates in the Cerrado Biome from 2001 to 2022, highlighting the annual deforestation converted to soy, based on crop year 2022/23.

2.1 DEFORESTATION CONVERTED TO SOY

Figure 11 shows the same information as Figure 10, highlighting the areas deforested annually between 2001 and 2022 that grew soy in crop year 2022/23. Figure 10 shows that the Cerrado Biome's deforested area between 2001 and 2022 was 30.04 million hectares (15.1% of the Cerrado), of which 5.21 million hectares (Figure 10) were planted with soy in crop year 2022/23, i.e., 17.3% of the area deforested over the last 22 years. Said another way, 82.7% (24.83 million hectares) of the deforested land was not converted to soy but to other uses. It also means that 77.5% of the Cerrado's soy in crop year 2022/23 – equivalent to 17.94 million hectares of soy – is free of deforestations occurred since 2000.

Considering only the deforestation that has occurred after 22nd July 2008 (2009 to 2022), the date that defines consolidated areas according to the Forest Code of 2012, 2.21 million hectares of soy in crop year 2022/23 was planted on deforested land, corresponding to 17.2% of the total deforestation during this period. Of this total, 1.73 million hectares are in MATOPIBA (30.8% of the soy in this region) and 0.48 million hectares are in Other States (2.7% of the soy in this region).

Furthermore, considering the deforestation from 2014 to 2022, 1.18 million hectares of deforested land was with soy in crop year 2022/23. This is 15.4% of the total deforestation after 2013, of which 0.92 million hectares are in MATOPIBA (16.4% of the soy in this region) and 0.26 million hectares in Other States (1.5% of the soy in this region). In other words, the percentage of soy in the Cerrado Biome's deforestation (soy footprint) shows a downward trend in the periods analysed above, albeit not very evident since conversion of native vegetation to soy in MATOPIBA is still significant.

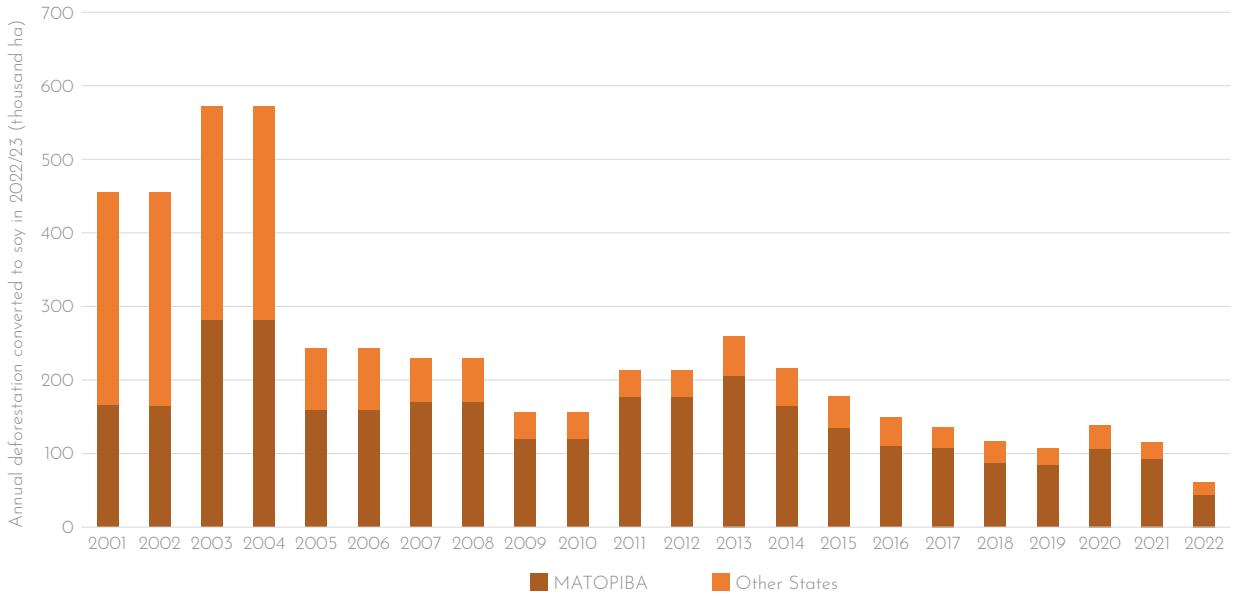


Figure 11. Soy expansion on deforested land from 2001 to 2022 in the Cerrado Biome, highlighting the MATOPIBA and Other States regions.

The analysis of soy expansion with deforestation is made by intersecting the PRODES-Cerrado deforestation maps, adopting the procedures reported in Agrosatélite (2018)[5].

2.2 DEFORESTATION CONVERTED TO SOY IN RECENT YEARS

Figure 12 shows the soy area on deforestations of up to five years, considering the latest three crop years, that is: for crop year 2022/23, the soy in PRODES deforestation from 2018 to 2022; for crop year 2021/22, the soy in PRODES deforestation from 2017 to 2021; and for

11. PRODES annually maps the deforestation occurring from August of the prior year to July of the current year. PRODES-2014, for example, maps the deforestation which occurred between August 2013 and July 2014.

crop year 2020/21, the soy in PRODES deforestation from 2016 to 2020. There has been a clear upward trend for soy expansion onto recent deforestation, both in MATOPIBA and in Other States.

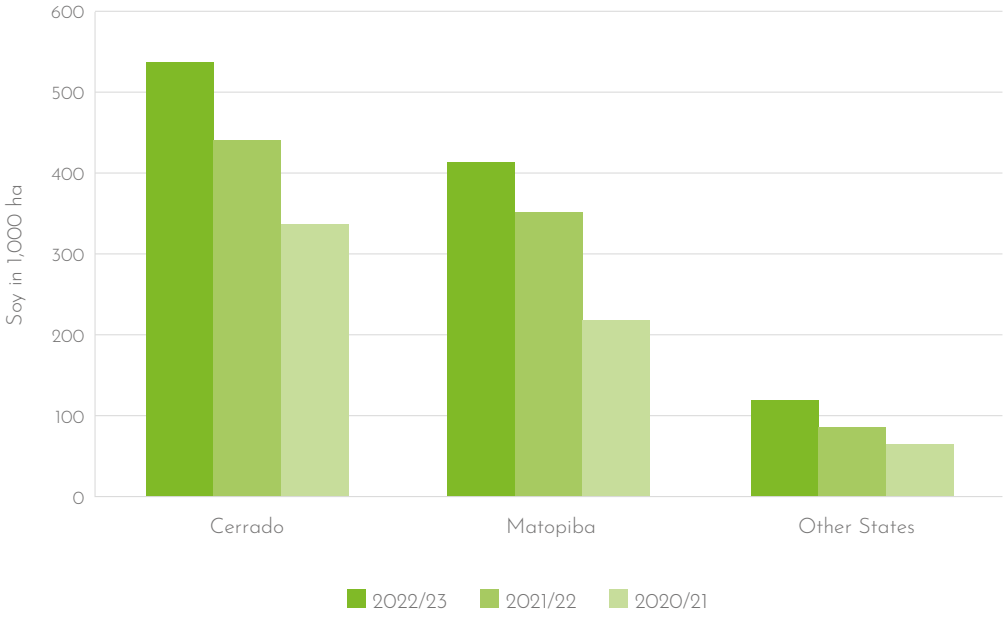


Figure 12. Area of soy grown on deforestations of up to five years, in each of the latest three crop years, showing a growing trend for direct conversion of native vegetation into soy in recent crop years, both in MATOPIBA and in Other States.

Figure 13 shows the soy area in the last three crop years, by the number of years after deforestation. It is quite evident from this analysis that, with each new crop year, the soy area on newly deforested land has grown.

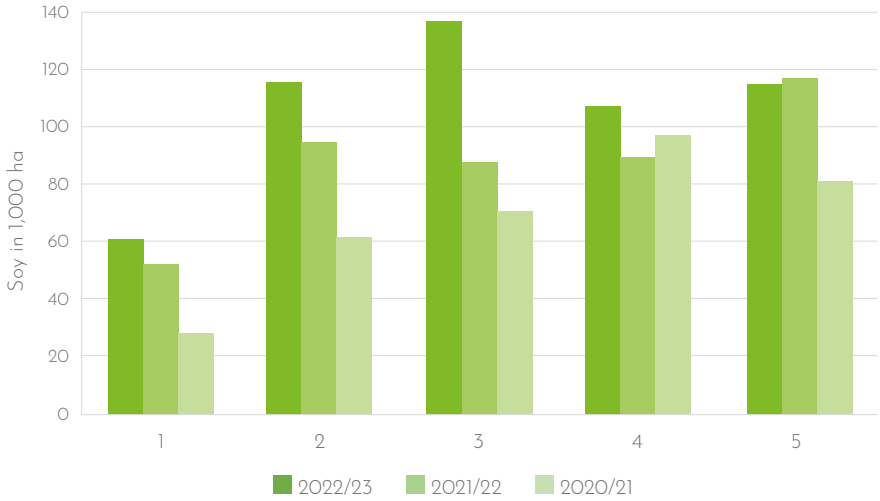


Figure 13. Area of soy grown on deforestations of one to five years old, showing an upward trend of soy area on deforestations with up to three years.

3. LAND USE AND LAND COVER CHANGE ATTRIBUTED TO SOY

The analysis of Item 2.1 provides an overall view of the soy footprint on deforestation in the Cerrado Biome, showing the annual deforested area converted to soy in crop year 2022/23. In this section, the focus is on an assessment of the tendency for soy to expand, based on the analysis fragmented into three periods, covering the last nine crop years. The scope of each analysed period should be long enough to effectively capture the land use and land cover changes due to soy expansion, while being short enough to portray the variations and trends in the pattern of land use and land cover changes in each of the three analysed periods.

The land use and land cover changes in each analysed period was classified as follows: (1) change from native vegetation to soy, here called "expansion with deforestation"[12]; (2) change from other land uses to soy, here called "expansion without deforestation"[13]; and (3) areas of retraction[14], made up of land which had soy at the beginning of the analysed period, but which reverted to other uses temporarily (e.g., fallow land or rotation crops) or permanently.

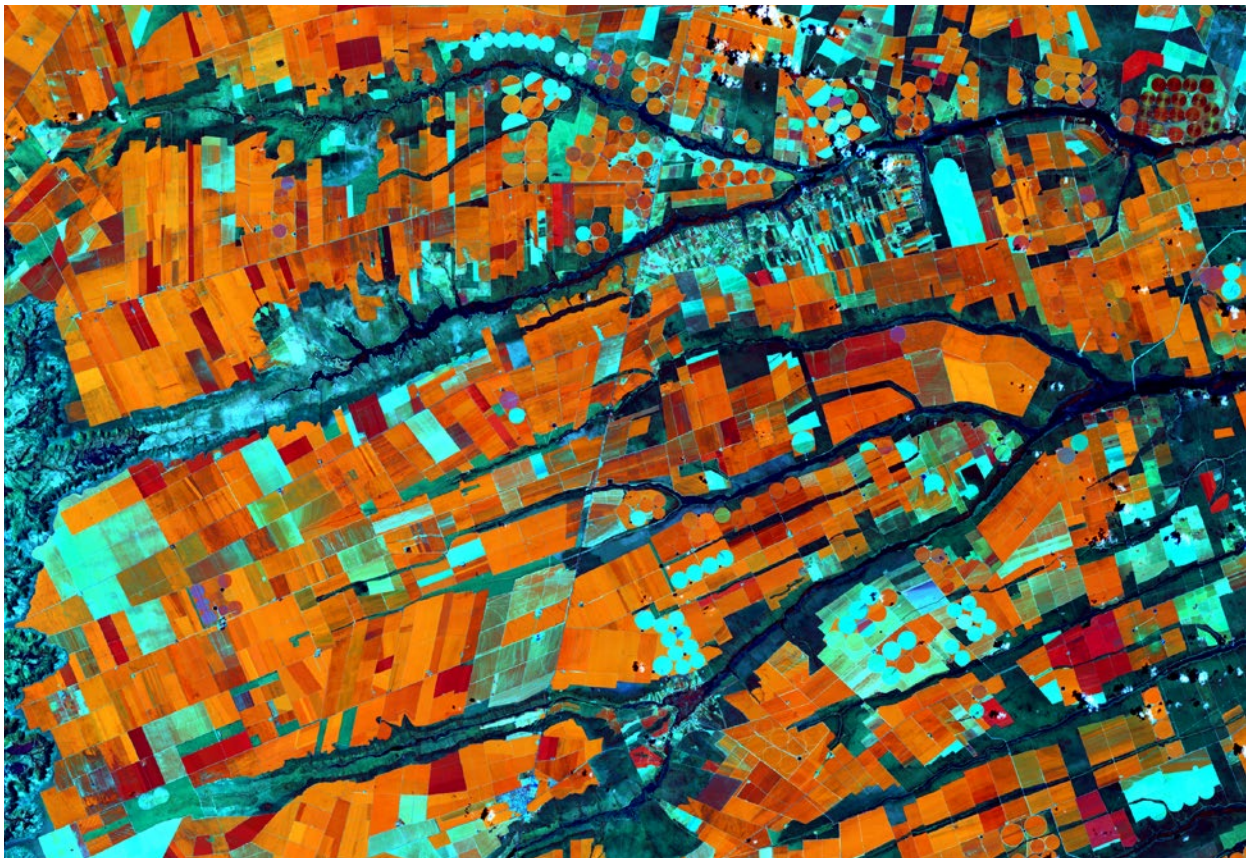
This analysis takes into consideration the availability of soy mappings in specific crop years, according to previous studies by Agrosatélite, following the methodology of Agrosatélite's previous studies (2015)[5].

