MATOPIBA: THE EXPANSION OF AGRICULTURE INTO REMNANTS OF NATIVE VEGETATION IN THE CERRADO BIOME

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† The starting point of this research are the results and discussions presented in Barbirato’s Master’s thesis in Ecosystem Services (2016), which was supervised by Professor Dr. Dan van der Horst (University of Edinburgh). Available at: https://figshare.com/s/9c8672b43ef31130425b

SUMMARY AND MAIN CONCLUSIONS

• MATOPIBA is Brazil’s new agricultural frontier. Grain and cotton production is expanding into the Cerrado biome (a global biodiversity hotspot). The region stretches for approximately 730,000 km² across 337 municipalities in the States of Maranhão, Tocantins, Piauí, and Bahia;

• The Cerrado region of MATOPIBA has the highest official deforestation rates in the biome. Agriculture is the major land use change vector and will probably continue to grow due to the availability of land, a business model based on the increasing value of land and its importance to the country’s economy;

• Data on tree cover loss (TCL) available on the Global Forest Watch platform (GFW) indicate that twenty municipalities alone accounted for a third of total TCL in MATOPIBA from 2009 - 2015;

• In 2015, the total area of remnants of native vegetation of the Cerrado biome in the MATOPIBA region was estimated at approximately 479,000 km², and the overall area of the twenty municipalities with the largest remnants of the biome accounted for a third of this total;

• Between 2001 and 2015, the area in which temporary crops are grown increased by almost 3.5 million hectares; the nominal production value rose tenfold to R$16.7 billion. In 2015, seven crops accounted for 98% of the total area used for growing temporary crops – soybeans accounted for 62%;

• In 2015, the highest average yields for corn and cotton were concentrated in consolidated agricultural areas. In the case of soybean, which is the main crop, the highest yields are scattered throughout the region rather than concentrated in leading producing municipalities;

• Soybean is the main crop with a production value close to R$10 billion in 2015. Production is highly concentrated - twenty municipalities account for approximately 70% of the production value. The variance between average yields (kg/ha/year) has increased in recent years, and unlike in other crops the highest values do not occur in leading producing municipalities;

• Data available on the MAPBIOMAS platform for the period 2000 - 2016 are discussed for MATOPIBA, and in general there are large area losses in classes such as "Dense Forest", "Open Forest" and "Rupetrian Fields" used for "Pasture", "Agriculture or Pasture" and "Annual Crops" in the period - although the dynamics of land use and land use change differ substantially from one another throughout the region;

• There are numerous challenges and opportunities for the sustainable use of the Cerrado region, not only in the MATOPIBA region. These should be associated with the planning of land use and occupation. The coordination and engagement of key actors will be essential for Brazil and domestic companies of the main agricultural chains to fulfill their international commitments in different thematic areas, as indicated in the “Cerrado Manifesto.”
INTRODUCTION

The Ministry of Agriculture, Livestock and Food Supply (MAPA) signed the MATOPIBA Agricultural Development Plan in November 2015 (MAPA 2015) through Ministerial Decree No. 244, following the launch of the Agricultural Development Plan for the region (Federal Decree, 2015). The geographical boundaries of the region (Figure 1) were proposed by EMBRAPA (Miranda et al., 2014). The Cerrado biome covers more than 90% of the area. The remaining area extends across the Amazon (around 7%) and Caatinga (approximately 2%) biomes.

The region stretches for approximately 730,000 km² across 31 micro-regions and 337 municipalities (Miranda et al., 2014) in four Brazilian states: 135 municipalities in Maranhão (MA), 139 in Tocantins (TO), 33 in Piauí (PI), and 30 in Bahia (BA). The micro-regions follow the IBGE classification, and 340,000 km² (almost half of the total area) correspond to agricultural establishments (just over 324,000). The total population is 5.9 million, of which more than half is in Maranhão (SIDRA-IBGE).
LAND USE CHANGES: AGRICULTURAL EXPANSION IN THE CERRADO IN THE MATOPIBA REGION

The region has experienced a strong agricultural expansion in recent years and is considered the country’s newest agricultural frontier (Miranda et al. 2014; OECD/FAO 2015; Richards 2015; Spera et al. 2016; Câmara et al. 2015). Not surprisingly, the official deforestation rates published by the Ministry of the Environment were high in several municipalities; some are even among the highest in the country (MMA/IBAMA/UNDP 2009, MMA/IBAMA 2011; MMA/IBAMA 2015; MMA 2017).

For example, from 2002 to 2008, official deforestation in São Desidério (BA) totaled 1,329 km², the equivalent of 9% of remnants of Cerrado vegetation existing in the municipality at the beginning of the analyzed period, and 2,000 km² in Formosa do Rio Preto (BA), the equivalent of 12.4% of natural vegetation (MMA/IBAMA/UNDP 2009). The deforestation trend in these and other municipalities continued in subsequent years. In 2011, official deforestation totaled 149 km² in São Desidério (BA), 195 km² in Formosa do Rio Preto (BA), and 209 km² in Uruçuí (PI) (MMA/IBAMA 2015).
The 2013-2015 period, the ten highest deforestation figures in the entire Cerrado biome (MMA 2017) were recorded in the MATOPIBA region, half of which in western Bahia: 337 km² in São Desidério, 295 km² in Jaborandi, 271 km² in Formosa do Rio Preto, 183 km² in Cocos, and 165 km² in Correntina. Two municipalities in Piauí (Uruçuí and Baixa Grande do Ribeiro with 228 km² and 187 km² respectively) and two in Maranhão (Balsas and Grajaú with 207 km² and 200 km² respectively) also stood out negatively for their high deforestation values. Tenth in the list of municipalities with the highest rates of deforestation throughout the Cerrado between 2013 and 2015 is the municipality of Peixes, in Tocantins, with 165 km² of deforested area.

