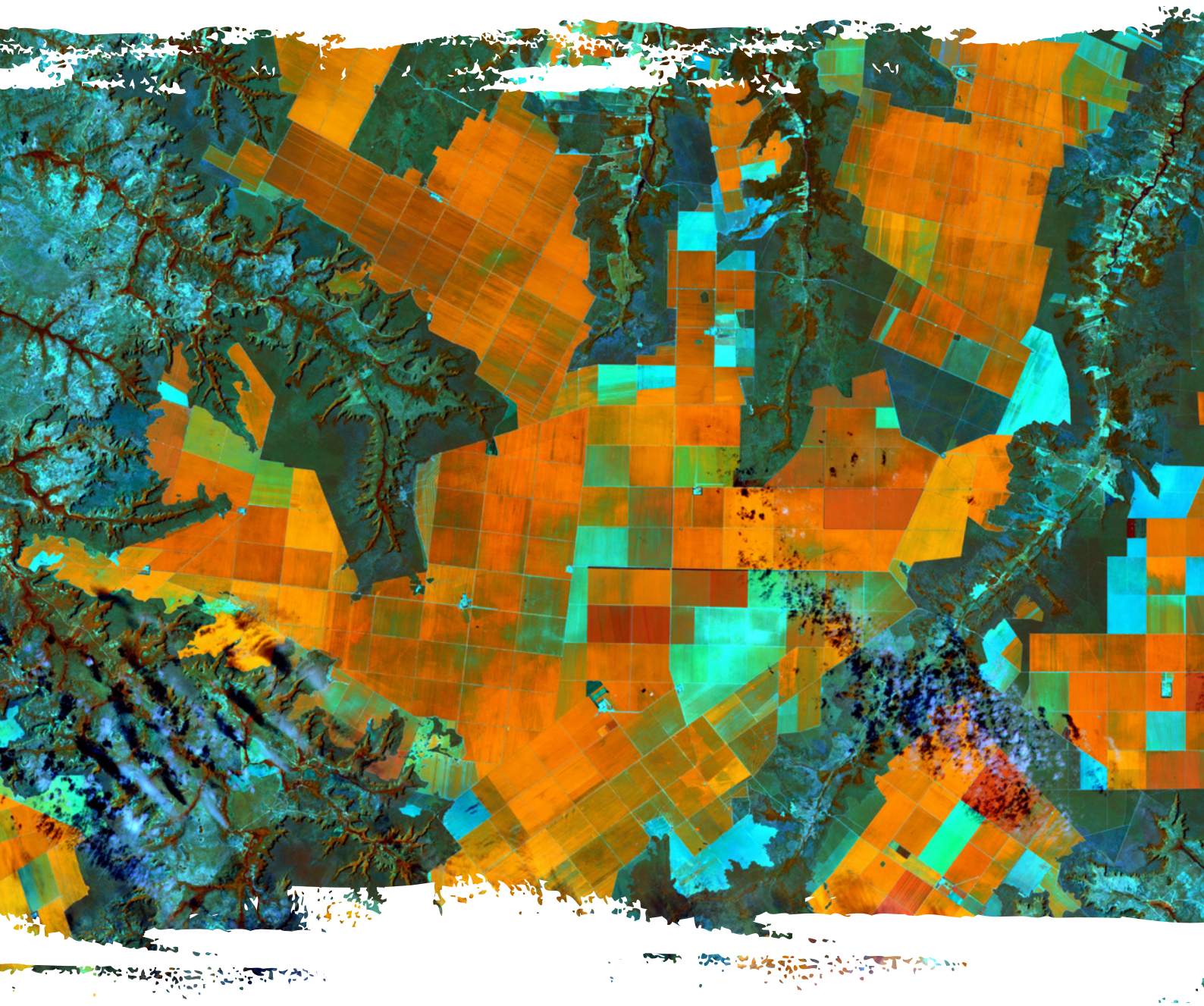
GEOSPATIAL ANALYSIS OF **SOY EXPANSION** IN THE **CERRADO BIOME**

2000 TO 2020



DEVELOPED BY:

agrosatélite
geotecnologia aplicada

SUPPORTED BY:

ABIOVE

Agrosatélite Coordinators
Bernardo Rudorff
Joel Risso

ABIOVE Coordinators
Bernardo Pires
Pedro Garcia

Technical Coordinator
Daniel Alves de Aguiar

Graphic Design and Publishing
W5 Publicidade
w5.com.br

Geoprocessing and Remote Sensing Team

Ana Sutili
Ana Theisges
André Fischer
Aquiles Schluter
Carolina Rosa
Caroline Silva
Claudia Ritzel
Cristian Back | mapping lider
Daniel Machado
Daniel Oliveira
Debora Ferreira
Gabriel Cabral
Gabriel Lemos
Guilherme Vanz
Lívia Crispin
Luana Quaresma
Lucas Kreutzfeld
Luiz Schramm
Monique Horst
Nicolas Moreira
Nildson Silva
Maria Botelho
Mariana Duarte
Matheus Oliveira
Matheus Pereira
Naiara Moreira
Renan Renzo

Agrosatélite Applied Geotechnology Ltd. Geospatial analysis of soy expansion in the Cerrado Biome: 2000/01 to 2020/21. – Florianópolis-SC, Brazil, 2021. 25 p. :il

ISBN: 978-65-991465-4-1

25p.

Technical Report.

1. Soy mapping – Crop year 2020/21. 2. Cerrado Biome. 3. Satellite images. 4. Native vegetation.
I. Rudorff, Bernardo. II. Risso, Joel. III. Title.

Summary

Executive Summary

The objective of this geospatial analysis of soy expansion in the Cerrado Biome is to depict, using satellite images, the dynamics of land use change associated with soy production. This initiative has been ongoing since 2015 and this is an important update as it completes two decades of assessments. During this time soy has increased its production area by approximately 170%, going from 7.5 million hectares in 2000/01 to 20.00 million hectares in 2020/21, representing almost 10% of the Biome's territory and 52% of Brazil's current soy area. The average rate of growth from 2001 to 2021 was 624,000 hectares per year; however, the soy market's favourable conditions in 2020 accelerated expansion in the 2020/21 crop year, increasing the area by 1.17 million hectares (85% above the average rate). In terms of the dynamics of change in land use, the Cerrado Biome includes the Matopiba region – Brazil's most recent agricultural frontier, encompassing the states of Maranhão, Tocantins, Piauí and Bahia – which differs from the remaining Cerrado states, called Other States in this study, which have a greater degree of consolidation. In Matopiba, the soy area went from 0.97 million hectares in 2000/01 to 4.72 million hectares in 2020/21, an almost fivefold increase taking this region's share in the Cerrado's soy area from 13% to 24%. In Other States, the soy area went from 6.56 million hectares in 2000/01 to 15.28 million hectares in 2020/21, an increase of 2.3 times representing 76% of the Cerrado's soy area.

Deforestation rates in the Cerrado, which were about three million hectares per year at the beginning of this millennium, have remained relatively stable over the past five years with an annual deforestation of approximately 700,000 hectares, or almost four times lower. Conversion of native vegetation to soy has followed the same trend, but with a marked difference between the Matopiba and Other States regions. At the beginning of the millennium, Other States was responsible for two-thirds of the deforestation, whereas it now contributes only one-third; consequently, Matopiba is currently responsibly for two-thirds of the total recent deforestation.

Of the total soy area in the Cerrado, 4.19 million hectares (14.4%) was grown on land deforested after the year 2000. This means that 79.0% of the Cerrado's soy area in the 2020/21 crop year – equivalent to 15.81 million hectares – was free of deforestation occurring after 2001. Considering only the deforestation that occurred after 22nd July 2008, the date in the 2012 Forest Code that defines consolidated areas, 1.47 million hectares (13.4% of the total post-2008 deforestation) have been converted to soy, of which 1.18 million hectares are in Matopiba (25.1% of the soy in this region) and 282,000 hectares are in Other States (1.8% of the soy in this region). In other words, the dynamics of soy expansion onto post-2008 deforested land differs greatly between the two regions.

A detailed analysis of the dynamics of land use change and land cover associated with the 4.40 million hectares of soy expansion between 2013/14 and 2020/21 shows that the expansion is due both to the incorporation of new areas from conversion of native vegetation or the intensification of land use from conversion of pastures, and to agricultural management practices with agricultural crop rotation and fallow land. In Other States, 1.48 million hectares expanded onto pastures (intensification) and 0.12 million hectares expanded onto deforested land; in Matopiba, only 0.26 million hectares expanded onto pastures, while 0.50 million hectares expanded onto deforested land. In the two regions, a significant part of soy expansion in the 2013/14 crop year was onto fallow land.

The analyses made in this study show that the soy expansion trend in the Cerrado continues and has even accelerated during the last crop year. Soy expansion with conversion of native vegetation, in the most recent period, is almost residual in Other States, but persists in Matopiba although at ever lower rates.