3.1 SOY EXPANSION WITH AND WITHOUT DEFORESTATION

To better capture the trend of soy expansion onto deforested land between 2014 and 2022, this analysis was prepared considering three periods of equal duration:

- First Period: deforestation mapped by PRODES between 2014 and 2016, converted to soy from crop year 2013/14 to crop year 2016/17;
- Second Period: deforestation mapped by PRODES between 2017 and 2019, converted to soy from crop year 2016/17 to crop year 2019/20; and
- Third Period: deforestation mapped by PRODES between 2020 and 2022, converted to soy from crop year 2019/20 to crop year 2022/23.

12. Expansion with deforestation corresponds to the land cover change of the Cerrado's native vegetation (regardless of the phytophysiognomy) at the beginning of each period to soy by the end of the same period.
13. Expansion without deforestation corresponds to the land use change of areas with uses other than soy at the beginning of each period which were converted to soy by the end of the same period. For example, pastures converted to soy is considered an intensification of land use, a situation that occurs frequently in Other States where there are many pastures with agricultural suitability for soy. Examples of other uses at the beginning of each period include: (a) areas with annual crop rotation (e.g., cotton and first-crop corn); (b) fallow land; and (c) areas of sugarcane in the process of renewal or conversion to soy.
14. Retraction are those areas which had soy at the beginning of each period and were converted to other uses by the end of the same period. For example: (a) areas with annual crop rotation (such as cotton and first-crop corn); (b) fallow land; (c) areas that reverted to sugarcane as a result of the sugarcane field renewal process; and (d) areas that have effectively ceased to be planted with soy due to abandonment or a change in its use, as occurred in the first decade of this millennium because of the considerable sugarcane expansion in the Centre-South region (https://www.mdpi.com/2072-4292/2/1/290).



The main objective of this fractionated analysis is to verify whether there is a trend to reduce or to increase direct conversion of native vegetation to soy among the selected periods, i.e., to validate the hypothesis whether the soy footprint in new deforestation is decreasing or increasing. It should be noted that each period was analysed independently, so that the deforestation outside the period under consideration does not have an impact on soy expansion with deforestation in the same period. For example, an area deforested in 2015 (First Period) and converted to soy in 2018 (Second Period) was not considered a direct conversion of native vegetation into soy in the second period. However, this deforested area reflects well the size of the soy footprint in the deforestation occurring in each period. Thus, the soy sector can objectively assess whether the efforts made to reduce the conversion of native vegetation associated with soy production are having the expected effect on the soy producers.

When analysing the three periods shown in Figure 14, it becomes evident that the soy expansion with deforestation in the Cerrado Biome decreased from the first to the second period, going from 214,000 hectares to 150,000 hectares. However, from the second to the third period, the soy footprint in deforestation doubled in size to 301,000 hectares. The upward trend of native vegetation conversion into soy in the third period can be seen in both Other States and MATOPIBA, even though the 238,000 hectares recorded in MATOPIBA (4.2% of the soy in this region) is far larger than the 63,000 hectares converted in Other States (0.4% of the soy in this region).

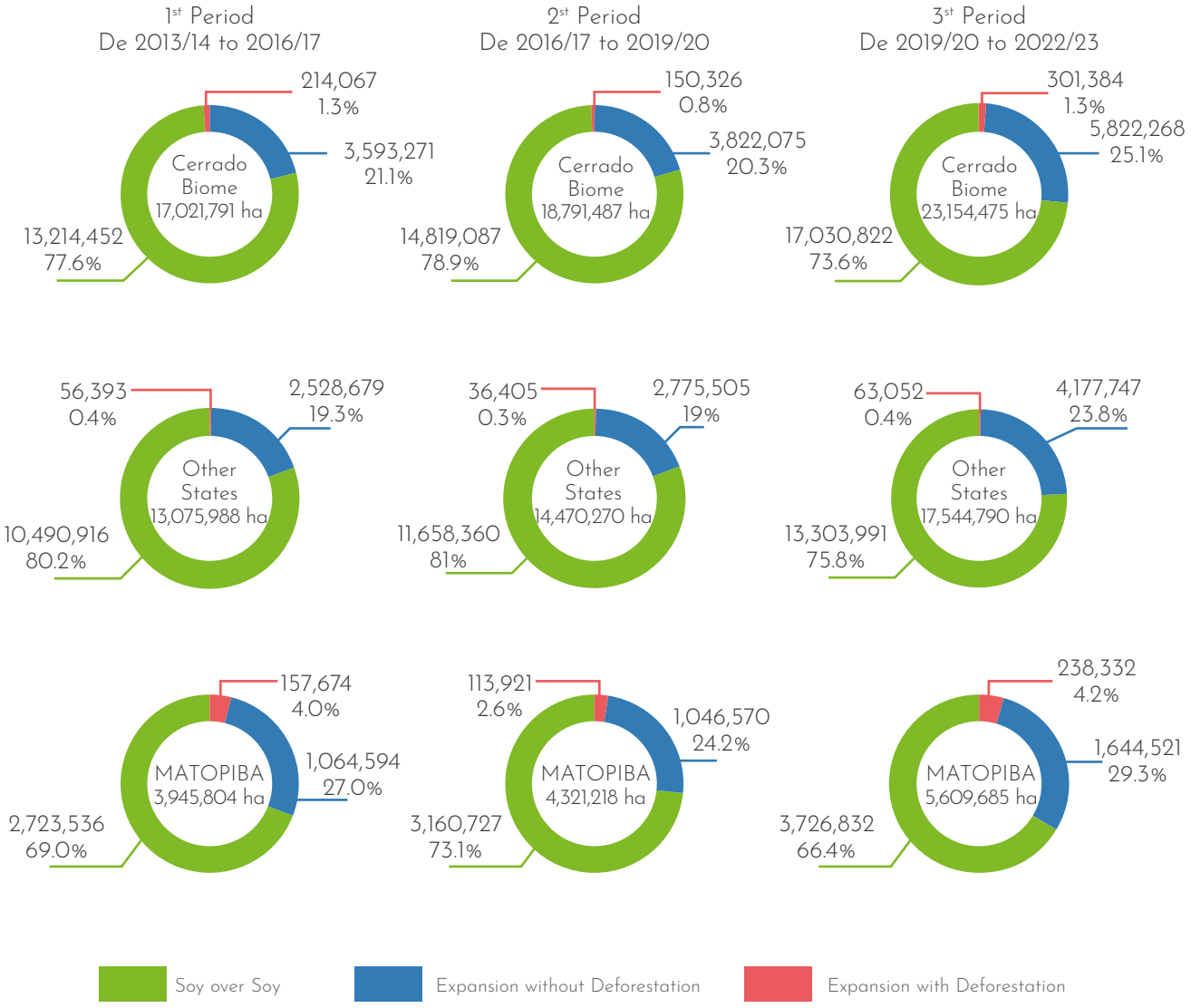


Figure 14. Area of soy over soy and expansion without and with deforestation in the Cerrado Biome, in Other States and in MATOPIBA in the following periods: First Period from 2013/14 to 2016/17; Second Period from 2016/17 to 2019/20; and Third Period from 2019/20 to 2022/23.

Note: Soy over Soy is the area that had soy from the beginning to the end of each period. For example, in MATOPIBA, at the beginning of the 3rd period, there were 4,321,218 hectares (soy area in crop year 2019/20), of which 3,726,832 hectares had soy at the end of this period (2022/23), indicating that 594,386 hectares that had soy in crop year 2019/20 no longer grew soy in 2022/23 (equivalent to the retraction indicated in the grey bar for MATOPIBA in Figure 17).

Alternatively, Figure 15 shows the soy expansion without and with deforestation considering only the soy expansion in each period, unlike Figure 14 which also considers the area that remains planted with soy. Given the significant soy expansion from the second to the third period, it should be noted that the percentage of expansion with deforestation has not changed significantly, but its absolute value has doubled, going from 150,000 hectares to 301,000 hectares in the Cerrado Biome, as already shown in Figure 14. Certainly, the "appetite" for conversion of native vegetation into soy was whetted by the commodity's favourable price and by the depleted stocks of deforested land with agricultural suitability, particularly in the MATOPIBA region, countering the market's desire to eliminate deforestation from the soy production chain.

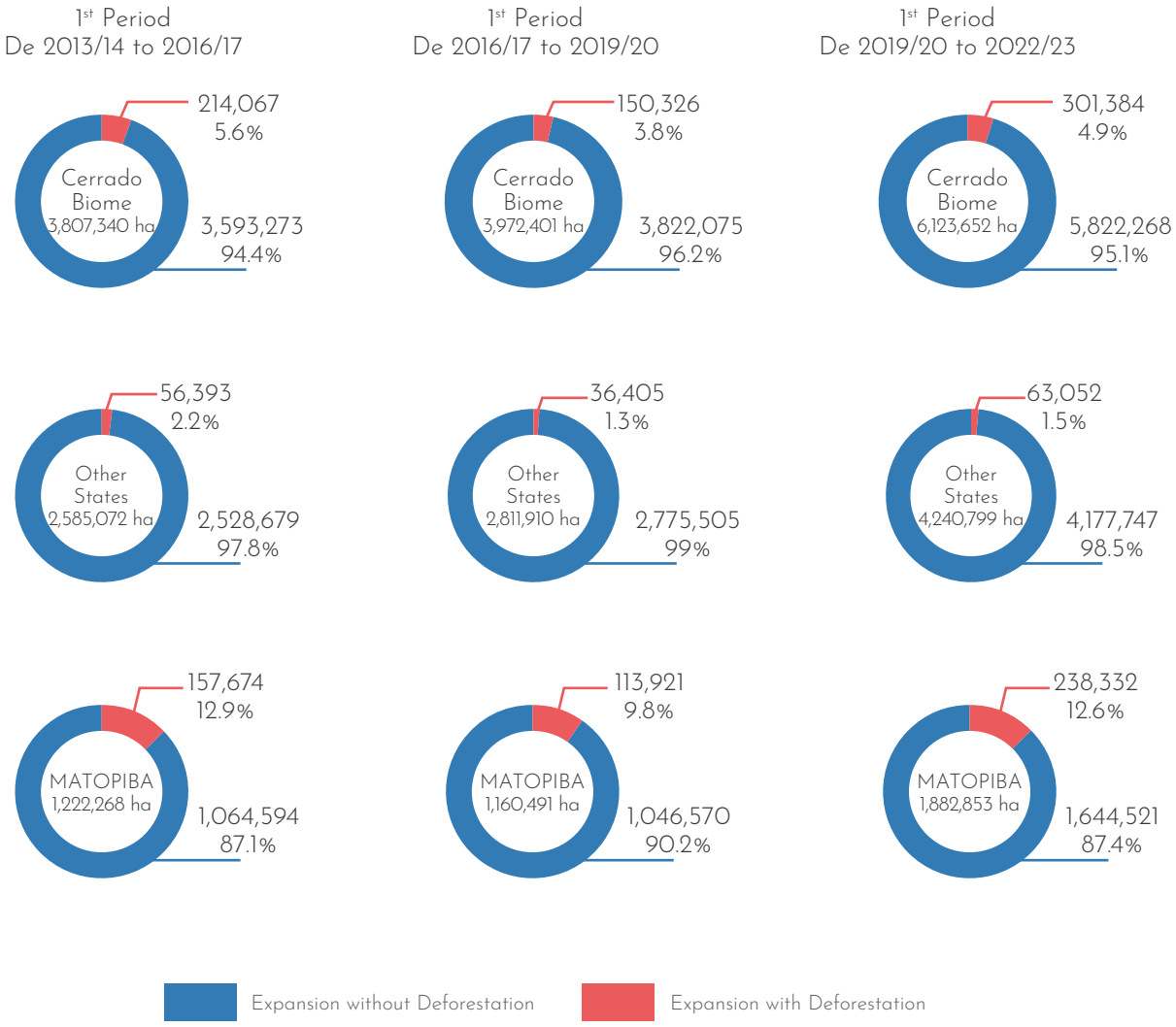


Figure 15. Soy expansion without and with deforestation in the Cerrado Biome, in Other States and in MATOPIBA in the following periods: First Period from 2013/14 to 2016/17; Second Period from 2016/17 to 2019/20; and Third Period from 2019/20 to 2022/23.

