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Cerrado: Agricultural Production and Areas Designated for Environmental Preservation Registered in the Brazilian Rural Environmental Registry (*Cadastro Ambiental Rural*)

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Abstract: In this study, authors analyzed value, production and area used for producing Cerrado's main agricultural products, and data on the farms located within this biome and registered in CAR up until April 2019, by microregion. The territory considered here comprised all microregions with at least 25% of its area covered by the Cerrado biome. The production, agricultural production, and planted area values used were the averages of the 2015 to 2017 harvests, and are shown in graphs and tables, as are maps of planted areas and groups of main annual crops, semi-perennial and perennial crops. The areas designated for environmental preservation (ADPs) are the result of the sum of permanent preservation areas (APP), legal reserves (RL) and additional vegetation areas within the farms. Authors' study shows that most of Brazilian cotton, eucalyptus for charcoal, orange, sugarcane, maize and soybean are produced in Cerrado, that 28% of Cerrado are ADPs within farms, and that 16% are areas planted with cotton, eucalyptus, orange, sugarcane, maize, soybean, coffee, beans, and potatoes. The territory occupied by agricultural areas and ADPs required by the Brazilian Forest Code shows that agricultural production and environmental preservation do coexist, and gather the maintenance of essential ecosystem services provided by the ADPs together with the development of the country's relevant agricultural production.

Key words: Brazilian Rural Environmental Registry, Cerrado, Brazilian Forest Code, environmental preservation, agricultural production.

1. Introduction

Over the last two decades, Brazilian agribusiness has made its agriculture diverse, created agroindustries to add value to products, and expanded its exports with new products to new markets [1]. Agribusiness has been driving Brazilian economy forward. Boasting US$ 102.14 billion revenue in exports in 2018, it employs one out of three people in the country, and accounted for 21.6% of the country's gross domestic product (GDP) in 2017 [2].

Following the introduction of new agricultural technologies suitable for Cerrado's typical soils in the 1970s, agricultural production developed itself and began advancing its territory and occupying the country's Central-West and Northeast regions.

Several scientists advised of the damaging effects of an uncontrolled agricultural expansion to Cerrado's environment, and pointed to a commonplace: the need to assure the maintenance of areas for environmental protection and conservation [3-6].

Regarding the challenges faced in a consonant coexistence of natural resources and agribusiness, Lopes and Daher [7] appraise that actions for the deployment of the Brazilian Forest Code would be important to produce a reasonable and sustainable framework for the exploitation of this wide region. Ten years have passed, and although the Forest Code

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referred to by the authors was replaced by the current one in 2012, the New Forest Code has kept as mandatory that at least 20% of the farm's area be reserved for environmental preservation. This percentage increases in areas of great ecological and biodiversity interest, such as areas within the Amazon biome.

Technology is also essential for sparing scarce natural resources: 171 million hectares are estimated to have been spared in Brazilian agricultural production between 1985 and 2006, which is nearly 20% of the country's territory, and this is mainly due to productivity increase [8-10].

The Brazilian Rural Environmental Registry (*Cadastro Ambiental Rural*, CAR), created by the Brazilian Forest Code (Br. Law no. 12.651, of May 25, 2015), enables registering, for each farm, its location, its perimeter, its native forest remnants, permanent preservation areas, restricted use areas, consolidated and legal reserve areas. CAR is registered using Brazilian Rural Environmental Registry National System (SICAR), a nation-wide electronic system coordinated by the Brazilian Forest Service. The information available in SICAR are used as basis for public policies, programs, projects, monitoring and planning actions, and for fighting illegal logging. Thus, CAR data enable real-time, consistent assessment of the areas designated for environmental preservation in farms, and secured by law. It is worth highlighting that no inference is made here regarding the type of or state of the native vegetation within these farms.

The Brazilian environmental law determines that different percentages of areas are to be preserved as legal reserves within farms, according to the biome in which the farm is located. For example, farms located within the Legal Amazon and those located within the Cerrado biome are required to designate 35% of the farm's total area for environmental preservation in the form of legal reserves. The Legal Amazon encompasses the states which are part of the Amazon basin, and includes all the states in the North region, as well as the whole of Mato Grosso and most of Maranhão. Somewhat differently, farms located in the Cerrado biome and which are not within the Legal Amazon region must designate 20% of their total area as legal reserves. Farms within the Amazon biome must designate at least 80% of their areas as legal reserves.

In this context, our study aimed to analyze agricultural production in the Cerrado biome, and analyze data about areas designated for environmental preservation in farms registered in CAR up until April 2019, by microregion.

2. Material and Methods

Authors' study area, the Cerrado biome spreads over the central portion of the Brazilian territory, and stretches from the shoreline of the state of Maranhão throughout portions of the states of Piauí, Bahia, Mato Grosso, Mato Grosso do Sul, to nearly the whole of Tocantins and Goiás, the whole of the Brazilian Federal District (Distrito Federal, DF), to small portions of Rondônia and Pará, reaches over half of the state of Minas Gerais and a third of the state of São Paulo, and finally a small portion in the state of Paraná. The Cerrado biome occupies 203.4 million hectares, approximately 24% of the Brazilian territory [11] (Fig. 1). Cerrado "lato sensu"—a savannah phytophysiognomy - is a complex of several plant formations, from grassland vegetation to 'cerradão', which is a forest formation, and encompasses a series of intermediate vegetation forms (known as *campo sujo*, *campo cerrado* and *cerrado "stricto sensu"*, in Portuguese). Riparian formations (*veredas* and *mata de galeria*, in Portuguese) are also part of the Cerrado biome [12-14].

With the aim of making the physical boundaries of the Cerrado biome Fig. 1) compatible with the country's political and administrative structure, all microregions covered by Cerrado in at least 25% of their areas were taken into account in this study's analyses Fig. 2). Cerrado portions within the states of Paraná, Rondônia and Pará were disregarded in this study, because they

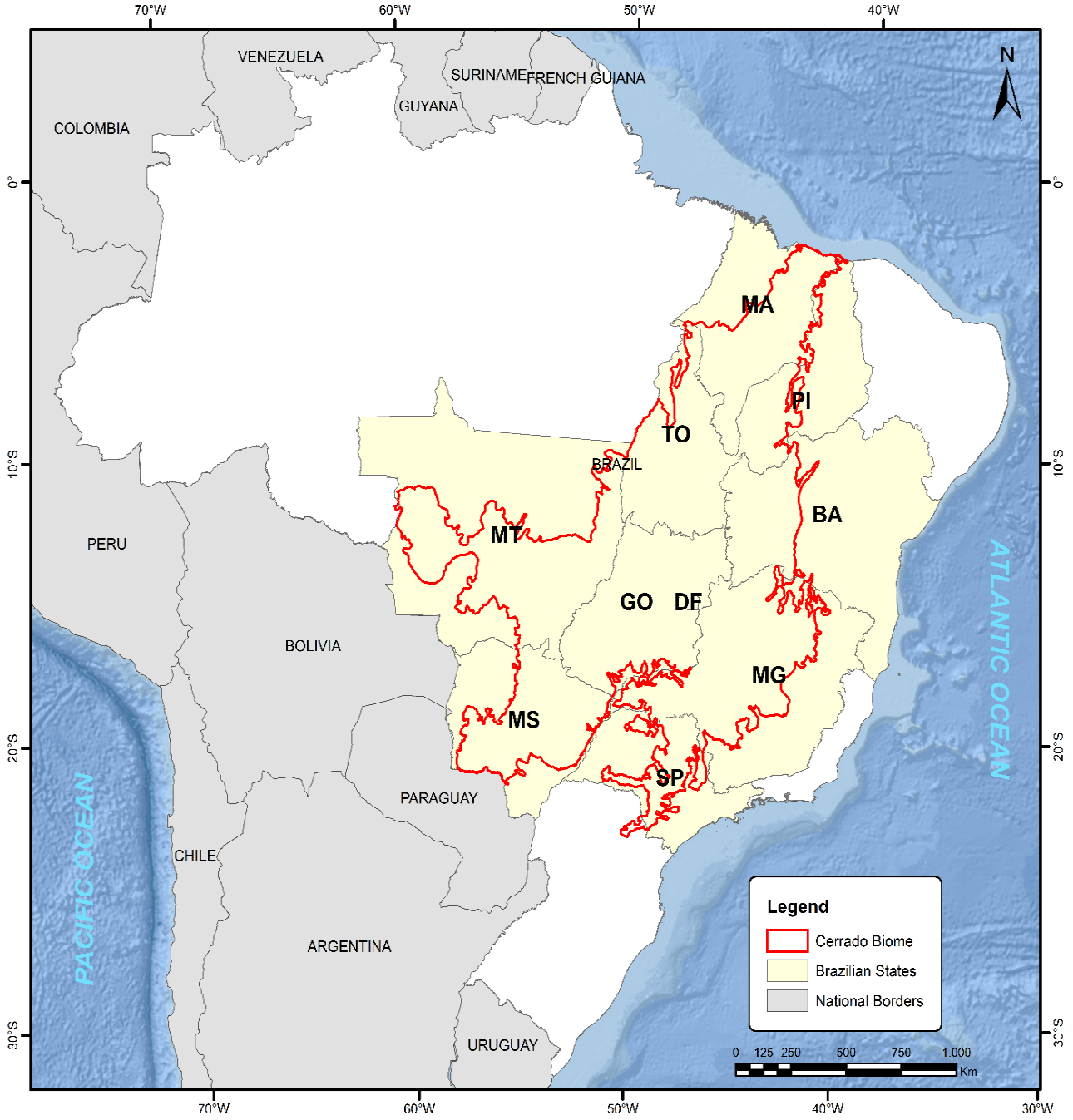

Fig. 1 Location of the Cerrado biome in Brazil.

were not representative in terms of total agricultural production.