1. Dynamics of Soy Expansion in the Cerrado Biome

Brazil is divided into six biomes, each with a typical phytophysiognomy, one of which is the Cerrado Biome. Soy production in Brazil historically started in southern Brazil, in the Atlantic Forest Biome, and has gathered prominence in the Cerrado Biome since the 1980s, with the development of new technologies that allow soy to be grown in areas previously disregarded. The Cerrado Biome covers about 25% of Brazil's territory, with a little over 50% of its native vegetation preserved. Currently 52% of Brazil's soy area is in the Cerrado Biome, where the Matopiba region[1] (Figure 1) merits a highlight as Brazil's newest agricultural frontier and where soy expansion with conversion of native vegetation is still relevant. In the Cerrado's more consolidated region, called Other States[2] in this study (Figure 1), there is a large stock of open land with agricultural suitability for soy and ample opportunities for soy expansion through intensification of land use, as has been observed.

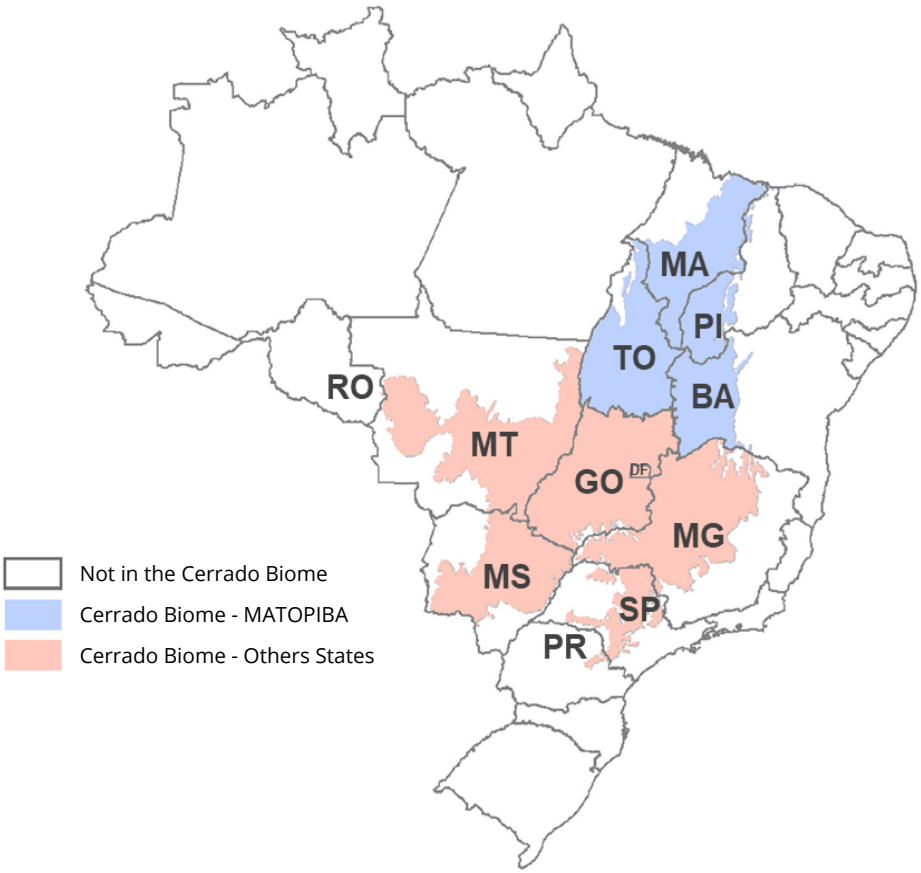


Figure 1. Map of Brazil highlighting the "Other States" and "Matopiba" regions of the Cerrado Biome.

1. Matopiba is a region formed by the states of Maranhão (MA), Tocantins (TO) Piauí (PI) and Bahia (BA), essentially the parts located within the Cerrado Biome and the transitions to the Amazon Biome, where there has been an intense transformation of the landscape caused by the expansion in high-tech annual agriculture. The small portion of Matopiba located in the Amazon Biome is not part of this study.
2. Other States is a region formed by part of the states of Mato Grosso (MT), Goiás (GO), Minas Gerais (MG), Mato Grosso do Sul (MS), São Paulo (SP), Paraná (PR) and the Federal District (DF).

1.1 Evolution of the soy area

The 2020/21 crop year completes two decades of detailed analyses, by Agrosatélite, of the dynamics of soy expansion in the Cerrado Biome using images acquired from satellites[3]. Through these images, it was possible not only to assess the gradual increase in the Cerrado's soy area but also to detail the transitions that occurred in terms of land use changes over the last two decades. This period coincides with greater environmental awareness for the preservation of natural resources by seeking alternatives to the clearing of new areas, such as better utilisation of land already cleared and new technologies to increase productivity. However, preservationist appeals face growing opportunities for increasing food production, both for the domestic market and for exports that strongly boost Brazilian agribusiness.

Objective information on the spatial distribution of soy crops and their association with the recent conversion of native vegetation, in addition to the knowledge of land stocks suitable for soy production, provide key elements for seeking a balance between environmental preservation and increased soy production. In this sense, satellite images not only show what has happened in the region as a result of soy production, but also make it possible to plan land use for the sustainable development of agriculture.

This study integrates the results of Agrosatélite's previous studies which mapped soy production in the Cerrado Biome for the crop years 2000/01, 2006/07, 2013/14, 2016/17, 2018/19 and 2019/20, supported by GBMF (Gordon and Betty Moore Foundation), GTC/TNC (Cerrado Working Group and The Nature Conservancy) and ABIOVE (Brazilian Association of Vegetable Oil Industries)[4], including an updated map for the 2020/21 crop year. These mappings made it possible to obtain the spatial distribution of the crops, as well as estimates of planted areas, at the level of the rural property, through municipalities and states, up to the Biome as a whole[5].

The analysis of this historical mapping sequence aims to broaden understanding of the recent soy expansion in the Cerrado Biome, especially in the Matopiba region, Brazil's new agricultural frontier, where expansion through conversion of native vegetation is more evident than in the Other States region, where expansion is largely due to intensified land use that has already been cleared for some time and is suitable for soy crops.

Figures 2 to 8 show the Cerrado soy maps in seven crop years (2000/01, 2006/07, 2013/14, 2016/17, 2018/19, 2019/20 and 2020/21). Four areas of each map have been featured to highlight the less consolidated regions where soy production has become more relevant, starting

3. The images used in this study were acquired from the Landsat and Sentinel-2 satellites in visible, near 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 allows the same location to be revisited in intervals of two to five days, which favours obtaining cloud-free images during the period propitious for identifying soy crops. Approximately 3,000 images were available to accurately identify the soy fields in the Cerrado Biome in the 2020/21 crop year through visual image interpretation techniques. The starting point was the 2019/20 soy crop map. The visual interpretation procedures also considered the analysis of the temporal series of images obtained by the MODIS sensor, transformed into the EVI (Enhanced Vegetation Index) in the form of 16-day temporal compositions through consultations with the web application of EMBRAPA's SatVeg project (www.satveg.cnptia.embrapa.br). The following RGB colour compositions of the images were used: 4-5-3 bands for the ETM+ sensor/Landsat-7; 5-6-4 bands for the OLI sensor/Landsat-8; and 8a-11-4 bands for the MSI sensor/Sentinel-2. It should be noted that the soy mapping of the 2016/17 crop by Agrosatélite was validated by a third party (University of Maryland), based on data obtained in the field, which determined the mapping's overall accuracy at 98.4%.
4. Reports are available for public consultation on https://agrosatelite.com.br/cases/#expansao-agricola.
5. The Cerrado Biome boundaries used in this study are those used by the IBGE (Brazilian Institute of Geography and Statistics) on a scale of 1:5,000,000 (https://www.ibge.gov.br/geociencias/informacoes-ambientais/15842-biomas.html).

in the year 2000. The first area highlighted is the Paranatinga/MT municipality, where the soy area in the Cerrado Biome went from 32,419 hectares in 2006/07 to 155,745 hectares in 2013/14, an almost fivefold increase in seven years. From 2013/14 to 2019/20, growth slowed and the average annual increase was 3,950 hectares. However, in the most recent crop year, the increase in Paranatinga's planted area was 20,146 hectares, or five times greater than that observed in the 2013/14-2019/20 period. The regions around Balsas in Maranhão state and Baixa Grande do Ribeiro in Piauí state (both in the second highlighted area), as well as the regions around Barreiras in Bahia state (third highlighted area) and around Porto Nacional in Tocantins state (fourth highlighted area), all of which are in the Matopiba region, also stand out due to the intense expansion of soy crops, whose area grew four to five times over the last two decades.

Figure 2. Map of soy production in the Cerrado for the 2000/01 crop year, highlighting regions showing significant expansion in soy crops.