While Figure 15 shows the soy expansion without and with deforestation in each of the three analysed periods, Figure 16 shows a breakdown of the conversion of native vegetation into soy by state, considering only the third period which was the period with most conversion. It should be noted that, in the Other States region, most of the deforestation was in the states of Goiás (264,000 hectares), Mato Grosso (232,000 hectares) and Minas Gerais (223,000 hectares), with 17,000 hectares, 15,000 hectares and 11,000 hectares, respectively, converted into soy. In the MATOPIBA region, most of the deforestation was in Maranhão state (701,000 hectares), followed by the states of Tocantins (542,000 hectares), Bahia (312,000 hectares) and Piauí (265,000 hectares). Maranhão state also had the largest conversion to soy with 101,000 hectares, followed by the states of Bahia with 71,000 hectares, Tocantins with 38,000 hectares and Piauí with 28,000 hectares. The MATOPIBA states accounted for 79% of the conversion of native vegetation into soy in the Cerrado Biome during the analysed period. Furthermore, from 2020 to 2022, this region accounted for 67% of the deforestation in the Cerrado, although it represents just 36% of the Biome's area.

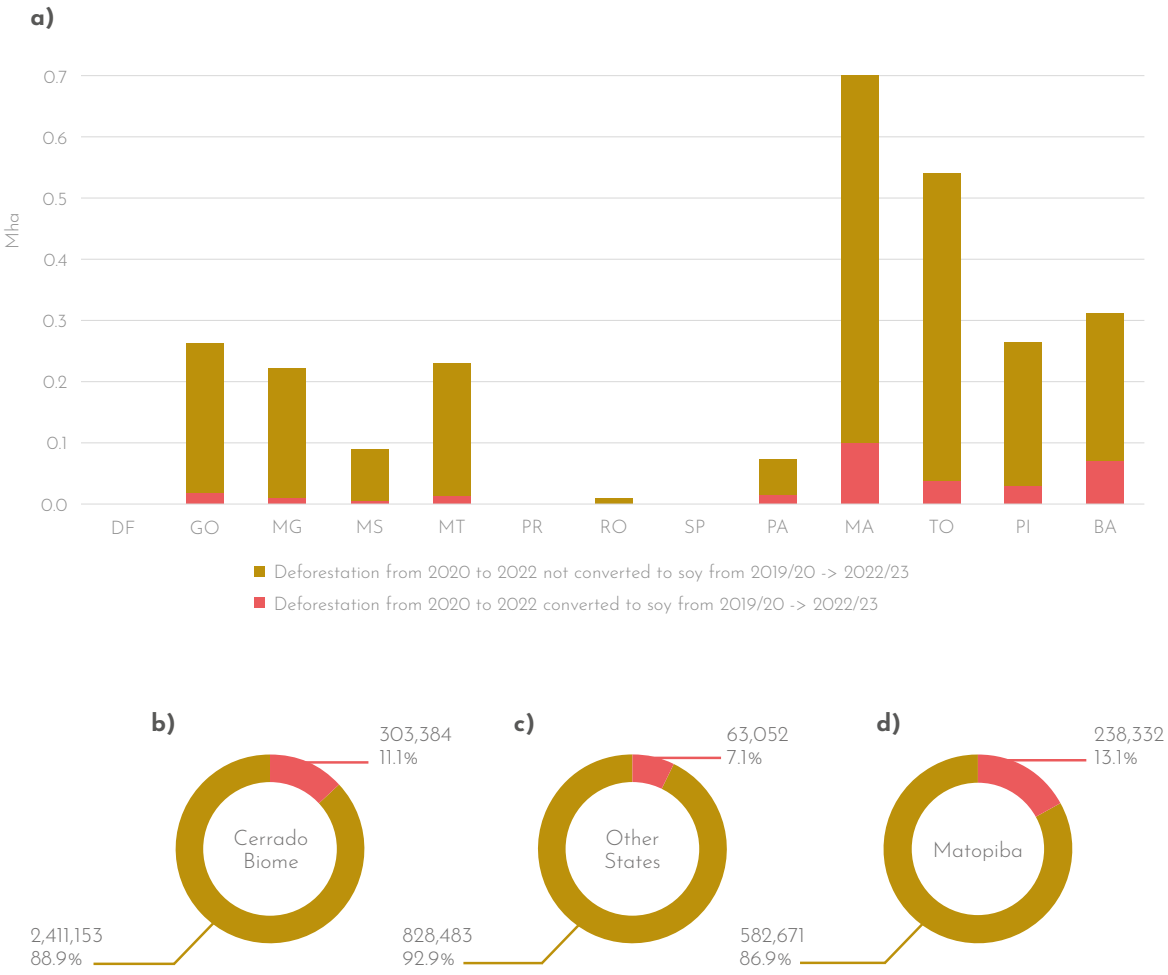


Figure 16. Deforested area from 2020 to 2022, converted into soy in crop years from 2019/20 to 2022/23, for (a) states in that part that falls within the Cerrado Biome; (b) Cerrado Biome; (c) Other States; and (d) MATOPIBA..

3.2 SOY EXPANSION WITH DEFORESTATION, BASED ON GFC MAPS

This item provides an analysis of the soy expansion with deforestation in the Forest and Non-Forest categories, as defined by FAO (2001). Using these categories, data from Global Forest Change (GFC) enabled the determination of the tree cover percentages for the Forest category (≥ 10% cover) and Non-Forest category (< 10% cover), based on the map called "Tree canopy cover for year 2010" (treecover 2010), which refers to the tree cover for the year 2010. The updating of this map for the year 2013, as well as obtaining the annual loss of tree cover between 2014 and 2022, were based on the GFC map called "Year of gross forest cover loss event" (loss year).

While Figure 15 shows the expansion of soy onto deforested areas mapped by PRODES, Figure 17 shows the expansion of soy onto land cleared of native vegetation in forest formations (≥ 10% tree cover) and non-forest formations (<10% tree cover). It should be noted that soy expansion onto PRODES deforestation is always greater than onto GFC deforestation because the PRODES map has a greater presence of native vegetation, which consequently results in a larger soy expansion onto deforested land. Another important aspect seen in Figure 17 is that the area of soy expansion onto forest formations is almost always greater than the expansion onto non-forest formations, which is partly due to the greater availability of areas suitable for soy crops in forest formations.

15. FAO (2001) defines forest as an area with a canopy cover equal to or more than 10%, an area greater than 0.5 hectares and trees over five metres tall. FAO, 2001. Global Forest Resources Assessment 2001. Rome, Italy. Available on: https://www.fao.org/3/ad652e/ad652e00.htm,
16. Global Forest Watch. 2023. Available on: https://www.globalforestwatch.org/.

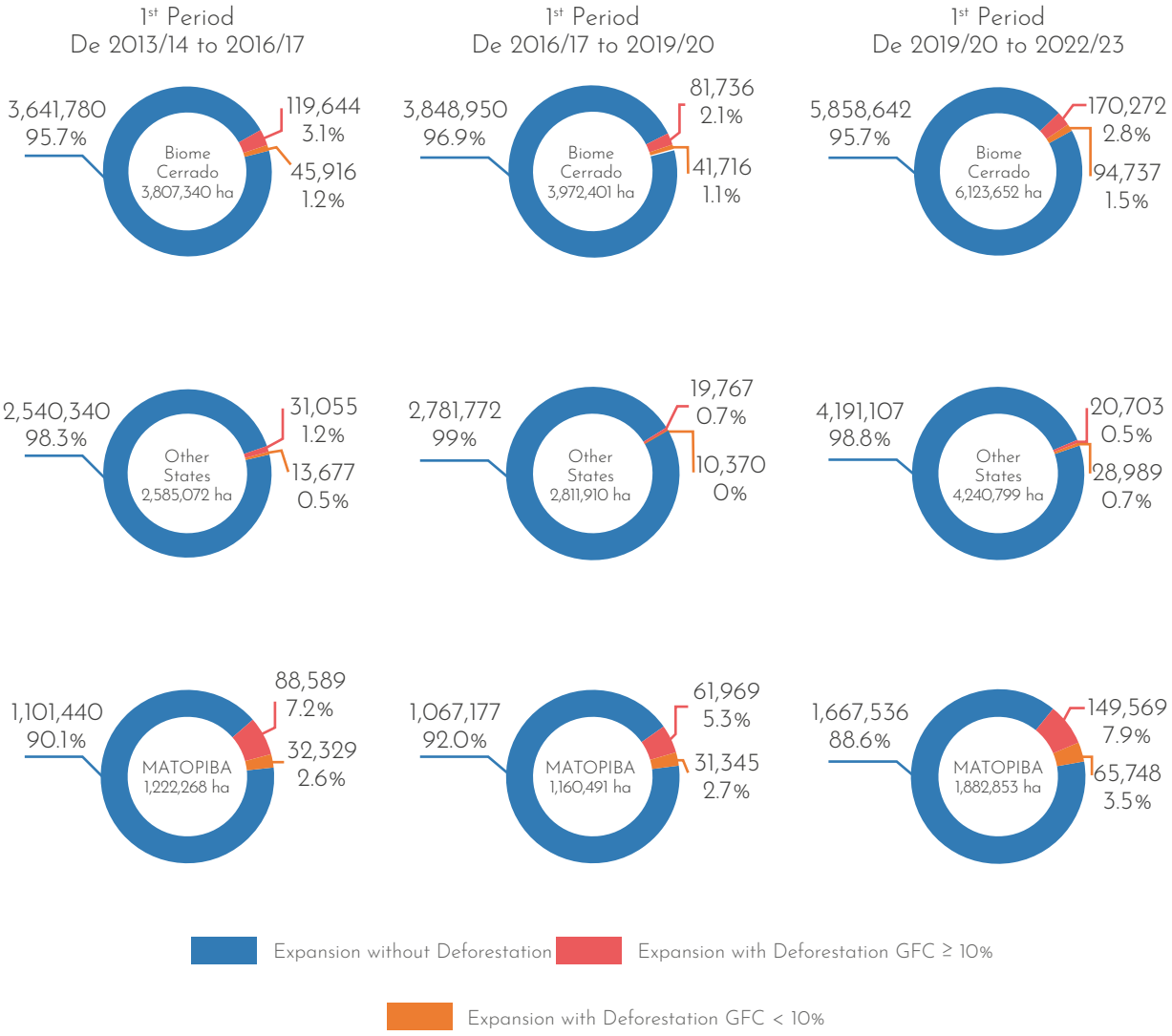


Figure 17. Soy expansion without deforestation and with deforestation for the Forest (GFC ≥ 10%) and Non-Forest (GFC < 10%) categories in the Cerrado Biome, in Other States and in MATOPIBA in the following periods: 1st Period from 2013/14 to 2016/17; 2nd Period from 2016/17 to 2019/20, and 3rd Period from 2019/20 to 2022/23.