Microregion data correspond to data on the cities which are partly or totally located within the Cerrado biome. “Cerrado” will be our term of choice to refer to the study area in this paper.

Due to the regularity of the microregions’ boundaries, we chose to use them as territory boundaries instead of using city boundaries, because these change more dynamically than those over time.

Cerrado’s most representative agricultural products were analyzed in terms of production value, total production and planted area: cotton, eucalyptus, orange, sugarcane, maize, soybean, coffee, bean and potato.

The results obtained are the averages of the values from 2015 to 2017.

The data on agricultural production were grouped in four production quarters, according to Garagorry and Chaib [15]. Quarter Q4 is the group that concentrates 25% of the production, called G25. The sum of Q4 and Q3 forms the group that concentrates 50% of the production, named G50. Q4, Q3 and Q2 together account for 75% of the production, hence G75.

According to the New Brazilian Forest Code of 2012, the Brazilian Rural Environmental Registry (CAR) [16] became a mandatory electronic registry for all farms. Using this spatial database on farms and their vegetation areas, Embrapa Territorial used geoprocessing techniques and tools to produce cartographic measurements and calculations on the areas dedicated to the preservation of native vegetation throughout this set of farms. Thus, we were able to detect, identify, qualify, quantify and map the areas which are designated for preservation in the farms registered in CAR using homogeneous and unified bases [17]. This geocoded data were queried and processed hierarchically by biome, state, city and up to each individual farm. All of our method's steps and phases are detailed and available under Embrapa [18]. The data were downloaded from CAR from March 26 to April 15, 2019. The computer systems used for processing the spatial database analysis carried out in this study are based on large-capacity, strong-performance equipment: 5 HP Intel Core i7, 3.4GHz, 16-GB RAM, 500-GB SSD HD, and 2-TB HD workstations; 1 SY480Gen10 Blade server equipped with 10-core Intel Xeon Silver processors, 192-GB RAM and 2 600-GB HDs, and a 192-TB HP MSA-2050 storage.

The main software used was ArcGIS, due to its capacity to process large spatial databases and its specialized modules for spatial analyses. All operations involving tabular data were performed using Microsoft Excel and its functions. Other software used were: ESRI ArcGIS for Desktop 10.7 equipped with the Spatial Analyst and Geo-statistical modules [19]; Google Earth Pro [20]; File Geo-database supported by ArcGIS 10.7 [21], and Microsoft Office equipped with Microsoft Excel for statistical functions.

All areas designated for environmental preservation (ADPs) in the farms registered in CAR were grouped and quantified by microregion. The ADPs are the result of the sum of permanent preservation areas (APP), legal reserves (RL) and additional vegetation areas within the farms. All native vegetation areas within the farms which did not qualify as APP or RL were classified as 'additional vegetation'. According to the Brazilian Forest Code, additional vegetation may not be deforested, but may be included in the environmental compensation program of other farms. It is worth highlighting that the CAR data used encompass all productive farms, not only the ones that produce the crops analyzed in this study.

Authors used the R statistical system [22] to produce the graphs, and the ArcGIS 10.6 software to create the maps and classify the analyzed areas.

3. Results and Discussion

Authors' Cerrado selection encompassed an area featuring 234.9 million hectares, 132 microregions, and 1,394 cities (Fig. 2).

The farms registered in CAR and located in Cerrado areas amount to 1 million and 47 thousand units, and their total area covers 166 million hectares or 70.7% of the whole area (Table 1).

Brazilian Federal District, Goiás and Tocantins are fully inserted in the Cerrado biome. Mato Grosso has the largest Cerrado area when compared to the remaining states, 20.3% (Table 1). Cotton, sugarcane, orange, maize, soybean and beans account for more than 50% of the country's total production value (Table 2).

Soybean has the highest production value, followed by sugarcane, maize and coffee (Fig. 3).

In terms of total production value, the country's most relevant vegetables are potatoes (40%), and the mostrelevant forest product is eucalyptus (41%) (Table 2 and Fig. 3).

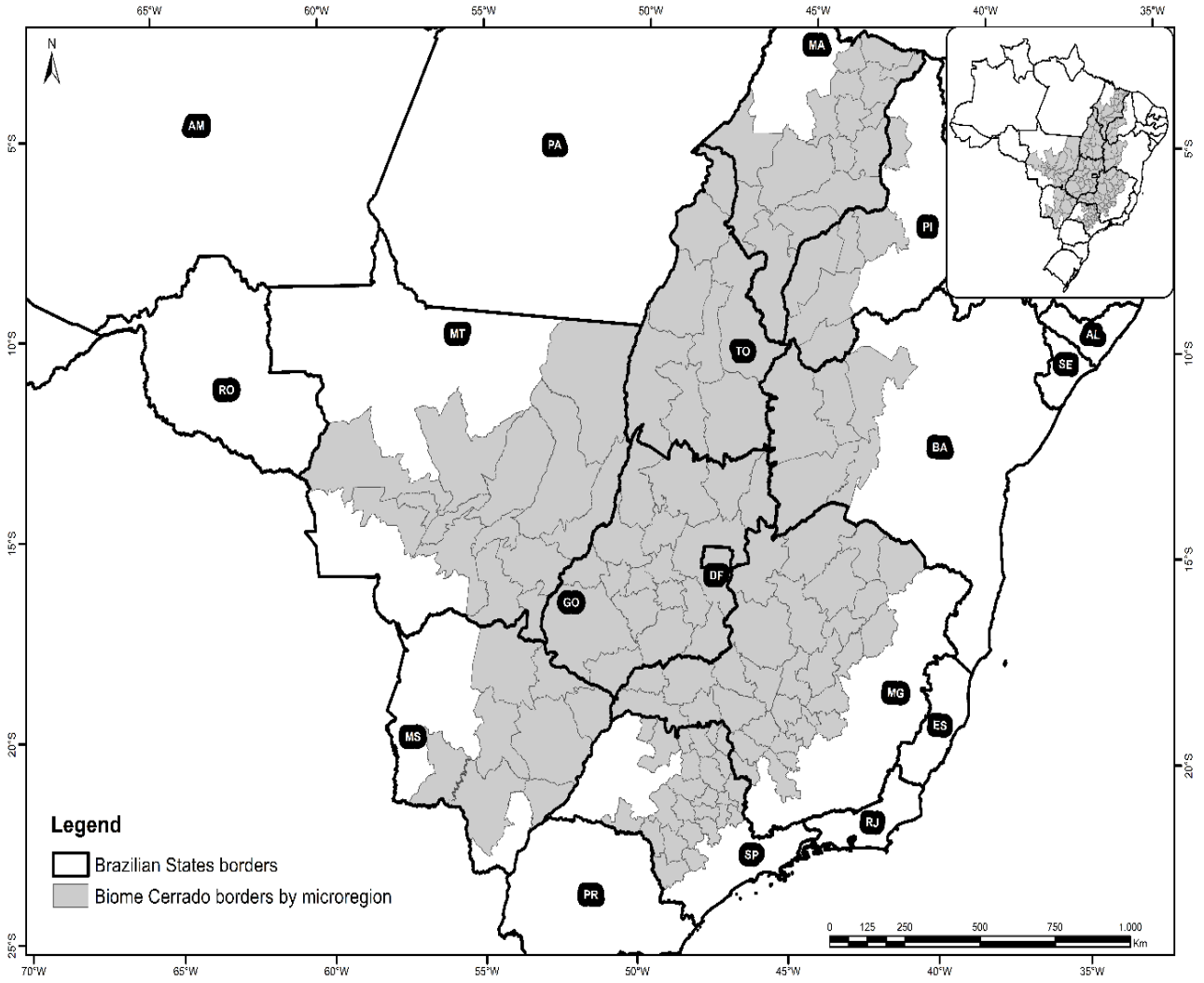

Fig. 2 Cerrado areas selected for use in this study. This selection encompasses the microregions which have at least 25% of their territories covered by Cerrado biome.

Table 1 Territorial dimension of Cerrado and the states, number and area of the farms registered in the Brazilian Rural Environmental Registry.

States	Cerrado areas	Cerrado participation			
		Cerrado	State	CAR farms area	CAR number of farms
	hectares	%		hectares	Units
PI	10 923 911	4.7	43.4	6 021 310	32 742
SP	11 609 477	4.9	46.8	9 682 628	159 915
BA	16 455 375	7.0	29.1	9 820 539	78 178
MS	22 391 158	9.5	62.7	19 734 797	48 254
MA	24 606 449	10.5	74.1	13 469 137	69 370
TO	27 772 057	11.8	100	17 581 197	69 834
GO/DF	34 589 138	14.7	100	26 830 382	163 149
MG	38 850 581	16.5	66.2	28 500 575	364 329
MT	47 716 378	20.3	52.8	34 535 354	62 127
Total	234 914 524			166 175 920	1 047 898

Source: [23, 24].

Table 2 Production value for all agricultural products in Cerrado (average for the 2015/2016/2017 harvests).

