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The MATOPIBA agricultural frontier in Brazil between 2001-2014, Tree Cover Loss and the impact of the Soybeans *Moratorium*

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ABSTRACT OF THESIS

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Abstract

MATOPIBA is located in Central/NE Brazil and is perhaps the last extensive agricultural frontier in the country. It is comprised of 337 municipalities and 31 micro regions across four states and covers an area of approximately 73 million ha. A complex agrarian structure is present with Rural settlements, Conservation Units, Indigenous reserves and *Quilombolas* all found in the area. Over 90% of MATOPIBA is situated in the *Cerrado* biome (a global hotspot for biodiversity) and over 60% is located within the "Legal Amazon". It is a crucial biome for Brazil's agricultural production but deforestation rates and indirect GHG emissions from land-use changes are high. Nearly half of its original vegetation was degraded or deforested and only 3% of its area is integrally protected. There is some evidence to suggest that deforestation rates in MATOPIBA may be higher than the *Cerrado* as a whole. The research compiled data on agricultural production and Tree Cover Loss for MATOPIBA from 2001 to 2014. Special attention is given to temporary crops and nine were identified as leading crops for the region as a whole. There is great level of specialization even among municipalities in the same micro region and this was one of the reasons why a linear relationship could not be established between TCL in the period and each individual crop. Soybean is the leading crop for MATOPIBA and average yields were found to be low. A comparison with yields for Brazil is presented for all crops found in MATOPIBA. The west of Bahia is the leading producer of soybeans but Balsas (Maranhão) is gaining importance. Tree Cover Loss (TCL) data was also compiled and there is an increasing trend. In the period, TCL for 334 municipalities was 5.56 ha and there was a satisfactory correlation with official deforestation rates observed until 2011. Interesting correlations of TCL with GDP/capita, illiteracy rate, HDI and number of settled families were found. Highest TCL rates were in micro regions in Bahia and Maranhão. Land-use change pressures occur at different magnitudes within the region (it is highest in Piauí) given the availability of land, level of production or productivity and level of intensification (yields). Low yields create further pressure on TCL if demand for food and commodities and production continue to increase. Climate change may already be affecting the yields in MATOPIBA, with harvest losses reported for 2015/2016. Furthermore, the research investigated the TCL in MATOPIBA before and after the Soybeans *Moratorium* for the Amazon biome implemented in July 2006. A statistical significant difference was found for the TCL between two periods (2001-2007 x 2008-2014) with average and sum of TCL of municipalities planting soybeans being higher after the *Moratorium* was implemented. This raises concern whether the pact is creating leakage deforestation from the Amazon towards this agricultural frontier in *Cerrado*.

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I dedicate this research to my family and beloved partner who always supported and inspired me in pursing my objectives.

Finally, this research is humbly dedicated to the Cerrado.

List of Figures

List of Tables

List of Appendix Figures

List of Appendix Tables

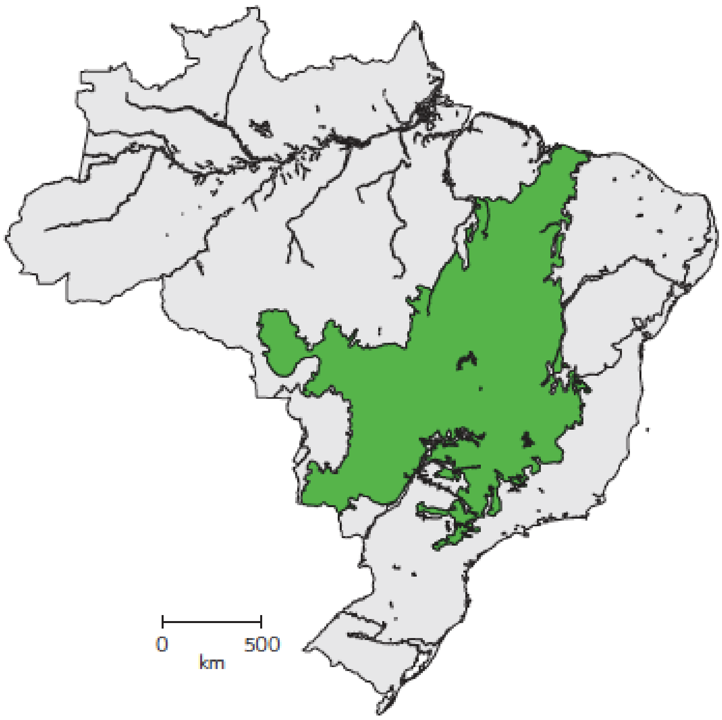
Table of Contents

1. Introduction

1.1 The *Cerrado*

The *Cerrado* (Figure 1) covers an area of 2,039,386 km^2 (~24% of Brazilian territory) (IBGE/MMA 2004) being the second most extensive ecosystem in South America (Franco et al. 2014). It is considered a global hotspot for biodiversity (Myers et al. 2000; Lapola et al. 2014; Gollnow & Lakes 2014; Batlle-Bayer et al. 2010) meaning it is an area with abundant number of endemic species and where high rates of habitat loss are present. Conservation efforts should be high for such areas (Myers et al. 2000).

Figure 1 Central Cerrado biome in Brazil (in green)



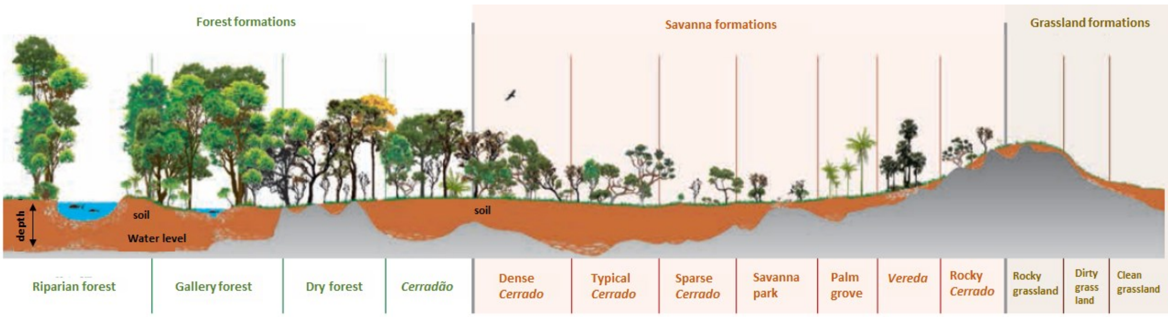
Source: Silva et al. (2016)

The regular and predictable drought period from May to September is key to determine the ecosystem structure and functions in *Cerrado* (Franco et al. 2014; Oliveira-Filho & Ratter 2002). Average annual temperature is between 20°C and 26°C but diurnal temperature ranges of 20°C are not uncommon during the winter (dry season) (Franco et al. 2014). It is characterized as a mesic savanna and while the average rainfall in most of the biome ranges from 1,000 to 2,000 mm, smaller sections of *Cerrado* can be found in drier (600–800 mm) or wetter areas (2,000–2,400 mm) (Franco et al. 2014; Oliveira-Filho & Ratter 2002).

Although soils are generally deep and well drained they were also exposed to extended periods of weathering and leaching, leading to a depletion in available nutrients over time (Haridasan 2008; Oliveira-Filho & Ratter 2002). The native species are highly adapted to the acid soils, high levels of aluminum (Al) and iron (Fe) and limited quantities of Phosphorus (P) and Calcium (Ca) (Haridasan 2008).

Some authors consider that the biodiversity in grasses, herbs and woody plants and the high variation in the landscape vegetation structure, in particular along topographic gradients in watersheds, are distinctive aspects of the savanna of Central Brazil (Franco et al. 2014). The vegetation cover structure will mostly depend on edaphic factors (such as soil fertility and effective depth in relation to the water table) and fluctuation of soil water regime (Oliveira-Filho & Ratter 2002). In the long term, fire plays a significant role in determining the sharpness of the boundary and species composition, gradients and dynamics at the forest-savanna edge (Hoffmann, Geiger, et al. 2012; Hoffmann, Jaconis, et al. 2012; Hoffmann et al. 2002). The biome is characterized by the diversity in ecosystems physiognomy (Figure 2) including forest formations (~ 40.22 million ha), savanna (~ 75.66 million ha) and grasslands (~ 8.06 million ha) (Magalhães & Miranda 2014).

Figure 2: Phytophysiognomy of the Cerrado. Areas along streams, rivers and on top of water abundant and nutrient-rich alluvial deposit soils will favour the formation of denser and taller canopies



Source: adapted from Ribeiro & Walter (2008)

1.2 Agricultural expansion in *Cerrado*

At the global scale, savannas are commonly converted to agriculture and grazing fields (Hoffmann et al. 2002) and this is also the case in Brazi, where agriculture relies on *Cerrado* land (Smith, Winograd, Gallopín, et al. 1998; Rada 2013; Espírito-Santo et al. 2016). Nearly 50% of the natural vegetation cover has been deforested or is degraded (MMA/IBAMA

2015). Pressures in land-use changes are likely to increase in the future when coupled with climate change predictions (Franco et al. 2014; Spera et al. 2016).

Since the 1970's the Cerrado has seen crop fields and pastures expand into its area, firstly in *Minas Gerais*, *Goiás*, *Mato Grosso* and *Mato Grosso do Sul* states (Rada 2013; Richards 2015; Barretto et al. 2013; Lapola et al. 2014; Frederico 2013; Santos et al. 2012; Pereira et al. 2012). The *boom* in agriculture lead Brazil to emerge as a major exporter/global player in the commodities market (OECD/Food and Agriculture Organization of the United Nations 2015; Gollnow & Lakes 2014; Richards 2015; Eloy et al. 2016; Lapola et al. 2014) but also resulted in high deforestation rates in the biome (MMA/IBAMA/PNUD 2009; MMA/IBAMA 2011; MMA/IBAMA 2015) and emissions from land-use change and deforestation in 2012 accounted for 62% of the total emissions of 176 Tg CO2e for the "Land Use Change and Forestry" sector in the country (MCTI 2014). The *Cerrado* is the second most affected biome in terms of anthropogenic disturbances (after *Mata Atlântica*) and only 3.1% of its area is integrally protected (TERRACLASS/MMA 2015).

Total planted area for crops in *Cerrado* in 1970 was 8 million ha and this figure increased to 48.2 million ha by 2006, nearly half of the total cultivated area in Brazil then (98 million ha) (Pereira et al. 2012). In 2006, according to IBGE Agricultural Census, the share of *Cerrado* production over total Brazilian production was about 98% for cotton (from 50% in 1970) and over 60% for soybeans (from only 6.9% in 1970) and other permanent and temporary crops also saw an increase in its share over total national production (but not all, rice for example had its share reduced from 53% to 28% from 1970 to 2006) (Pereira et al. 2012).

1.3 MATOPIBA: Agricultural expansion and Tree Cover Loss (TCL)

The study area is the "MATOPIBA" region established by Ministry Ordinance in November 2015 (MAPA 2015) following the launching of the Agricultural Development Plan for the region (Federal decree 2015). The geographical delimitation of the region was based on studies and technical recommendation prepared by EMBRAPA (Miranda et al. 2014).