3.3 LAND USE AND LAND COVER CHANGES

Figure 18 shows the dynamics of land use and land cover changes in the process of soy expansion and retraction, both in Other States and in MATOPIBA, for the same periods analysed in the previous item: First Period from 2013/14 to 2016/17; Second Period from 2016/17 a 2019/20; and Third Period from 2019/20 to 2022/23.

Once again, the third period stands out when compared to the two prior periods by showing not only the biggest expansion with and without deforestation, but also the smallest retractions in both regions, so that the average annual growth rate was 1.457 million hectares, very much higher than the average annual rates seen in the first period (494,000 hectares) and the second period (590,000 hectares).

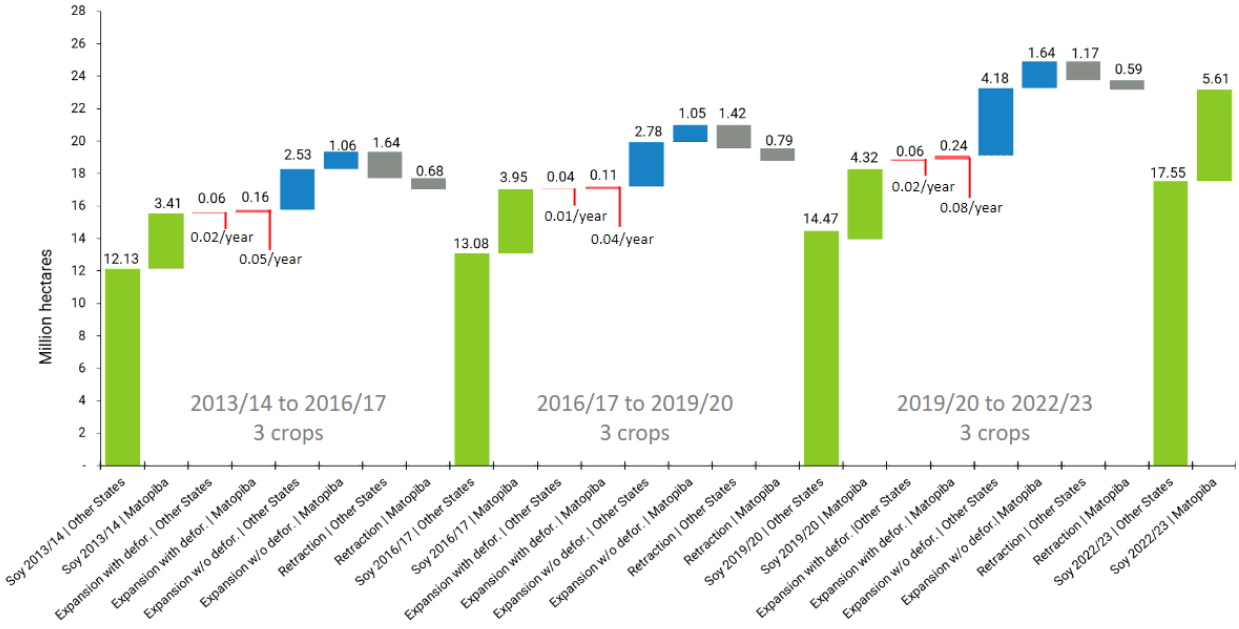


Figure 18. Land use and land cover changes involved in the process of soy expansion and retraction in Other States and in MATOPIBA in the following periods: First Period from 2013/14 to 2016/17; Second period from 2016/17 to 2019/20; and Third Period from 2019/20 to 2022/23. Below the expansion bars with deforestation (orange) is the annual rate of native vegetation conversion to soy.

3.4 DETAILS OF THE DYNAMICS OF EXPANSION AND RETRACTION

Figures 19 and 20 show cut-outs of two distinct areas in terms of the Cerrado Biome's soy expansion dynamics, in order to illustrate the spatial distribution of the soy crops and their expansion with and without deforestation, in addition to those that suffered retraction in the period from 2013/14 to 2022/23[17]. In these Figures, soy expansion without deforestation onto pastures, fallow land and other uses is shown in blue without hatching, and in blue with hatching when the soy expansion is onto fields of corn, first-crop cotton or sugarcane. Soy areas that retracted are shown in grey without hatching when switched to fallow land or other uses, and grey with hatching when they rotated with corn, first-crop cotton or sugarcane.

From 2013/14 to 2022/23, the soy area expanded by 7.61 million hectares, though a much larger area was impacted in this period as a result of the soy production dynamics, in which some of the crops rotated with other agricultural crops (corn, first-crop cotton and sugarcane renewal) or were left fallow. In the same way, areas formerly used for corn, first-crop cotton or sugarcane or that were left fallow could have reverted to soy. Soy expansion dynamics therefore consist of incorporating into the production system areas coming from conversion of native vegetation or from intensification of land use through conversion of pastures, as well as the agricultural management practice of rotating crops or fallow land.

17. In order to quantify the soy expansion-retraction dynamics, satellite images were used to assess the soy area in crop year 2022/23 which has expanded without deforestation since 2013/14, separating them into: (a) agricultural crops (corn, first-crop cotton and sugarcane); (b) fallow and other uses; and (c) pastures (Áreas de Pastagens do Brasil, 2014, based on LAPIG/MapBiomas). Also based on satellite images, the soy area in crop year 2013/14 that has retracted due to crop rotation or that will not have soy in crop year 2022/23 (fallow land or other uses) was assessed.

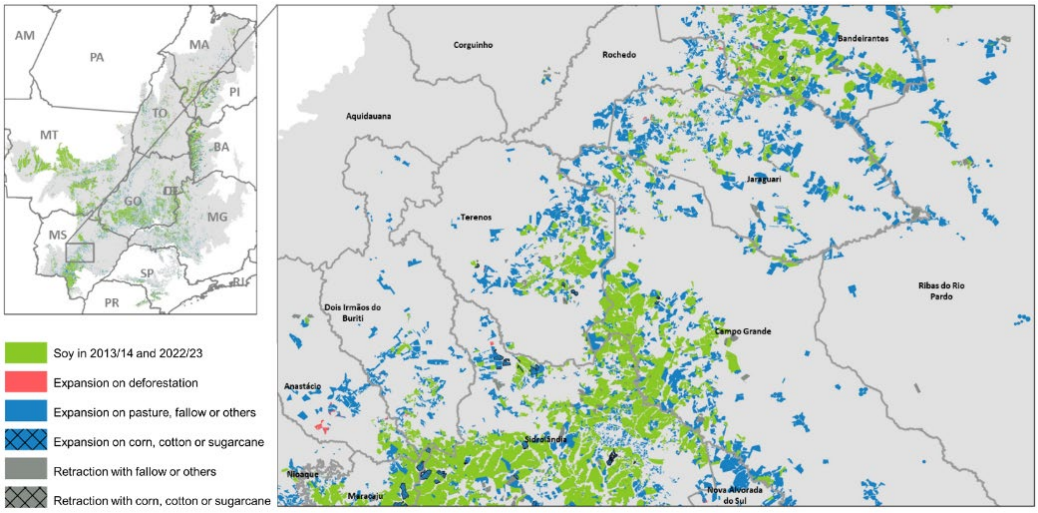


Figure 19. Dynamics of the soy area from 2013/14 to 2022/23 in the central region of Mato Grosso do Sul state, near the capital Campo Grande, which concentrates large tracts of pasture with high agricultural suitability for soy and which, in recent years, has been increasingly converted to soy. This had made Mato Grosso do Sul the Cerrado Biome state with the second largest area of soy expansion in this period (1.25 million hectares), losing only to Goiás (1.87 million hectares).

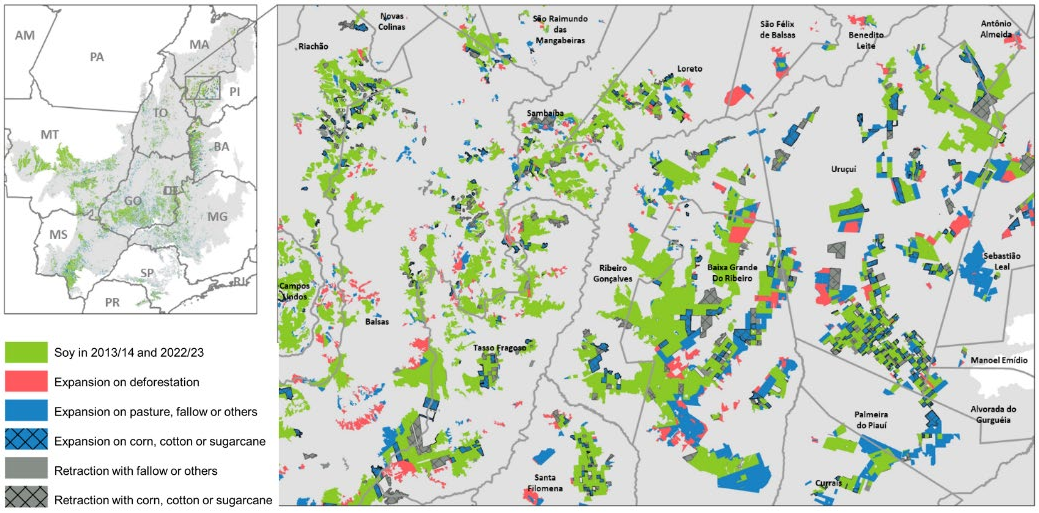


Figure 20. Dynamics of the soy area from 2013/14 to 2022/23 in the south of Maranhão state and in Piauí state. This region is located in the most recent Brazilian agricultural frontier, where expansion with deforestation is most present in the Cerrado Biome and where corn and first-crop cotton are also grown, rotating with soy.

The results of this detailed analysis are shown in Figure 21, illustrating the transitions in land use and land cover changes associated with the dynamics of soy in Other States and in MATOPIBA. In addition, Figures 22, 23 and 24 show the results of the analyses made for the first period from 2013/14 to 2016/17, for the second period from 2016/17 to 2019/20 and for the third period from 2019/20 to 2022/23, respectively.

Figure 21 also shows that, in the Other States region, 1.57 million hectares with soy in crop year 2013/14 suffered a retraction, going to fallow land (0.98 million hectares) or other crops (0.59 million hectares) in 2022/23. On the other hand, soy expanded onto 3.63 million hectares of pastures, 1.42 million hectares of other crops and 0.26 million hectares of native vegetation, which represents just 5% of the region's expansion with deforestation, where expansion onto pastures (68%) predominates. In the MATOPIBA region, the 0.92 million hectares of soy expansion onto native vegetation represented 42% of the expansion area, while the contribution of pastures was only 22% (Figure 21).

It should be noted that, in both regions, a significant part of the soy expansion was onto land that was fallow in crop year 2013/14. The expansion onto land that had had annual crops was partly due to soy rotating with first-crop corn – still very common, especially in some regions of Goiás and Minas Gerais states – or due to the renewal of sugarcane fields rotating with soy or even being replaced by soy crops, which have greater profitability (Canasat/Agrosatélite Project). Another point regarding crop rotation is the replacement in recent years of first-crop cotton with soy in a large part of Mato Grosso state, since the practice of growing second-crop cotton has been increasing in this state.