Production value			
Agricultural products	Cerrado	Brazil	Brazil Cerrado participation
1000 R$		%	
Cotton	7 219 233	7 392 139	98
Sugar cane	32 475 983	49 811 929	65
Orange	4 469 559	7 543 145	59
Maize	18 557 896	33 437 605	56
Soy	55 288 273	102 511 855	54
Bean	3 845 368	7 569 038	51
Eucalyptus	4 784 443	10 514 267	45
Potato	1 719 901	4 323 655	40
Coffee	7 143 473	18 587 069	38
Total	130 719 687	231 176 435	57

Source: [25].

Table 3 Agricultural production and planted area for Cerrado's main agricultural products (average for the 2015/2016/2017 harvests).

	Production media			Planted area		
Products	Cerrado	Brazil	Brazil participation of Cerrado agricultural production	Cerrado	Brazil	Brazil participation of Cerrado agricultural area
	Tonnes		%	Hectares		%
Cotton	3 693 725	3 771 434	98	957 671	988 062	97
Eucalyptus (coal)	4 076 979	5 035 292	81			
Orange	12 175 976	17 220 619	71	402 731	663 025	61
Sugar cane	495 097 851	759 134 095	65	6 380 793	10 217 144	62
Maize	47 690 287	82 382 783	58	9 002 594	16 530 700	54
Soy	56 515 044	102 819 641	55	18 739 935	33 175 466	56
Bean	1 438 310	2 912 592	49	892 590	3 048 473	29
Potato	1 560 814	3 791 974	41	45 569	126 657	36
Coffee	1 097 595	2 783 563	39	657 096	1 932 830	34
	Cubic meters					
Eucalyptus (log)	9 417 080	25 782 485	36			
Eucalyptus (cel.)	23 569 454	67 378 796	35			
Eucalyptus (firewood)	11 872 107	46 867 781	25			
Eucalyptus (total)				3 521 388	7 474 821	47
	Heads					
Cattle	86 745 735	216 115 160	40			
Poultry	384 023 435	1 368 147 889	28			
Pigs	10 828 802	40 281 667	27			

Source: [25].

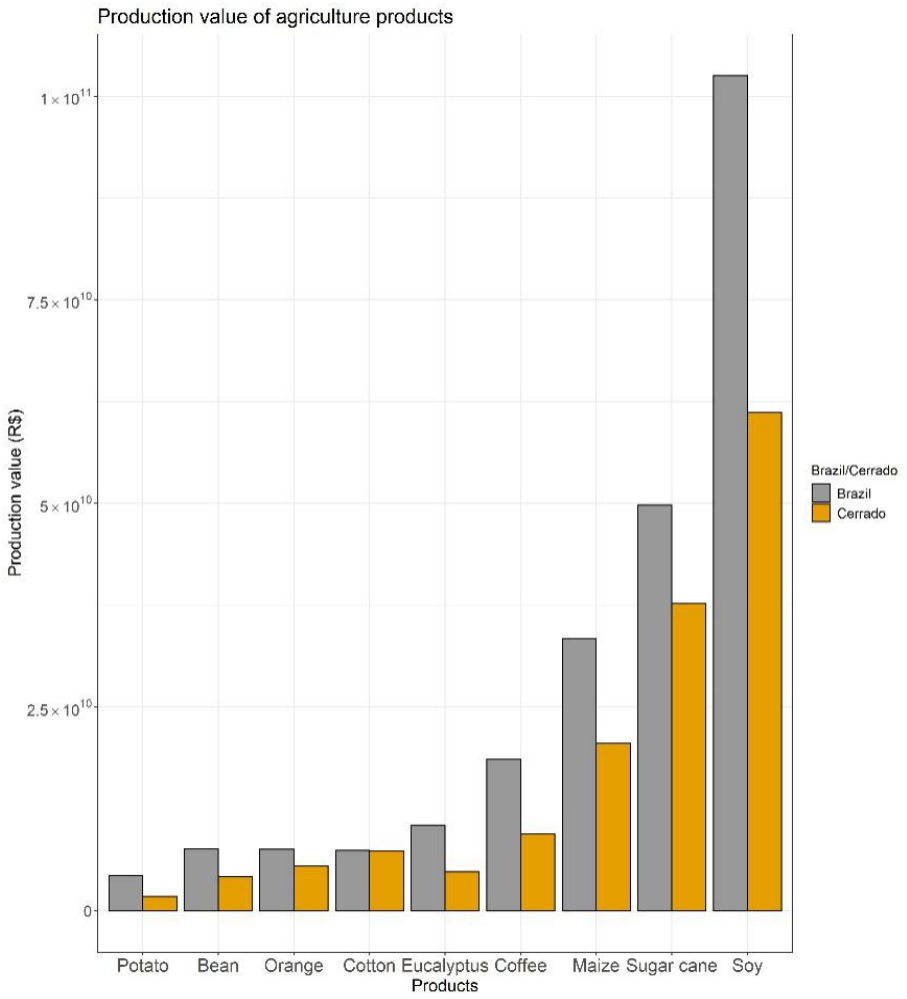

Fig. 3 Production value for the main agricultural products in Cerrado (average for the 2015/2016/2017 harvests).

Table 3 and Fig. 4 show that 98% of the Brazilian cotton is produced in Cerrado. Cotton is also the most planted crop in terms of planted area.

Another highlight is the eucalyptus charcoal production, which accounts for 81% of Cerrado's the total production.

Authors divided eucalyptus into categories because these categories occupy different territories, and because charcoal production is measured in tons, while the remainder are measured in cubic meters. Next come orange (71%), sugarcane (65%), maize (58%), soybean (55%), beans (49%), and bovines (40%). In terms of planted area, these are Cerrado' figures: 97% cotton, 62% sugarcane, 61% orange, 56% soybean, 54% maize, 47% eucalyptus, 36% potato, 34% coffee and 29% beans (Table 3).

Planted area figures for the main agricultural products compared to Cerrado's total area are shown in Table 4. The average area planted with cotton occupies 0.4% of Cerrado's total area. However, since part of the cotton crops are planted after soybean, and there are no data available on the first and second cotton harvests, the area planted with cotton was not included in the total planted area figures. Together, soybean and maize (first-harvest) occupy 11% of Cerrado's planted area.

The total planted area for soybean, maize (first-harvest), sugarcane, orange, eucalyptus, coffee, beans (first-harvest), and potato crops occupied 14.5% of Cerrado's area.

In terms of planted area, soybean, maize, and sugarcane occupy the largest areas among temporary crops (Fig. 5).

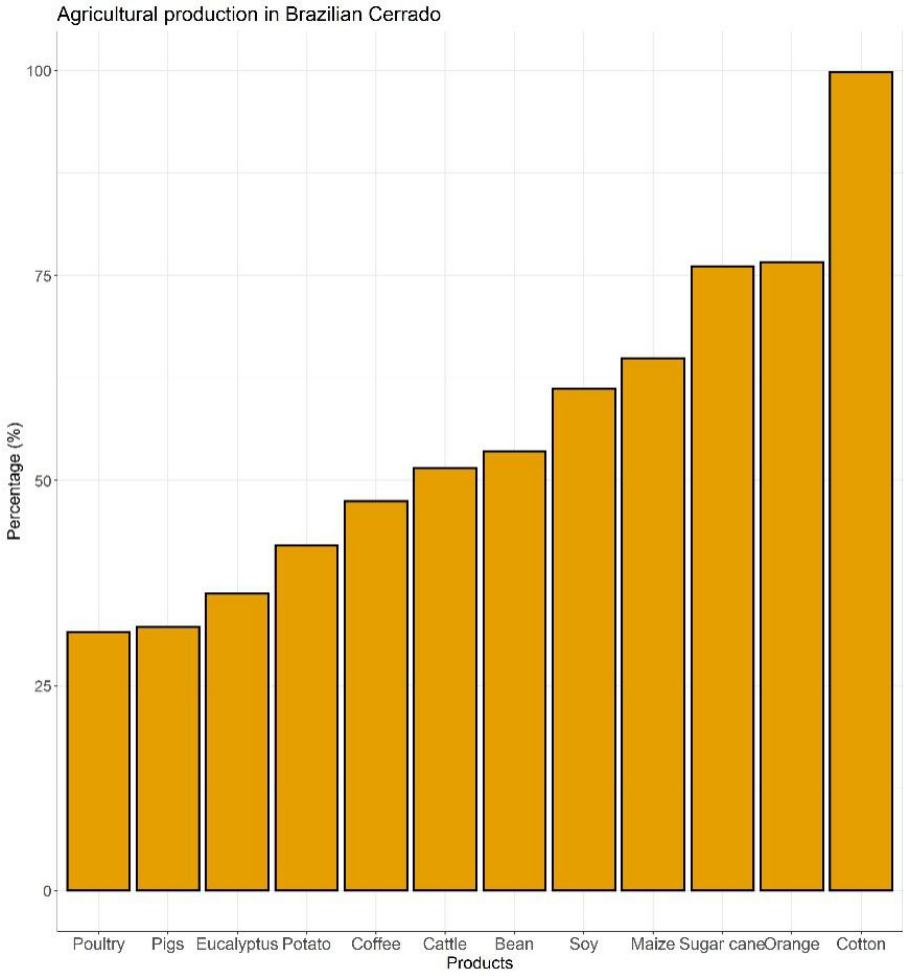

Fig. 4 Average production percentage for Cerrado's main products in comparison to the country's total figures.