**OBJECTIVES AND METHODS**

This study is intended to characterize the dynamics of agricultural expansion and deforestation in the territory and therefore answer the following questions:

1. Based on data for tree cover loss available in the Global Forest Watch, what was the size of remnants of native vegetation of the Cerrado biome in the MATOPIBA region (by municipality) in 2015 and where are the largest remnants of the biome located?

2. Considering the relevance of agriculture to the region, what was the status of the main agricultural crops in 2015 (i.e. where are the highest values of production, planted areas and highest/lowest average yields located)?

3. Considering the size of the MATOPIBA region, where should efforts be focused to reduce pressures on the Cerrado vegetation cover or increase the average yields of the main temporary crops?

**What is “tree cover loss”?**

“Tree Cover” in the data set of the Global Forest Watch platform is defined as any vegetation higher than five meters and may take the form of natural forests or managed plantations. The database is based on high-resolution maps of forest cover change (30m x 30m resolution). The algorithm for detecting forest changes is based on satellite imagery - Landsat 5 thematic mapper (TM), Landsat 7 thematic mapper plus (ETM+) and Landsat 8 operational ground imaging (OLI) sensors. More than one million images were analyzed. “Tree cover loss” (TCL) is defined as a “stand-replacement disturbance or the complete removal of the tree cover canopy at the Landsat pixel scale.” It is important to emphasize that the TLC detected by satellite imagery can be the result not only of deforestation but also of forest management practices (e.g., wood harvesting in managed forests) or natural disturbances in the ecosystem (e.g., diseases and damages caused by storms). Natural fires (due to lightning in storms) and fires caused by humans contribute to tree cover loss as well.

In the research for the master’s thesis (BARBIRATO 2016), the TCL and deforestation values for different periods were matched for 40 municipalities and a significant relation (p-value <0.0001), \( R^2 = 0.9121 \) was found, with normality and homoscedasticity assumptions met (p-value = 0.6047 for the Shapiro-Wilk test; p-value = 0.865 for the Bartlett test).

\[
\log [\text{deforestation}] = 0.9292 \times \log [\text{PCA}] + 0.5364
\]

1 Hansen et al 2013; e colaboração com a Universidade de Maryland, Google, U.S. Geological Survey e NASA
Methods

The estimate of remnants of Cerrado in the year 2008 is based on official data (IBAMA/MMA 2008) of the PMDBBS – Project for Satellite-based Deforestation Monitoring of Brazilian Biomes. The shapefile can be downloaded from the LAPIG-Maps website, an online tool of the Federal University of Goiás/Image Processing and Geoprocessing Laboratory- LAPIG). This is illustrated in Figure 3. The files containing the polygons of the municipalities and the land structure of the MATOPIBA region were obtained on the “Geoweb MATOPIBA” platform (EMBRAPA, 2015).

![Figure 3: Remnants of Cerrado in MATOPIBA in the base year 2008: the result of the intersection between the map of remnants of the biome in 2008 and the boundary delimitation of the MATOPIBA region.](http://www.qgis.org/en/site/forusers/download.html)
RESULTS


Considering remnants of Cerrado biome in the MATOPIBA region of approximately 499,496 km² (base year 2008), tree cover loss in the period 2009-2015 totaled 20,286 km² or roughly 4% of remnants of Cerrado. In the period from 2009 to 2015, a few municipalities (twenty) accounted for a third of the total tree cover loss in remnants of Cerrado in the MATOPIBA region (Figure 4). In 2015, tree cover loss totaled 3,625 km², the equivalent of more than 335,000 soccer fields. In the top twenty municipalities with the highest observed values, the tree cover loss area was larger than 108,000 soccer fields (totaling 1,175 km²), or the equivalent of 32.41% of the total area.

<table>
<thead>
<tr>
<th>Municipality</th>
<th>State</th>
<th>TLC (km²) 2009-2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Formosa do Rio Preto</td>
<td>BA</td>
<td>956</td>
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<tr>
<td>2 Baixa Grande do Ribeiro</td>
<td>PI</td>
<td>695</td>
</tr>
<tr>
<td>3 Corretina</td>
<td>BA</td>
<td>577</td>
</tr>
<tr>
<td>4 Grajaú</td>
<td>MA</td>
<td>495</td>
</tr>
<tr>
<td>5 Cotegipe</td>
<td>BA</td>
<td>374</td>
</tr>
<tr>
<td>6 Santa Rita de Cásia</td>
<td>BA</td>
<td>339</td>
</tr>
<tr>
<td>7 São Desidério</td>
<td>BA</td>
<td>320</td>
</tr>
<tr>
<td>8 Balsas</td>
<td>MA</td>
<td>297</td>
</tr>
<tr>
<td>9 Santa Filomena</td>
<td>PI</td>
<td>279</td>
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<td>10 Peixe</td>
<td>TO</td>
<td>270</td>
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<td>11 Codó</td>
<td>MA</td>
<td>267</td>
</tr>
<tr>
<td>12 Mansidão</td>
<td>BA</td>
<td>240</td>
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<tr>
<td>13 Tuntum</td>
<td>MA</td>
<td>223</td>
</tr>
<tr>
<td>14 Barra do Corda</td>
<td>MA</td>
<td>220</td>
</tr>
<tr>
<td>15 Barreiras</td>
<td>BA</td>
<td>212</td>
</tr>
<tr>
<td>16 Caxias</td>
<td>MA</td>
<td>203</td>
</tr>
<tr>
<td>17 Ribeiro Goçalves</td>
<td>PI</td>
<td>199</td>
</tr>
<tr>
<td>18 Riachão das Neves</td>
<td>BA</td>
<td>194</td>
</tr>
<tr>
<td>19 Parnarama</td>
<td>MA</td>
<td>189</td>
</tr>
<tr>
<td>20 Bom Jesus</td>
<td>PI</td>
<td>186</td>
</tr>
</tbody>
</table>