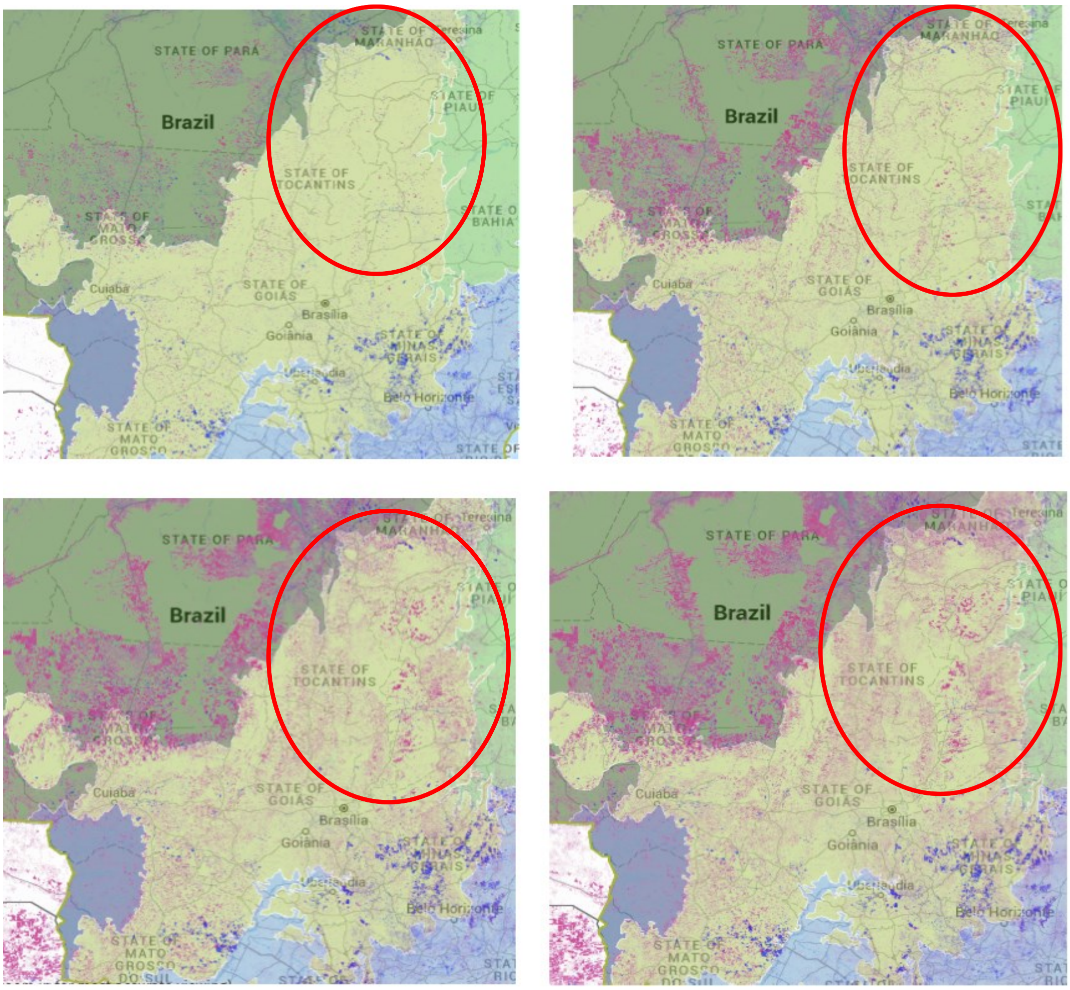
The MATOPIBA encompasses approximately 73 million ha across 31 micro regions and 337 municipalities (Miranda et al. 2014) within four States in Brazil: *Maranhão*, *Tocantins*, *Piauí* and *Bahia* (Figure 3). The name is an acronym based on the states' initial letters, "MA", "TO", "PI" and "BA". The micro regions follow IBGE classification and approximately 33.929 million ha are represented by 324.326 agricultural establishments (Miranda et al. 2014). Total population is 5.9 million (3.4 million in MA and 1.49 in TO; 750,000 in BA and 256,000 in PI) (Mangabeira et al. 2015)

Figure 3: Delimitation of MATOPIBA in Brazil

Source: EMBRAPA - GITE (2015)

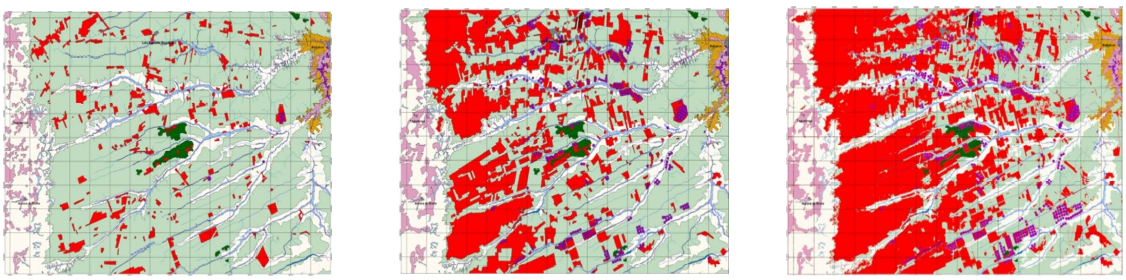
Tree Cover Loss (TCL) data shown in Global Forest Watch (GFW) online map indicates high rate of TCL in the region between 2001-2014 (Figure 4). Land-use images for Barreiras in western Bahia between 1985 and 2010 (Figure 5) illustrate the expansion of agriculture in that region in the period.

Figure 4: Tree Cover Loss (TCL) in Cerrado and MATOPIBA. Years are 2002 (top left), 2006 (top right), 2012 (bottom left) and 2014 (bottom right). Cerrado biome is shaded in light green and and within the red line is the core of MATOPIBA (Hansen/UMD/Google/USGS/NASA 2013)



Source: Hansen/UMD/Google/USGS/NASA, accessed through Global Forest Watch

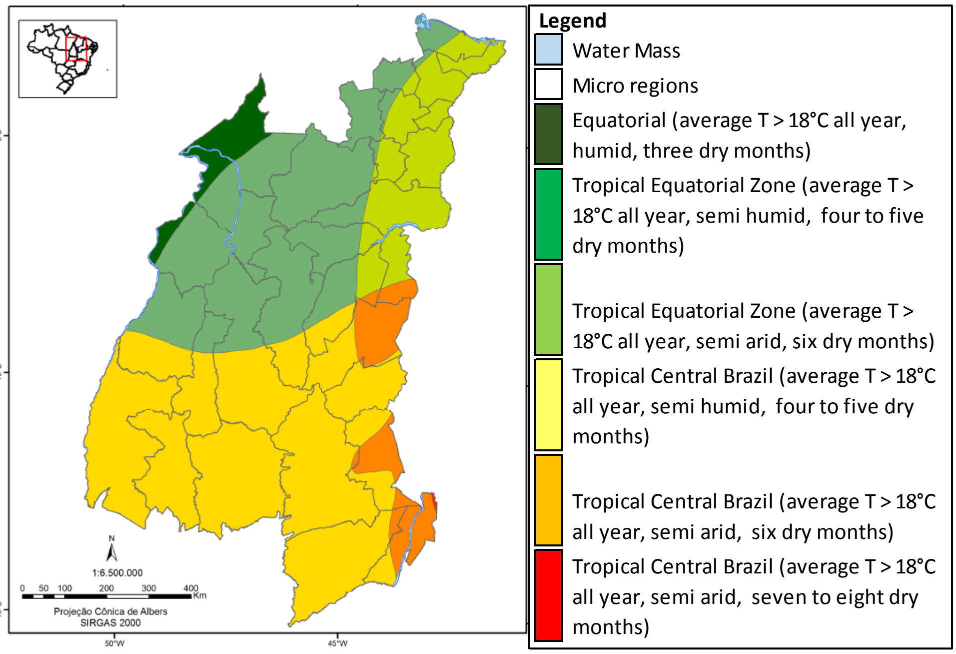
Figure 5: Barreiras land-uses in 1985, 2000 and 2010. Red areas represent agricultural fields and pink areas are *pivots* for irrigation (common in this area). Adapted from Miranda et al. (2014)



Based on meteorological data from 1992 to 2013, from 27 stations located in MATOPIBA, mean temperatures were 27.2°C (Maranhão), 26.23°C (Tocantins), 27.72°C (Piauí) and 24.41°C (Bahia) and average annual precipitation was 1,559 mm (Maranhão), 1,624 mm

(Tocantins), 1,067 mm (Piauí) and 896 mm (Bahia) (Magalhães & Miranda 2014). The climatic units in MATOPIBA are shown in Figure 6.

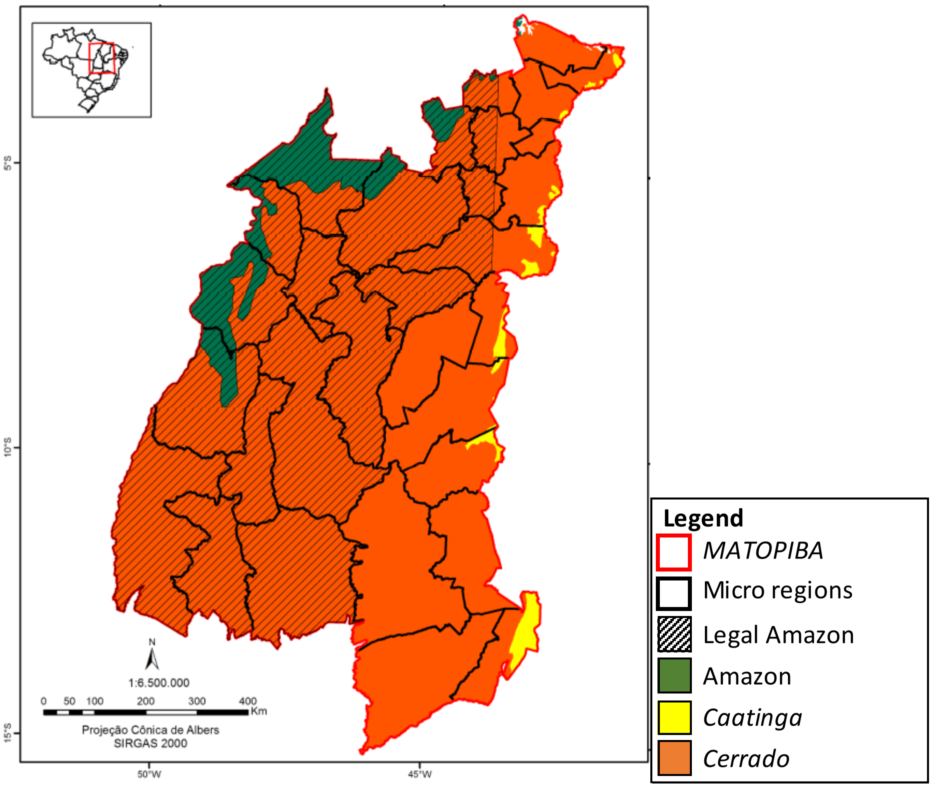
Figure 6: Climatic units in MATOPIBA (IBGE classification). Adapted from Eduardo de Miranda et al. (2014)



The presence of the *Cerrado* biome along the four states of *Maranhão, Tocantins, Piauí* and *Bahia* was one criteria used in the delimitation of MATOPIBA *(Miranda et al. 2014)*. This biome covers 91% (~ 66.54 million ha) of the total area. The Amazon (7.3% or approximately 5.32 million ha) and *Caatinga* (1.7% or approximately 1.2 million ha) biomes are the other two biomes present.

Further to the biomes distinctness there is another “layer” of political and administrative particularity in the region. It refers to the areas within the domain of “*Amazônia Legal*” (Legal Amazon) (Figure 7), which is present in 62% of the MATOPIBA and in 60% of the *Cerrado* within the area (Magalhães & Miranda 2014). The “*Amazônia Legal*” is defined in the Constitution (Brazil 1988) with the objective of planning and promoting the development of the region (Magalhães & Miranda 2014).