Table 4 Planted area and participation compared with total amounts for Cerrado's main agricultural products.

Products	Planted area*	Planted area participation of Cerrado total area
	hectares	%
Soy	18 739 935	8
Maize (first-harvest)	7 003 618	3
Sugar cane	6 380 793	2.7
Eucalyptus	3 521 388	1.5
Coffee	657 096	0.3
Orange	402 731	0.2
Bean (first-harvest)	371 501	0.2
Potato	45 569	0.02
Total		14.5

* average for the 2015/2016/2017 harvests.

Source: [23-25].

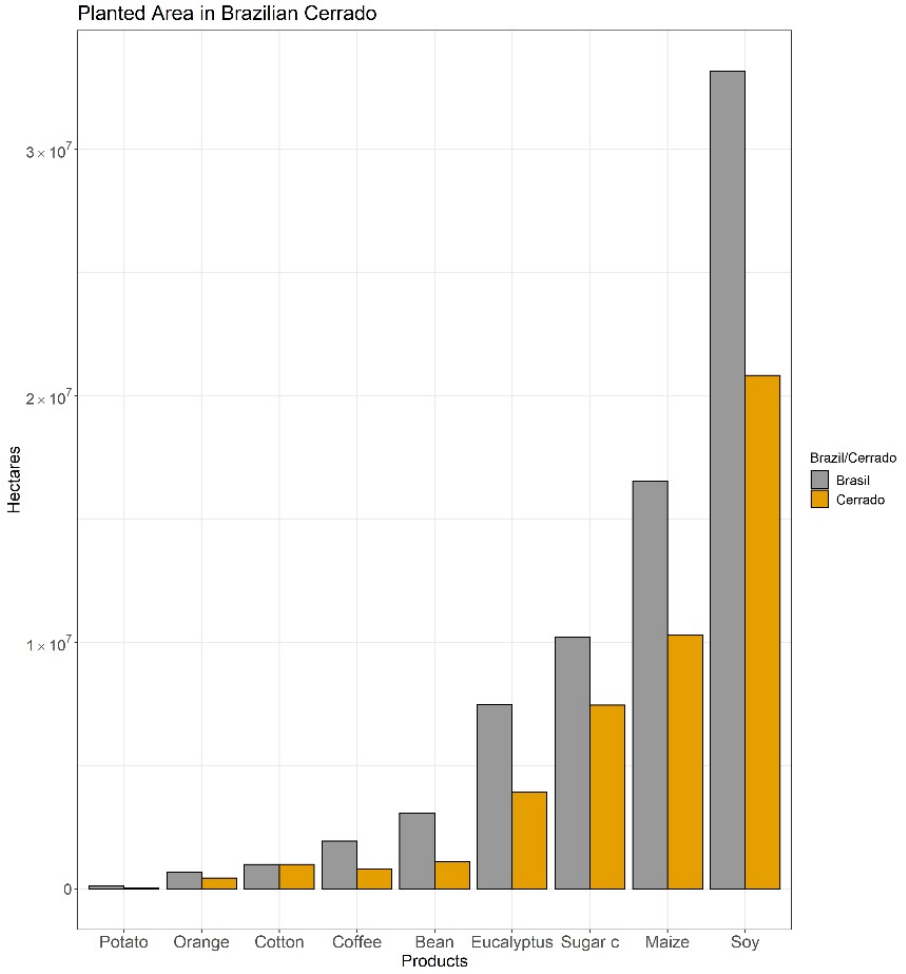

Fig. 5 Planted area for Cerrado's main agricultural products (average for the 2015/2016/2017 harvests).

Table 5 Total amount of areas designated for environmental preservation in farms in Cerrado and in Brazil.

States	Areas designated for environmental preservation (ADPs)			
	Cerrado of States			Cerrado of Brazil
	hectares	ADP/ farms	ADP/ State	ADP/ country
			%	
MA	7 479 042	55.5	54.7	3.2
TO	9 668 594	55.0	63.3	4.1
PI	3 607 979	59.9	55.1	1.5
BA	5 279 587	53.8	59.7	2.2
MATOPIBA	*26 035 203*	*55.5*	*32.6*	*11.1*
GO/DF	9 052 874	33.7	77.6	3.9
MT	15 319 717	44.4	72.4	6.5
MS	4 596 232	23.3	88.1	2.0
MG	10 216 377	35.8	73.4	4.3
SP	1 682 050	17.4	83.4	0.7
Total	66 902 454	40.3	28.5	28.5
Brazil	193 351 988	48	22.7	

Source: [23, 24].

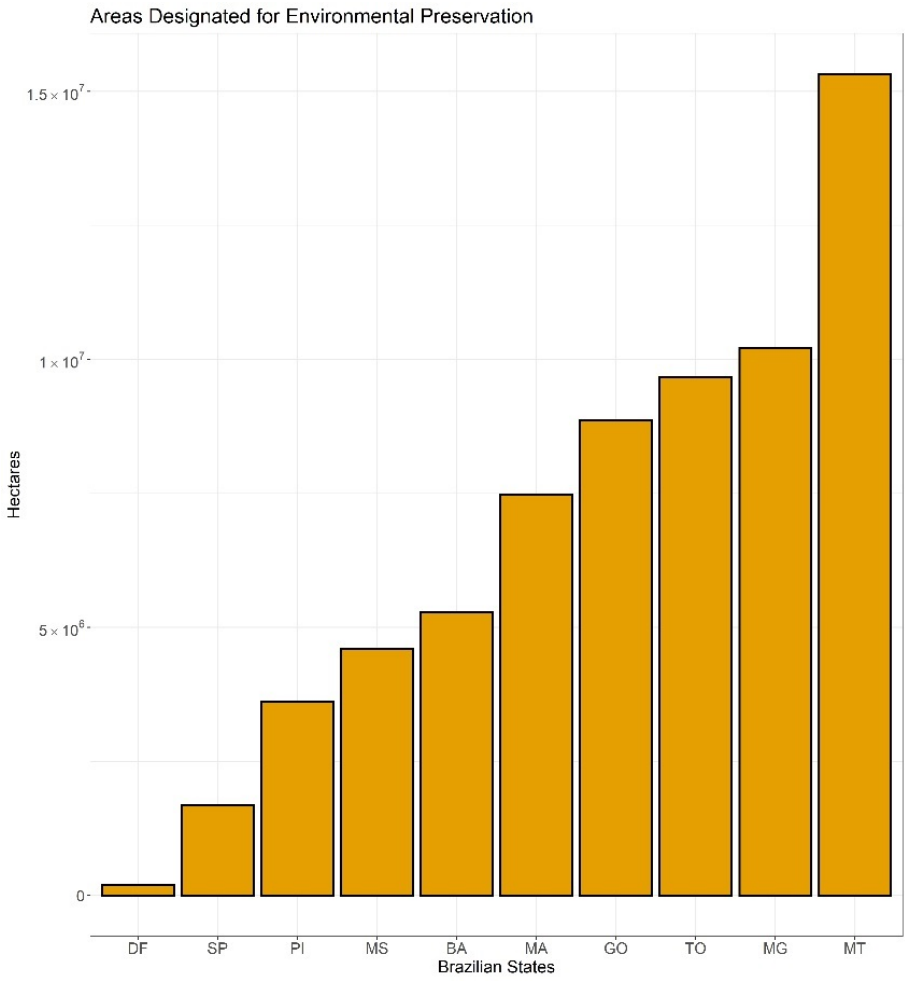

Fig. 6 Areas designated for environmental preservation in farms registered in the Brazilian Rural Environmental Registry and located in Cerrado areas (2018).

Cerrado has a total amount of 66.9 million hectares of ADP, which corresponds to 40.3% of the farms' areas and to 28.5% of Cerrado's area (Table 5 and Fig. 6).

Mato Grosso leads the ranking of ADP hectares: 44.4% of the farms' areas, 72.4% of the state's Cerrado areas, and 6.5% of the country's Cerrado areas. It is also the state that contributes the most with ADP areas to the country's Cerrado. The MATOPIBA region concentrates the highest percentages of ADP in farms–between 53.8% and 59.9% –which corresponds to 32.6% of the region's Cerrado and to 11.1% of the country's Cerrado (Table 5).

The data about Mato Grosso do Sul are underestimated, because, unlike the remaining states, it had not migrated the whole of its CAR data on farmers to SICAR until our study was concluded. This explains the small 10.8% ADP figures for Mato Grosso do Sul in spite of the fact that Cerrado occupies the largest part of the state (Table 5 and Fig. 6). Fig. 7 shows the distribution of the ADPs over Cerrado's microregions. Legal Amazon's boundaries are shown in the map by the different ADP percentages in the Cerrado biome, according to the Brazilian Forest Code for the Legal Amazon, as previously described. Thus, we verified ADP figures above 30% within the boundaries of the Legal Amazon.

When analyzing areas designated for preservation in Cerrado (Fig. 7), we noted that several microregions in the Central-West and North regions have ADP rates higher than 50% within the Legal Amazon region. We also verified ADP figures above 40% in the west region of the state of Bahia and through the whole of Piauí.