The remnants of the Cerrado biome in the MATOPIBA region in 2015 (479,210 km²) were calculated by subtracting:

A. the tree cover loss area observed in each polygon of remnants of Cerrado (base year 2008) for each municipality in the period 2009-2015; from
B. the total area (i.e., sum) of each polygon of remnants of Cerrado for each municipality (base year 2008).

Medidas consideradas: 120m x 90m
Figure 5 shows the twenty largest remnants of the Cerrado biome in the MATOPIBA region in 2015 after data collection and compilation. The combined area of these twenty largest remnants totals 156,506 km², accounting for a third of the total remnants of Cerrado in the MATOPIBA region.

Agricultural Crops in the MATOPIBA Region in 2015

Between 2001 and 2015, the area of permanent crops fell by approximately 10,000 hectares (51,825 hectares in 2015), but the production value almost tripled in the period (nominal values), reaching approximately R$600 million. The area used for temporary crops more than doubled in the same period (from 2.5 million to 5.9 million hectares) and was responsible for generating R$16.7 billion in 2015, an amount ten times higher than in 2001.

Seven crops (soybeans, cotton, corn, sugarcane, rice, beans, cassava) accounted for 98% of the total area of temporary crops in the MATOPIBA region in 2015. Three crops (soybeans, cotton and corn) accounted for 85%; two (soybeans and cotton) accounted for 68%; and soybeans accounted for 62% of the total area of temporary crops in the MATOPIBA region in 2015 (Figures 6 and 7).
Figure 6: Importance of crops in the MATOPIBA region. Special mention should be made of the importance of soybeans and of the concentration of its production value (R$) in few municipalities.

Figure 7: Planted area (ha) and production value (R$1,000) of the main temporary crops in the MATOPIBA region in 2015.

Source: SIDRA-IBGE (PAM)
In 2015, the area of temporary crops in three municipalities alone (São Desidério, Formosa do Rio Preto and Luís Eduardo Magalhães, all in western Bahia) accounted for 22% of the total area of temporary crops, and generated R$5.1 billion in revenues - almost a third of the total amount generated in temporary crops in the MATOPIBA region in 2015 (Figure 8).

- The most significant agricultural changes between 2001 and 2015 throughout the MATOPIBA region occurred in Formosa do Rio Preto, where the area of temporary crops increased by more than 360% (to almost 460,000 hectares) and the nominal production value rose by more than 1,600% in relation to 2001 (to approximately R$1.4 billion).

- The most important municipality regarding temporary crops continues to be São Desidério, where the total area of these crops almost doubled in the period 2001-2015 (approximately 600,000 hectares in 2015), and almost R$2.8 billion in revenues were generated (almost 1,000% in relation to nominal values in 2001).

**Figure 8: Comparison of temporary crops (planted area and production value) in 2001 and 2015 and regional relevance of six municipalities (all in Bahia): Formosa do Rio Preto (FRP), São Desidério (SD), Barreiras, Luis Eduardo Magalhães (LEM), Correntina, and Riachão das Neves (RN)**

* FRP = Formosa do Rio Preto; SD = São Desidério; LEM = Luís Eduardo Magalhães; RN = Riachão das Neves

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*Figure 8: Comparison of temporary crops (planted area and production value) in 2001 and 2015 and regional relevance of six municipalities (all in Bahia): Formosa do Rio Preto (FRP), São Desidério (SD), Barreiras, Luis Eduardo Magalhães (LEM), Correntina, and Riachão das Neves (RN)*
**SPECIALIZATION AND IMPORTANCE OF SOYBEAN**

Soybean is the most important crop grown in the MATOPIBA region, having generated almost R$10 billion in revenues in 2015, in a planted area of 3.68 million hectares. Between 2001 and 2015, the number of municipalities growing soybean more than doubled (from 70 to 157). Figure 9 shows the evolution by State, year by year.

Production is highly concentrated and ten municipalities (six in Bahia, two in Maranhão and two in Piauí) (Figure 10) generated more than R$5.7 billion in soybean production in 2015, for a planted area of approximately 2 million hectares. The revenue generated in these ten municipalities accounts for almost 60% of the total revenue from soybean production in the entire region in 2015. The first four municipalities alone (São Desidério, Formosa do Rio Preto, Correntina, and Barreiras - all in Bahia) account for a third of the total.