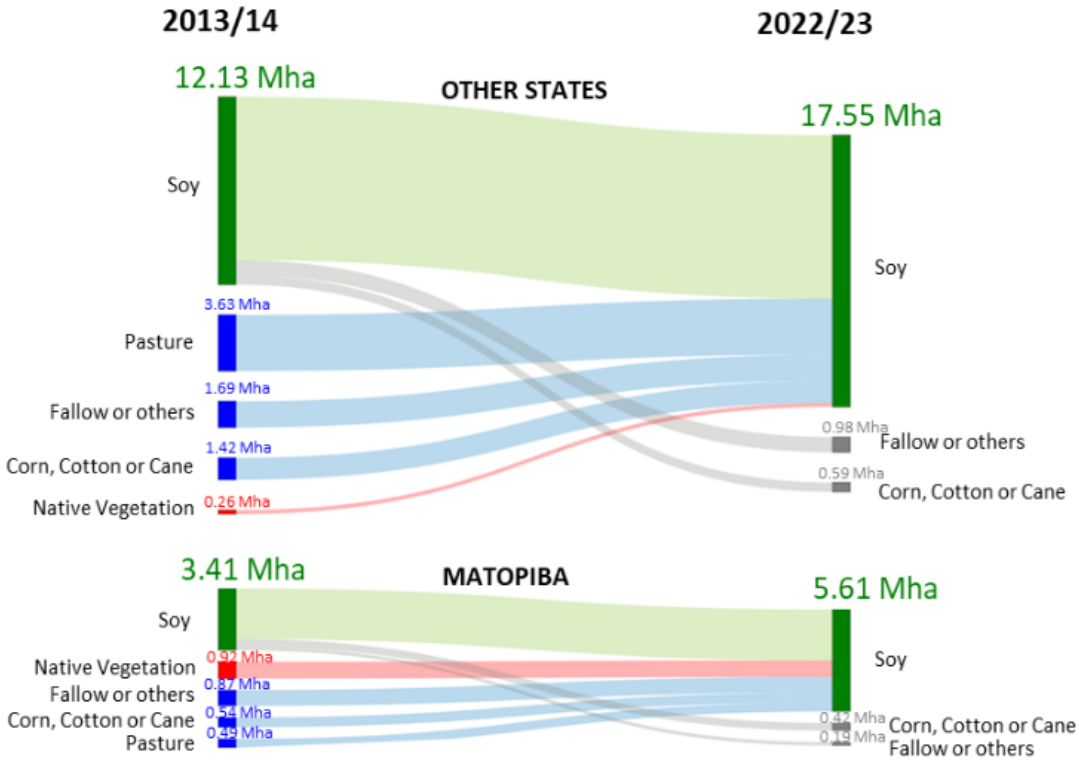


Figure 21. Sankey diagram illustrating the dynamics involved in the land use and land cover changes related to soy expansion and retraction from crop year 2013/14 to crop year 2022/23 in Other States and in MATOPIBA.

18. Project described and commented on https://agrosatelite.com.br/cases/#canasat.

The results of the analyses in land use and land cover changes associated with the transitions involved in the expansion and retraction process of soy crops in each of the three periods (Figures 22, 23 and 24) draw attention to the increased contribution of pastures to soy expansion in Other States in the third period (Figure 24). This more than doubled when compared to the first two periods (Figures 22 and 23), emphasising the importance of intensifying land use to free areas with agricultural suitability for expansion of deforestation-free soy crops. Although in much smaller proportions, native vegetation conversion to soy is still a reality that was intensified in the last period, particularly in MATOPIBA where expansion onto native vegetation went from 0.11 million hectares to 0.24 million hectares from the second period (Figure 23) to the third period (Figure 24).

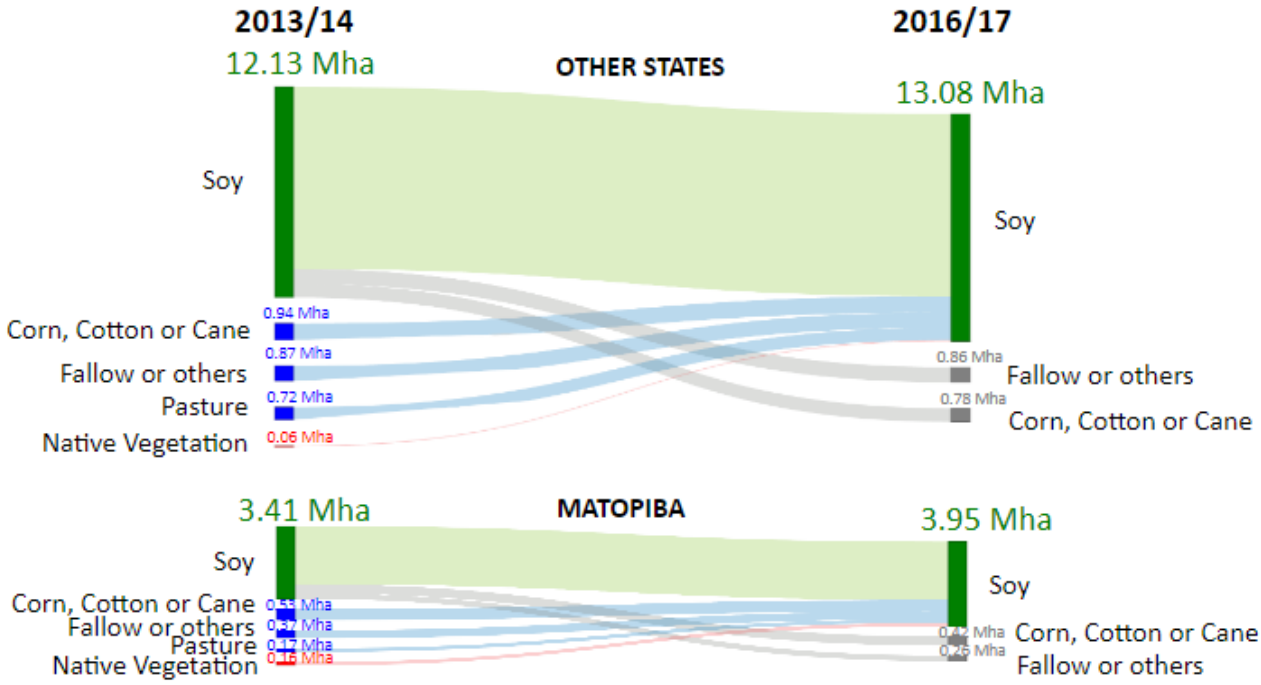


Figure 22. Sankey diagram illustrating the dynamics involved in the land use and land cover changes as they relate to soy expansion and retraction from crop year 2013/14 to crop year 2016/17 in Other States and in MATOPIBA.

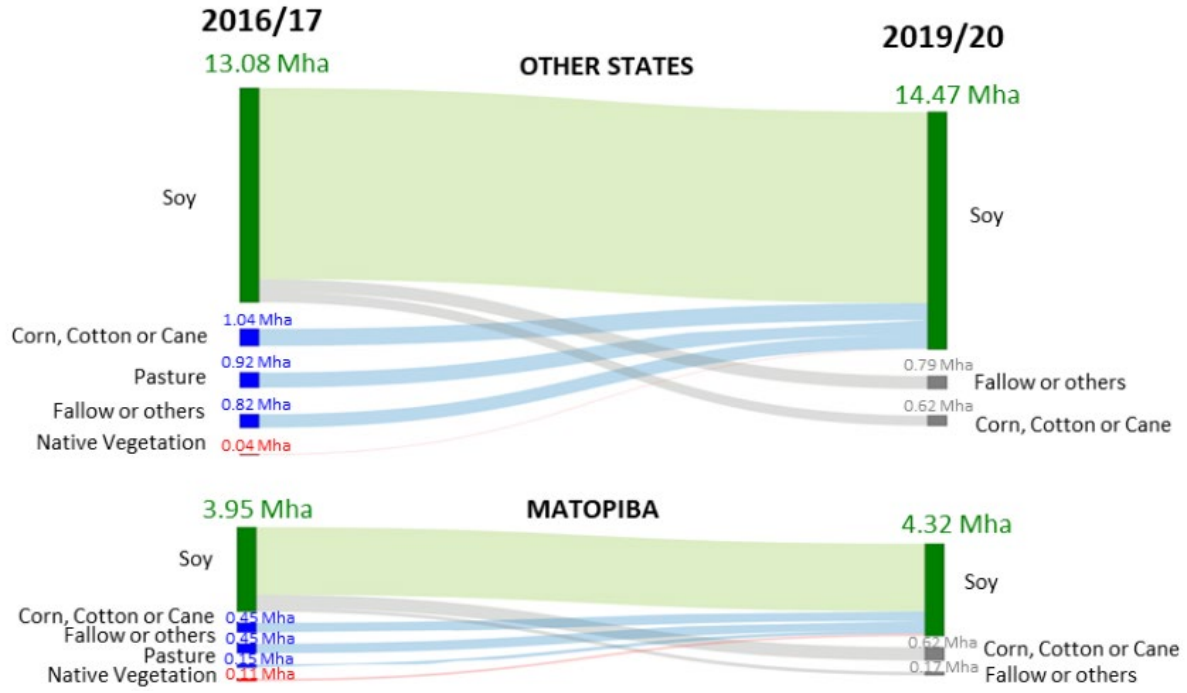


Figure 23. Sankey diagram illustrating the dynamics involved in the land use and land cover changes as they relate to soy expansion and retraction from crop year 2016/17 to crop year 2019/20 in Other States and in MATOPIBA.

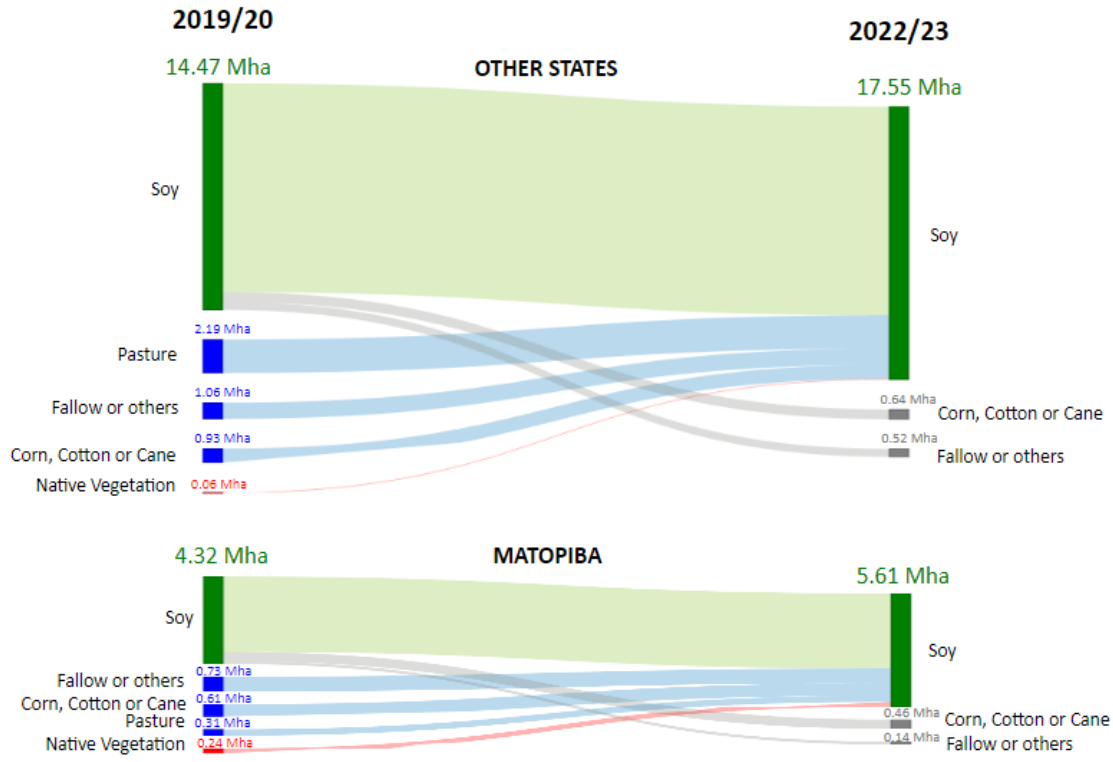


Figure 24. Sankey diagram illustrating the dynamics involved in the land use and land cover changes as they relate to soy expansion and retraction from crop year 2019/20 to crop year 2022/23 in Other States and in MATOPIBA.

4. FINAL CONSIDERATIONS

The Cerrado Biome covers an area of 198.45 million hectares, of which 23.15 million hectares was with soy in crop year 2022/23, representing 11.7% of the Biome and 50.1% of Brazil's total soy area. Over the last nine crop years, the soy area in the Cerrado Biome has grown 49%, expanding onto 7.61 million hectares, at an average rate of 848,000 hectares per year. However, in the last three years alone, soy expanded onto 4.36 million hectares, raising the average annual rate to 1.457 million hectares, the majority of which (95.1%) was onto pastures, fallow land or due to annual crop rotation. Just 4.9% of the expansion occurred with conversion of native vegetation.