Figure 7: Biomes and the Legal Amazon in MATOPIBA. Adapted from (Magalhães & Miranda 2014)



The biomes spatial distribution and the "Legal Amazon" concept directly shape land-use strategies, which have to comply with the Brazilian Forestry Code (FOREST CODE 2012; Magalhães & Miranda 2014). In particular, the requirements for a "legal reserve" of land (*"reserva legal")* within each property are dependent on the properties' locations. For occupancies that occurred after 18th July 1989 (Federal Law 1989) in *Cerrado* biome, the rural property has to preserve 20% of its total area as "legal reserve". If the rural property is located within the limits of the "Legal Amazon" the requirement towards land "legal reserve" increases to 35%, regardless if occupation took place before or after July 1989.

There are 42 Conservation Units (~ 8.84 million ha; in 25 micro regions) (Table 1), 865 rural settlements (with nearly a hundred thousand settled families) part of the Agrarian Reform (~ 3.7 million ha; in 29 micro regions), 28 indigenous reserves (~ 4.16 million ha; in nine micro regions) and 34 "*quilombola*" communities (~ 250,000 ha; in ten micro regions) in MATOPIBA (Fonseca & Miranda 2014) (Figure 8).

Figure 8: Areas legally attributed in MATOPIBA. Adapted from (Fonseca & Miranda 2014)

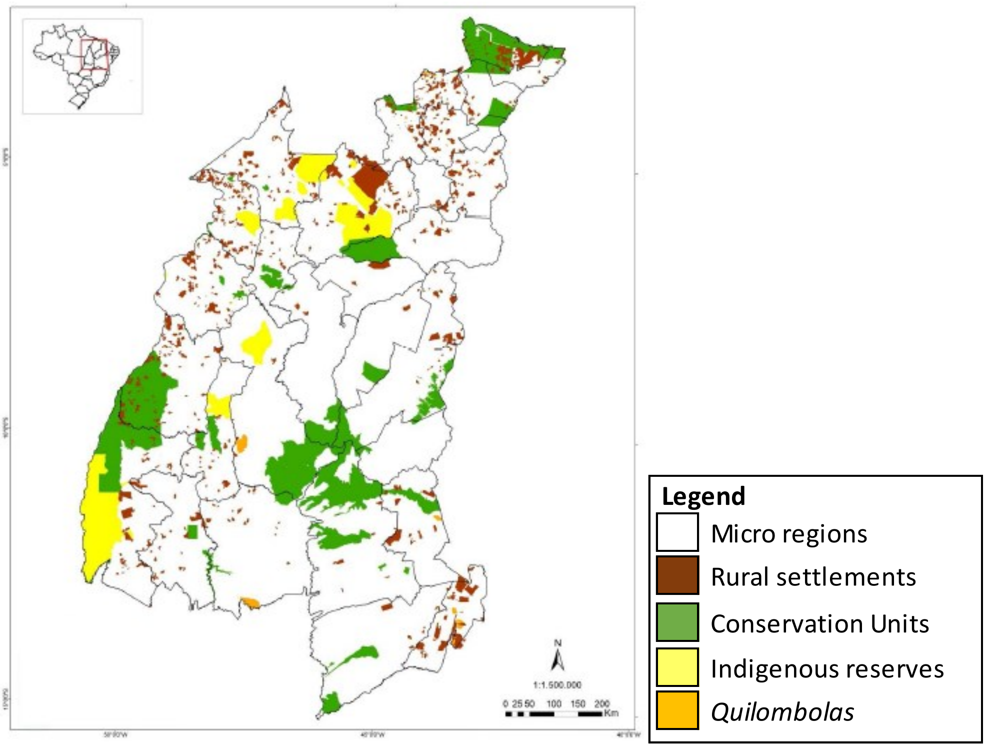


Table 1: Conservation units in Cerrado. Categories are listed as per the Brazilian Forest Code (FOREST CODE 2012). Despite being a biodiversity hotspot only 3% of *Cerrado* is integrally protected

Sustainable Use (SU)	#	Area (ha)	%
Forests	11	55,700	0.0%
Extractive Reserve	6	88,000	0.0%
Reserve for Sustainable Development	2	68,600	0.0%
Environmental Protection Area	68	10,875,200	5.3%
Area with relevant Ecological Interest	15	7,900	0.0%
Private Reserve of Natural Heritage	160	101,500	0.0%
Total SU	***262***	***11,196,800***	***5.5%***
Integral Protection (IP)	**#**	**Area (ha)**	**%**
Ecological Station	28	1,137,000	0.6%
Natural Monument	12	31,400	0.0%
Park	66	4,841,000	2.4%
Refuge for wildlife	5	246,000	0.1%
Biological Reserve	6	8,200	0.0%
Total IP	***117***	***6,263,600***	***3.1%***
Total SU+IP	***379***	***17,460,400***	***8.6%***

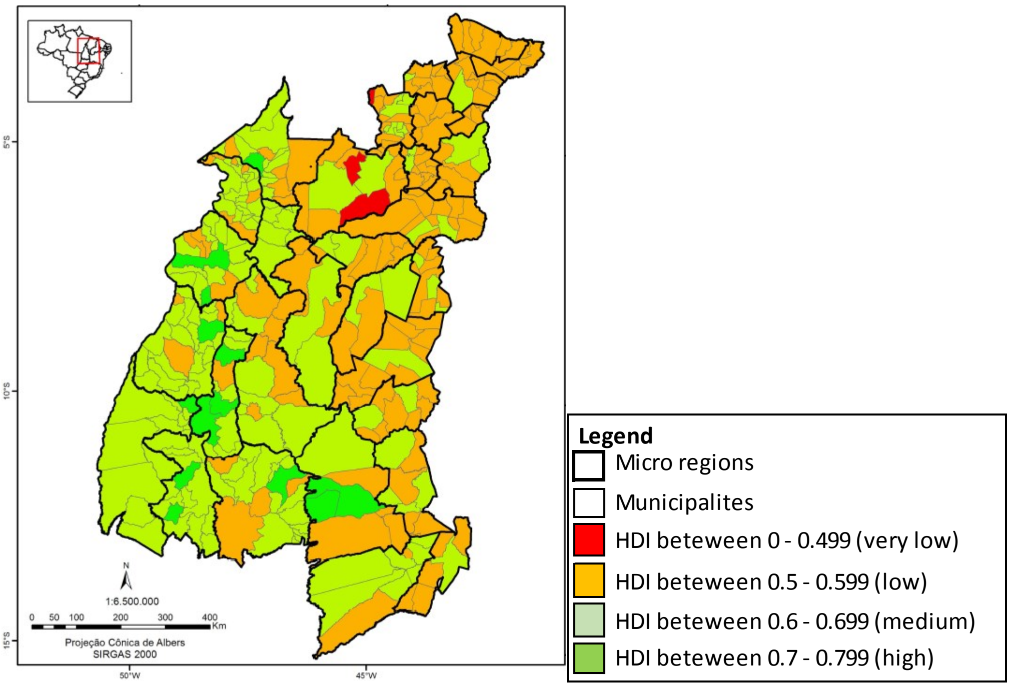
Source: Adapted from TERRACLASS/MMA (2015)

According to the Secretariat for the Promotion of Racial Equality (SEPPIR), *Quilombola* communities are groups with their own historical trajectory, whose origin refers to donations or purchase of land after the end of the slave system (end of XIX century in Brazil) or occupation of land in the process of resistance to the slave system itself (SEPPIR 2014)

The agrarian reform settlements are agricultural units and follow regulatory instructions defined by the National Institute of Colonization and Agrarian Reform (INCRA) following the Land Statute (Federal Law 4504 1964). The creation of a rural settlement is based on demands from social movements or existence of local conflicts and in each case INCRA conducts studies and collects data on soil types, agricultural potential, water regime, capacity in terms of number of families to be settled and development of guidelines (INCRA 2016).

According to Fonseca & Miranda (2014) the strategic approach towards the development of the area, in particular the agricultural expansion and the pursue of sustainable development, shall take into account the complex agrarian structure of the region. On top of this complexity there is also the component of inequality present in MATOPIBA. This is illustrated in Figure 9 where very low scores for Human Development Index (HDI) are found in many municipalities (Eduardo de Miranda et al. 2014).

Figure 9: Human Development Index (HDI) in MATOPIBA. Adapted from Eduardo de Miranda et al. (2014)

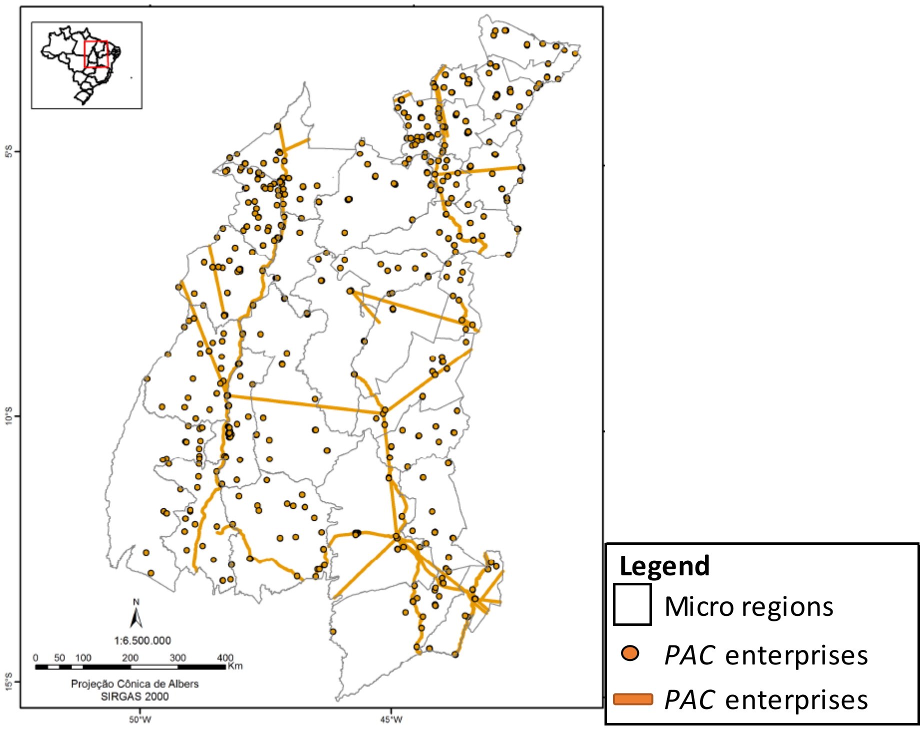


The region has experienced great agricultural expansion in recent years and is referred to as the "latest agricultural frontier" in Brazil (Miranda et al. 2014; OECD/Food and Agriculture

Organization of the United Nations 2015; Richards 2015; Spera et al. 2016; Câmara et al. 2015) but deforestation rates have been high (MMA/IBAMA/PNUD 2009; MMA/IBAMA 2011; MMA/IBAMA 2015).

The urbanization process and public/private investments in different infrastructure projects, including transportation, warehouses, logistics and energy, have also increased in recent years, as illustrated in Figure 10 with national development projects part of “PAC” (Program for Acceleration of Growth) in Brazil.

Figure 10: Program for Accelerated Growth (PAC) projects in MATOPIBA. It is not only agriculture that drives land-use changes in MATOPIBA. Adapted from Eduardo de Miranda et al. (2014). Concession for different mining activities and oil and gas extraction are also present (Magalhães & Miranda 2014)



1.4 Climate Change in the context of the study area

Despite the uncertainties in climate models for South America the predictions for Central and Northeast Brazil seem to be in agreement with respect to increased temperatures, decreased precipitation and longer drought periods by 2100, with Tocantins being an exception to that (Houghton et al. 2001; van Oldenborgh et al. 2013; Pachauri et al. 2014; Chou et al. 2014; Solman 2013).