São Desidério and Formosa do Rio Preto stand out, with 350,000 and 360,000 hectares of soybean crops respectively in 2015. Together, they generated more than R$2.2 billion in revenues from this crop alone. An interesting finding of the research was that the same concentration in production was already occurring in 2001, although the crop was grown by a smaller number of municipalities. In both 2001 and 2015, the soybean area in the twenty municipalities with the highest values of production was around 70% of the total soybean area in the MATOPIBA region.
According to the Municipal Agricultural Production (PAM) report of the Ministry of Agriculture, Livestock and Food Supply (MAPA 2016a), in Brazil in 2015:

- The area of temporary and permanent crops totaled more than 76 million hectares and the cereal grain harvest alone exceeded 209 million tons;
- Soybean and corn were the most important crops - the same is true of the MATOPIBA region;
- The soybean and corn harvests reached 97.5 million 85 million tons respectively;
- Soybean, corn, sugarcane and coffee production accounted for 60.2% of the total cultivated area;

In 2015, the municipalities of São Desidério and Formosa do Rio Preto (both located in the west of Bahia) ranked second and in soybean revenues in the country - more than R$1 billion in production value, behind only Sorriso (MT), which generated more than R$1.5 billion from this crop in 2015 (MAPA 2016a). In terms of planted area in the country, Formosa do Rio Preto ranks fifth and São Desidério seventh, totaling together more than 600,000 ha (PAM 2015). Agricultural GDP in 2015 was over R$263 billion (MAPA 2016b), a 1.8% growth in relation to 2014 (when Brazilian GDP shrank to 3.8%), thus highlighting the importance of agriculture in the country’s economy.
OTHER IMPORTANT TEMPORARY CROPS - WHERE?

Figure 11 shows the spatial distribution of the main temporary crops in the MATOPIBA region in 2015.

**Sugarcane** was grown in 142 municipalities, and the total revenue from this crop in the MATOPIBA region in 2015 totaled approximately R$439 million, in 98,300 hectares of planted area. Pedro Afonso (TO) and São Raimundo das Mangabeiras (MA), with 29,000 and 17,110 hectares of planted area respectively, generated 43% of the total revenue - the top ten municipalities accounted for almost 81% of the total production value for sugarcane. They are: Pedro Afonso (TO), São Raimundo das Mangabeiras (MA), Aldeias Altas (MA), Campestre do Maranhão (MA), Coelho Neto (MA), Caxias (MA), Bom Jesus (PI) do Tocantins (TO), Tupirama (TO), Angical (BA), and Codó (MA).

In turn, **rice** was grown in 302 municipalities, and the total revenue from this crop in the MATOPIBA region in 2015 was approximately R$642 million, in 335,000 hectares of planted area. Lagoa da Confusão (TO) and Formoso do Araguaia (TO), with 43,600 and 24,139 hectares of planted area respectively, generated almost half of the total revenue - the top ten municipalities accounted for approximately 68% of the total production value for rice. They are: Lagoa da Confusão (TO), Formoso do Araguaia (TO), Dueré (TO), Pium (TO), Baixa Grande do Ribeiro (PI), Cristalândia (TO), Uruçuí (PI), Crixás do Tocantins (TO), Grajaú (MA), and São Mateus do Maranhão (MA).

**Herbaceous cotton** was produced in 24 municipalities, and the total revenue from this crop in the MATOPIBA region in 2015 was R$2.74 billion, in approximately 354,000 hectares of planted area. São Desidério (BA), with 117,303 hectares of planted area accounted for almost half of the total revenue - the top five municipalities accounted for approximately 83% of the total production value for cotton. They are: São Desidério (BA), Luís Eduardo Magalhães (BA), Barreiras (BA), Riachão das Neves (BA), and Formosa do Rio Preto (BA). Herbaceous cotton was the crop with the highest value added per hectare planted (revenue of more than R$10,000/ha in some municipalities).

**Corn** crops were found in 329 municipalities, and the total revenue from this crop in the MATOPIBA region in 2015 was close to R$2 billion, in approximately 982,000 hectares of planted area. São Desidério (BA) and Uruçuí (PI), with 74,000 and 53,037 hectares of planted areas respectively, accounted for almost 20% of total revenue - the top ten municipalities accounted for approximately 57% of the total production value for corn that year. They are: São Desidério (BA), Uruçuí (PI), Formosa do Rio Preto (BA), Balsas (MA), Campos Lindos (TO), Luís Eduardo Magalhães (BA), Baixa Grande do Ribeiro (PI), Barreiras (BA), Riachão das Neves (BA), and Tasso Fragoso (MA).

**Cassava** was grown in 306 municipalities, and the total revenue from this crop in the MATOPIBA region in 2015 was a little over R$309 million, in approximately 122,000 hectares of planted area. Production is more fragmented than in other temporary crops, and the top ten municipalities accounted for approximately 31% of the total production value for cassava. They are: Barreirinhas (MA), Correntina (BA), Itapecuru Mirim (MA), Bacabal (MA), Cocos (BA), Pirapemas (MA), Bom Jesus da Lapa (BA), Tutóia (MA), Nina Rodrigues (MA), and Cantanhede (MA).

**Beans** were grown in 255 municipalities, and the total revenue from this crop in the MATOPIBA region in 2015 was approximately R$352 million, in almost 233,000 hectares of planted area. Barreiras (BA), São Desidério (BA) and Luís Eduardo Magalhães (BA) totaled almost 80,000 hectares of planted areas and accounted for approximately 57% of the total revenue - the top ten municipalities accounted for approximately 68% of the total value or production of beans. They are: Barreiras (BA), São Desidério (BA), Luís Eduardo Magalhães (BA), Uruçuí (PI), Bom Jesus (PI), Dueré (TO), Wanderley (BA), Cristópolis (BA), and Balsas (MA).
Figure 11: Temporary crops in the MATOPIBA region in 2015. (A) Ten municipalities with the highest production values (R$1,000) for soybean, located in western Bahia, southern Maranhão, and western Piauí. (B) Ten highest production values (R$1,000) for rice (orange – western Tocantins and western Piauí) and sugarcane (green – eastern Maranhão and central Tocantins) and five highest values of production for herbaceous cotton (yellow - western Bahia). (C) Ten highest production values (R$1,000) for corn (green - western Bahia, southern Maranhão, and western Piauí) and cassava (orange - northern Maranhão and western Bahia). (D) Ten highest production values for beans (western Bahia, southern Maranhão, and western Piauí).
In soybean production:

- The twenty municipalities with the highest average yields (kg/ha/year) in the MATOPIBA region in 2015 (Figure 1 in the Annex) accounted for only 3% of the total production value of soybeans. The same holds true for the 20 lowest yields - 3% of the total production value. A trend toward improved average yields in the MATOPIBA region was observed between 2001 and 2015, but the variance between the highest and lowest yields has increased in recent years (2012 to 2015) (Figure 12). In 2015, the highest and lowest yields were scattered throughout the MATOPIBA region - no region stands out either positively or negatively - and often both high and low yields are found in neighboring municipalities in the same micro-region.