Figure 3. Map of soy production in the Cerrado for the 2006/07 crop year, highlighting regions showing significant expansion in soy crops.

Figure 4. Map of soy production in the Cerrado for the 2013/14 crop year, highlighting regions showing significant expansion in soy crops.

Figure 5. Map of soy production in the Cerrado for the 2016/17 crop year, highlighting regions showing significant expansion in soy crops.

Figure 6. Map of soy production in the Cerrado for the 2018/19 crop year, highlighting regions showing significant expansion in soy crops.

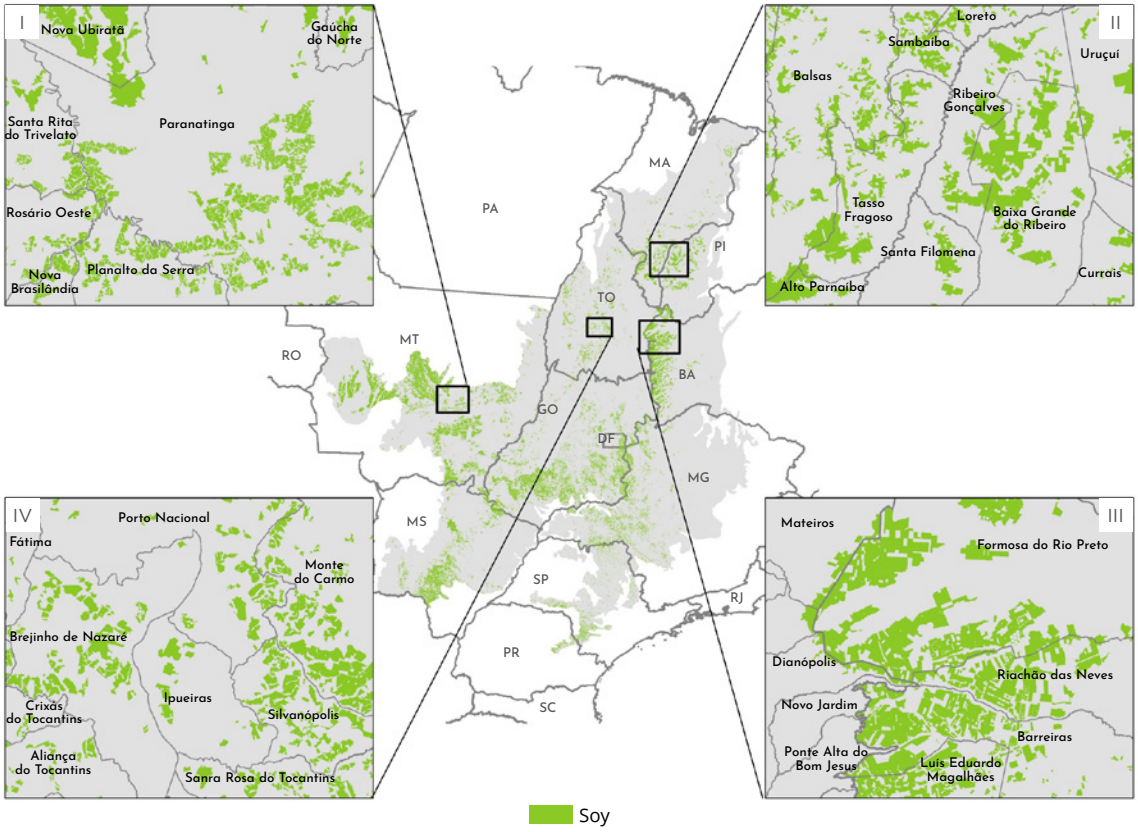


Figure 7. Map of soy production in the Cerrado for the 2019/20 crop year, highlighting regions showing significant expansion in soy crops.

Figure 8. Map of soy production in the Cerrado for the 2020/21 crop year, highlighting regions showing significant expansion in soy crops.

Table 1 shows the soy areas 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
	ha	ha	ha	ha	ha	ha	ha
DF	39,862	55,101	80,211	88,572	93,496	85,447	84,867
GO	1,678,199	2,323,737	3,472,889	3,644,519	3,954,372	4,106,060	4,379,545
MG	683,194	803,508	1,267,109	1,531,541	1,778,323	1,789,656	1,953,439
MS	694,317	959,161	1,375,051	1,652,907	1,848,181	2,020,460	2,166,916
MT	3,019,902	3,982,035	5,524,610	5,630,600	5,636,978	5,780,725	5,883,555
PR	50,909	64,819	70,952	79,499	91,831	94,532	96,070
SP	389,653	242,462	402,992	496,431	618,544	646,924	719,162
RO	0	0	0	431	489	453	476
Other States	**6,556,036**	**8,430,823**	**12,193,814**	**13,124,500**	**14,022,214**	**14,524,257**	**15,284,031**
MA	221,542	434,510	680,550	748,482	816,521	831,302	902,364
TO	76,905	256,767	675,835	914,009	1,018,243	1,089,381	1,171,582
PI	57,711	223,587	617,219	653,375	718,304	718,562	799,638
BA	614,069	771,528	1,433,741	1,627,367	1,629,217	1,669,201	1,843,368
MATOPIBA	**970,227**	**1,686,393**	**3,407,345**	**3,943,233**	**4,182,285**	**4,308,446**	**4,716,951**
TOTAL	**7,526,263**	**10,117,215**	**15,601,159**	**17,067,733**	**18,204,499**	**18,832,703**	**20,000,982**

Table 1. Soy area in the Cerrado Biome in hectares, by state and for the Other States and Matopiba regions, for the crop years 2000/01, 2006/07, 2013/14, 2016/17, 2018/19, 2019/20 and 2020/21.

Over the last two decades, the soy area in the Cerrado Biome has gone from 7.53 million hectares in 2000/01 to 20.00 million hectares in 2020/21, an increase of 12.47 million hectares (170%) at an annual rate of 624,000 hectares, of which 436,000 hectares were in Other States and 188,000 hectares were in Matopiba. The soy area in Matopiba went from 0.97 million hectares in 2000/01 to 4.72 million hectares in 2020/21, corresponding to an almost fivefold increase and taking this region's share in Cerrado soy area from 13% to 24%. Currently, the Cerrado Biome has 52% of Brazil's soy area[6]. Figure 9 illustrates, in graphic form, the soy area in Other States and in Matopiba (Table 1), including the annual expansion rates in each period shown.

6. CONAB (National Supply Company). Acompanhamento da safra brasileira de grãos, v.8– Safra 2020/21, n.11 – Décimo primeiro levantamento, Brasília, p. 1-108, August 2021.

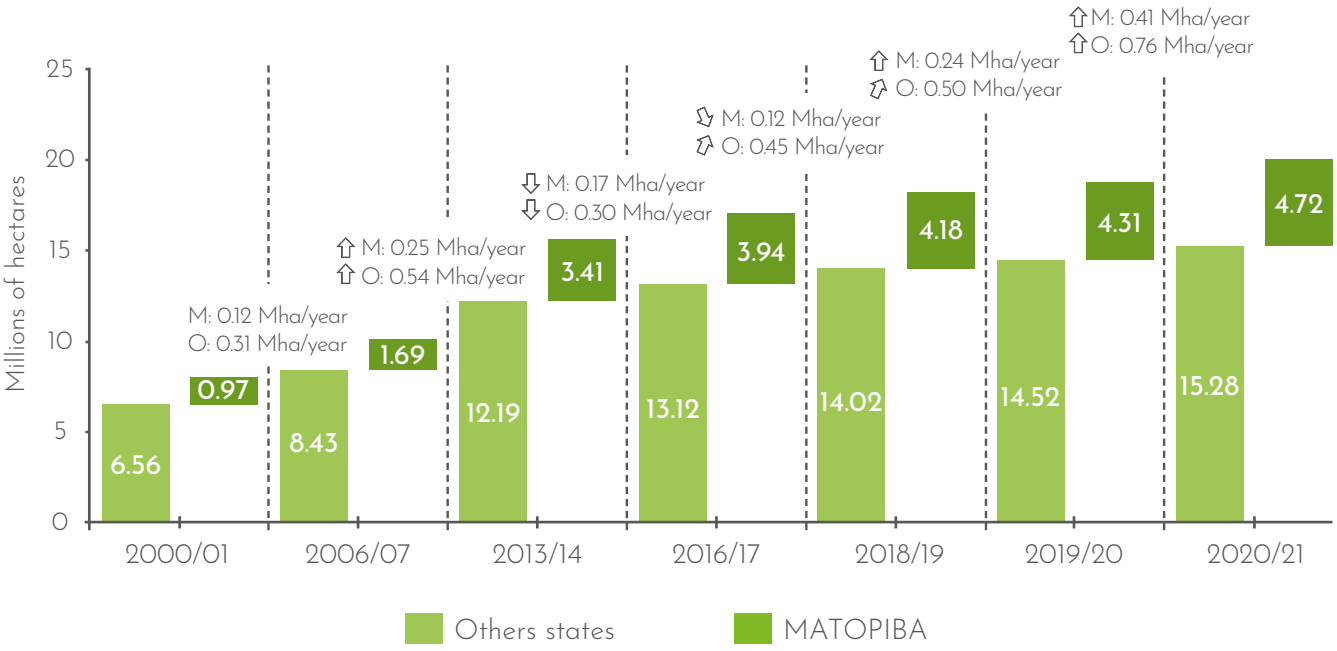


Figure 9. Evolution of soy area in Other States and in Matopiba for crop years from 2000/01 to 2020/21, and annual rates of increase in the soy area for the six periods analysed: 2000/01 to 2006/07; 2006/07 to 2013/14; 2013/14 to 2016/17; 2016/17 to 2018/19; 2018/19 to 2019/20; and 2019/20 to 2020/21.