In the analysis broken down into the three selected periods, there was a reduction in the conversion of native vegetation to soy, from 214,000 hectares in the first period to 150,000 hectares in the second period. However, the soy footprint in deforestation increased in the third period, reaching 301,000 hectares, or 100,000 hectares annually in post-2017 deforestation. The soy area in post-2017 deforestation represents 0.4% of the soy area in Other States and 4.2% of the soy area in MATOPIBA.

The land use and land cover changes associated with soy expansion differ significantly between the MATOPIBA region and the Other States region, particularly as they relate to the conversion of native vegetation, since the stocks of cleared land suitable for growing soy are restricted in these regions, especially in the states of Maranhão, Piauí and Bahia, as detailed in the second part of this study.

The geospatial analysis using remote sensing satellite images made it possible to carry out a broad assessment of the soy expansion dynamics in the Cerrado Biome, confirming the significant increase in recent rates of soy area expansion, in addition to characterising the land use change transitions that take part in the expansion process of agricultural areas linked to the soy sector.

PART II

AVAILABILITY OF AREAS WITH AGRICULTURAL SUITABILITY

1. INTRODUCTION

The second part of this study consists of updating the land use and land cover map from 2018 to 2022, in order to identify the anthropized areas and the areas covered with native vegetation that are suitable for soy expansion, taking into consideration the main designations of the rural territory of the Cerrado Biome.

In 2019, Agrosatélite[19], supported by ABIOVE, carried out a study of the stocks of land suitable for soy cultivation in the Cerrado Biome, based on maps available in 2018. Since then, there have been significant changes in the Biome that justify this updating, including the new, and improved boundaries of the Biome, released by IBGE[20] in 2019. This alteration reduced the Cerrado Biome's area by 2.7% (5.55 million hectares), going from 204.01 million hectares to 198.46 million hectares. However, the area impacted was much larger – 20.06 million hectares ceased to be part of the Biome, while another 14.51 million hectares were incorporated into the Biome. Other changes in the Cerrado Biome that should be highlighted are: (1) growth of 5.01 million hectares (27.6%) in the soy area from crop year 2018/19 to crop year 2022/23; (2) loss of 3.34 million hectares of native vegetation through deforestation in the last four years; and (3) increase of 29.1% in the number of farms registered with the Rural Environmental Registry (CAR) between 2019 (918,957 properties) and 2023 (1,186,618 properties), which had an impact on the increase in Areas of Permanent Preservation (APP) and Legal Reserves in the farms now registered with CAR.

2. MATERIAL AND METHODS

The land use and land cover map available on Agrosatélite was updated for the year 2022, taking into consideration the new Cerrado Biome boundaries, the PRODES annual deforestation maps, the maps showing pastures and water bodies from MapBiomas Collection 8, Agrosatélite's mapping of soy, corn, cotton and sugarcane in crop year 2022/23, and the updated databases of CAR and Special Areas[19].

The agricultural suitability of the territory incorporated into the new Cerrado Biome boundaries was calculated from maps available on Agrosatélite, obtained through a methodology similar to that found in the report: Geospatial Analysis of Soy in the Cerrado Biome: Dynamics of Expansion | Agricultural Suitability for Soy | System for Assessing Financial Compensation: 2001 to 2019[19].

In summary, the modelling of agricultural suitability considered the edaphoclimatic characteristics following the methodology of Agricultural Climate Risk Zoning (ZARC) (ASSAD et al., 2008), that annually recommends whether or not specific soy cultivars should be planted in each Brazilian municipality. Agrosatélite carried out this modelling to assess the edaphoclimatic suitability for soy at the landscape level, making it possible to identify the degree of variability within the same municipality. In addition to the aspects related to soil and climate, the modelling included, in its definition of agricultural suitability for soy, the concept of restrictions related to slope, which limits mechanised agriculture, and to altitude, which enables the regional identification of areas with a greater or lesser suitability for soy cultivation.

Based on both the map of land use and land cover, and on the map of agricultural suitability, it was possible to determine the native vegetation and anthropized categories, with and without agricultural suitability, for the main designations of interest in the rural territory of the Cerrado Biome.

3. RESULTS OF AGRICULTURAL SUITABILITY FOR SOY IN THE ANTHROPIC AND NATIVE VEGETATION CATEGORIES

The main results of the assessment of land stocks, with and without agricultural suitability for soy in the Cerrado Biome, in Other States and in MATOPIBA, for areas that were anthropized by 2022 and for areas covered with native vegetation, are shown in Figures 25 to 28 and in Table 4. In addition to the areas with and without agricultural

19. Agrosatélite Geotecnologia Aplicada Ltda. Geospatial Analysis of Soy Crop in the Cerrado Biome: Expansion Dynamic | Agricultural Suitability | Evaluation System for Financial Compensation - 2001 to 2019. - Florianópolis, 2020. 60 p. ISBN: 978-65-991465-1-0. Available on: https://agrosatelite.com.br/static/img/cases/pdf/en/relatorio_ccm_us.pdf or https://psacerrado.com.br/landing/media/report/45d4fd3cfd92fb1a5dbe0df0da265b908e716f85.pdf.
20. The boundaries of the Cerrado Biome used in this study are those adopted by IBGE in 2019, on a scale of 1:250,000, available on: https://www.ibge.gov.br/geociencias/cartas-e-mapas/informacoes-ambientais/15842-biomas.html?edicao=25799&t=acesso-ao-produto.
21. ASSAD, E. D.; MARIN, F. R.; PINTO, H. S.; ZULLO JR, J. Zoneamento Agrícola de Riscos Climáticos do Brasil: Base Teórica, Pesquisa e Desenvolvimento. Informe Agropecuário (Belo Horizonte), v. 29, pg. 47-60, 2008.

suitability, also shown are the areas that cannot be legally converted into other uses, such as Indigenous Lands, Conservation Units with Full Protection, Quilombola Communities, Areas of Permanent Preservation and Legal Reserves.

Areas of native vegetation on land with agricultural suitability for soy were assessed in rural properties with soy in crop year 2022/23, as well as in other properties. In anthropized areas with suitable land, other than those already growing soy, the areas with pastures were identified as the main source of land for soy expansion without deforestation. Figure 25 shows that the Cerrado Biome has 102.52 million hectares of native vegetation (51.7%), 94.59 million hectares of anthropized areas (47.7%) and a water bodies surface area of 1.34 million hectares (0.7%).

In the Cerrado portion covered with native vegetation, there are 19.45 million hectares of surplus native vegetation with agricultural suitability for soy, of which 4.55 million hectares are in farms registered with CAR that cultivated soy in crop year 2022/23. The surplus native vegetation in the remaining properties (14.90 million hectares) is slightly overestimated because it includes part of the properties not yet registered with CAR, in which the Areas of Permanent Preservation and Legal Reserves are unknown, therefore could not be discounted. In the anthropized areas, in addition to the 23.15 million hectares with soy, there are 40.37 million hectares with agricultural suitability, of which 20.96 million hectares are pastures and 19.41 million hectares are with other uses, such as sugarcane, cotton, fallow land, etc. The details are shown in Table 4, by state.

In similar manner, Figure 26 shows the information related to the Other States region, which has 54.16 million hectares of native vegetation (42.4%), 72.79 million hectares of anthropized land (56.9%) and 0.87 million hectares with water bodies (0.7%). In the area with native vegetation, there are 10.56 million hectares of native vegetation surplus with agricultural suitability for soy, of which 2.43 million hectares are in farms with soy in crop year 2022/23. In the anthropized portion, there are 17.54 million hectares with soy and 32.94 million hectares with suitability for soy, of which 18.24 million hectares are pastures and 14.70 million hectares are with other uses such as sugarcane, cotton, fallow land, etc.

Figure 27 shows the results for the MATOPIBA region, which has 48.36 million hectares of native vegetation (68.5%), 21.80 million hectares of anthropized land (30.9%) and 0.47 million hectares with water bodies (0.7%). In the area with native vegetation, there are 8.89 million hectares of native vegetation surplus with agricultural suitability for soy, of which 2.12 million hectares are in farms with soy in crop year 2022/23. In the anthropized area, there are 5.61 million hectares with soy, in addition to 7.43 million hectares with agricultural suitability for soy, of which 2.71 million hectares are pastures and 4.72 million hectares are mainly fallow land, cotton and corn. Of the 2.71 million hectares of pastures, 2.25 million hectares (83.2%) are located in the state of Tocantins and 0.35 million hectares (13.8%) are in Maranhão state, with 72,300 hectares (2.7%) in Bahia state and 8,000 hectares (0.3%) in Piauí state (Table 4), showing the scarcity of anthropic areas with suitability for soy compared to the 8.89 million hectares of suitable areas in the native vegetation areas found in the states of Tocantins (3.62 million hectares), Maranhão (2.85 million hectares), Bahia (1.49 million hectares) and Piauí (0.93 million hectares) (Table 4).

The most obvious difference between these two regions is in the percentage of the anthropized area – 57% in Other States and 31% in MATOPIBA. The lower degree of anthropization in MATOPIBA, considered to be the last agricultural frontier, means that the area of pastures with suitability for soy was 6.7 times smaller than that in the consolidated region of Other States. As a consequence, direct conversion of native vegetation to soy is much more evident in MATOPIBA, the agricultural frontier region. For this reason, the increase in the Cerrado Biome's deforestation rates, especially in the last three years, is due to increased deforestation in the MATOPIBA region (Figure 10).

Finally, Figure 28 shows an overall view of the land use and cover in the 114,599 rural properties with over ten hectares of soy in crop year 2022/23. These properties cover 28.9% of the Cerrado Biome, an area of 57.38 million hectares, and it should be noted that 33.7% (19.32 million hectares) of these properties is covered with native vegetation. However, the Areas of Permanent Preservation and Legal Reserves with native vegetation registered with CAR cover only 18.3% (10.48 million hectares), showing a deficit of native vegetation which, in part, is found in the 3.1% (1.77 million hectares) of anthropized land (Figure 28). On the other hand, there are 4.55 million hectares with surplus native vegetation that are suitable for soy. In terms of pastures with potential for conversion to soy, there is an area of 3.95 million hectares in these same properties. Considering that, over the last three crop years, the net expansion in the soy area was 4.36 million hectares, involving conversion of 2.80 million hectares of pastures (Figure 24), it is obvious that the 3.95 million hectares of pastures in soy-producing farms will run out in the near future, particularly in a scenario where soy expansion rates remain high. In other words, the largest opportunity for soy expansion is mostly found in the 17.01 million hectares of pastures that are in the properties of livestock farmers, not soy farmers.[22].

The anthropized area without agricultural suitability for soy is indirectly important for soy expansion because a great part of the 20.87 million hectares in these conditions are in properties presumably owned by livestock farmers. These areas could be used more intensively, thus freeing up enough areas with suitability to meet the demand for soy expansion in the Cerrado Biome, without impacting livestock farming to the point of causing new deforestation.

The long-term projection made in 2019 by the Ministry of Agriculture (MAPA)[23] indicated that, in the ten-year period from 2018/19 to 2028/29, the soy area in the Cerrado Biome would grow by between 4.5 million hectares and 5.0 million hectares. This study reveals that this projection has been virtually fulfilled with an expansion of 4.36 million hectares in just four crop years, showing the intention of farmers to expand soy area in the Biome. However, continued expansion could be frustrated by the depletion of suitable areas, particularly in a scenario that restricts opening up new areas through conversion of native vegetation.

22. Figure 25 shows that there are 20.96 million hectares of suitable pastures in the Cerrado Biome, while Figure 28 shows that 3.95 million hectares of these pastures are located in soy-producing farms. Therefore, the difference between total suitable pastures in the Biome and suitable pastures in soy-producing farms provides the area of pastures in the remaining properties that, presumably, are mostly in livestock farms.
23. Documents available on: https://www.gov.br/agricultura/pt-br/assuntos/politica-agricola/todas-publicacoes-de-politica-agricola/projecoes-do-agronegocio/projecoes-do-agronegocio-2018-2019-2028-2029/view.