- The highest yields occur mainly in regions with higher rainfall rates throughout Tocantins - although low yields also occur in neighboring municipalities - and there is a concentration of low average yields in the eastern border of Piauí and in northern Maranhão - where there are soybean plantations at only a few tens of kilometers from the coast.
In herbaceous cotton production:

- The five highest yields were found in southern Maranhão (Alto Parnaíba, Balsas and Tasso Fragoso, 4,200 kg/ha/year in a total area of approximately 21,000 ha) and in western Bahia (São Desidério and Luís Eduardo Magalhães, with yields slightly over 4,000 kg/ha/year in a total area of about 147,000 ha).

- The five highest yields accounted for almost 70% of the production value in 2015, with the five lowest yields representing less than 5%. Low average yields per hectare also occur in western Bahia, in municipalities like Correntina and Bom Jesus da Lapa - although only Correntina, with 38,000 hectares of planted area is relevant in the region.

In corn production

- The twenty highest average yield values are found almost entirely in western Bahia (top eight: Correntina with 9,780 kg/ha/year, Jaborandi, Cocos, Barreiras, Luís Eduardo Magalhães, Formosa do Rio Preto, Riacho das Neves and São Desidério, with 8,100 kg/ha/year), and Piauí (southwestern portion).

- The ten municipalities with the highest values accounted for almost 40% of the production value in 2015 whereas the ten lowest values represented only 0.08%. The lowest values are concentrated in specific regions in neighboring municipalities, on the eastern border in Bahia and the northernmost portion of Maranhão - except for a value found in the eastern border in Piauí.

CHARACTERIZATION OF THE DYNAMICS IN LAND USE CHANGE IN DIFFERENT MUNICIPALITIES

Balsas (MA):

In the period 2000-2016, data from the "Brazilian Annual Land Use and Land Cover Mapping Project" (MapBiomas) indicated that the "Annual Crops" class increased by more than 18 times (to around 225,000 hectares in 2016). Furthermore, 62,000, 31,000 and 40,000 hectares in the "Pasture", "Agriculture or pasture" and "field vegetation" classes respectively were converted to "Annual Crops", as also were 65,000 and 15,000 hectares of "Open Forest" and "Dense Forest" respectively.

- High official deforestation rates and tree cover loss values.
- New agricultural frontier area (soybean, corn and beans).
- The advance of agriculture and livestock occurs not only in areas previously used for agriculture or pasture but also in areas previously covered with "field vegetation" and "open forest" - which are two typical ecosystems of the Cerrado biome - and "Dense Forest".
Santa Rita de Cássia (BA) and Formosa do Rio Preto (BA):

In the period 2000-2016, data from the "Brazilian Annual Land Use and Land Cover Mapping Project" (MapBiomas) indicated that in "Formosa do Rio Preto" (FRP) the "Annual Crops" class increased by more than six times (to about 470,000 hectares), while the "Pasture", "Agriculture or pasture" and "Pasture in natural fields" classes fell by half (to approximately 106,000 hectares). Agriculture ("annual crops") also expands into "Field Vegetation", "Dense Forest" and "Open Forest" areas, which together lost about 300,000 hectares in the period.

Over the same period in Santa Rita de Cássia (SRC), although the "Annual Crops" class increased more than thirty times to about 12,000 hectares, it is still much smaller than the area dedicated to "Pasture" and "Agriculture or pasture", which increased from around 40,000 hectares to approximately 100,000 hectares in 2016. Agriculture and livestock expand mainly into "Dense Forest" and "Open Forest" areas, which together have lost around 50,000 hectares in the period.

- Although they are neighboring municipalities located in western Bahia, FRP and SRC are very different in relation to the dynamics of land use and land-change use. Livestock is much more relevant for Santa Rita de Cássia (although pasture yield is low) where the average rainfall is lower than in FRP, limiting soybean expansion, for example. While FRP is a national hub for cereal grain production (mainly soybeans, with fields located on the plateau on the border with Tocantins), livestock is less relevant and found in lower parts of the municipality as well as where the opportunity cost of land is lower.

Largest remnants of the Cerrado biome:

Special mention should be made of the relevance of western Bahia and the mid-southern portion of Maranhão to the issues of both rapid and high tree cover losses in recent years and largest remnants of Cerrado in the MATOPIBA Region. In FRP, for example, there are still large remnants of the Cerrado biome due to the size of the municipality. However, agriculture is advancing rapidly (in the west-east direction), and soybean is being grown inside the Environmental Protection Area (APA) of Rio Preto, for example. The municipality is a national soybean production hub and has extensive farmland areas - that is, circumstances indicate that the Cerrado will continue to lose original vegetation cover while agriculture becomes increasingly consolidated in this area.