Table 2 shows the percentage variation in soy area for the 2020/21 crop year, compared to the previous crop year. The favourable soy prices in 2020 led to an accelerated expansion in the last crop year, causing an increase in the Cerrado's soy area of 6.2% (1.17 million hectares). Of this increase, 5.2% (760,000 hectares) were in Other States and 9.5% (408,000 hectares) were in Matopiba. These values are well above the average annual growth rate observed in the Cerrado Biome (625,000 hectares), in Other States (437,000 hectares) and in Matopiba (187,000 hectares). For the Cerrado Biome, the increase in the soy area in the last year was 85% above the average annual rate of the last 20 years.

It is worth noting that Agrosatélite's team of image analysts had an enormous collection of satellite images at its disposal, thus enabling a careful analysis to identify correctly and to map precisely the soy area in the 2020/21 crop year. The estimated soy area determined by this mapping shows values higher than those published by CONAB for those states with practically all the soy area within the Cerrado Biome. For example, Agrosatélite's estimate for the states of Goiás and Bahia were, respectively, 686,000 hectares and 142,000 hectares higher than CONAB's estimate. A field work carried out by Agrosatélite in Goiás state to assess the soy map quality and no inconsistencies were found that would justify a revision of the map. With approximately 700 samples of land use collected in the field in Goiás, the overall mapping accuracy

was 98.3% for this state. Therefore, Agrosatélite is confident that its estimates of the soy area in the Cerrado Biome, as presented in this report, faithfully represent the soy area for the 2020/21 crop year. It should be emphasised that the map for the 2016/17 crop year, prepared by Agrosatélite using the same methodology as the 2020/21 map, underwent a validation process by a third party (University of Maryland), which indicated the overall mapping accuracy at 98.4% for the Cerrado Biome.

States	2019/20 (a)	2020/21 (b)	Var. % (b*100/a)-100
DF	85,447	84,867	-0.7
GO	4,106,060	4,379,545	6.7
MG	1,789,656	1,953,439	9.2
MS	2,020,460	2,166,915	7.2
MT	5,780,725	5,883,555	1.8
PR	94,532	96,070	1.6
SP	646,924	719,162	11.2
RO	453	476	5.1
Other States	**14,524,257**	**15,284,031**	**5.2**
MA	831,302	902,364	8.5
TO	1,089,381	1,171,582	7.5
PI	718,562	799,638	11.3
BA	1,669,201	1,843,368	10.4
MATOPIBA	**4,308,446**	**4,716,951**	**9.5**
TOTAL	**18,832,703**	**20,000,982**	**6.2**

Table 2. Variation in soy area, in hectares and as a percentage of the Cerrado Biome, by state and for the Other States and Matopiba regions, comparing the 2019/20 and 2020/21 crop years.

2. Deforestation in the Cerrado

Figure 10 shows the Cerrado Biome's deforestation rates estimated by PRODES-Cerrado from 2001 to 2020. The annual deforestation rates, which were approximately three million hectares per year at the start of this millennium, have, over the last five years, fallen to less than one--quarter of that amount, to 0.7 million hectares annually. The reduction was more accentuated in the Other States region, which, at the beginning of the millennium, accounted for two-thirds of the Biome's deforestation. This situation has been reversed and Matopiba now accounts for two-thirds of the deforestation, even though it represents just one-third of the Cerrado's territory. Figure 10 also shows the Cerrado Biome's total deforestation from 2001 to 2020 (29.13 million hectares), as well as the deforestation in the three periods analysed in this study: Period 1 (2001-2006) with 15.40 million hectares; Period 2 (2007-2013) with 8.02 million hectares and Period 3 (2014-2020) with 5.71 million hectares.

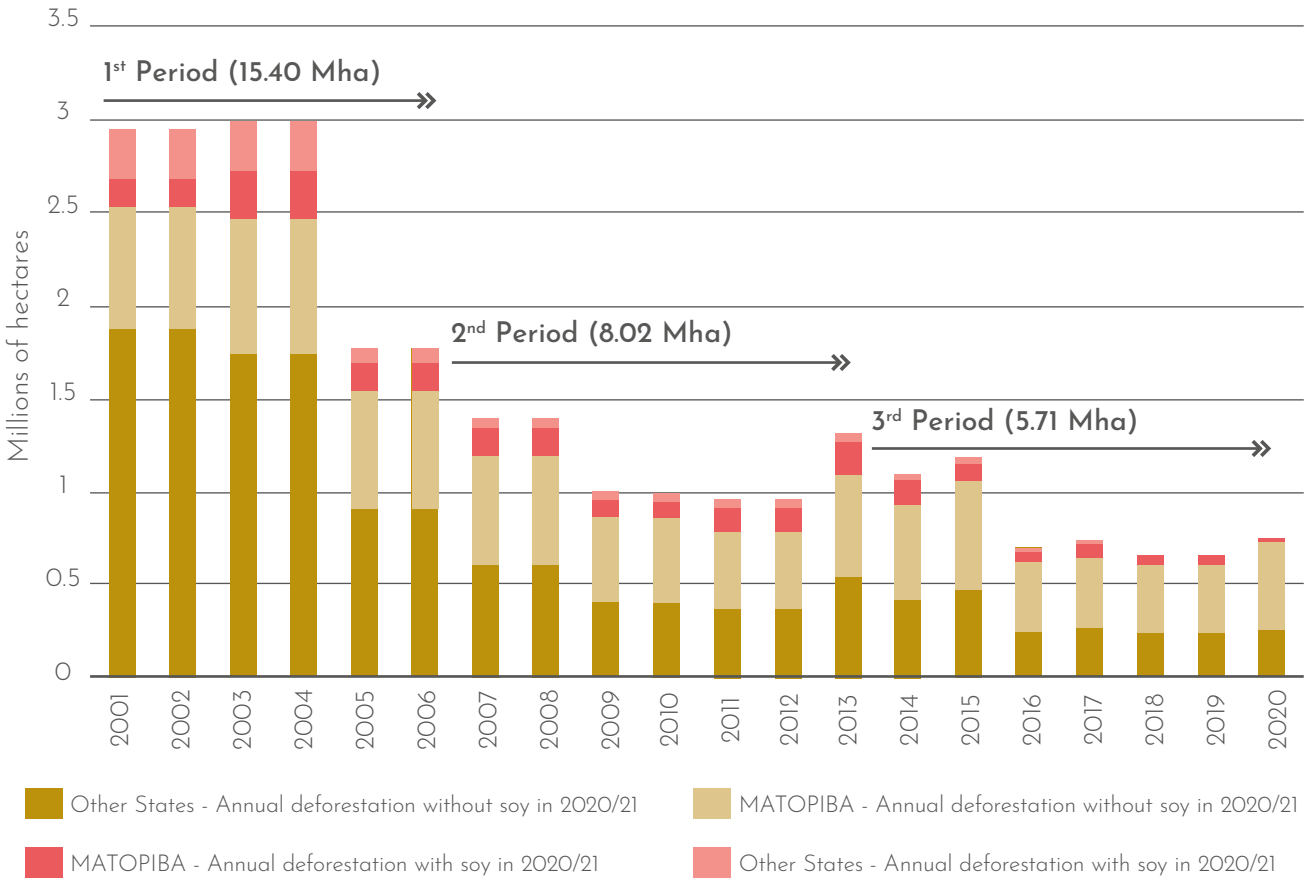


Figure 10. Annual deforestation rates in the Cerrado Biome from 2001 to 2020 (29.13 million hectars) in each of the three periods analysed in this study, highlighting annual deforestation converted to soy based on the 2020/21 crop year.

2.1 Deforested areas converted to soy

Of the total area deforested in the Cerrado Biome from 2001 to 2020 (29.13 million hectares, Figure 10), soy occupied 4.19 million hectares in the 2020/21 crop year. These numbers show that 14.4% of the deforestation over the last twenty years was converted to soy, either directly or indirectly. In other words, 85.6% of the deforested area was not converted to soy but destined for other land uses. This means, therefore, that 79.0% of the Cerrado's soy area in the 2020/21 crop year – equivalent to 15.81 million hectares – is free from deforestations after 2001.