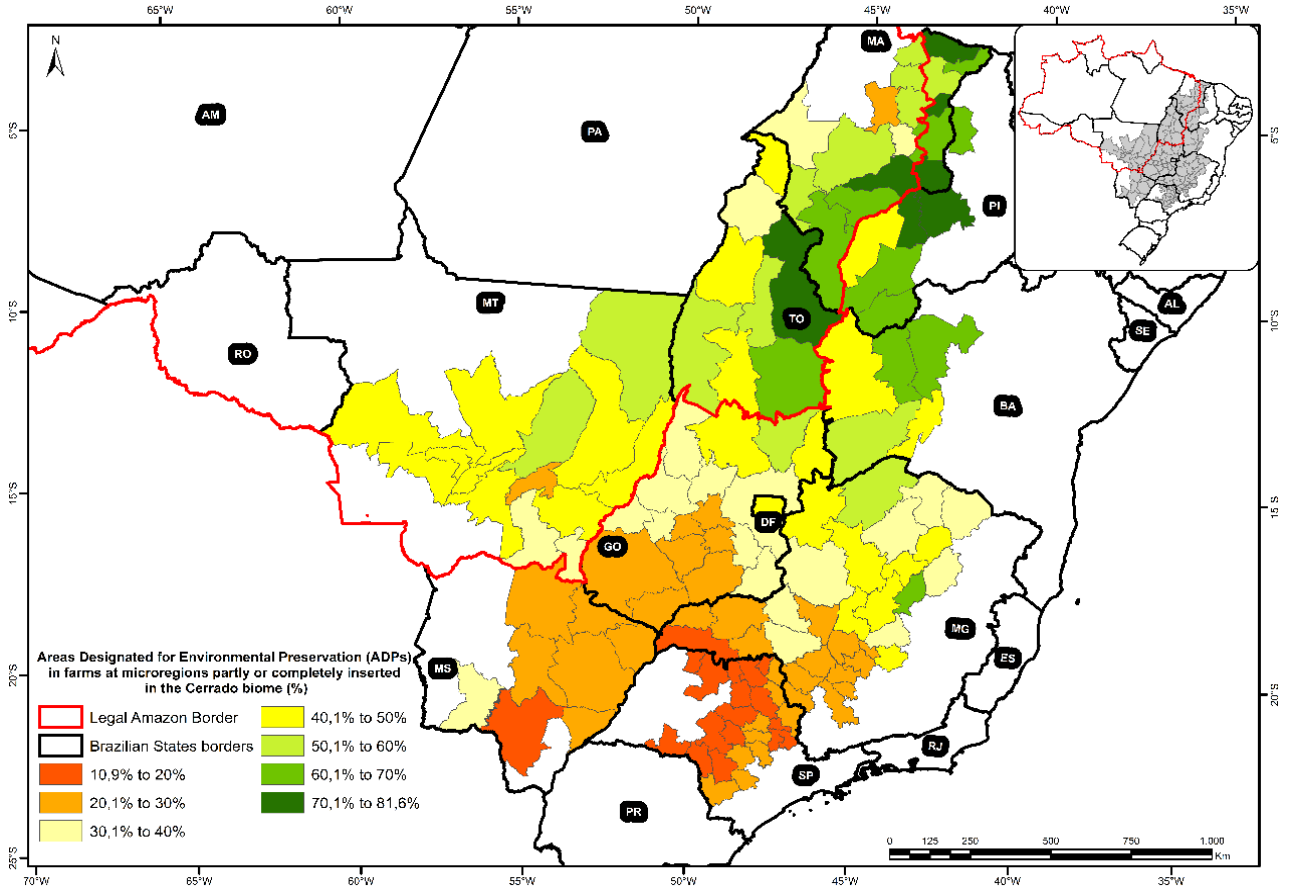

Fig. 7 Areas designated for environmental preservation in farms at microregions partly or completely inserted in the Cerrado biome.

São Paulo shows the lowest ADP value (17.7%). ADPs in early settled microregions, and which have higher numbers of farms smaller than four fiscal modules may, according to the Brazilian Forest Code, designate less than 20%of their areas for environmental preservation, as the microregions of the state of São Paulo depict [26]. Microregions located in Matopiba and areas at agricultural boundaries show ADP rates above 60%.

The most relevant agricultural products were selected for a more detailed analysis of their distribution in Cerrado, and were divided into annual crops (soybean and maize) and semiperennial and perennial crops (sugarcane and eucalyptus).

3.1 Soybean

Soybean is the agricultural product with the highest added value, and Brazil is ranked as its top exporter and second largest world producer [27].

Soybean production has increased nearly five times from 1990 to 2018, but the planted area has only tripled (Fig. 8), which is an indication of the importance of increasing crop productivity as one of the main factors for production consolidation [28].

The expansion of soybean crops, and the socioeconomic development of Brazilian cities between 1991, 2000, and 2010 were analyzed by Martinelli [29], who detected higher Human Development Index (HDI) in cities that produced soybean in comparison to those which did not, especially those located in agricultural boundaries.

The microregions featuring planted areas above 700 thousand hectares are located in the south portion of Mato Grosso do Sul, in the southwest of Goiás, in the north of Mato Grosso, and in the west portion of Bahia Fig. 9). The microregions of the G50 group (accountable for 50% of the production, G50 = Q4 +

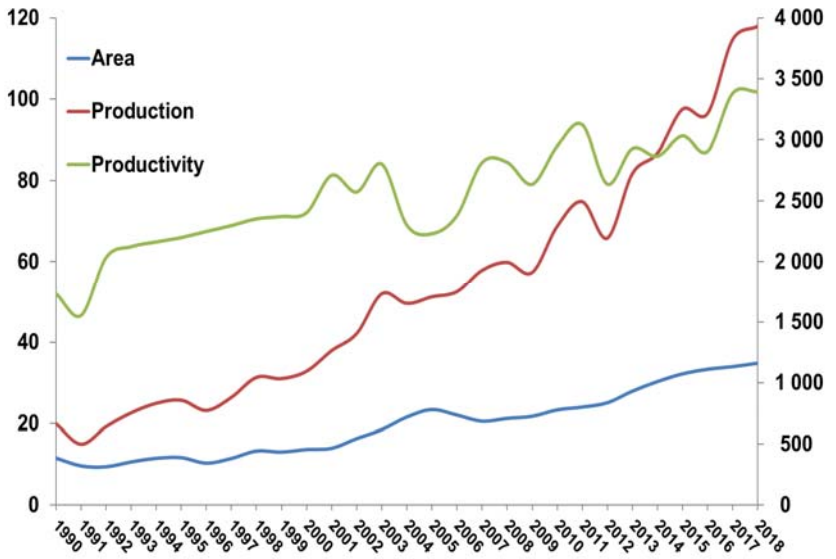

Fig. 8 Planted area, agricultural production and productivity for soybean in Brazil from 1990 to 2018.
Source: [25].

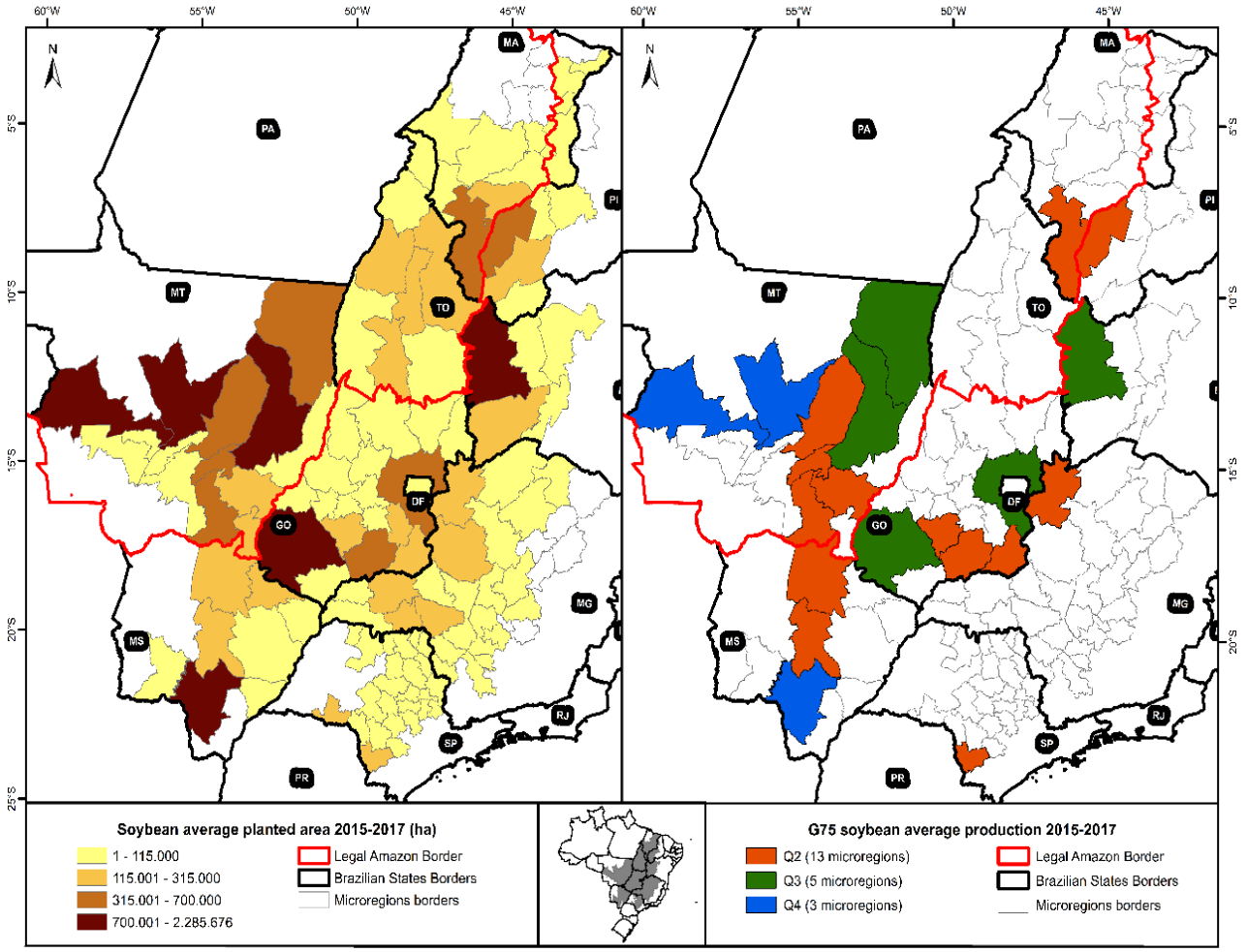

Fig. 9 Planted area and production groups (G75) for soybean at the microregions within the states in the Cerrado biome (average for the 2015/2016/2017 harvests).