The results of the research indicate that there are large remnants of Cerrado not only in regions where the biome is already protected-such as in portions of Indigenous Lands and full protection or sustainable use CU (western Tocantins, western Bahia and central-eastern region of Maranhão), but also in regions where there has been a strong agricultural expansion in recent years (western Bahia, western Piauí, and southern Maranhão).
Low average yields:

Another important finding of the research concerns current opportunities for average yield gains in the production of main crops, thus reducing the pressure associated with the conversion of remnants of the Cerrado biome to agricultural areas. There are rapid and intense land use changes in progress in municipalities where the average yield is very low for more than one crop such as Urbano Santos, in northern Maranhão. The municipality is among those with the lowest average yields for corn (ranking 315th among 328) and soybean (ranking 147th among 157).

In Urbano Santos, in the period 2000-2016, data from the "Brazilian Annual Land Use and Land Cover Mapping Project" (MapBiomas) indicated the emergence of the "Annual Crops" class (with 365 hectares), while the "Pasture" and "Agriculture or pasture" classes increased almost threefold (to nearly 17,000 hectares). On the other hand, the "Open Forest" and "Rupestrian Fields" classes had their areas reduced by nearly half to some 17,500 hectares. The municipality still has more than 135,000 hectares of "Dense Forest" thus reinforcing the need to seek greater yields from different crops to reduce pressure on the Cerrado vegetation cover.

Another municipality that stood out in this aspect was Currais (the central-south portion of Piauí). In soybean production, the average yield was 2,191 kg/ha/year (ranking 141st among 157), in an area of almost 45,000 hectares and a production value of approximately 1% of total production in the MATOPIBA region in 2015. In the 2000-2016 period, data from the “Brazilian Annual Land Use and Land Cover Mapping Project” (MapBiomas) indicated that the "Annual Crops" class increased from 38 to 25,000 hectares, expanding mainly into the "Open Forest" class. In turn, the "Pasture" and "Agriculture or pasture" classes increased more than threefold to nearly 62,000 hectares - an expansion of more than 40,000 hectares into "Open Forest" class areas. The "Open Forest", "Dense Forest" and "Rupestrian Fields" classes had their combined area decreased by approximately 70,000 hectares - half of this loss in the "Open Forest" class alone.
The expansion of agriculture through the Cerrado has allowed Brazil to emerge as a major exporter and a global leader in the agricultural commodities market (OECD/FAO 2015, Gollnow & Lakes 2014; Richards 2015; Eloy et al. 2016; Lapola et al. 2014). However, the biome is also a global biodiversity hotspot (Myers et al. 2000) and the country’s second most affected biome regarding anthropogenic disturbances, with only 3.1% of its original area fully protected through Conservation Units - CU (TERRACLASS/MMA 2015). Besides, important hydrographic regions in the country have their water sources originated in the Cerrado biome, such as the basis of the Tocantins, Paraíba and São Francisco rivers (ANA-SNIRH).

Intensive agriculture is an relevant factor for land use change, and temporary crops are becoming increasingly consolidated in new Cerrado areas of the MATOPIBA region, beyond the West of Bahia and Tocantins, such as in Balsas (Maranhão), and Baixa Grande do Ribeiro and Uruçuí (Piauí). Espírito Santo et al. (2016) explain that between 2001 and 2015, the intensity of land use conversion and natural regeneration (e.g., in abandoned pastures) in the Cerrado show considerable spatial and temporal variations. Land use changes are influenced by many variables, including biophysical and anthropogenic change vectors (e.g., soil properties, density of paved roads in the area and global demand for commodities).

In general, the data collected on tree cover loss confirm that the losses in remnants of the Cerrado biome (base year 2008) are high throughout the region. However, there are specific regions where values and rates are substantially higher. This is due, for example, to the size of remnants of the biome in the municipality in the base year 2008, which in turn depends ultimately on the size of the municipality - in the West of Bahia the municipalities tend to be larger than in Tocantins or Maranhão - and on the expansion dynamics of temporary crops in each municipality.

In the case of soybean in the MATOPIBA region, production is highly concentrated, and the top ten producing municipalities accounted for more than half of total production in 2015. Land use changes, such as from typical Cerrado vegetation to agricultural fields or pastures, occur at different levels of intensity and speed, even in the same micro-region. The results of this research confirm that these few municipalities influence total production as observed in Garagorry et al. (2015) and Spera et al. (2016). These municipalities that stand out have consolidated fields for agricultural production (for example, western Bahia excels in all crops except rice), while in others agriculture is at the beginning of regional consolidation (e.g., western Piauí and southern Maranhão). Tocantins (southwestern region) stands out in rice production only.

Another important variable for land use change patterns is the average price of the hectare in the Cerrado area. In the MATOPIBA region, due to the occupation history and levels of development and consolidation of the agricultural sector, the price of land (R$/ha) tends to be lower than in other states like São Paulo, Rio Grande do Sul or Mato Grosso (Fernandes et al., 2016). The trend is that land use changes will continue to accelerate and intensify in this region in the coming years. This trend is because of the lower costs of opportunity for different land uses in the MATOPIBA region, coupled with investors’ business models focused on increasing the price of agricultural land rather than - or in addition to - commodity production revenues (Steinweg et al., 2017).

4 The concept takes into account the concentration of endemic species and the rate of loss of habitats and species.
5 Rice and sugarcane for Tocantins.
For the trend in land use change to be reversed, issues such as average yields of temporary crops considering different cropping methods (mainly for soybean, corn, and cotton in the MATOPIBA region) need to be increasingly incorporated into the discussions of biodiversity and water conservation strategies in priority areas of the biome. For the year 2015, this study shows that in corn and cotton crops the highest average yields are concentrated in areas where the agriculture has already been consolidated. In the case of soybean, which is the main crop, the highest yields are scattered throughout the region and were not found in municipalities with outstanding production. It is necessary to investigate the reason for the high variance in the average yield of soybean in the region, the margin for increasing current yields with the existing technology, as well as why the highest and lowest yields frequently occur in neighboring municipalities.