Considering only the deforestation that occurred after 22nd July 2008, the date that defines consolidated areas in accordance with the 2012 Forest Code, the deforested area in the Cerrado Biome was 10.92 million hectares, of which 1.47 million hectares (13.4%) were directly or indirectly converted to soy (86.6% are free from deforestation after 2008). Of this amount 1.18 million hectares are in Matopiba, corresponding to 25.1% of this region's soy area (74.9% are free from deforestation after 2008), while 0.28 million hectares are in Other States, corresponding to 1.8% of the soy planted in this region (98.2% are free from deforestation after 2008). As can be seen, the dynamics of soy expansion into post-2008 deforestation differs widely between the two regions.

3. Land Use and Land Cover Change Attributed to Soy

The land use and land cover change caused by soy expansion in the Cerrado Biome was analysed based on the following classification: 1) land cover change from native vegetation to soy, called expansion with deforestation[7] in this study; 2) land use change to soy, called expansion without deforestation[8] in this study; and 3) retraction areas[9], land where soy had been grown but was subsequently changed to other uses, either temporarily or permanently.

This classification considers both the availability of soy maps in specific crop years, in accordance with Agrosatélite's previous studies (Footnote 2), and the number of years in each period analysed. The main focus of this analysis is to assess the trend of soy expansion with deforestation over time. The scope of each period analysed should therefore be long enough to effectively capture the land use and land cover changes caused by soy expansion, and short enough to portray variations and trends in the pattern of land use and land cover changes over the twenty crop years analysed.

The analysis of soy expansion with deforestation in 2020/21 was carried out through a simple intersection with the databases of the PRODES-Cerrado deforestation maps[10], adopting the procedure reported by Agrosatélite (2018)[11].

3.1 Soy expansion with and without deforestation

To get a better idea of soy's direct contribution to deforestation since 2001, the analysis of soy expansion with deforestation was divided into three periods as follows: First Period with six crop years; Second Period with seven crop years and Third Period with seven crop years, as shown in Figure 10. The definition of these periods also took into consideration the availability of soy maps in specific years (2000/01 to 2006/07, 2006/07 to 2013/14, and 2013/14 to 2020/21, following the methodology used in Agrosatélite's previous studies (2015)[12]. This three-part analysis shows the changing trend in native vegetation conversion rates to soy over time.

7. Expansion with deforestation corresponds to land cover change caused by deforestation of native vegetation land (regardless of the phytophysiognomy) at the start of each period, and converted to soy within the same period.
8. Expansion without deforestation corresponds to land use change caused by soy expansion into areas with other uses at the start of each period, and converted to soy by the end of the same period. For example, a pasture converted to soy corresponds to an intensification of land use, a situation which occurs frequently in Other States where many pastures have agricultural suitability for soy production. Examples of other uses at the beginning of each period are: a) rotation with annual crops (e.g., cotton and first-crop maize); b) fallow areas; and c) sugarcane fields in the process of renewal or conversion to soy.
9. Retraction areas are those which had soy at the start of each period but which had changed to other uses by the end of that period. Examples are: a) rotation with other annual crops (e.g., cotton and first-crop maize); b) fallow areas; c) renewed sugarcane fields that rotated with soy; and d) areas that effectively ceased to be planted with soy through abandonment or a change in its use, such as that which occurred in the first decade of this millennium with the large-scale expansion of sugarcane in Brazil's Centre-South region (https://www.mdpi.com/2072-4292/2/1/290).
10. PRODES annually maps deforestation occurring in the period from August of the previous year to July of the current year. PRODES-14, for example, maps deforestation in the period from August 2013 to July 2014.
11. Report available for public consultation on https://agrosatelite.com.br/cases/#expansao-agricola.
12. Report available for public consultation on https://agrosatelite.com.br/cases/#expansao-agricola.

Total deforestation converted into soy for the three periods (Figure 11) is 3.25 million hectares, which implies that 77.6% of the area deforested after 2001 and converted to soy (4.19 million hectares, Figure 10) was accounted for in the fractionated analysis, thus indicating that the number of years in each period adequately represents the time involved in the process of converting deforested land into soy crops. Deforestation that passes through transitional land uses (pastures, for example) takes longer to be converted into soy and is accounted for as expansion without deforestation.

By analysing the three periods presented in Figure 11, one can observe that the percentual of soy expansion with deforestation in the Cerrado Biome has been falling. Even in Matopiba, where soy expansion with deforestation was significant in the first two periods (39.6% from 2000/01 to 2006/07, and 33.0% from 2006/07 to 2013/14, Figure 11), there was a pronounced drop in the period from 2013/14 to 2020/21 (10.5%, Figure 11).

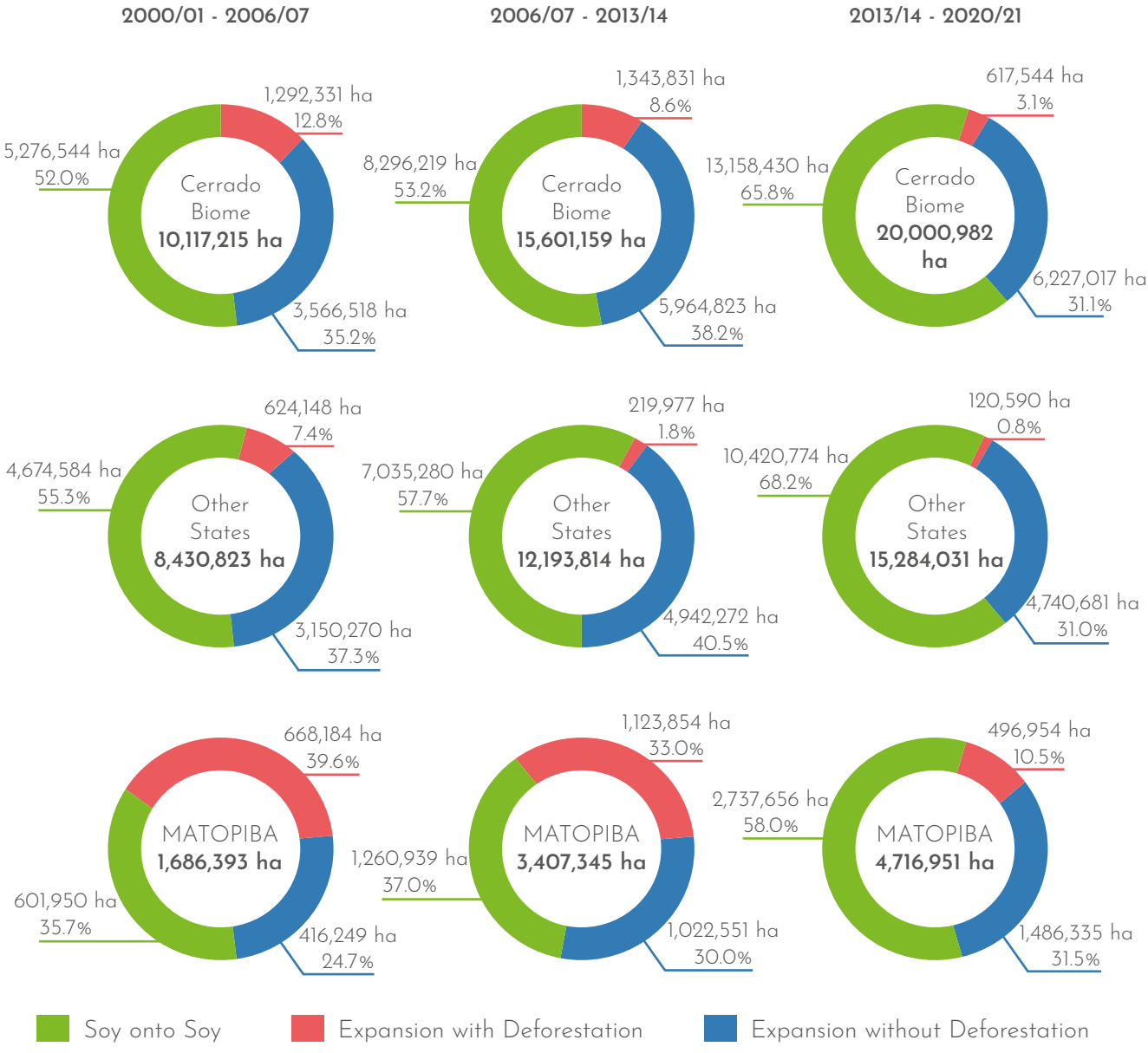


Figure 11. Soy expansion with and without deforestation in the Cerrado Biome, Other States and Matopiba in three periods: 2000/01 to 2006/07; 2006/07 to 2013/14; 2013/14 to 2020/21.