Cerrado Biome

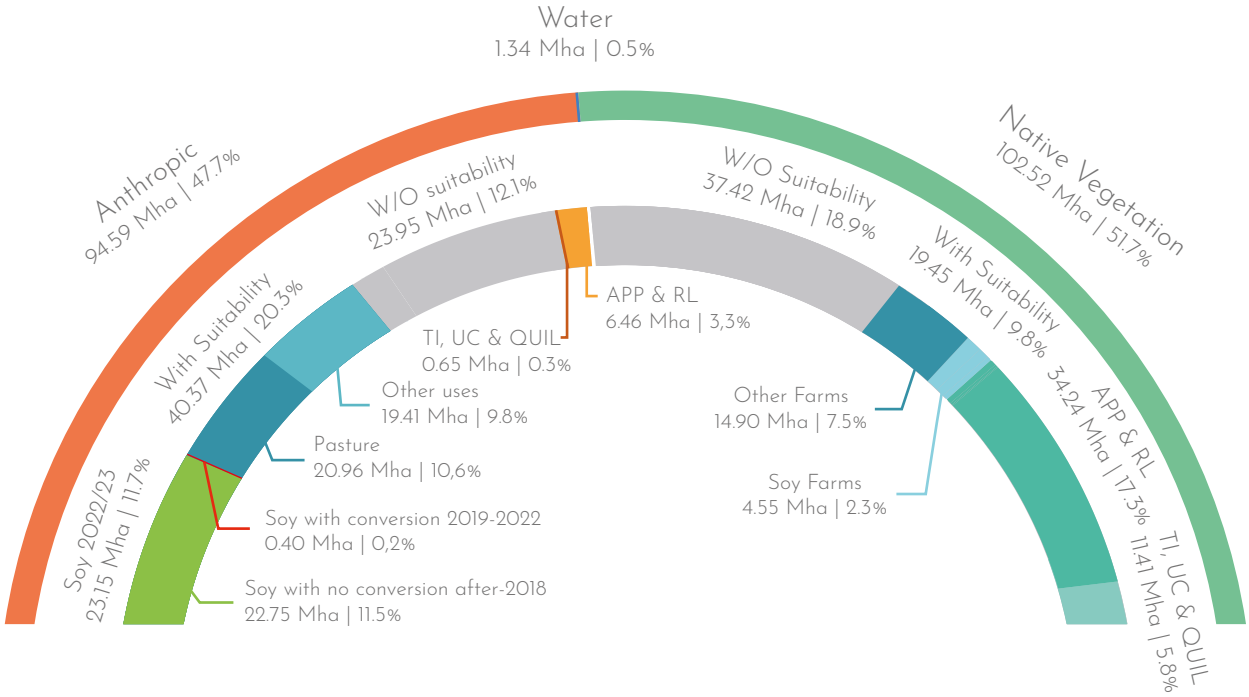


Figure 25. Representation of the Anthropic, Native Vegetation and Water Bodies categories for the Cerrado Biome. The second level breaks down the Anthropic and Native Vegetation categories into the groups "With Suitability" and "Without Suitability", showing the soy area in crop year 2022/23 and the Areas of Permanent Preservation (APP) and Legal Reserves (LR) registered with CAR, in addition to Indigenous Lands (TI), Conservation Units with Full Protection (UC) and Quilombola Communities (QUIL). In the Native Vegetation category "With Suitability", the areas in properties with soy and other properties are highlighted. In the Anthropic category "With Suitability", the areas with other uses and with pastures are highlighted. The break down by state is shown in Table 4.

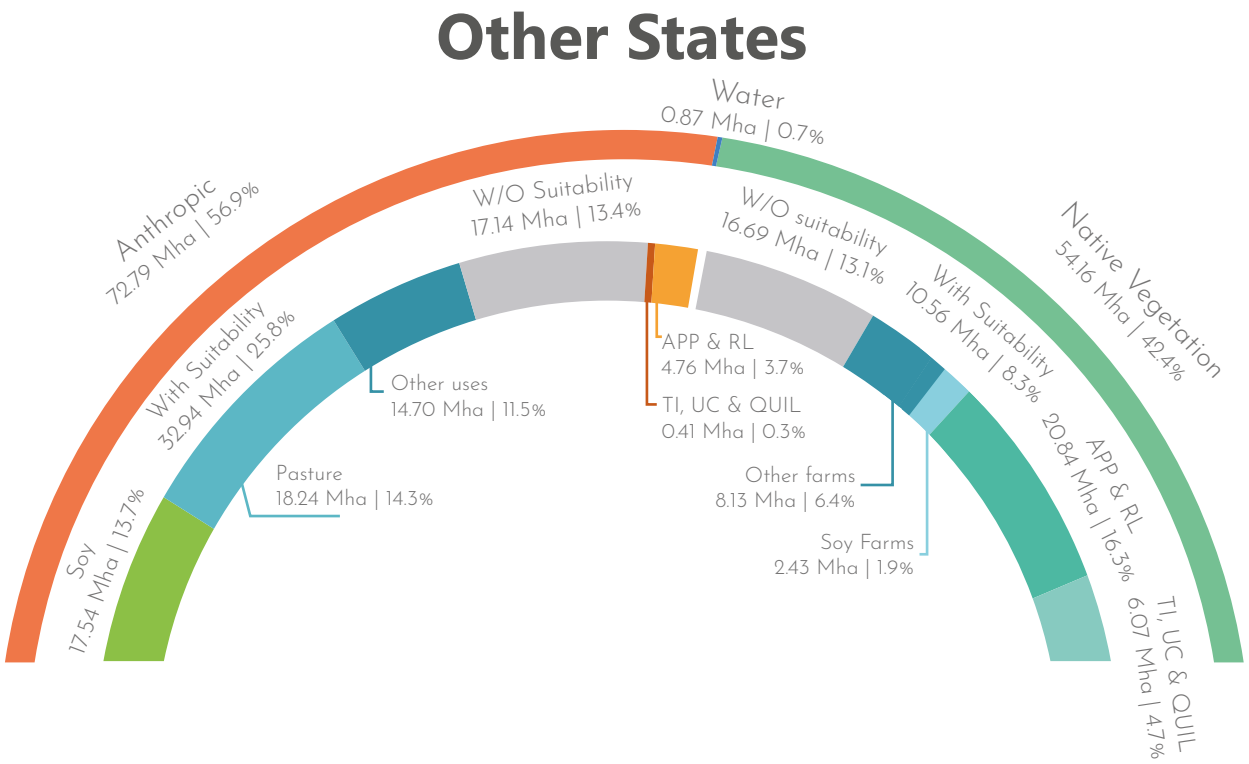


Figure 26. Representation of the Anthropic, Native Vegetation and Water Bodies categories for the Other States region. The second level breaks down the Anthropic and Native Vegetation categories into the groups "With Suitability" and "Without Suitability", showing the soy area in crop year 2022/23 and the Areas of Permanent Preservation (APP) and Legal Reserves (LR) registered with CAR, in addition to Indigenous Lands (TI), Conservation Units with Full Protection (UC) and Quilombola Communities (QUIL). In the Anthropic category "With Suitability", the areas with pastures and other uses are highlighted.

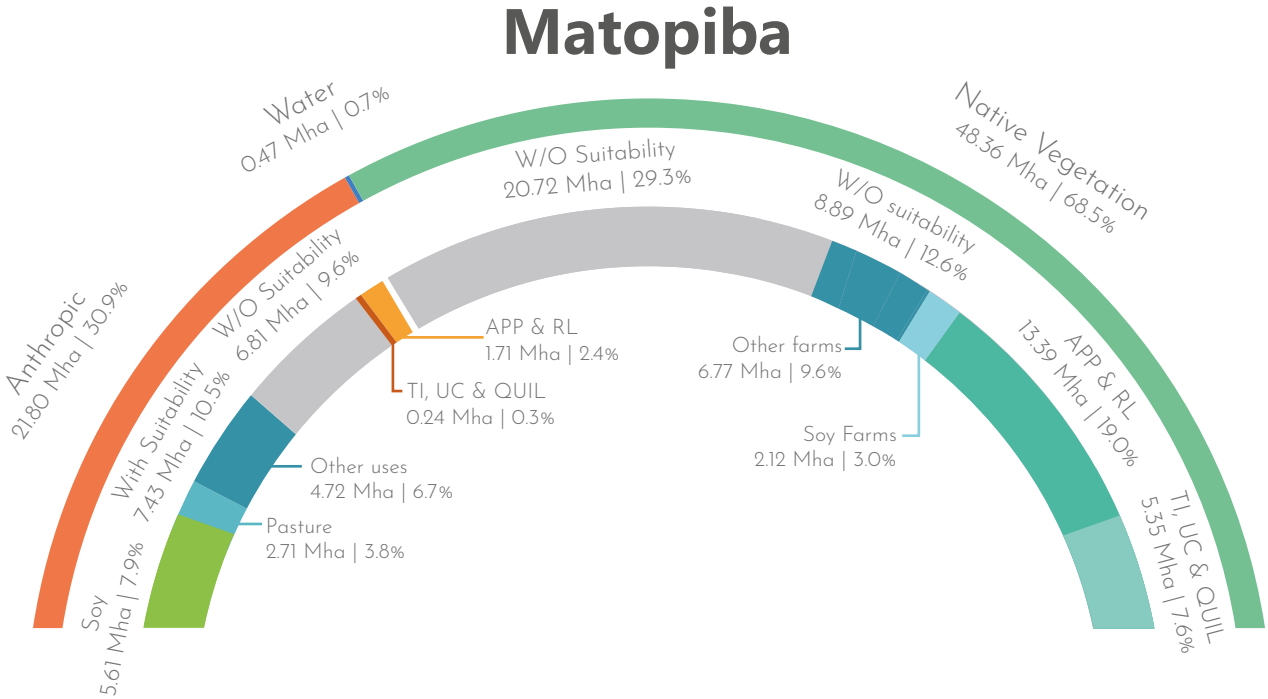


Figure 27. Representation of the Anthropic, Native Vegetation and Water Bodies categories for the MATOPIBA region. The second level breaks down the Anthropic and Native Vegetation categories into the groups "With Suitability" and "Without Suitability", showing the soy area in crop year 2022/23 and the Areas of Permanent Preservation (APP) and Legal Reserves (LR) registered with CAR, in addition to Indigenous Lands (TI), Conservation Units with Full Protection (UC) and Quilombola Communities (QUIL). In the Anthropic category "With Suitability", the areas with pastures and other uses are highlighted.

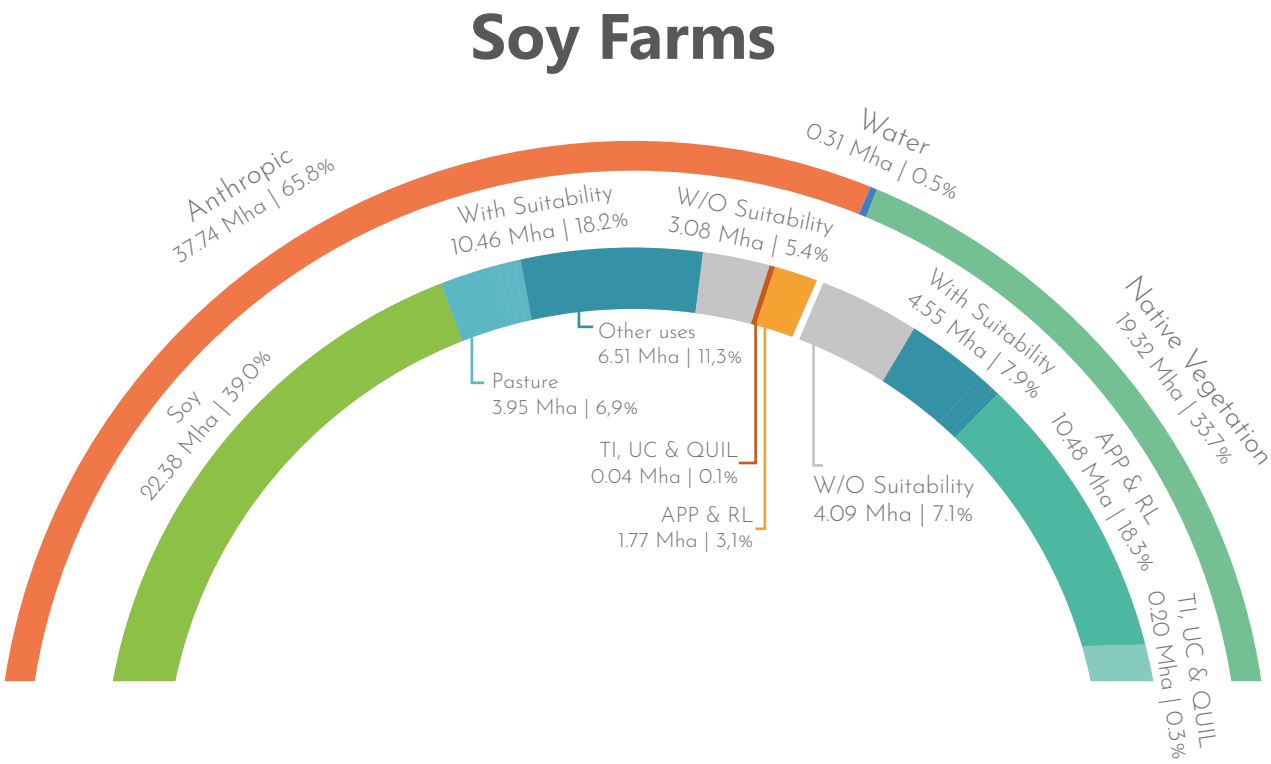


Figure 28. Representation of the Anthropic, Native Vegetation and Water Bodies categories for the soy-producing farms in the Cerrado Biome that are registered with CAR. The second level breaks down the Anthropic and Native Vegetation categories into the groups "With Suitability" and "Without Suitability", showing the soy area in crop year 2022/23 and the Areas of Permanent Preservation (APP) and Legal Reserves (LR) registered with CAR, in addition to the small areas of Indigenous Lands (TI), Conservation Units with Full Protection (UC) and Quilombola Communities (QUIL) that intersect with the analysed farms. In the Anthropic category "With Suitability", the areas with pastures and other uses are highlighted.