The expected increase in the demand for cereal grains, food, and beef in the coming decades will increase the pressure for the conversion of native areas into agricultural land (OECD/FAO 2015, TERRACLASS/MMA 2015). On the other hand, impacts associated with climate change will also create new pressures for production increases (OECD/FAO 2015). These impacts are already observed in the MATOPIBA region, for example in the 2015/2016 harvests, in which the National Food Supply Company (CONAB) reported significant crop losses due to adverse effects of climate change, including high temperatures and prolonged drought periods (CONAB 2016).

Official estimates from the Ministry of the Environment (TERRACLASS/MMA 2015) indicate that approximately half of the Cerrado biome has already been deforested or degraded (nearly one million km2, or the equivalent of more than 92 million soccer fields). Although alarming, this opens up space for opportunities, such as the introduction and strengthening of the integrated crop, livestock, and forest production systems - some of which are already in place in various areas of the country, including, in this case, agro-ecological-based production systems. This would increase the production and income generation capacity of producers while maintaining a greater diversity of "landscapes" in the already severely fragmented biome. The average yield gain per hectare in agricultural practices would reduce the pressure for production increases through its expansion into areas previously covered with native Cerrado vegetation. Also, Silva et al. (2016) sustain that Brazil could reduce its GHG emissions even by increasing livestock production, if only livestock activities were limited to areas that were already open or abandoned in the past – i.e., without new deforestation and adopt good production practices.

As shown by Strassburg et al. (2017), key actors need to make an unequivocal commitment and join efforts in all sectors in the Cerrado region. The moment may be one of crisis, but it also presents countless opportunities with existing policies, as stated by the authors (Strassburg et al., 2017). Recent initiatives such as the "Cerrado Manifesto" calling on the soybean and meat market chains to defend the biome by eliminating deforestation indicate the need for a new trajectory for land use and sustainable agriculture in the Cerrado. The manifesto, signed by more than 50 Civil Society Organizations, calls for immediate actions by investors and buyers in these markets to dissociate their production and investment chains from recently converted natural Cerrado areas. In October, one month

CONCLUSION

This study demonstrated that in the MATOPIBA region few municipalities (i.e., twenty) have determining participation for the region concerning the values found in this research for:

A. The total area of tree cover loss in remnants of the Cerrado biome in the period 2009-2015;
B. The total area of remnants of the Cerrado biome estimated for the year 2015; and

The authors understand that efforts on different themes should focus on priority areas, namely:

A. Areas with the largest remnants of the Cerrado biome;
B. Areas where agriculture has already been consolidated, i.e., in few municipalities (of a total of 337) and considering three temporary crops (soybean, corn, and cotton);
C. Areas already opened by agriculture and livestock (i.e., abandoned/degraded pastures) and introducing and/ or strengthening integrated, agroforestry and silvopastoral systems.

after the launch of the manifesto, European companies and political leaders such as the Prince of Wales (UK) endorsed the document in advance of COP 23 (UN International Conference on Climate Change), presided over by Fiji and held in Germany. The Conference is the time when countries and global political leaders discuss the rules that will guide the future of the Paris Climate Agreement. Endorsement of the manifesto was expanded at the end of January 2018 during the World Economic Forum, thus demonstrating the relevance of its content.

Agriculture and conservation can and should coexist in in the Cerrado of the MATOPIBA region, and efforts must go beyond the requirements of the Forest Code (2012). The adoption of a strategic spatial approach integrating strategies for biodiversity and water conservation, increase in biomass/carbon stocks, development and increase of average yields (kg/h/year) of the main agricultural crops and livestock, and the strengthening of integrated production systems in a climate change scenario would be highly positive and is extremely desirable.

BIBLIOGRAPHIC REFERENCES


Fonseca, M.F. & Miranda, E.E. de, 2014. MATOPIBA: Caracterização do Quadro Agrário - Nota Técnica 6, Campinas. Available at: https://www.embrapa.br/gite/publicacoes/

GLOBAL FOREST WATCH. Interactive online forest monitoring and alert system. Available at: http://www.globalforestwatch.org/map/


MAPBIOMAS. The Brazilian Annual Land Use and Land Cover Mapping Project, São Paulo, 2015. Available at: http://mapbiomas.org/map


UFG-LAPIG. Federal University of Goiás - Image Processing and Geoprocessing Laboratory (Lapig). Lapig-Maps online tool available at: http://maps.lapig.iesa.ufg.br/lapig.html
### Soy production in 2015