Note: Soybeans onto soybeans is the total area of soybeans (inside of the circle) that remains as soybeans in the following period. The difference between the total area of soybeans and soybeans onto soybeans for the following period is the area that is no longer soybeans (retraction; see grey bars in Figure 13 or Figure 16).

While Figure 11 shows the soy expansion with and without deforestation in each of the analysed periods, Figure 12 shows the total deforested area in the Cerrado Biome from 2014 to 2020 and that part of this area with soy in crop year 2020/21. In this period, during which deforestation rates fell in comparison with the two prior periods, the Cerrado's native vegetation conversion to soy also fell (617,000 hectares, or 10.6%, Figure 12b). In Other States, the deforested area was 2.24 million hectares, with 121,000 hectares (5.4%, Figure 12c) converted to soy. Matopiba had a deforested area of 3.57 million hectares, of which 497,000 hectares (13.9%, Figure 12d) were converted to soy. It should be noted that part of the deforestation that occurred between 2014 and 2020 could still be converted to soy in future years, increasing the soy area on more recently deforested land.

Of the states in the Matopiba region, Tocantins had the largest area of soy with deforestation in the period 2014-2020 (147,000 hectares), followed by Maranhão (130,000 hectares), Bahia (118,000 hectares) and Piauí (101,000 hectares), as illustrated in Figure 12a. Tocantins also led total deforestation in this same period, with 1.33 million hectares, followed by Maranhão with 1.10 million hectares deforested (Figure 12a). In Other States, the largest soy area with deforestation was in Mato Grosso (55,000 hectares), followed by Goiás (35,000 hectares). These two states together represent 74.3% of the soy area with deforestation in this region (Figure 12a).

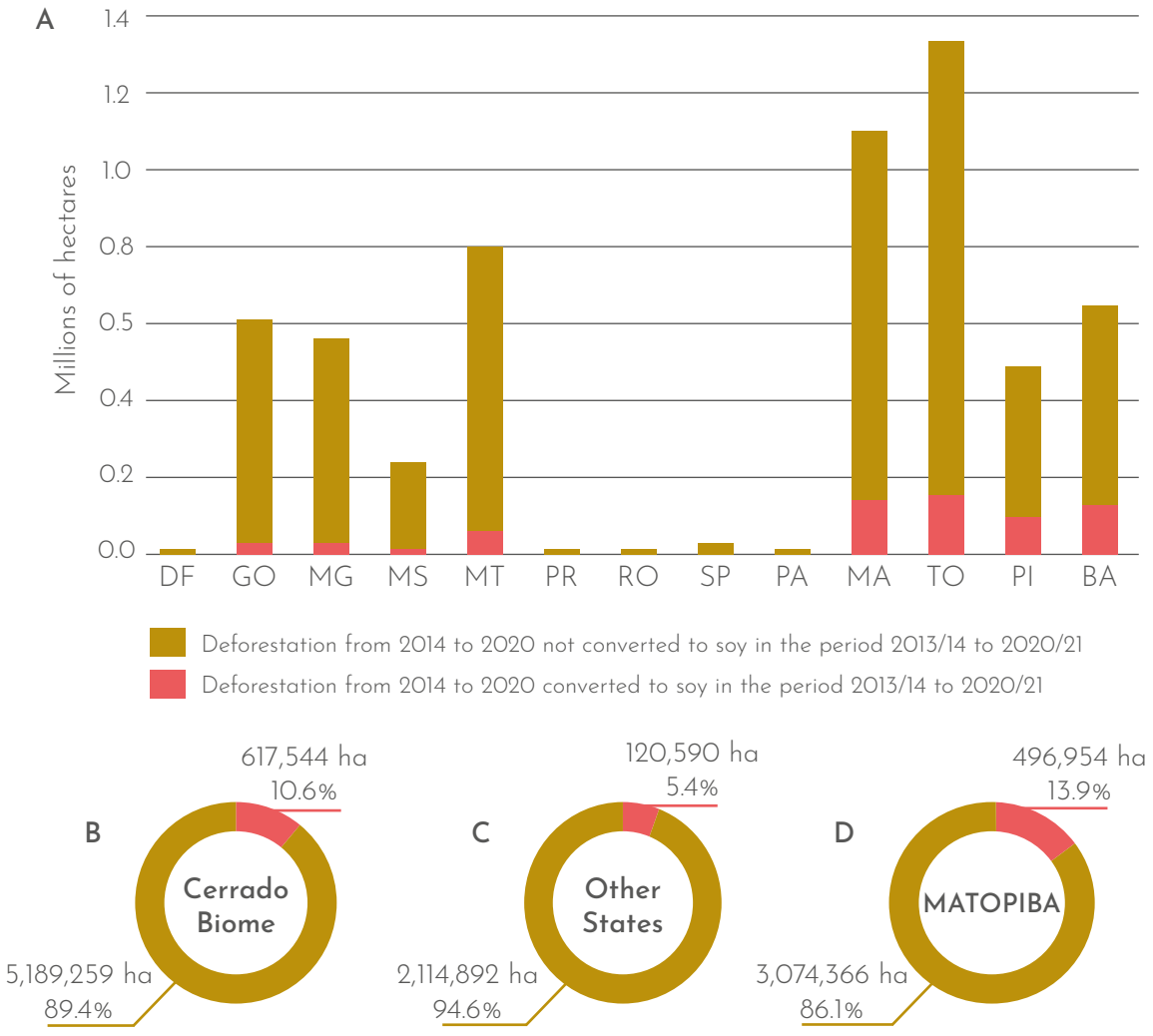


Figure 12. Deforested area in the 2014-2020 period (PRODES-Cerrado/INPE), with and without conversion to soy, based on the 2020/21 crop year for: a) that part of the states within the Cerrado; b) Cerrado Biome; c) Other States; and d) Matopiba.

3.2 Land use and land cover change from 2000/01 to 2020/21

Figure 13 shows the results of the dynamics of land use and land cover change in the soy expansion and retraction process in Other States and Matopiba, both for the seven crop years from 2013/14 to 2020/21 (results of this study) and for the two previous periods – six crop years from 2000/01 to 2006/07 and seven crop years from2006/07 to 2013/14 (Agrosatélite, 2015; 2018)[12].

The relative presence of soy in Matopiba is significantly less than in Other States, but it has been growing over time. As explained earlier (Item 1.1), this region's share in the area dedicated to soy production in the Cerrado Biome went from 13% in 2000/01 to 24% in 2020/21. Despite this growth, the average rate of native vegetation conversion to soy, which reached 161,000 hectares/year between 2006/07 and 2013/14, fell to 71,000 hectares/year in the most recent period (2013/14 to 2020/21). In Other States the average rate of native vegetation conversion to soy has been gradually falling and reached 17,000 hectares/year in the most recent period (Figure 13).