Q3) are also the same, plus the microregion around the Brazilian Federal District.

3.2 Maize

Brazil is the world's third largest producer and the second largest exporter for maize [27]. The average Brazilian productivity for this crop is of 5400 kg/ha, but several farmers in different regions are reaching average productivities above 12,000 kg/ha.

The expansion of maize crops within Cerrado has increased a lot over the last decades, mainly under sequential cropping after soybean, because of early development soybean varieties (Fig. 10).

Second-harvest maize accounted for 77% of the total amount of maize planted in the last three harvests (on average) analyzed in this study. First-harvest maize crops accounted for 22% of the total.

Thus, maize production areas are concentrated in the same microregions with high soybean production rates. The Alto Teles Pires, in Mato Grosso, and Sudoeste de Goiás microregions concentrate 25% of the Brazilian production.

After selecting the microregions with highest soybean and maize production rates using the ADP in Fig. 7 authors obtained the data shown in Table 6.

The microregions showing strongest participation in Brazilian soybean and maize production also show ADP values of 46.3% at the Barreiras (BA) microregion, 29.2% at Sudoeste de Goiás, and 39.7% at Entorno de Brasília.

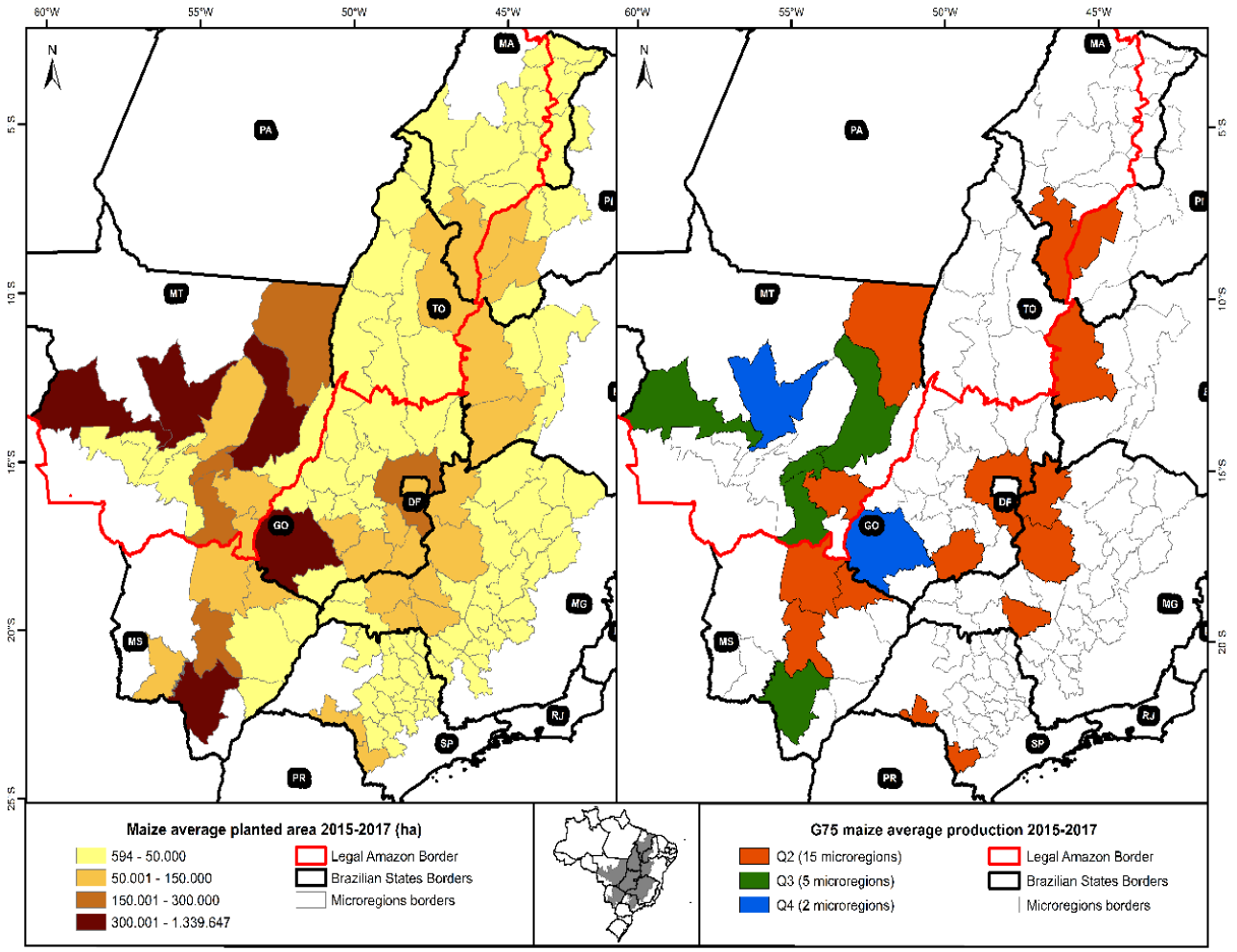

Fig. 10 Planted area and production groups (G75) for maize at the microregions within states in the Cerrado biome (average for the 2015/2016/2017 harvests).

Table 6 Areas designated for environmental preservation in farms (2018) at G50's microregions (average for the 2015/2016/2017 harvests).

Microregion	G50 group (50% of total production)		ADP in farms (%)
	soy	corn	
Norte Araguaia (MT)	x		52
Barreiras (BA)	x		46.3
Alto Teles Pires (MT)	x	x	42.7
Parecis (MT)	x	x	42.6
Canarana (MT)	x	x	41.8
Around Brasília (GO)	x		39.7
Rondonópolis (MT)		x	30.8
Southwest of Goiás (GO)	x	x	29.2
Primavera do Leste (MT)		x	22.6
Dourados (MS)	x	x	17.5

In these regions, the Brazilian Forest Code demands that at least 20% of the farms' areas are preserved (Table 6). Mato Grosso's microregions show values ranging from 52% to 22.6%. Within the Legal Amazon region, the Brazilian Forest Code demands that at least 35% of the farms' areas are preserved in the Cerrado biome, and 80% in the Amazon biome. Microregions in the north portion of the state of Mato Grosso, such as Norte Araguaia, where the Amazon biome predominates, show higher ADP values, such as 52%. The remainder of Mato Grosso's microregions are mostly located in Cerrado.

Average planted area data on soybean and maize (first-harvest) account for 11% of the Cerrado region (Table 4). Among the microregions that produce 50% of the country's total soybean and maize, Dourados (MS) shows the lowest ADP value, 17.5%. However, throughout the remaining G50 microregions, areas designated for environmental preservation are larger than areas designated for soybean and maize production. The Norte Araguaia (MT), Alto Teles Pires (MT), Parecis (MT), Canarana (MT), Entorno de Brasília (GO) and Barreiras (BA) microregions designate at least three times more areas for environmental preservation than areas for annual crops. In other three microregions, Rondonópolis (MT), Primavera do Leste (MT) and Sudoeste de Goiás (GO), the ADP areas are at least twice the size of soybean and maize areas.

As aforementioned, Mato Grosso do Sul made only part of its SICAR data available, therefore the 17.5% ADP value for Dourados (MS) is underestimated (Table 6).

3.3 Sugarcane

Brazil is the world's largest sugarcane producer. The crop's expansion throughout Cerrado started increasing in 2007, especially in Goiás and Mato Grosso do Sul, favored by ethanol production, a clean and renewable energy source fostered by federal public policies such as the Brazilian National Agroenergy Plan (Plano Nacional de Agroenergia, PNA) from 2006 to 2011. This expansion occurred primarily in agricultural areas used for annual crops, and secondarily in pasture areas, and tends to increase, because sugarcane showed the best average profitability among Brazilian agricultural activities in 2018, followed by soybean and maize [30-32].

The São José do Rio Preto, São Joaquim da Barra, Ribeirão Preto and Jaboticabal microregions in São Paulo, and Dourados microregion in Mato Grosso do Sul concentrate 25% of the Brazilian sugarcane production. The Meia Ponte microregion in Goiás, and the Uberaba and Frutal microregions in Minas Gerais, together with Araraquara, Assis and Jaú in São Paulo, concentrate 50% of the country's production and planted areas above 180 thousand hectares (Fig. 11).