In addition to climate change, dynamics present at the landscape level will regulate the changes in ecosystems through cycles of disturbance and recovery and this may also involve additional feedbacks with microclimate (Chapin III et al. 2012) and water dynamics (Hunke et al. 2015). A recent study by Spera et al. (2016) identified that the expansion of agriculture throughout the core region of MATOPIBA has been altering the evapotranspiration through a reduction in water recycling. It is also argued that wood encroachment in dry forest Cerrado ecosystem may also reduce water recycling and river run-off (Honda & Durigan 2016). Wood encroachment is currently observed in some parts of *Cerrado* but not in MATOPIBA (TERRACLASS/MMA 2015)

Land-use change from natural vegetation to agricultural fields is among the most direct and substantial anthropogenic disturbance in ecosystems (Chapin III et al. 2012) and induce land degradation in a variety of ways and with different magnitudes and adverse effects (Hunke et al. 2015).

Franco et al. (2014) suggest that climate change will most likely revert the natural process of forest expansion occurring in the biome in the past few millennia and tree cover loss is expected to increase through feedbacks involving fire and resource limitation (water and nutrient). These feedbacks are expected to outweigh the induced growth due to higher concentrations of CO_2 in the atmosphere and may lead to fundamental changes in processes occurring both above and below ground, probably also impacting species performance, distribution and biodiversity.

2. Research questions

The dissertation aims to answer the following research questions (RQs):

2.1. RQ 1

How do the main agricultural crops correlate with tree cover loss (TCL) in the study area?

The underlying hypothesis is that the agricultural development in the region in recent years is a relevant driver for TCL. It is expected that a positive and linear correlation of each individual main crop with TCL is present at the state level.

2.2. RQ 2

Has TCL in the study area increased after the "Soybeans Moratorium" (July 2006) was adopted for the Amazon biome?

The aim is to investigate whether there is any increase in TCL in the study area after the implementation of the "Soybeans Moratorium" in July 2006. The hypothesis is that there may exist a "leakage" or "spill-over" effect of TCL towards the agricultural frontier in MATOPIBA. In December 2014 the reference date for the *Moratorium* was adjusted to July 2008 (AGROSATÉLITE/GTS 2016) to be in line with the new Brazilian Forest Code (FOREST CODE 2012) but the analysis will focus on the initial date since it was applicable until the end of 2014.

The Soybeans *Moratorium* is a supply chain pact signed by the Brazilian Association of Vegetable Oils Industry (ABIOVE) and the Brazilian Association of Grains Exporters (ANEC) aiming to prevent deforestation of the Amazon biome and the conversion to new soybeans plantations (Rudorff et al. 2011; Oliveira 2016; AGROSATÉLITE/GTS 2016). The Soybean Working Group (GTS) was created, as a partnership of public, private and third sectors and deforestation is monitored through satellite images and onsite third-party verification (AGROSATÉLITE/GTS 2016). Annual reports are made available in ABIOVE website and the Moratorium was renewed indefinitely in May 2016[1].

[1] http://www.abiove.org.br/site/index.php?page=moratoria-da-soja&area=NS0zLTE= (accessed on 14/04/2016)

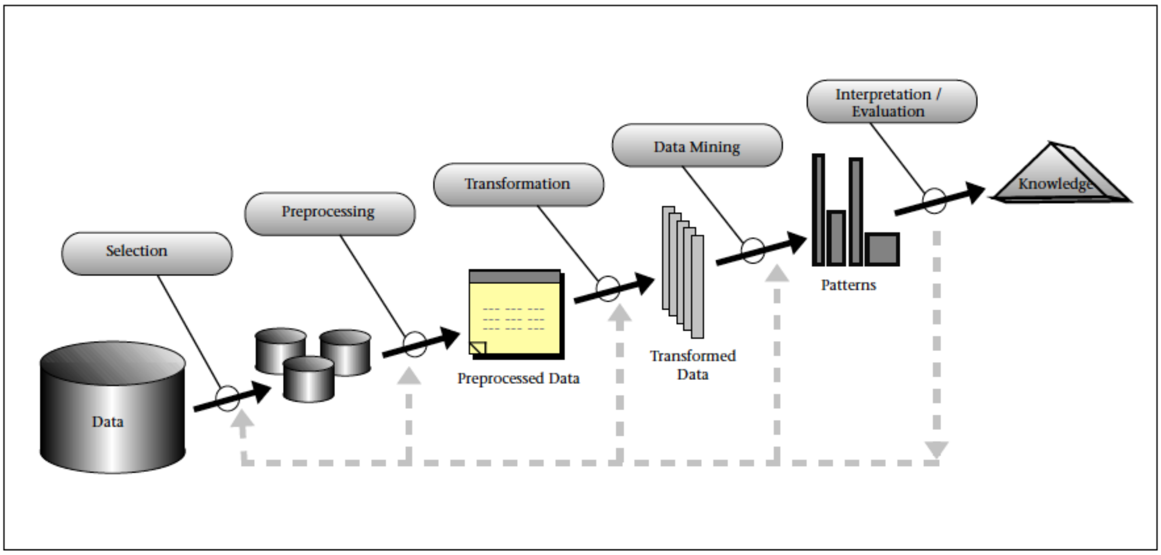
3. Methods

After identifying a gap in the published literature for the study area the method applied in the research consisted of exploring secondary data available on the variables of interest, namely: tree cover loss (TCL), which is to be used as a *proxy* for deforestation) and the current level of agricultural production in the municipalities in MATOPIBA. A special attention will be given to soybeans.

The method of exploring data would fit a process referred to as “KDD” (Knowledge Discovery in Databases). Fayyad et al. (1996) notes that the term first appeared in 1989 (Piatetsky-Shapiro 1990) and emphasizes that knowledge is the ultimate outcome of data-driven discovery. Fayyad et al. (1996) also explain that while KDD it is the process of generating knowledge through data, data mining is only a particular step in the overall process (Figure 11).

Frawley et al. (1992) refer to it as the process of identifying valid, novel, potentially useful and ultimately understandable patterns in data. Therefore, the methods applied in this research aim to build knowledge (on TCL and agricultural crops) based on secondary data available from completely unrelated sources that are publicly available on the Internet.

Figure 11: Overview of KDD steps applied in the research



Source: Fayyad et al. (1996)

3.1 KDD steps in RQ 1

- **First step**: Identify the goal, namely: assessing the correlation of individual main agricultural crops and TCL in the study area;

- **Second step**: Select the sources of data and period of analysis.

TCL is sourced from Global Forest Watch Commodities (GFW) online map (Hansen/UMD/Google/USGS/NASA 2013). Data on agriculture was downloaded from IBGE (Brazilian Institute of Geography and Statistics) SIDRA database (SIDRA/IBGE n.d.). Data for temporary and permanent crops (PMA: Agricultural Municipal Production) and Livestock (PPM: Livestock Municipal Inquiry - bovines) was downloaded.

In order to rank the main crops in each state the data was downloaded at the micro region level and includes: agricultural production in "Quantity" (tonne), "Total value" (R$ 1,000), "Yield" (kg/ha/year) and "Area planted" (ha) for each micro region in MATOPIBA. Period of analysis is 2001 to 2014.

- **Third step**: Data cleaning and pre-processing. Actions performed:
  (a) Separate the TCL data and agricultural data in two different spreadsheets for pre-analysis and treatment. TCL data is compiled with "municipalities" in rows and "years", "area", "micro region" and "sum of TCL in the period" in columns. Original agricultural data downloaded had "municipalities" and "crops" in rows and "years" in columns. The data was transformed to "municipalities" and "years" in rows and "crops" in columns. The spreadsheets were prepared with the idea of crops acting as independent variables "explaining" the "sum of TCL" for each municipality. This is the basic format in the ".csv" file which was created in order to import into "R" software;
  (b) Correct data on area of municipality sourced from GFW database (IBGE official data was applied instead);
  (c) Rank the crops present in each micro region, by quantity and value generated in the period. Only crops present in all fourteen years of the analysis period were considered. For each micro region, the "top 3" crops for either the "quantity produced" or "value generated" were selected. All crops appearing in each micro region made it to the final state ranking. This was applied for both permanent and temporary crops.

It was decided at this stage that the data treatment and analysis would be conducted first in "Excel" and then "R" would be used for more complex analysis (such as regressions, linear models assumptions verification tests and t-test).

- **Fourth step:** Data reduction. For the temporary crops, an additional download was done in the SIDRA-IBGE system in order to collect data for the identified main temporary crops, this time for each municipality. After an initial analysis of permanent and temporary crops, it was decided to focus on temporary crops given its relevance in terms of quantity and value generated in the period;

- **Fifth step**: Classification, summarization (tables, plots, trends and graphs and initial regression analysis of the data (including summary statistics in order to better understand how TCL relates with different crops in each state;

- **Sixth step:** Exploratory analysis of data. At this stage it was considered that additional demographic data would add knowledge to the analysis. Variables such as illiteracy rate, Human Development Index (HDI), number of settlement families, GDP/capita, and population were downloaded for the municipalities. Source of data is also SIDRA-IBGE system;

- **Seventh step:** Attempt to relate TCL with municipality area size (by state and municipality area size category) and TCL with each individual crop (by state and municipality area size category). TCL ratio (%) over total municipality area was divided as follows: "high" TCL ratio, > 10%; "medium", between 5% and 10%; and "low", < 5%. Municipality area (ha) was divided as follows: municipalities > 500,000 ha were classified as "large"; those between 100,000 ha and 500,000 ha were considered as "medium"; and those < 100,000 ha were classified as "small". These categories have proven to be useful in the analysis and the categories were defined based on a visualisation of data distribution (frequency).

A ".csv" file was created with "municipalities" in rows and other variables in columns (e.g. area, category area size, sum of TCL 2001-2014, population, individual crops variables, HDI, TCL ratio (%) over total area, category TCL ratio, GDP/capita and settlement families). Key variables were transformed (square root and log) in order to minimize variances in municipalities' differences. Regression analysis was done considering the square root (and log) of TCL and the square root (and log) of largest area planted for each crop in the period, for each municipality. The idea was to investigate, in each state, if the largest planted area in the period, for any given crop, could explain the level of TCL observed in the same period. Because the ranking was done at the micro region level, some municipalities without any planted area (ha) of a particular crop in the period appeared with "zero" value. These were transformed to an insignificant value ("0.0001") and were not transformed by log or square root.

- **Eight step:** Interpretation and visualization of results (including any linear models)

- **Ninth step:** Discuss the findings and results. Documentation and discussion of how the findings build on the existing knowledge for the study site

Steps six to eight were conducted in software "R".

3.1.1 TCL data: from online database to the spreadsheet

The GFW database is based on high-resolution maps of forest cover change from (Hansen et al. 2013) and is a collaboration between the GLAD (Global Land Analysis & Discovery) lab at the University of Maryland, Google, USGS, and NASA. The resolution is 30m x 30m and the algorithm for forest change detection is based on satellite images from Landsat 5 thematic mapper (TM), the Landsat 7 thematic mapper plus (ETM+), and the Landsat 8 Operational Land Imager (OLI) sensors (over one million images were analyzed) (Hansen et al. 2013).