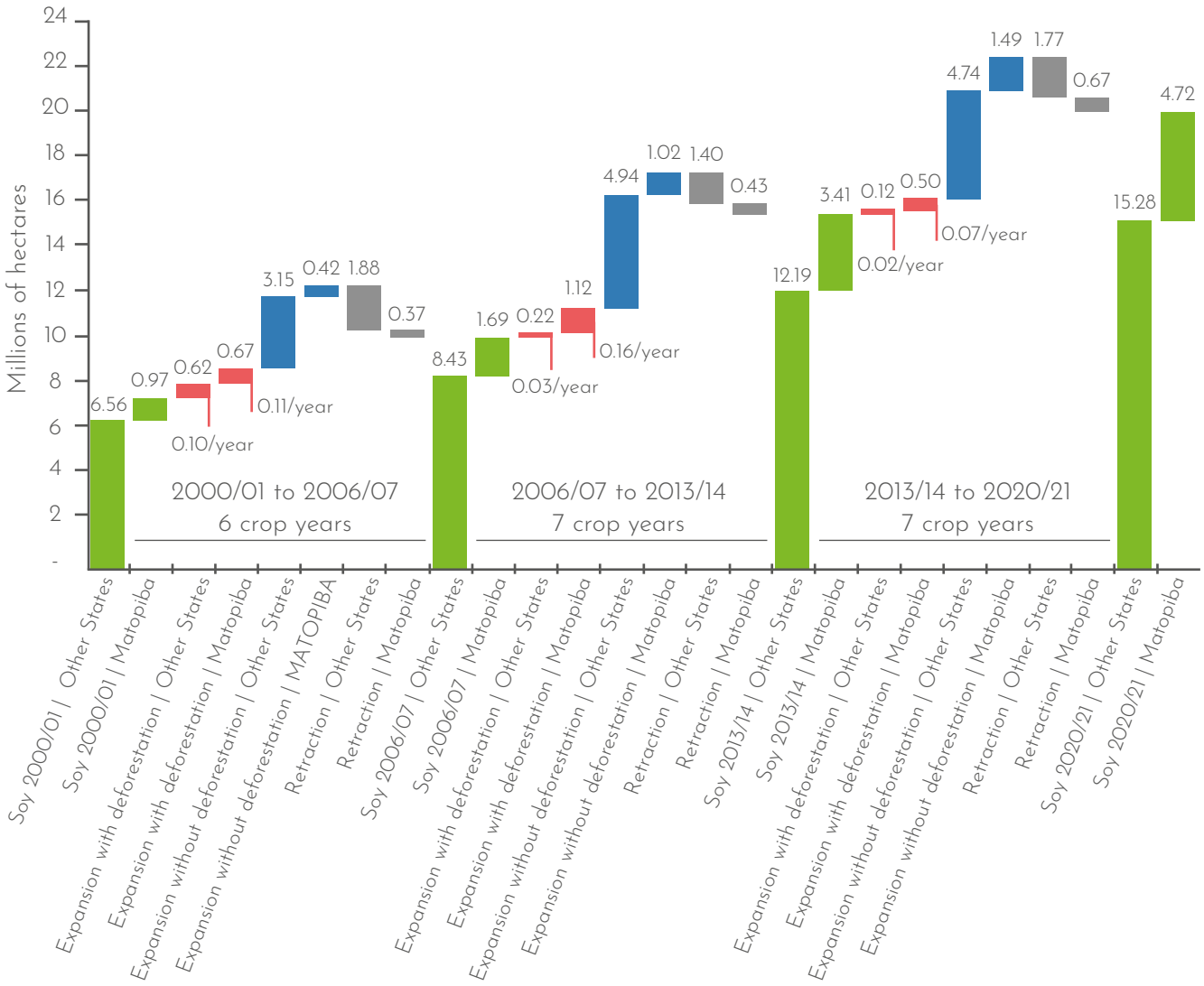


Figure 13. Land use and land cover changes during soy expansion and retraction in Other States and Matopiba in Period 1 (2000/01-2006/07), Period 2 (2006/07-2013/14) and Period 3 (2013/14-2020/21). The numbers shown below the bars of expansion with deforestation are the annual rates of native vegetation conversion to soy.

13. Reports available for public consultation on https://agrosatelite.com.br/cases/#expansao-agricola.

3.3 Breakdown of the dynamics of expansion and retraction | 2013/14 to 2020/21

Figures 14 and 15 highlight two distinct areas in terms of the dynamics of soy expansion in the Cerrado Biome, illustrating the spatial distribution of the soy area and soy expansion with and without deforestation, as well as those areas that had retractions in the period from 2013/14 to 2020/21[13]. In these figures, blue areas without hatching represent soy expansion onto pastures, fallow land or other uses; blue areas with cross-hatching represent expansion onto first-crop of maize or cotton, or sugarcane. Former soy areas (retraction) are shown in grey without hatching when they were converted to fallow land or other uses, while grey with cross-hatching represents crop rotation with first-crop of maize or cotton, or sugarcane.

From 2013/14 to 2020/21, soy's net expansion was 4.40 million hectares. Total expansion was higher (6.85 million hectares) due to the dynamics of soy production, as part of the area may rotate to other agricultural crops (first-crop of maize or cotton, or sugarcane renewal) or become fallow land (Footnote 9, Figures 14 and 15). In the same way, areas previously used for first-crop of maize or cotton, sugarcane or fallow land can revert to soy crops. Therefore, the dynamics of soy expansion consist of incorporating into the production system those areas resulting from native vegetation conversion or from intensification of land use through conversion of pastures, as well as the agricultural management practice of rotating agricultural crops and fallow land.

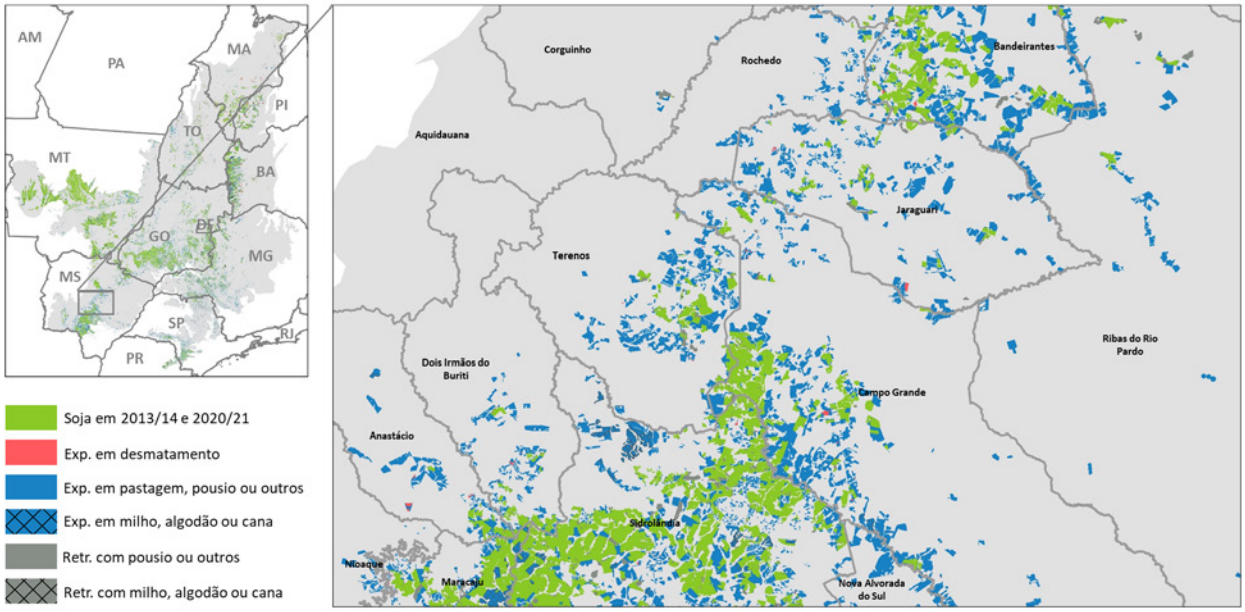


Figure 14. Soy territorial dynamics from 2013/14 to 2020/21 in the central region of Mato Grosso do Sul state, near the state capital Campo Grande, which concentrates a large extension of pastures with high agricultural suitability for soy and which, in recent years, has been experiencing a growing conversion of these areas into soy. This, in recent years, has made Mato Grosso do Sul the second-largest area of soy expansion in the Cerrado Biome, together with Goiás state.

14. To quantify soy expansion-retraction dynamics, satellite images were used to assess the soy area in the 2020/21 crop year that expanded without deforestation in 2013/14, separating them into: a) agricultural crops (first-crop of maize or cotton and sugarcane); b) fallow land and other uses; and c) pastures (Áreas de Pastagens do Brasil, 2014, LAPIG database/MapBiomas). Still using satellite images, the retraction in soy area in the 2013/14 crop year was due to crop rotation that converted soy area into other uses in that year.

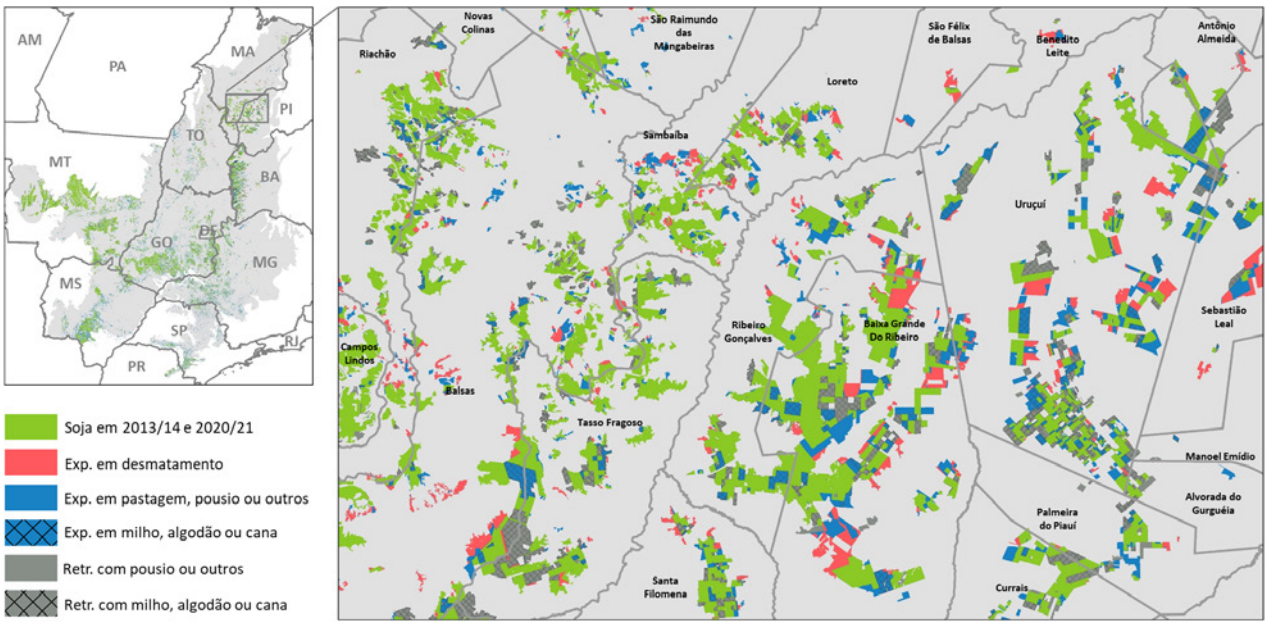


Figure 15. Soy territorial dynamics from 2013/14 to 2020/21 in southern Maranhão and Piauí states. This region is located in Brazil's most recent agricultural frontier, where expansion with deforestation in the Cerrado Biome is most present and where first-crop of maize or cotton are rotated with soy.