<table>
<thead>
<tr>
<th>Municipality</th>
<th>Average productivity (kg/ha)</th>
<th>Planted area (ha)</th>
<th>Percent accumulated production value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Serra do Ramalho</td>
<td>4,000</td>
<td>2,450</td>
<td>0.10%</td>
</tr>
<tr>
<td>2 Colinas</td>
<td>3,600</td>
<td>2,000</td>
<td>0.17%</td>
</tr>
<tr>
<td>3 Governador Eugênio Barros</td>
<td>3,600</td>
<td>300</td>
<td>0.18%</td>
</tr>
<tr>
<td>4 Vila Nova dos Martins</td>
<td>3,524</td>
<td>2,180</td>
<td>0.25%</td>
</tr>
<tr>
<td>5 Sucupira</td>
<td>3,422</td>
<td>11,280</td>
<td>0.56%</td>
</tr>
<tr>
<td>6 Acauãlandia</td>
<td>3,420</td>
<td>10,389</td>
<td>0.89%</td>
</tr>
<tr>
<td>7 Taguatinga</td>
<td>3,400</td>
<td>1,500</td>
<td>0.94%</td>
</tr>
<tr>
<td>8 Cedilândia</td>
<td>3,307</td>
<td>75</td>
<td>0.94%</td>
</tr>
<tr>
<td>9 Gurupi</td>
<td>3,305</td>
<td>9,834</td>
<td>1.21%</td>
</tr>
<tr>
<td>10 Almas</td>
<td>3,300</td>
<td>8,000</td>
<td>1.46%</td>
</tr>
<tr>
<td>11 Buriti Bravo</td>
<td>3,300</td>
<td>800</td>
<td>1.48%</td>
</tr>
<tr>
<td>12 Chapada da Naz禹idade</td>
<td>3,300</td>
<td>15,000</td>
<td>1.93%</td>
</tr>
<tr>
<td>13 Divinópolis do Tocantins</td>
<td>3,300</td>
<td>3,000</td>
<td>2.01%</td>
</tr>
<tr>
<td>14 Governador Edison Lobão</td>
<td>3,300</td>
<td>11,000</td>
<td>2.28%</td>
</tr>
<tr>
<td>15 Guaraí</td>
<td>3,300</td>
<td>11,000</td>
<td>2.28%</td>
</tr>
<tr>
<td>16 Itinga do Maranhão</td>
<td>3,300</td>
<td>5,083</td>
<td>2.44%</td>
</tr>
<tr>
<td>17 Miranorte</td>
<td>3,300</td>
<td>2,260</td>
<td>2.50%</td>
</tr>
<tr>
<td>18 Natividade</td>
<td>3,300</td>
<td>1,000</td>
<td>2.53%</td>
</tr>
<tr>
<td>19 Rio dos Bois</td>
<td>3,300</td>
<td>8,500</td>
<td>2.75%</td>
</tr>
<tr>
<td>20 Santa Maria do Tocantins</td>
<td>3,300</td>
<td>10,000</td>
<td>3.01%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td><strong>104,711</strong></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Municipality</th>
<th>Average productivity (kg/ha)</th>
<th>Planted area (ha)</th>
<th>Percent accumulated production value</th>
</tr>
</thead>
<tbody>
<tr>
<td>138 São Francisco do Maranhão</td>
<td>2,400</td>
<td>240</td>
<td>0.01%</td>
</tr>
<tr>
<td>139 Alvorada do Gurguéia</td>
<td>2,343</td>
<td>8,451</td>
<td>0.19%</td>
</tr>
<tr>
<td>140 Bunti</td>
<td>2,250</td>
<td>13,500</td>
<td>0.48%</td>
</tr>
<tr>
<td>141 Currais</td>
<td>2,191</td>
<td>44,856</td>
<td>1.38%</td>
</tr>
<tr>
<td>142 Caseara</td>
<td>2,175</td>
<td>11,400</td>
<td>1.58%</td>
</tr>
<tr>
<td>143 Recursolândia</td>
<td>2,160</td>
<td>3,000</td>
<td>1.62%</td>
</tr>
<tr>
<td>144 Barra do Ouro</td>
<td>2,146</td>
<td>10,300</td>
<td>1.80%</td>
</tr>
<tr>
<td>145 Anapurus</td>
<td>2,100</td>
<td>6,800</td>
<td>1.94%</td>
</tr>
<tr>
<td>146 Cristalândia do Piauí</td>
<td>2,100</td>
<td>120</td>
<td>1.95%</td>
</tr>
<tr>
<td>147 Urbano Santos</td>
<td>2,100</td>
<td>1,350</td>
<td>1.98%</td>
</tr>
<tr>
<td>148 Cristalândia</td>
<td>2,000</td>
<td>3,150</td>
<td>2.03%</td>
</tr>
<tr>
<td>149 Goianorte</td>
<td>2,000</td>
<td>120</td>
<td>2.03%</td>
</tr>
<tr>
<td>150 Palmeirante</td>
<td>2,000</td>
<td>13,000</td>
<td>2.24%</td>
</tr>
<tr>
<td>151 Araguaína</td>
<td>1,980</td>
<td>5,500</td>
<td>2.33%</td>
</tr>
<tr>
<td>152 Sebastião Leal</td>
<td>1,921</td>
<td>18,708</td>
<td>2.63%</td>
</tr>
<tr>
<td>153 Estreito</td>
<td>1,911</td>
<td>350</td>
<td>2.64%</td>
</tr>
<tr>
<td>154 Palmeira do Piauí</td>
<td>1,648</td>
<td>15,470</td>
<td>2.87%</td>
</tr>
<tr>
<td>155 Magalhães de Almeida</td>
<td>1,608</td>
<td>3,325</td>
<td>2.92%</td>
</tr>
<tr>
<td>156 Antônio Almeida</td>
<td>1,590</td>
<td>4,068</td>
<td>2.98%</td>
</tr>
<tr>
<td>157 São Bernardo</td>
<td>1,300</td>
<td>1,000</td>
<td>2.99%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td><strong>165,408</strong></td>
<td></td>
</tr>
</tbody>
</table>

Figure 1: Twenty municipalities with the highest (green) and lowest (yellow) average productivity (kg/ha/year) in soy production in 2015 in Matopiba.
About Imaflora:
Imaflora (Instituto de Manejo e Certificação Florestal e Agrícola) is a Brazilian non-profit organization established in 1995 to promote the conservation and sustainable use of natural resources and generate social benefits in the forestry and agricultural sectors.

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