"Tree Cover" in the dataset is defined as all vegetation taller than 5 meters and may be present in the form of natural forests or managed plantations. "Tree cover loss" (TCL) is defined as a *"stand replacement disturbance, or the complete removal of tree cover canopy at the Landsat pixel scale"* (Hansen/UMD/Google/USGS/NASA 2013). It is important to highlight that TCL may be the result not only of deforestation (i.e. clearing of natural forest to other land uses) but also forestry management practices (e.g. timber harvesting in forest plantations) or natural ecosystem disturbances (e.g. disease or storm damage). Natural and/or human-induced fires are also another important cause of TCL. The data on TCL for the study area was collected using the "Analysis" tool provided in the GFW website (Hansen/UMD/Google/USGS/NASA 2013) as follows:

Step 1: Select Area of interest (i.e. Administrative unit). The button "Next" leads to next step;

Step 2: Refine area - Administrative unit (i.e. Brazil) and province/district (i.e. municipalities located in the MATOPIBA region, listed in Ministry Ordinance (MAPA 2015). The button "Next" leads to next step;

Step 3: Select a variable to analyse – Forest change analysis, option "Tree Cover Loss", canopy cover density > 30%. The button "Perform analysis" leads to next step;

Step 4: A window with the analysis appears at the screen, listing "Total Area (hectare)" of the municipality selected and data on annual "Tree Cover Loss (hectare)" for the period 2001-2014. The data can be downloaded in ".csv" format.

The tool allows for a selection of municipalities but the results are presented in a consolidated manner for the selected area. Therefore, the steps mentioned above were performed for each municipality individually. Each municipality data was downloaded in a separate file and the data was then compiled and treated in one "Excel" spreadsheet. The TCL used in the regression analysis consists, for each municipality, of the "sum of TCL" between 2001-2014. The municipalities of MATOPIBA are listed in Appendix II (Tables 1 - 4) as per Ministry Ordinance (MAPA 2015).

3.1.2 Missing and/or corrected data

The municipalities listed in Table 2 required manual editing. The ones highlighted in orange colour (three in total; two in Bahia and one in Tocantins) were not found in the online database and therefore not included. An email was sent to GFW/WRI on 1st June 2016 in order to clarify/confirm. As of 14th August 2016 no response was received.

Table 2: Municipalities not found or with inconsistencies in names or clustered or swop data with another municipality. Municipalities' areas were corrected with IBGE official data (sourced from SIDRA). More details please refer to Appendix III (Tables 5 and 10)

State	Municipality	Microregion	Action
BA	*Luis Eduardo Magalhães*	*BARREIRAS*	Not found in GFW database. Not used in the analysis
BA	*Wanderley*	*COTEGIPE*	Not found in GFW database. Not used in the analysis
MA	*Matões do Norte = Mates do Norte* in GFW database?	*ITAPECURU MIRIM*	It seems so. Included
MA	*Chapadinha = Chapadão do Céu* in GFW database?	*CHAPADINHA*	It seems so. Included
MA	*Santa Filomena do Maranhão = Santa Fé de Goiás* in GFW database?	*ALTO MEARIM E GRAJAÚ*	It seems so. Included
TO	*Dois Irmãos do Tocantins*	*MIRACEMA DO TOCANTINS*	Clustered with *Divinópolis do Tocantins*. TCL allocated in terms of proportion to total area (61.55%). 38.15% was applied to *Divinópolis do Tocantins*. Included
TO	*Guaraí*	*MIRACEMA DO TOCANTINS*	Clustered with *Tupirama*. TCL allocated in terms of proportion to total area (76.1%). 23.9% was applied to *Tupirama*. Included
TO	*Lajeado = Lajedão* in GFW database?	*PORTO NACIONAL*	It seems so. Included
TO	*Palmeiras do Tocantins*	*BICO DO PAPAGAIO*	Not found in GFW database. Not used in the analysis
TO	*Paranã = Paraná* in GFW database?	*DIANÓPOLIS*	It seems so. Included
TO	*Ponte Alta do Tocantins = Ponte Alta do Norte* in GFW database?	*JALAPÃO*	It seems so. Included

Appendix III (Table 6) lists the area (ha) of managed forests plantations in MATOPIBA in 2014 sourced from SIDRA/IBGE. Because the TCL does not distinguish vegetation cover disturbance, to consider the managed forests' areas when estimating the deforestation rate based on TCL for any given area will certainly increase the precision. This research opted not to include these areas in the analysis because they are not relevant in the context of the study area.

3.2 KDD steps in RQ 2

- **First step**: Identify the goal, namely: investigate whether TCL in MATOPIBA increased after the start of the Soybeans *Moratorium* in the Amazon (July 2006);

- **Second step:** Select the sources of data for analysis: data was already collected for RQ 1;

- **Third step:** Data cleaning and pre-processing actions consisted of calculating for each municipality: the "sum", "average", "mean", "min", "max" and "median" of TCL considering two periods, 2001-2007 and 2008-2014 (two periods of seven years). These were arranged in columns and “municipalities” in rows. The division of years take into account the start date of the Soybeans Moratorium for the Amazon (July 2006);

- **Fourth step:** Data reduction. From agricultural data downloaded from SIDRA/IBGE, only municipalities producing “soybeans” in any year between 2001-2014 were selected. Calculate the total quantity produced in the period. Based on the same two periods mentioned above, count the number of municipalities with soybeans crops in each period and calculate the respective average yield;

- **Fifth step:** Summarization of data, including tables, plots, boxplots, trends and summary statistics;

- **Sixth step:** Exploratory data analysis and import new “.csv” file created to “R”;

- **Seventh step:** Analysis in “R”, including testing assumptions for the selection of test for significant difference between the two periods. After log transformation the variables presented a normal distribution, therefore a paired parametric t-test (paired) was chosen;

- **Eight step:** Interpretation and visualization of results (plots)**;**

- **Ninth step:** Discuss the findings and assess if the RQ can be answered with the results;

3.3 Data analysis and software used

The analysis was done using Excel and R. The latter was used for plots of TCL against different variables, regression analysis, testing of assumptions for linear model and tests for significant difference between two periods. The spreadsheets generated as part of the research are listed in Appendix VII - Table 25 and are recorded in the CD-ROM enclosed to this dissertation. The codes applied to the imported “.csv” file are also saved in the CD-ROM.

3.4 Limitations in the methods and errors

Firstly, the research is limited to the availability of data. Because deforestation rates for the *Cerrado* are not readily available for all municipalities (in addition to the latest report by the Ministry of Environment refer to the period 2010-2011) (MMA/IBAMA 2015) TCL data was used instead. As explained in the methods, TCL does not necessarily equal deforestation. Nonetheless, a validation was done based on official data for deforestation in *Cerrado* (for municipalities in the study area) and TCL was overall a good *proxy* for deforestation (more on this refer to “Results” section). The same validity needs to be checked for any other area selected for analysis, in Brazil or elsewhere.

Another limitation refers to the bi-dimensionality of data. Because georeferenced software is not used, the analysis is limited to the municipality, micro region or state level, and does not produce a visual assessment of changes detected over time. Furthermore, the analysis is done for the whole period (2001-2014) and also does not detect yearly changes for independent or dependent variables.

Furthermore, the research was conducted without collecting primary data or conducting interviews with relevant stakeholders in the study area. Due to time constraints these were not feasible.

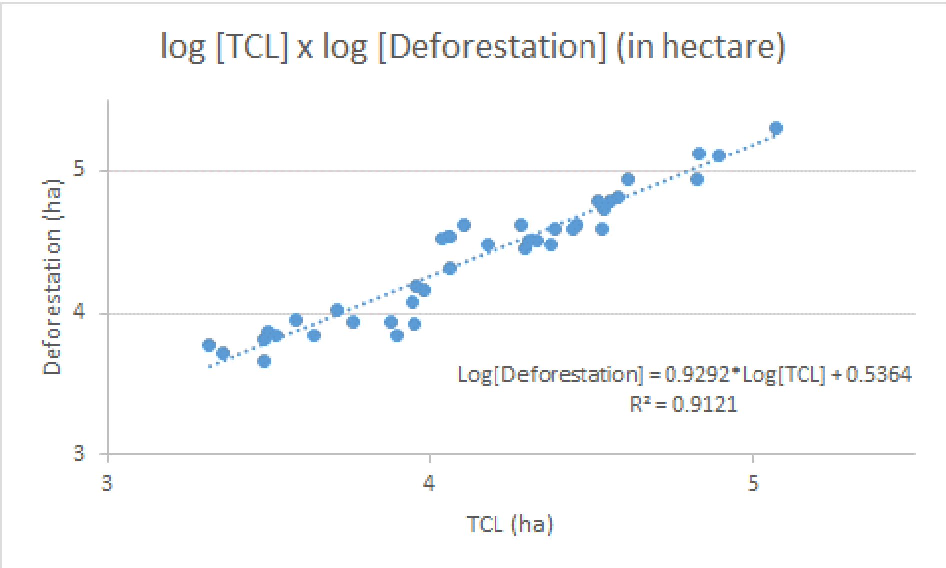
The author acknowledges that the data manipulation needed was time consuming and increases the chance of errors. The author thrived to manipulate the data cautiously and used formulas and pivot tables to minimize errors. Previous experiences handling large amounts of data and previous lectures on “R” as part of my MSc were of great value. Hence, I would not recommend the same methods to others researchers who are not comfortable with the steps presented.

4. Findings and results

4.1 Validation of TCL as a *proxy* for deforestation

The model consists of 40 points (municipalities) in MATOPIBA (Figure 12). TCL data was paired with deforestation data observed for the periods of 2002-2008 (sum in the period), 2009/2010 and 2010/2011 (latest year for which official data is available on deforestation in *Cerrado*) based on reports by the Ministry of Environment (MMA/IBAMA/PNUD 2009; MMA/IBAMA 2011; MMA/IBAMA 2015). Further details on data, calculations and outliers deleted are available in Appendix III (Tables 7-9). The relationship was significant (p-value < 0.0001) and the assumptions of normality and homogeneity of variances were met (Shapiro-Wilk test p-value was 0.6047; Bartlett test p-value was 0.865).

Figure 12: TCL x deforestation model for MATOPIBA. Deforestation data was compiled based on Ministry of Environment reports



4.1.1 TCL (ha) and TCL ratio (%) as function of area size, location (state) and categories

Total TCL between 2001-2014 was 5.56 million ha based on data for 334 municipalities. An increasing trend is present for the period (Figure 13), TCL (ha) was highest in Maranhão and TCL ratio (%) over state area was highest in Bahia (Table 3). The greatest TCL ratios (%) were in micro regions in Maranhão (Appendix III, Table 11). In total, TCL occurred in nearly 8% of MATOPIBA area.

Figure 13: TCL in MATOPIBA (2001-2014). Increasing trend is present.