Figure 29 shows, spatially and graphically, the areas of native vegetation, pastures and other uses that are suitable for soy, in each state of the Cerrado Biome. The figures are taken from Table 4 and represent the land not located in the Special Areas (Indigenous Lands, Conservation Units with Full Protection and Quilombola Communities), but include settlements and Areas of Environmental Protection, where agricultural activity is allowed. It should be noted that, in the states of the MATOPIBA region (except Tocantins), there are few areas with suitable pastures. In Other States, however, anthropized areas with suitability are much larger, especially in the state of Goiás, Mato Grosso do Sul, Minas Gerais and Mato Grosso, which are highly representative of the Cerrado Biome.

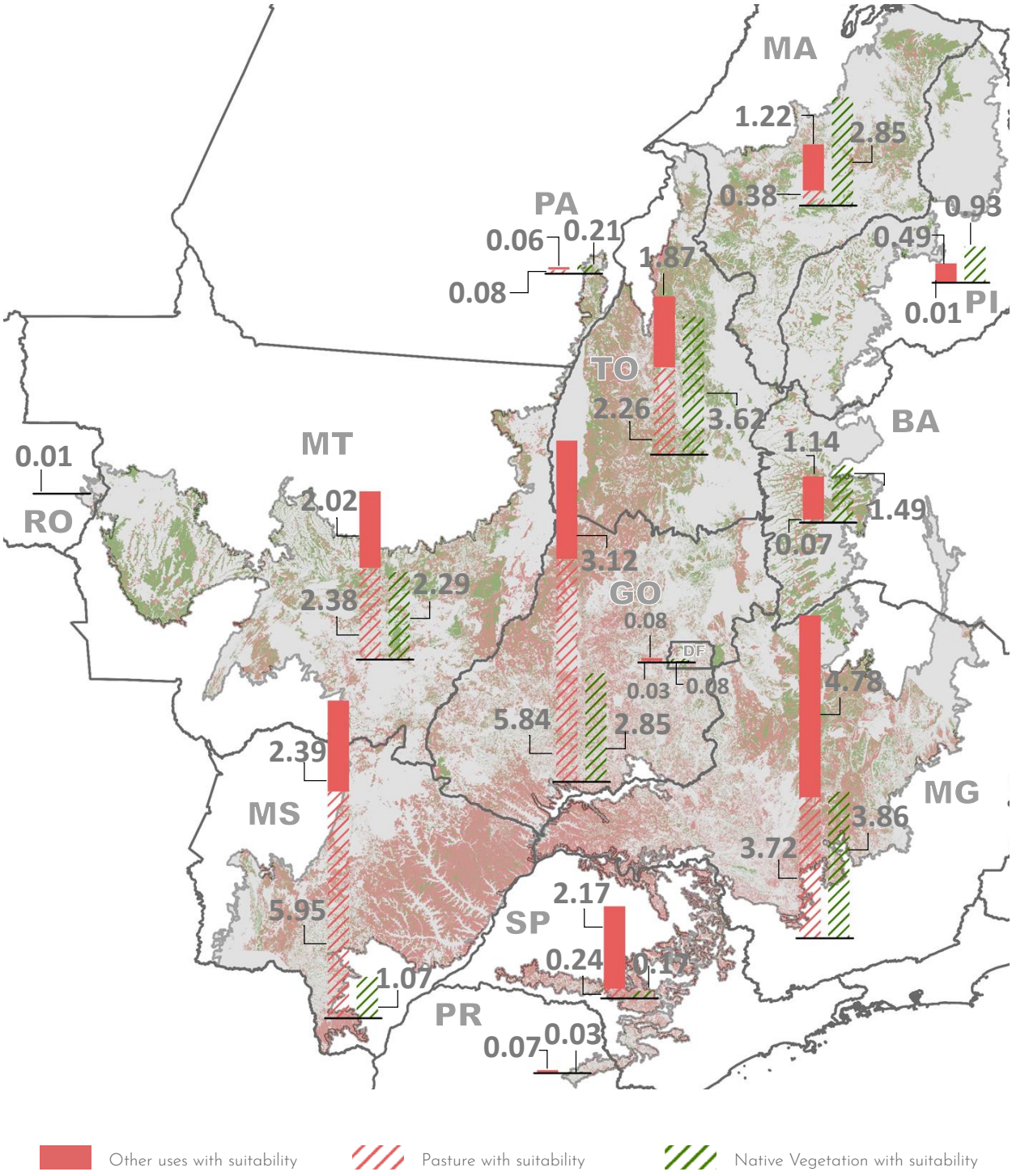


Figure 29. Areas of native vegetation (green), pastures (hatched) and other uses – except soy (red) – that are suitable for growing soy, by state.

		OTHER STATES							
	Class	DF	GO	MG	MS	MT	PA	PR	RO
NATIVE VEGETATION	With Suitability	82,512	2,845,339	3,862,494	1,066,726	2,289,225	212,204	25,623	2,902
	W/O Suitability	116,143	4,715,085	5,545,403	1,406,572	4,504,972	152,486	53,332	43,315
	APP & RL	5,030	4,666,941	4,635,928	3,206,380	7,812,482	139,888	14,733	38,418
	TI, QUI, UC_PI	23,990	484,536	600,427	316,076	4,505,071	19,778	3	98,074
	Subtotal Native Vegetation	**227,675**	**12,711,902**	**14,644,251**	**5,995,753**	**19,111,750**	**524,356**	**93,691**	**182,709**
ANTHROPIC	Soy 2022/23	102,860	5,390,252	2,318,198	2,929,638	6,045,772	62,947	90,567	24,632
	Pasture With Suitability	29,623	5,840,928	3,722,810	5.950.789	2.380.722	77,344	2,384	734
	Other Uses With Suitability	82,333	3,119,727	4,776,035	2,387,658	2,019,978	63,954	72,442	6,800
	Pasture and Other Uses W/O Suitability	126,241	4,589,190	4,391,545	4,075,600	3,119,117	92,675	45,931	40,521
	APP & RL	658	1,469,300	1,484,321	741,499	793,743	26,212	7,144	7,736
	TI, QUI, UC_PI	662	78,602	92,821	73,325	155,160	3,141	1	389
	Subtotal Anthropic	**342,377**	**20,488,000**	**16,785,729**	**16,158,508**	**14,514,491**	**326,273**	**218,469**	**80,812**
WATER BODIES		**6,026**	**270,373**	**283,971**	**68,367**	**147,263**	**20,365**	**247**	**31**
TOTAL		**576,078**	**33,470,274**	**31,713,951**	**22,222,628**	**33,773,504**	**870,995**	**312,407**	**263,551**

	OTHER STATES		MATOPIBA					Cerrado Biome
	SP	Subtotal	MA	TO	PI	BA	Subtotal	
NATIVE VEGETATION	172,375	10,559,399	2,851,289	3,622,249	931,778	1,485,487	8,890,804	19,450,203
	156,001	16,693,309	6,456,721	4,180,228	7,018,351	3,068,380	20,723,680	37,416,990
	320,997	20,840,797	3,755,709	5,666,231	2,396,140	1,576,665	13,394,745	34,235,541
	18,980	6,066,934	1,584,663	3,276,772	317,535	167,411	5,346,381	11,413,314
	668,352	**54,160,439**	**14,648,382**	**16,745,481**	**10,663,804**	**6,297,943**	**48,355,609**	**102,516,049**
ANTHROPIC	579,924	17,544,790	1,130,406	1,424,778	970,406	2,084,096	5,609,685	23,154,475
	239,322	18,244,656	375,530	2,255,956	8,040	72,291	2,711,817	20,956,473
	2,168,218	14,697,144	1,215,636	1,874,933	489,825	1,136,837	4,717,231	19,414,375
	657,850	17,138,669	3,489,177	1,715,445	944,556	661,841	6,811,018	23,949,687
	216,567	4,747,179	629,519	872,388	133,689	78,275	1,713,871	6,461,051
	9,903	414,003	98,924	131,615	1,512	3,585	235,635	649,638
	3,871,782	**72,786,441**	**6,939,192**	**8,275,114**	**2,548,027**	**4,036,925**	**21,799,258**	**94,585,700**
WATER BODIES	**73,990**	**870,633**	**117,189**	**260,131**	**87,119**	**8,584**	**473,024**	**1,343,657**
TOTAL	**4,614,124**	**127,817,513**	**21,704,763**	**25,280,726**	**13,298,950**	**10,343,452**	**70,627,891**	**198,445,405**

Table 4. Native Vegetation and Anthropic categories, with and without agricultural suitability for soy, outside of Areas of Permanent Preservation (APP) and Legal Reserves (LR) registered with CAR and of Special Areas such as Indigenous Lands (TI), Conservation Units with Full Protection (UC_PI) and Quilombola Communities (QUIL), by state and by region (Other States and MATOPIBA) of the Cerrado Biome.

4. FINAL CONSIDERATIONS

The Cerrado Biome has 94.59 million hectares of anthropized land (47.7%) and 102.52 million hectares preserved with native vegetation (51.7%), in addition to 1.34 million hectares (0.7%) of water bodies. The anthropized category has 23.15 million hectares of soy, 20.96 million hectares of pastures suitable for soy, and 19.41 million hectares with other uses that could possibly rotate with soy (e.g., sugarcane, cotton, fallow land, etc.). The remaining 23.95 million hectares of anthropized land, without suitability for soy, play an important role in the process of livestock farming intensification to free pastures suitable for soy expansion. In the native vegetation category, there are 19.45 million hectares of native vegetation surplus with suitability for soy, of which 4.55 million hectares are in soy-producing farms.

In the period covered by this study (2018/19 to 2022/23), soy expanded onto 5.01 million hectares at an average annual rate of 1.25 million hectares – more than double of the historical average rate for the Cerrado Biome between 2000/01 and 2018/19 (0.59 million hectares per year). This has led to a considerable reduction of the available pastures suitable for soy within soy-producing farms. Consequently, deforestation-free soy expansion – even in the more consolidated Other States region – will be jeopardised in the medium and long term. In the MATOPIBA region, deforestation-free soy expansion is already jeopardised, especially in the states of Piauí, Bahia and Maranhão.

At the present rate of expansion, the stocks of suitable pastures on soy-producing farms will run out in the short term. Therefore, it becomes necessary to promote mechanisms to encourage soy production linked to productivity gains on livestock farms. The option of converting native vegetation with suitability for soy should be adopted less and less because of the environmental issues linked to the loss of biodiversity, to the scarcity of water resources and to the emission of greenhouse gases, not to mention the growing pressure exerted by the market for the acquisition of soy free from deforestation.

GRANTEE

ABIOVE

EXECUTION

agrosatélite

A part of serasa experian