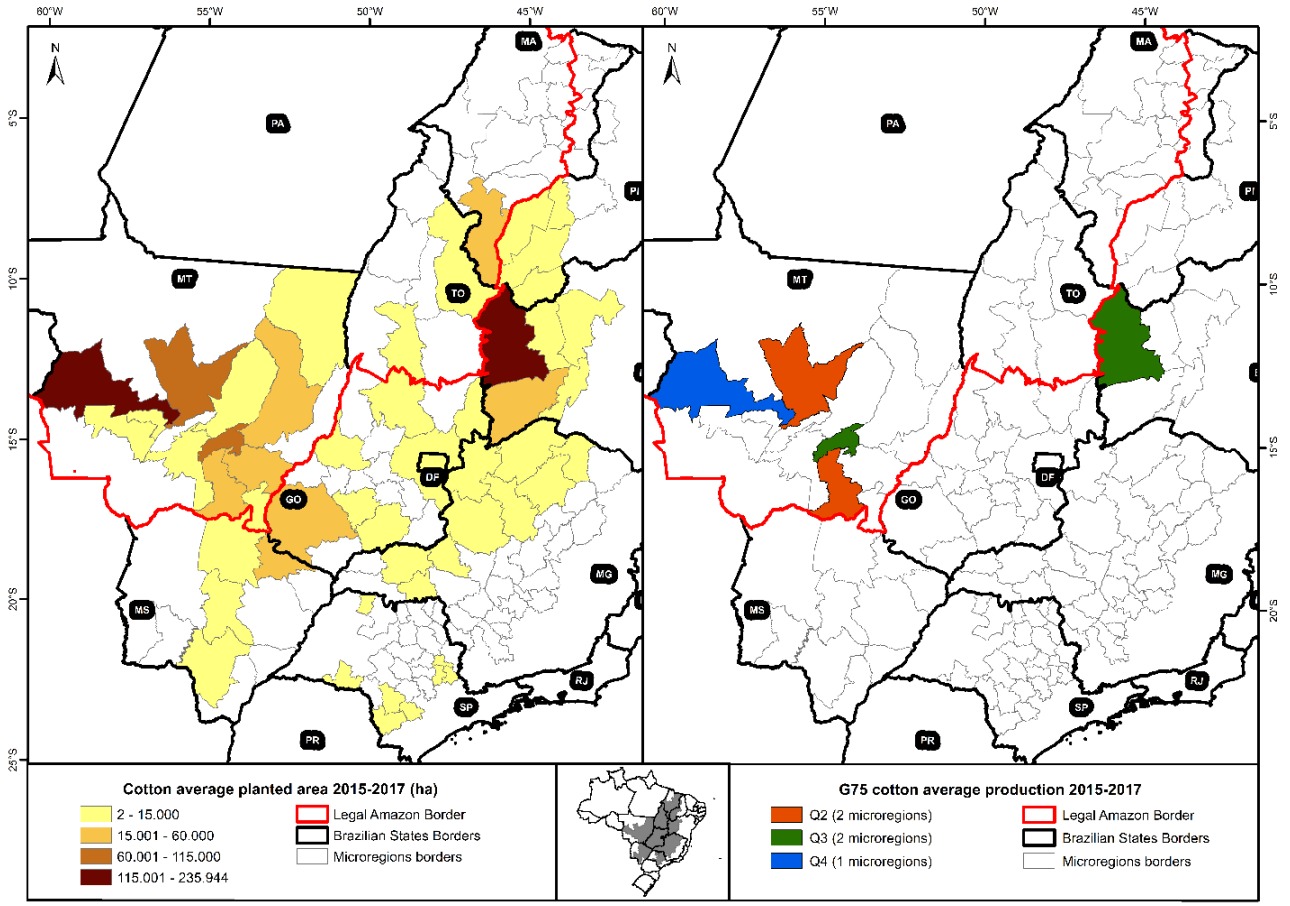

Fig. 11 Planted area and production groups (G75) for sugarcane at the microregions within states in the Cerrado biome (average for the 2015/2016/2017 harvests).

3.4 Eucalyptus

Eucalyptus crops account for 75% of the country's silvicultural production. The higher production value associated with eucalyptus crops is due to the fact that 53.7% of the Brazilian production is directed to the paper and pulp industry [33]. Eucalyptus production is divided into four main categories: logs for paper and pulp, logs for other uses, charcoal and fuelwood.

Each of these categories of eucalyptus produced in Cerrado have different production values: charcoal production has the strongest participation, with 43%, followed by paper and pulp, with 31%, then logs for other uses, with 13%, and fuelwood, with 12% [34].

The Três Lagoas and Paranaíba microregions in Mato Grosso do Sul, Bauru in São Paulo, and Paracatu, Salinas and Capelinha in Minas Gerais stand out among the largest eucalyptus areas in Cerrado (Fig. 12 and (Table 7). In the Paranaíba (MS) microregion there was a strong expansion in eucalyptus crops in the last years, from 89 thousand hectares in 2013 to nearly 205 thousand in 2017. Because eucalyptus production begins six years after planting, Paranaíba is not featured among the group of main eucalyptus producers in this study, but might be in it in the coming years.

The microregions in Mato Grosso do Sul and São Paulo concentrate 50% of the total eucalyptus production for paper and pulp. Microregions in São Paulo and Minas Gerais stand out in the production of logs for other uses. Minas Gerais concentrates 50% of the production of eucalyptus charcoal. Eucalyptus production for fuelwood takes place in several states and is concentrated in Goiás, Minas Gerais, São Paulo and Mato Grosso do Sul (Fig. 15).

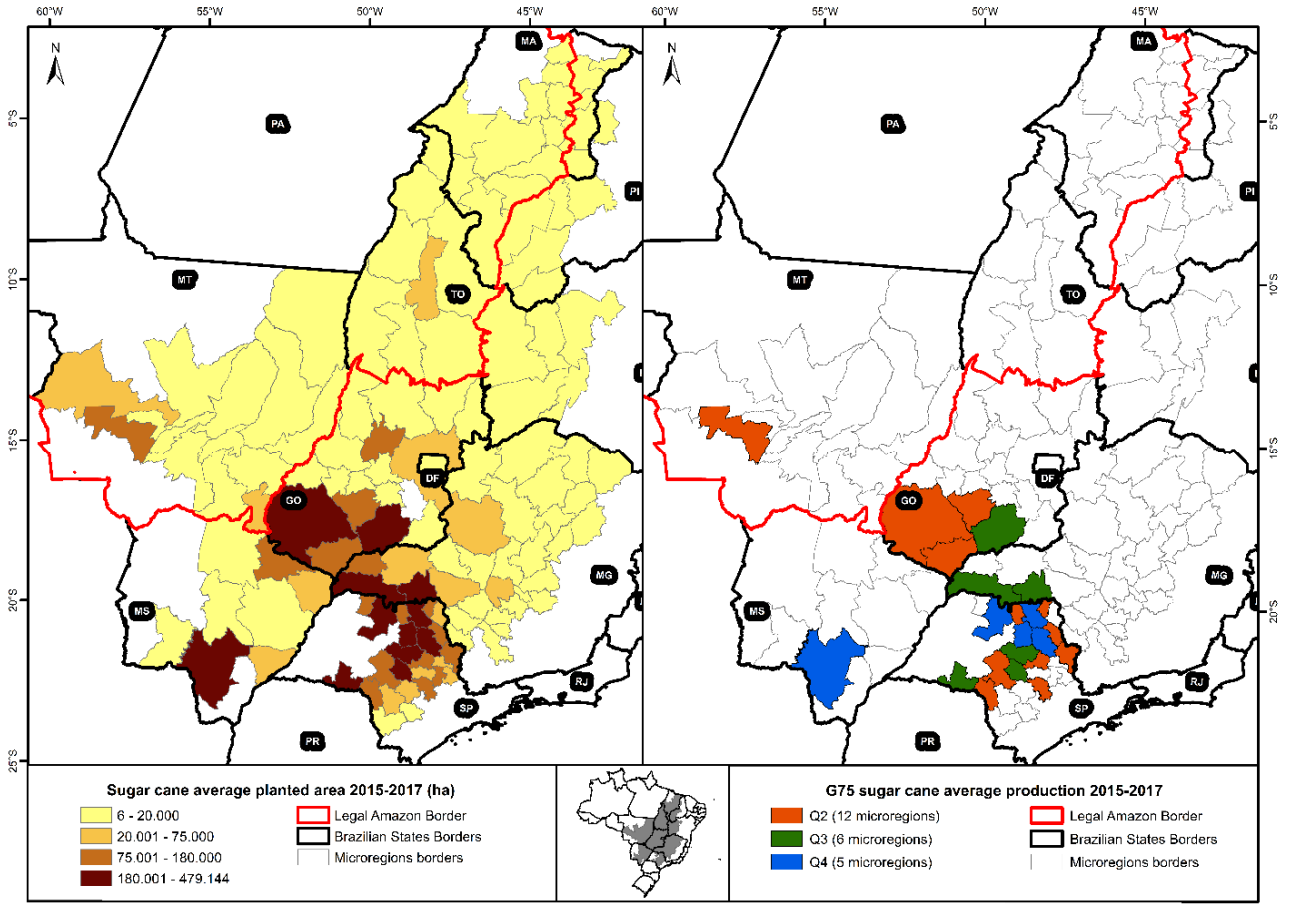

Fig. 12 Planted area for eucalyptus at the microregions within states in the Cerrado biome (average for the 2015/2016/2017 harvests).