The result of this analysis breakdown is shown in Figure 16, which illustrates the transitions in land use and land cover associated with soy dynamics in Other States and in Matopiba.

In Other States, net expansion in soy area was 3.08 million hectares, representing 70.0% of the soy expansion in the Cerrado Biome for this period. Total soy expansion can be broken down as follows:

- 1.98 million hectares expanded onto fallow land;
- 1.48 million hectares expanded onto pastures (intensification);
- 1.29 million hectares expanded onto annual crops (first-crop of maize or cotton and sugarcane);
- 0.12 million hectares expanded onto deforested land.

In addition, soy retraction totalled 1.77 million hectares, as part of the soy fields in 2013/14 were turned into fallow land (1.11 million hectares) or planted with first crop of maize or cotton or sugarcane (0.66 million hectares) in 2020/21 (Figure 16, Other States).

In Matopiba, the net expansion in soy area was 1.32 million hectares, representing 30.0% of the soy expansion in the Cerrado Biome for this period. Total soy expansion can be broken down as follows:

- 0.69 million hectares expanded onto fallow land;
- 0.26 million hectares expanded onto pastures (intensification);
- 0.53 million hectares expanded onto annual crops (first-crop of maize or cotton and sugarcane);
- 0.50 million hectares expanded onto deforested land.

In addition, soy retraction totalled 0.67 million hectares, as part of the soy crops in 2013/14 were turned into fallow land (0.21 million hectares) or planted with first crop of maize or cotton or sugarcane (0.46 million hectares) in 2020/21 (Figure 16, Matopiba).

In both regions, a significant part of the soy expansion was onto land that was fallow in the 2013/14 crop year. Expansion onto annual crops is partly due to soy's rotation with first-crop of maize – a practice that is still very common, especially in some regions of Goiás and Minas Gerais states – or to sugarcane renewal rotating with soy or even to converting sugarcane fields into soy fields as these have a higher profitability (Canasat Project/Agrosatélite)[15]. Another point related to crop rotation in recent years is the substitution cotton fields to soy fields in a good part of Mato Grosso state. In the Other States region, expansion onto pastures is more evident due to the considerable stock of pastures with agricultural suitability. In Matopiba, Brazil's newest agricultural frontier where agricultural consolidation is still in full swing and where cleared land with agricultural suitability is relatively scarce, the soy with conversion of native vegetation accounted for 10.5% (0.50 million hectares) of the soy area, compared to 0.8% (0.12 million hectares) in Other States, which is more consolidated with ample stocks of anthropised land with agricultural suitability for soy.

The contribution of pastures conversion to soy was more relevant in Other States (1.48 million hectares) than in Matopiba (0.26 million hectares) with a total of 1.74 million hectares in the Cerrado Biome as a whole in this more recent period.

An analysis based on CAR, the Rural Environmental Registration, revealed that 95% (19.07 million hectares) of the soy area in the 2020/21 crop year was grown on land that has a CAR (90,000 properties with a minimum soy area of ten hectares), while the remaining 5% (0.93 million hectares) was grown on land without a CAR.

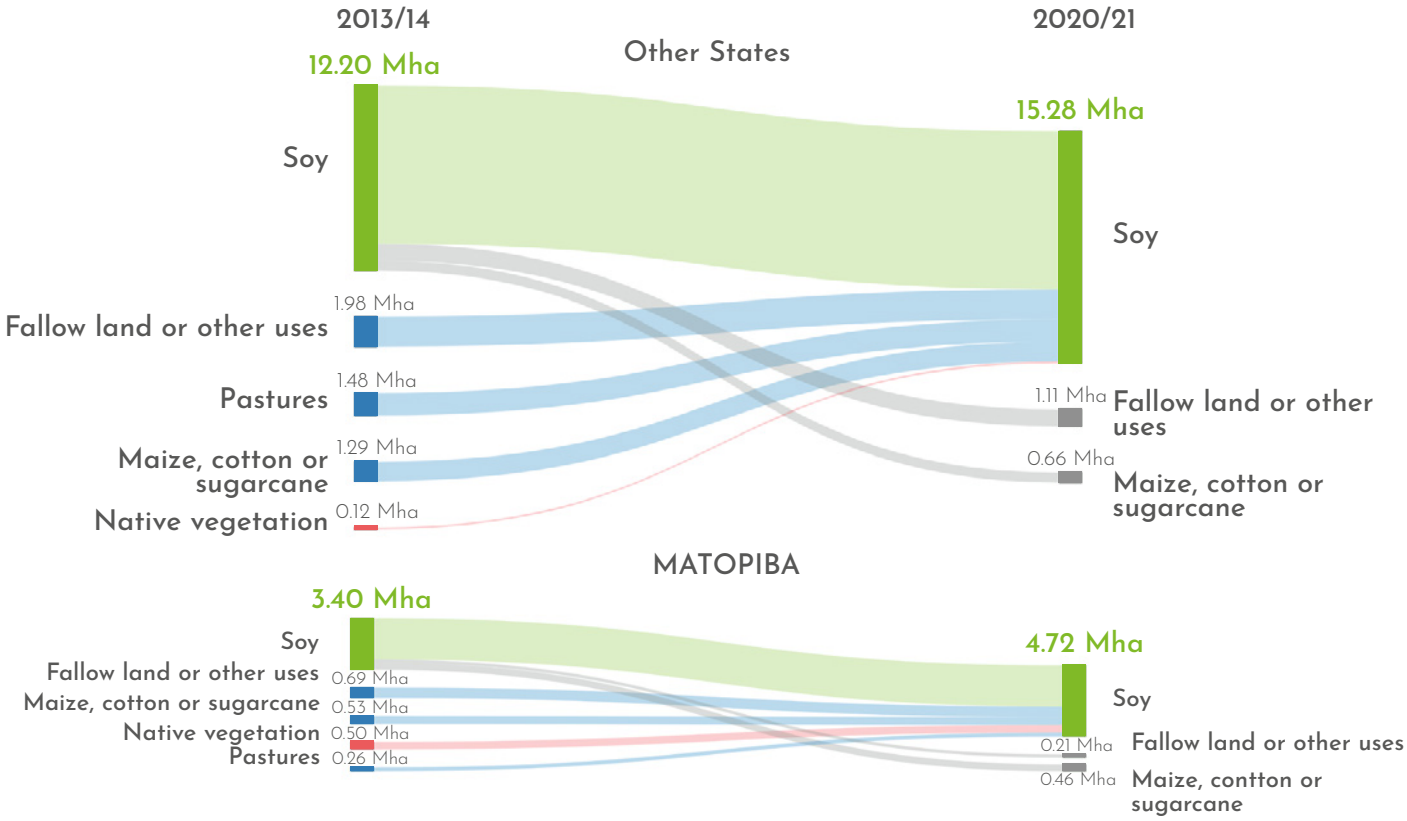


Figure 16. Sankey Diagram illustrating the soy area for the 2013/14 and 2020/21 crop years, along with the transitions in land use and cover that occurred in the period, for Other States and for Matopiba.

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

4. Final considerations and recommendations

In the 2020/21 crop year, soy area in the Cerrado Biome had the biggest annual increase (1.17 million hectares), 85% above the average annual rate for the last two decades, giving a total soy area of 20.0 million hectares covering 9.8% of the Cerrado Biome.

The dynamics of land use change associated with soy production differ significantly between Other States and Matopiba, especially as regards of native vegetation conversion. In Other States, the soy associated with native vegetation conversion in the most recent period (2013/14 to 2020/21) represented just 0.8% (0.12 million hectares) of the soy area of crop year 2020/21, whereas in Matopiba it represented 10.5% (0.50 million hectares) and for the Cerrado as a whole 3.1% (0.62 million hectares).

A comparison of the two seven-year periods confirms the recent trend that conversion of native vegetation in the Cerrado Biome is slowing down. While the average rate of conversion was 161,000 hectares/year from 2006/07 to 2013/14, this fell to 71,000 hectares/year in the period 2013/14 to 2020/21.

agrosatélite
geotecnologia aplicada

www.agrosatelite.com.br

ABIOVE

www.abiove.org.br

ISBN: 978-65-991465-4-1

CBL

9 786599 146541