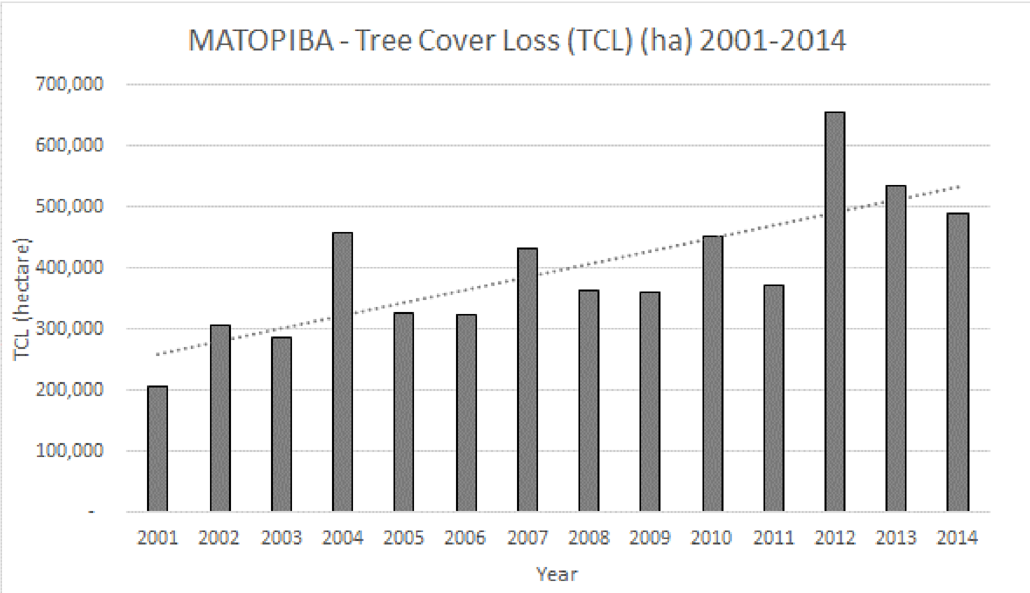


Table 3: TCL (ha) and TCL ratio (%) by state

State	TCL Area (ha)	TCL ratio (%) over State area
BAHIA	1,297,376	10.41%
MARANHÃO	2,124,101	8.86%
PIAUÍ	801,760	9.77%
TOCANTINS	1,336,790	4.83%

TCL is positively related with the municipality area size (Figure 14) but the correlation is different in each state (Figure 15). “Small” municipalities (i.e. area < 100,000 ha) are more present in Maranhão (Figure 16). More than 70% of the municipalities in Piauí fall in the category “medium”, approximately 30% in Bahia are considered “large” municipalities and half of municipalities in Maranhão are “small”. Appendix III (Figures 1 – 4) show details of TCL analysis by state.

Figure 14: TCL (ha) is dependent on municipality size. Data transformation with square root or log are needed to formulate a linear model of TCL as a function of area size

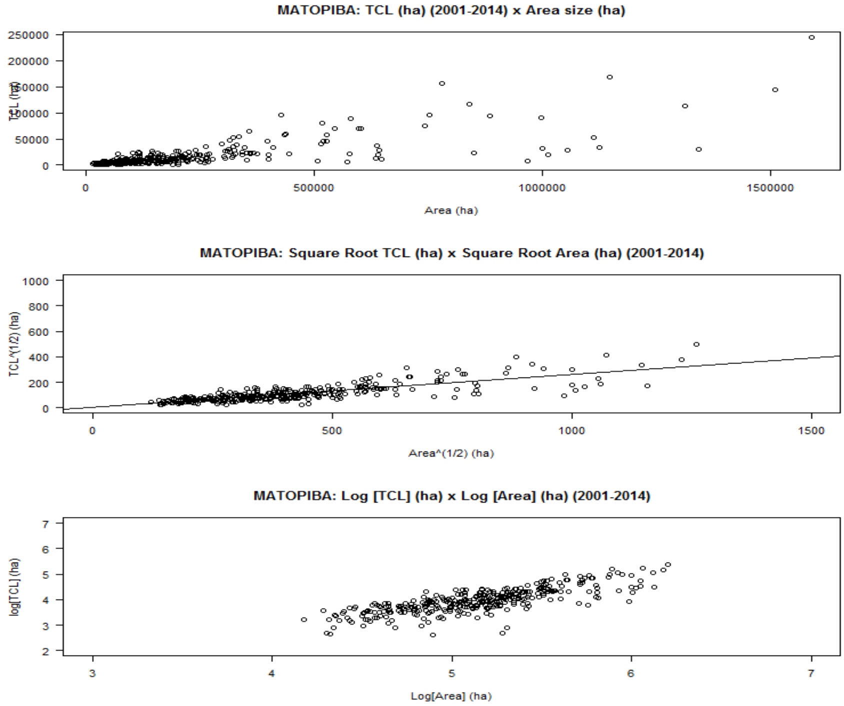


Figure 15: TCL (sq. root) by municipality area (sq. root) by state

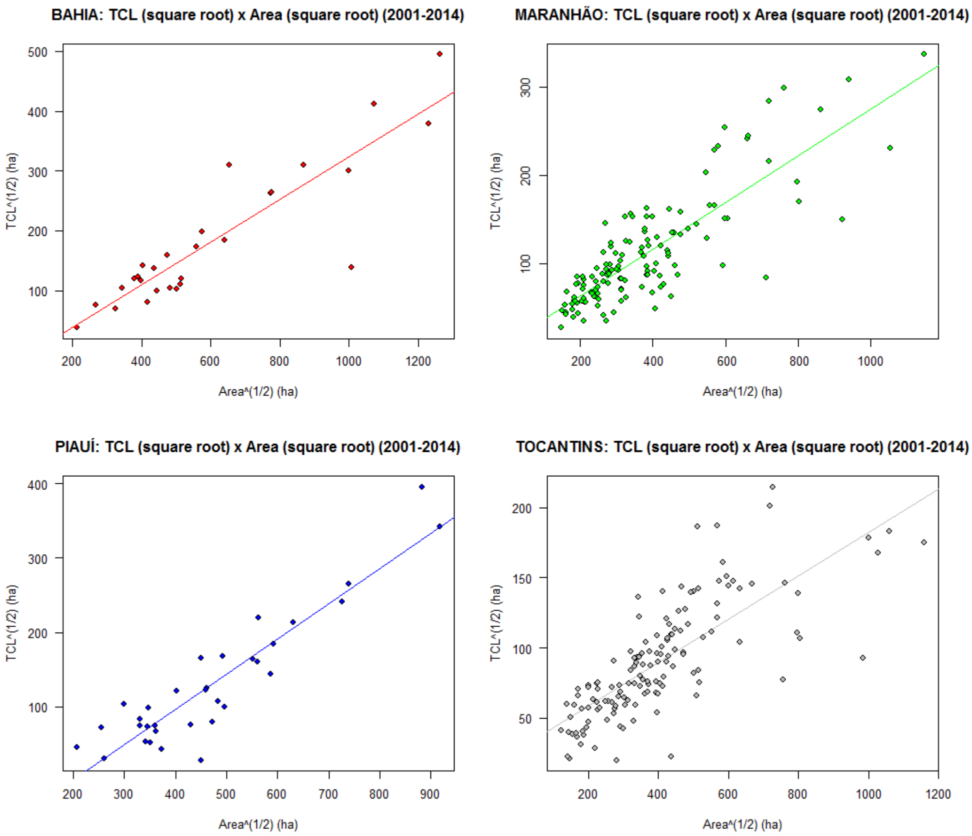
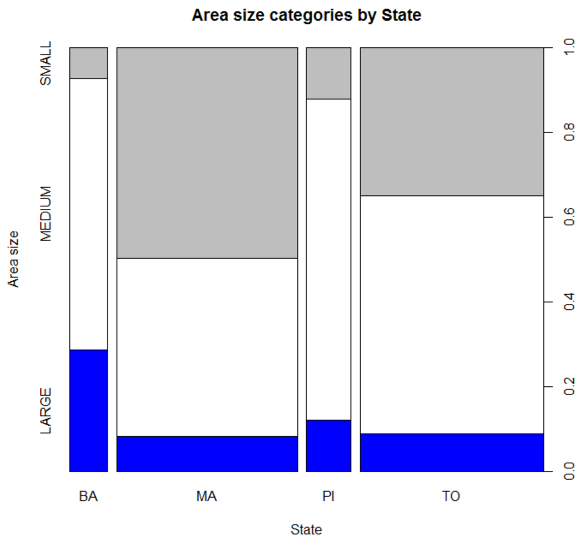


Figure 16: Proportion of area size categories by state. Total number by category area: *n* SMALL = 121, *n* MEDIUM = 177, *n* LARGE = 35



TCL ratio (% over total area) categories distribution among states were more or less similar (Appendix III; Figure 9), with the clear exception of Tocantins, where less municipalities (~10%) observed "high" TCL ratio category (i.e. TCL ratio > 10% of municipality area) in the period. On the other hand, in Maranhão, approximately 40% of municipalities experienced a "high" rate of TCL. Several smaller municipalities observed high TCL ratios.

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Despite the positive correlation between area size and TCL in each state, the assumptions for a linear model were not met (Tables 4 and 5). The transformation with square root achieved one success in the normality test of the residuals while the log-transformation was more effective in adjusting the variance of residuals (i.e. increasing homoscedasticity) (refer Appendix III – Figure 6).

Table 4: Linear model "Sqrt TCL (ha) as response variable and "Sqrt Area (ha)" as explanatory variable, by state

State	Coefficient	R^2	p-value	Shapiro-Wilk p-value	Bartlett p-value
BA	0.35749 ***	0.7993	1.476e-10 26 DF	0.00114	9.005e-06
MA	0.26444 ***	0.6899	< 2.2e-16 133 DF	0.01771	< 2.2e-16
PI	0.47402 ***	0.8449	4.381e-14 31 DF	0.7899	0.0003264
TO	0.1549 ***	0.5863	< 2.2e-16 135 DF	0.00369	< 2.2e-16

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5: Linear model "Log TCL (ha)" as response variable and "Log Area (ha)" as explanatory variable, by state

State	Coefficient	R^2	p-value	Shapiro-Wilk p-value	Bartlett p-value
BA	1.1939 ***	0.8107	6.847e-11 26 DF	0.00764	0.1489
MA	0.90408 ***	0.6571	< 2.2e-16 133 DF	0.003007	0.2077
PI	1.559 ***	0.6804	3.568e-09 31 DF	0.003772	0.000535
TO	0.77697 ***	0.5946	< 2.2e-16 135 DF	4.803e-07	0.9294

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

An alternative approach was also attempted relating the TCL with municipality area size category. Similarly, the assumptions for linearity were not met (Tables 6 - 7). Plots are shown in Appendix III (Figures 7 - 8).

Table 6: Linear model "Sqrt TCL" as response variable and "Sqrt Area" as explanatory variable by municipality area size category

Area size	Coefficient	R^2	p-value	Shapiro-Wilk p-value	Bartlett p-value
SMALL	0.22656 ***	0.2624	1.908e-09 119 DF	0.2608	< 2.2e-16
MEDIUM	0.31552 ***	0.4049	< 2.2e-16 175 DF	0.03114	< 2.2e-16
LARGE	0.2649 *	0.1742	0.01262 33 DF	0.07778	0.009661

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Table 7: Linear model "Log TCL" as response variable and "Log Area" as explanatory variable, by municipality area size category

Area size	Coefficient	R^2	p-value	Shapiro-Wilk p-value	Bartlett p-value
SMALL	0.817 ***	0.262	1.965e-09 119 DF	0.0005182	5.109e-07
MEDIUM	1.1061 ***	0.3112	7.231e-16 175 DF	1.56e-06	< 2.2e-16
LARGE	0.9168 *	0.1132	0.04814 33 DF	0.01565	6.545e-08

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

4.2 Agricultural crops and bovine livestock

The quantity (ton), value (R$ 1,000) and average yield (kg/ha/year) for each permanent and temporary crop in MATOPIBA for the period are summarized (Tables 8-13). Values for Brazil are also shown (right columns), lines in bold are the main crops identified in MATOPIBA and yields in red indicate a lower value than the national average.

The summary shows that the temporary crops are more relevant (higher quantities and higher monetary values). For each micro region, the three main crops by “quantity” or “value generated” were identified (only crops present in all fourteen years of analysis). Any crop in the “top 3” for any of these two criteria in each micro region was considered as a main crop in the state. Some crops are more representative for the whole state while other crops (e.g. pineapple in Maranhão and Tocantins, beans in Bahia and Maranhão) are more concentrated in certain micro regions even within one single state. The ranked crops ranked by state are shown in Figures 17 – 18. For further details on the ranking per micro region, in each state, refer to Appendix IV Tables 12 - 15 (temporary crops) and Tables 16 - 19 (permanent crops).