Table 7 Areas designated for environmental preservation in farms (2018) at Brazil's G50 microregions for sugarcane and eucalyptus production (average for the 2015/2016/2017 harvests).

Microregion	G50 group (50% of total production)					ADP in farms (%)
	Sugar cane	Eucalyptus				
		paper and cel	log	coal	firewood	
Jaboticabal (SP)	x					10.9
São Joaquim da Barra (SP)	x					11.9
São José do Rio Preto (SP)	x					14.3
Ribeirão Preto (SP)	x					17.2
Dourados (MS)	x					17.5
Bauru (SP)		x	x		x	17.6
Frutal (MG)	x					18.3
Avaré (SP)			x			18.4
Três Lagoas (MS)		x				20.4
Piracicaba (SP)					x	20.7
Meia Ponte (GO)	x					22.7
Itapetininga (SP)		x	x		x	22.8
Botucatu (SP)			x			22.9
Uberlândia (MG)			x		x	23
Uberaba (MG)	x					24.1
Itapeva (SP)		x			x	24.3

Table 7 to be continued

Formiga (MG)			x	25.8
Passos (MG)			x	25.9
Patrocínio (MG)			x	30.6
Salinas (MG)			x	37.2
Capelinha (MG)	x	x	x	38.5
Paracatu (MG)		x	x	39.8
Três Marias (MG)		x		42.5
Pirapora (MG)		x		47.2

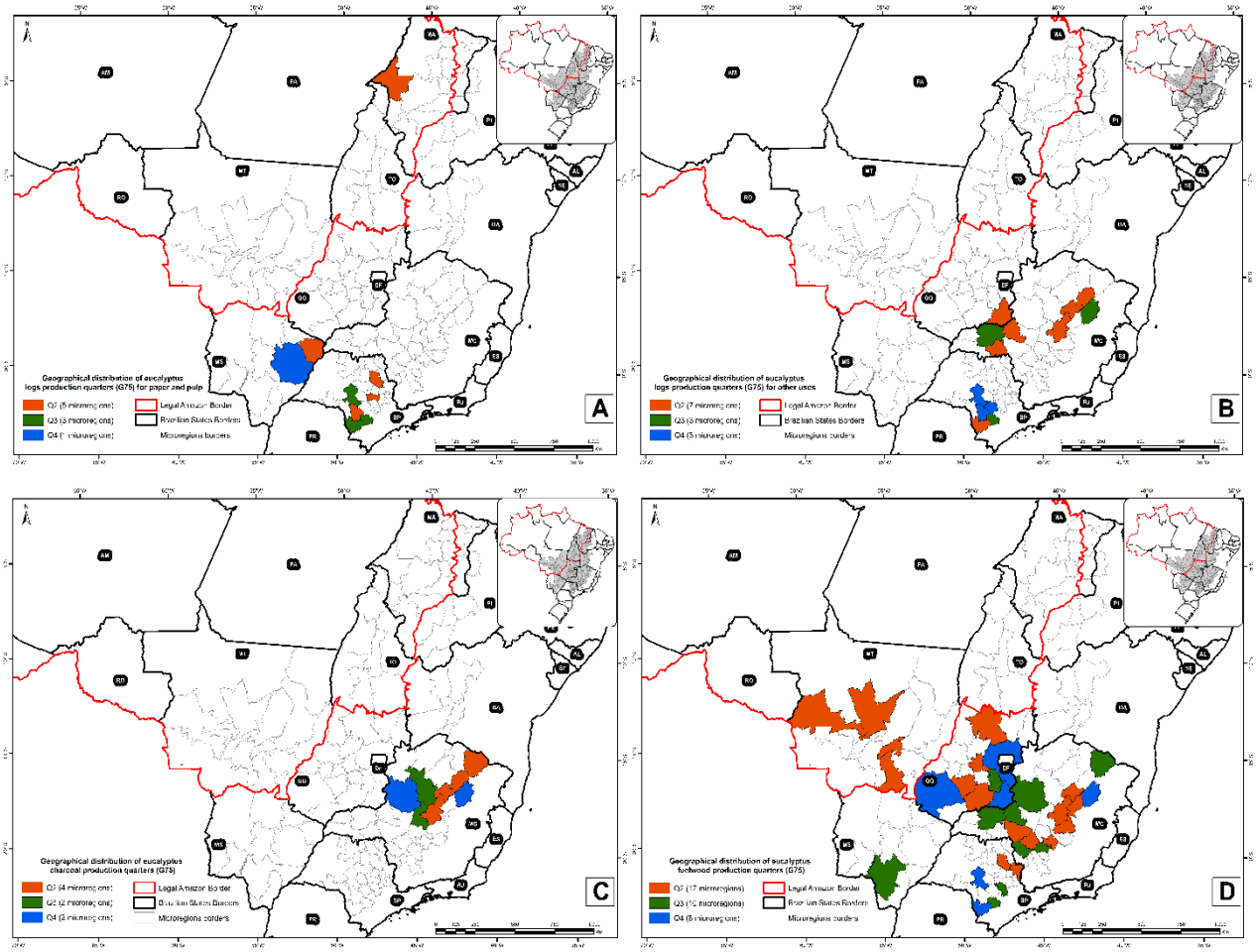

Fig. 13 Eucalyptus production at the microregions within states in the Cerrado biome (average for the 2015/2016/2017 harvests). Production of (A) logs for paper and cellulose (in cubic meters), (B) logs for other uses (in cubic meters), (C) charcoal (in tons), and (D) fuelwood (in cubic meters).

ADP values for sugarcane vary between 10.9 and 24.1% among microregions in the states of São Paulo, Minas Gerais, Mato Grosso do Sul and Goiás (Table 7). The territories occupied with eucalyptus crops change according to the crop's objectives. Crops for pulp and paper are concentrated in microregions in the states of Mato Grosso do Sul and São Paulo, whereas crops for log production for other uses and for fuelwood are concentrated in the states of São Paulo and Minas Gerais. Charcoal production is concentrated in Minas Gerais. The microregions in Cerrado which concentrate eucalyptus productions show ADPs ranging between 17.6 in Bauru (SP) and 47.2 in Pirapora (MG) (Table 7).

4. Conclusions

The Brazilian Forest Code demands that all farms equal to or larger than four fiscal modules designate at least 20% of their total areas to the permanent preservation of natural plant cover in Cerrado areas, and at least 35% in Cerrado areas within Legal Amazon's boundaries.

In the Cerrado areas analyzed in this study, 40.3% of the territory is designated for environmental preservation within farms, which designate 14.5% of their areas for main annual and perennial crops.

Hirakuri [35] state that after the Soybean Moratorium in 2006, the expansion of soybean crops is no longer an important cause for deforestation in Cerrado. The crop's technological development has been the major factor to its advancement. New cultivars and management technologies for soil and crop are launched steadily. The data published in this study show that, in a large territory such as Matopiba, which depicts well the country's agricultural boundary expansion, 55% of the farms are occupied by preservation areas, which amount to over 30% of the whole region (Table 5). Microregions in Maranhão and Piauí are part of the G75 production group for soybean and maize, and the amount of areas designated for environmental preservation surpass 40% in Piauí and 60% in Maranhão (Fig. 7).

Crops such as sugarcane and eucalyptus, which are traditionally grown in São Paulo and Minas Gerais, also showed strong expansion into the Central-West region, especially Goiás and Mato Grosso, over the last decades.

An example of agricultural production expansion in Cerrado is shown in [36]. They evaluated the expansion of sugarcane crops in the states of Goiás and DF between 2003 and 2013. According to their analysis, sugarcane areas increased six times in this period, from 142 thousand hectares to 847 thousand hectares, and 62% of this expansion occurred onto pasture areas, and 38% onto soybean areas. Only 6% of this expansion relied on the use of new Cerrado areas.

Land-use intensification by producing two or three successive harvests in a year has increased the country's agricultural production for annual crops and pastures without the need for using new areas [37, 38]. Studies show that agricultural intensification may result in the use of less areas, especially when associated with economic and environmental planning on a landscape and watershed level. Thus, there is room for the expansion of the agricultural industry while abiding by the Brazilian Forest Code and maintaining the country's biodiversity and ecosystem services, as shown in this territory analysis [36-39].

Mato Grosso is the country's leader in agricultural production for soybean, maize and cotton, and its farmers designate 44% of their farms for environmental preservation. This shows that farmers are accountable for the country's environmental preservation and contribute to it by maintaining and conserving the native vegetation areas within their farms [23].

Areas designated for environmental preservation promote several ecosystem services, such as soil and water preservation, conservation and rehabilitation of ecological processes such as the pollination of fruit and annual crops, natural biodiversity conservation and shelter against natural enemies that control plagues and diseases [40]. Besides, the microclimate created by forest formations aids the nearby crops [41]. The data shown in this study support the Brazilian Forest Code as an instrument that combines agricultural production and environmental preservation, and as such it may aid farmers and the country's environmental preservation efforts to increase and develop themselves together.

Discussing whether these values are considered adequate, high or low was not our goal in this study, because a qualitative assessment would depend on jointly analyzing the multiple environmental factors involved. Embrapa Territorial has been carrying out studies on the biodiversity of the phytophysiognomies of APP and RL areas within Cerrado regions. These studies may further contribute to assessments on the

conditions of these environmental preservation areas in the future.

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