Table 8: Temporary crops Quantity (ton) produced (2001-2014)

Temporaray Crop	BA: ton	MA: ton	PI: ton	TO: ton	Brazil: ton
Pineapple	***36,913***	***331,720***	***2,178***	***550,338***	***22,147,460***
Herbaceous cotton (seed)	***11,652,701***	***536,822***	***373,776***	***129,356***	***49,007,297***
Garlic	16,545	-	-	-	1,426,930
Groundnut (shell)	9,808	573	44	50,871	3,917,810
Rice (paddy)	***492,811***	***6,198,689***	***1,194,822***	***5,625,206***	***164,955,692***
Oats (grain)	-	-	-	-	5,344,307
Sweet potato	3,193	185	92	-	7,192,652
English potato	-	-	-	-	47,504,380
Sugar cane	***8,316,071***	***32,428,052***	***482,925***	***11,918,821***	***7,984,674,582***
Onion	3,373	-	13	-	19,363,779
Rye (grain)	-	-	-	-	69,254
Barley (grain)	-	-	-	-	3,917,509
Peas (beans)	-	-	-	-	75,719
Fava (grain)	-	3,760	2,081	-	173,897
Beans (beans)	***917,168***	***408,387***	***186,080***	***234,635***	***43,959,962***
Tobacco (sheet)	557	-	12	-	11,492,287
Jute (fiber)	-	-	-	-	31,177
Flax (seed)	-	-	-	-	138,203
Malva (fiber)	-	-	-	-	174,739
Castor (berry)	21,677	8	715	1,576	1,264,944
Manioc	***5,462,612***	***9,131,947***	***503,843***	***4,118,360***	***339,862,901***
Watermelon	***41,534***	***376,489***	***53,859***	***1,751,648***	***26,969,883***
Melon	120	522	-	8,406	6,107,548
Corn (grain)	***17,928,488***	***6,815,526***	***3,711,922***	***3,233,444***	***749,806,765***
Rami (fiber)	-	-	-	-	12,854
Soybean	***34,467,777***	***16,130,505***	***9,731,263***	***12,725,889***	***838,072,275***
Sorghum (grain)	468,004	490	51,283	306,822	23,976,812
Tomato	23,735	73,237	3,095	13,105	53,293,353
Total	***79,863,087***	***72,436,912***	***16,298,003***	***40,668,477***	***10,404,934,971***

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Table 9: Temporary crops Value (R$ 1,000)[2] (2001-2014)

Temporaray Crop	BA: value (R$ 1,000)	MA: value (R$ 1,000)	PI: value (R$ 1,000)	TO: value (R$ 1,000)	Brazil: value (R$ 1,000)
Pineapple	***32,215***	***134,614***	***1,289***	***503,524***	***15,415,820***
Herbaceous cotton (seed)	***17,253,419***	***914,398***	***361,550***	***187,072***	***66,230,971***
Garlic	53,650	-	-	-	5,053,799
Groundnut (shell)	2,635	700	53	45,507	4,186,884
Rice (paddy)	***243,054***	***3,269,585***	***690,281***	***2,946,633***	***82,763,742***
Oats (grain)	-	-	-	-	1,787,596
Sweet potato	1,080	145	45	-	3,932,322
English potato	-	-	-	-	31,587,076
Sugar cane	***826,948***	***2,998,331***	***27,735***	***878,860***	***332,936,788***
Onion	2,957	-	13	-	12,044,345
Rye (grain)	-	-	-	-	28,106
Barley (grain)	-	-	-	-	1,653,330
Peas (beans)	-	-	-	-	102,937
Fava (grain)	-	10,457	5,714	-	379,006
Beans (beans)	***1,417,977***	***669,527***	***347,204***	***449,271***	***63,074,129***
Tobacco (sheet)	1,698	-	9	-	53,925,950
Jute (fiber)	-	-	-	-	24,143
Flax (seed)	-	-	-	-	102,573
Malva (fiber)	-	-	-	-	167,889
Castor (berry)	12,579	5	485	966	979,695
Manioc	***1,280,641***	***1,789,415***	***61,481***	***432,841***	***81,331,303***
Watermelon	***10,913***	***129,573***	***14,489***	***576,237***	***9,355,843***
Melon	55	224	-	7,254	4,332,394
Corn (grain)	***6,249,755***	***2,624,649***	***1,754,171***	***1,287,933***	***228,119,162***
Rami (fiber)	-	-	-	-	18,655
Soybean	***22,032,933***	***10,264,899***	***6,609,678***	***8,418,836***	***523,995,927***
Sorghum (grain)	132,564	169	17,090	95,565	5,245,658
Tomato	18,140	68,807	4,274	11,100	36,060,505
Total	***49,573,213***	***22,875,498***	***9,895,561***	***15,841,599***	***1,564,836,548***

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[2] Exchange rate USD/BRL as of 20/07/2016 was 3.26. Source: www.bloomberg.com

Table 10: Temporary crops average yields (2001-2014)

Temporaray Crop	BA: Average yield (kg/ha/year)	MA: Average yield (kg/ha/year)	PI: Average yield (kg/ha/year)	TO: Average yield (kg/ha/year)	Brazil: Average yield (kg/ha/year)
Pineapple	23,623	19,837	8,890	20,474	25,042
Herbaceous cotton (seed)	3,426	1,399	2,683	2,437	3,392
Garlic	4,987	-	-	-	8,990
Groundnut (shell)	2,250	1,775	1,550	2,448	2,516
Rice (paddy)	1,303	1,446	1,306	2,051	4,078
Oats (grain)	-	-	-	-	1,730
Sweet potato	11,203	9,224	3,361	-	11,923
English potato	-	-	-	-	23,821
Sugar cane	41,581	44,681	46,031	43,881	74,945
Onion	9,426	-	4,333	-	21,881
Rye (grain)	-	-	-	-	1,274
Barley (grain)	-	-	-	-	2,713
Peas (beans)	-	-	-	-	2,413
Fava (grain)	-	370	375	-	372
Beans (beans)	999	439	471	864	873
Tobacco (sheet)	877	-	933	-	1,928
Jute (fiber)	-	-	-	-	1,359
Flax (seed)	-	-	-	-	858
Malva (fiber)	-	-	-	-	1,419
Castor (berry)	779	442	754	1,633	595
Manioc	10,044	7,498	11,164	18,242	13,940
Watermelon	17,272	7,846	26,696	23,654	21,570
Melon	30,000	1,757	-	25,167	23,179
Corn (grain)	3,438	1,522	2,836	2,450	3,969
Rami (fiber)	-	-	-	-	2,582
Soybean	2,657	2,583	2,359	2,599	2,697
Sorghum (grain)	1,712	1,558	2,241	1,788	2,336
Tomato	25,531	20,779	18,350	32,743	60,430

* average yield in years of production

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Table 11: Permanent crops Quantity (ton) produced (2001-2014)

Permanent Crop	BA: ton	MA: ton	PI: ton	TO: ton	Brazil: ton
Annatto (seed)	-	2,529	4	-	176,585
Apple	-	-	-	-	15,139,394
Arboreal cotton (seed)	-	-	-	-	16,190
Avocado	260	5,090	766	3,446	2,217,161
Banana (bunch)	**1,864,659**	**1,251,149**	**56,431**	**428,581**	***95,830,739***
Black pepper	-	**1,872**	-	-	***838,654***
Cashew nut	**32**	**64,448**	**19,734**	**5,343**	***2,293,648***
Cocoa (almond)	53	-	-	4	3,036,628
Coconut	***216,209***	***63,750***	***9,631***	***129,327***	***27,172,816***
Coffee (beans) Arabica	85,081	-	-	-	6,611,253
Coffee (beans) Canephora	-	-	-	-	2,194,889
Coffee (beans) Total	***408,462***	***156***	***2***	***130***	***37,315,924***
Fig	50	-	-	-	358,703
Grape	8,199	36	-	666	18,473,125
Guarana (seed)	-	-	-	-	51,521
Guava	22,005	294	-	525	4,659,769
Khaki	-	-	-	-	2,266,245
Lemon	161,193	3,798	294	1,463	14,488,898
Mango	***339,861***	***36,419***	***21,882***	***33,362***	***15,260,940***
Olive	-	-	-	-	1,149
Orange	***199,813***	***86,865***	***19,590***	***27,751***	***252,276,504***
Palm oil (coconut bunch)	-	-	-	-	15,169,181
Palmetto	-	-	-	-	1,143,062
Papaya	***1,751,073***	***26,601***	***90***	***5,067***	***23,809,824***
Passion fruit	99,680	1,977	-	12,718	9,363,257
Peach	-	-	-	-	3,079,930
Pear	-	-	-	-	268,216
Quince	-	-	-	-	13,547
Rubber (coagulated latex)	-	***32,249***	-	***22,175***	***2,981,004***
Sisal or agave (fiber)	-	-	-	-	2,873,654
Tangerine	12,803	664	281	3,991	15,727,530
Tea-of-India (green leaf)	-	-	-	-	251,418
Tung (dry fruit)	-	-	-	-	5,105
Walnut (nut)	-	-	-	-	48,933
Yerba mate (green leaf)	-	-	-	-	6,750,145
Total	***5,169,433***	***1,577,897***	***128,705***	***674,549***	***582,165,541***

Table 12: Permanent crops Value (R$ 1,000) (2001-2014)

Permanent Crop	BA: value (R$ 1,000)	MA: value (R$ 1,000)	PI: value (R$ 1,000)	TO: value (R$ 1,000)	Brazil: value (R$ 1,000)
Annatto (seed)	-	3,649	4	-	402,432
Apple	-	-	-	-	10,999,408
Arboreal cotton (seed)	-	-	-	-	14,377
Avocado	49	3,303	599	1,790	1,212,737
Banana (bunch)	***947,426***	***787,734***	***23,578***	***254,232***	***46,001,877***
Black pepper	-	***7,031***	-	-	4,316,786
Cashew nut	***28***	***45,637***	***16,241***	***5,258***	2,391,554
Cocoa (almond)	269	-	-	4	13,570,341
Coconut	***96,905***	***32,848***	***3,934***	***67,639***	***10,245,938***
Coffee (beans) Arabica	482,906	-	-	-	36,913,725
Coffee (beans) Canephora	-	-	-	-	8,301,736
Coffee (beans) Total	***1,702,452***	***103***	***4***	***138***	***135,517,156***
Fig	64	-	-	-	605,531
Grape	15,306	118	-	1,364	22,820,420
Guarana (seed)	-	-	-	-	300,716
Guava	11,235	186	-	350	3,100,755
Khaki	-	-	-	-	2,037,450
Lemon	50,688	1,536	86	628	5,714,759
Mango	***123,971***	***18,931***	***5,739***	***11,241***	***8,004,005***
Olive	-	-	-	-	2,348
Orange	***71,918***	***35,574***	***6,915***	***10,234***	***66,904,829***
Palm oil (coconut bunch)	-	-	-	-	2,548,448
Palmetto	-	-	-	-	2,241,830
Papaya	***1,027,122***	***15,879***	***45***	***3,192***	***13,489,481***
Passion fruit	72,197	1,766	-	8,053	7,487,566
Peach	-	-	-	-	3,367,426
Pear	-	-	-	-	295,669
Quince	-	-	-	-	14,827
Rubber (coagulated latex)	-	***52,092***	-	***30,270***	***6,068,152***
Sisal or agave (fiber)	-	-	-	-	2,592,496
Tangerine	4,655	296	133	2,214	6,826,996
Tea-of-India (green leaf)	-	-	-	-	96,281
Tung (dry fruit)	-	-	-	-	1,497
Walnut (nut)	-	-	-	-	170,318
Yerba mate (green leaf)	-	-	-	-	2,803,414
Total	***4,607,191***	***1,006,683***	***57,278***	***396,607***	***427,383,281***

Table 13: Permanent crops average yields (2001-2014)

Permanent Crop	BA: Average yield (kg/ha/year)	MA: Average yield (kg/ha/year)	PI: Average yield (kg/ha/year)	TO: Average yield (kg/ha/year)	Brazil: Average yield (kg/ha/year)
Annatto (seed)	-	496	2,000	-	1,102
Apple	-	-	-	-	29,846
Arboreal cotton (seed)	-	-	-	-	447
Avocado	8,667	8,429	9,220	6,939	15,258
Banana (bunch)	***22,281***	***9,757***	***10,916***	***7,399***	***13,791***
Black pepper	-	***1,140***	-	-	***2,366***
Cashew nut	***314***	***325***	***225***	***1,023***	***230***
Cocoa (almond)	248	-	-	2,000	333
Coconut	***15,048***	***3,749***	***8,966***	***13,116***	***7,044***
Coffee (beans) Arabica	2,739	-	-	-	1,381
Coffee (beans) Canephora	-	-	-	-	1,547
Coffee (beans) Total	***2,739***	***2,943***	***333***	***1,267***	***1,201***
Fig	25,000	-	-	-	8,703
Grape	22,830	11,000	-	18,000	17,372
Guarana (seed)	-	-	-	-	299
Guava	16,529	7,120	-	17,813	21,108
Khaki	-	-	-	-	19,898
Lemon	11,595	4,053	5,327	16,480	22,272
Mango	***13,131***	***6,125***	***9,782***	***7,710***	***15,123***
Olive	-	-	-	-	1,347
Orange	***20,573***	***6,124***	***9,573***	***9,951***	***22,814***
Palm oil (coconut bunch)	-	-	-	-	10,809
Palmetto	-	-	-	-	6,449
Papaya	***50,269***	***10,994***	***10,000***	***15,052***	***49,428***
Passion fruit	19,849	5,091	-	10,223	***14,078***
Peach	-	-	-	-	10,366
Pear	-	-	-	-	11,364
Quince	-	-	-	-	4,961
Rubber (coagulated latex)	-	***1,060***	-	***3,429***	***1,749***
Sisal or agave (fiber)	-	-	-	-	855
Tangerine	13,074	8,645	8,042	12,437	19,423
Tea-of-India (green leaf)	-	-	-	-	8,499
Tung (dry fruit)	-	-	-	-	2,266
Walnut (nut)	-	-	-	-	1,657
Yerba mate (green leaf)	-	-	-	-	6,452

* average yield in years of production

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Figure 17: Ranking temporary crops by state

Bahia	Count
Herbaceous Cotton (seed)	4
Sugar cane	4
Beans (grain)	1
Manioc	4
Corn (grain)	7
Soybeans	4

Piauí	Count
Rice (paddy)	6
Sugar cane	2
Beans (grain)	1
Manioc	1
Corn (grain)	8
Soybeans	6

Tocantins	Count
Pineapple	1
Rice (paddy)	9
Sugar cane	6
Manioc	8
Watermelon	2
Corn (grain)	8
Soybeans	14

Maranhão	Count
Pineapple	1
Herbaceous Cotton (seed)	2
Rice (paddy)	24
Sugar cane	15
Beans (grain)	2
Manioc	16
Corn (grain)	21
Soybeans	9

Figure 18: Ranking permanent crops by state

Bahia	Count
Banana (bunch)	6
Coffee (beans)	4
Papaya	6
Mango	4

Tocantins	Count
Banana (bunch)	16
Rubber (coagulated latex)	2
Coconut	4
Orange	2

Maranhão	Count
Banana (bunch)	30
Rubber (coagulated latex)	2
Cashew nut	12
Coconut	12
Orange	23
Papaya	1
Mango	3
Black pepper	1

Piauí	Count
Banana (bunch)	8
Cashew nut	5
Coconut	2
Orange	6
Mango	3

10 The Quantity (ton), Value (R$ 1,000) and Average yields of main crops by state are shown in Figures 19-30. The series are based on the micro regions that had the referred crops in all fourteen years of the period assessed.

Figure 19: Quantity (ton) main temporary crops (BAHIA). Soybeans production more than doubled since 2001. It is closely related with corn and herbaceous cotton (same area used for plantation). Manioc production reduced in the period and the trend for sugar cane is unclear

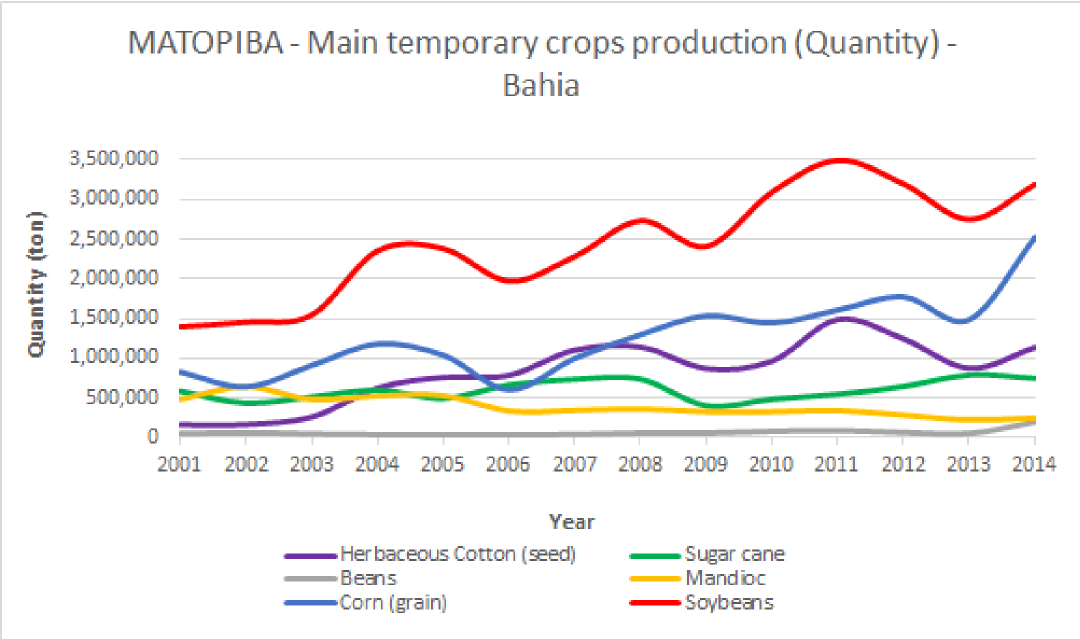

Figure 20: Value (R$ 1,000) main temporary crops (BAHIA). Soybeans and herbaceous cotton are the most important crops. Combined, they generated more than R$ 6 billion in 2014. Corn total value has been increasing over the years and bean has marginally increased its value while sugar cane is unclear and manioc value reduced
10 since 2001

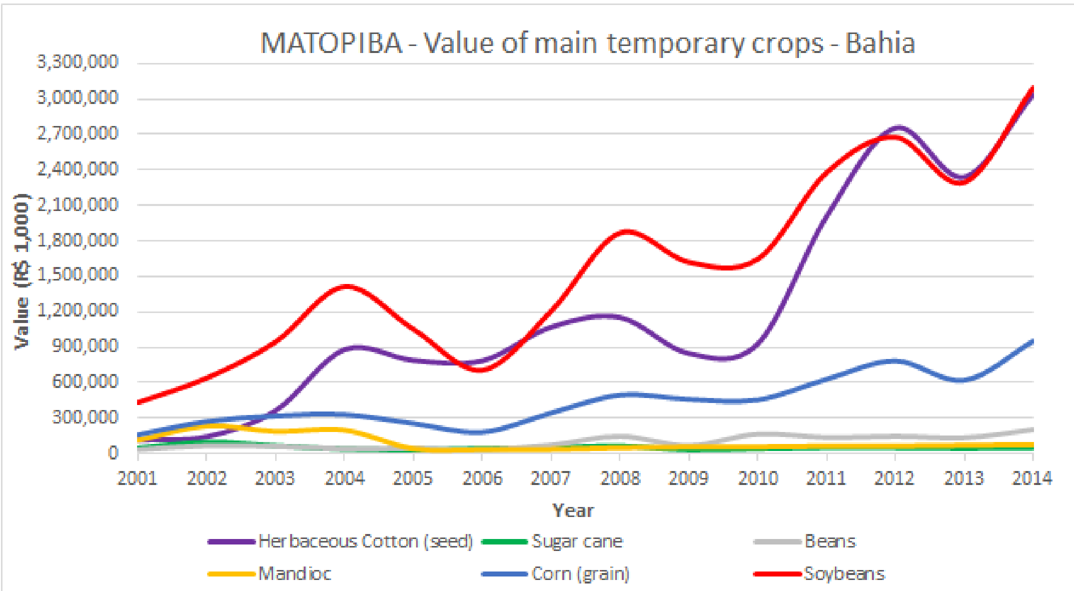

Figure 21: Average yields main temporary crops (BAHIA). Only corn yields have significantly increased since 2001.

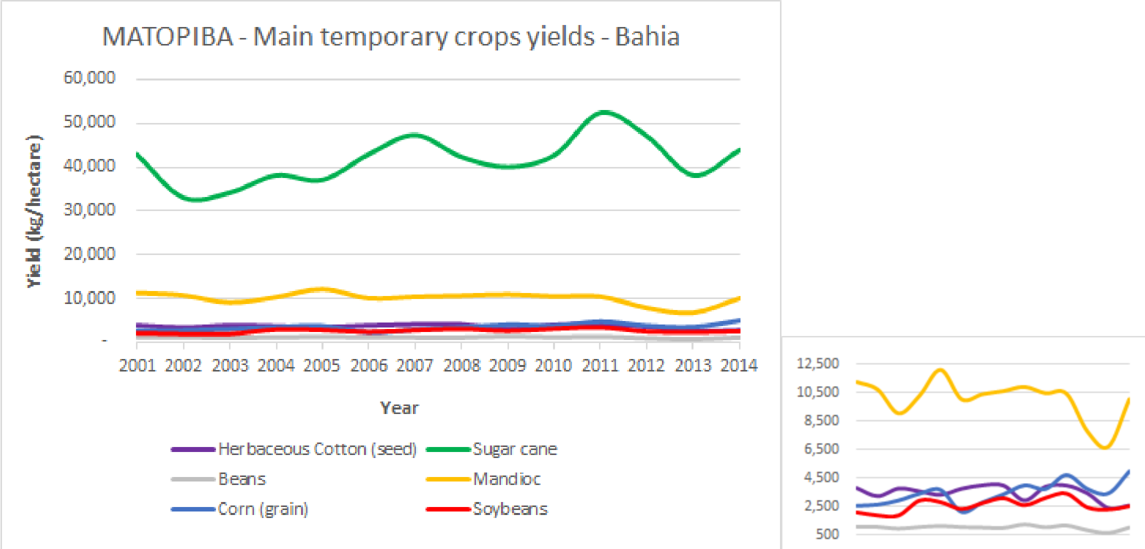

Figure 22: Quantity (ton) main temporary crops (MARANHÃO). Difference between sugar cane production and other crops is reducing. Soybean has steadily increased its share in total production since 2001 and corn shows a sharp increase since 2011. Sugar cane shows a decreasing trend after its peak in 2010

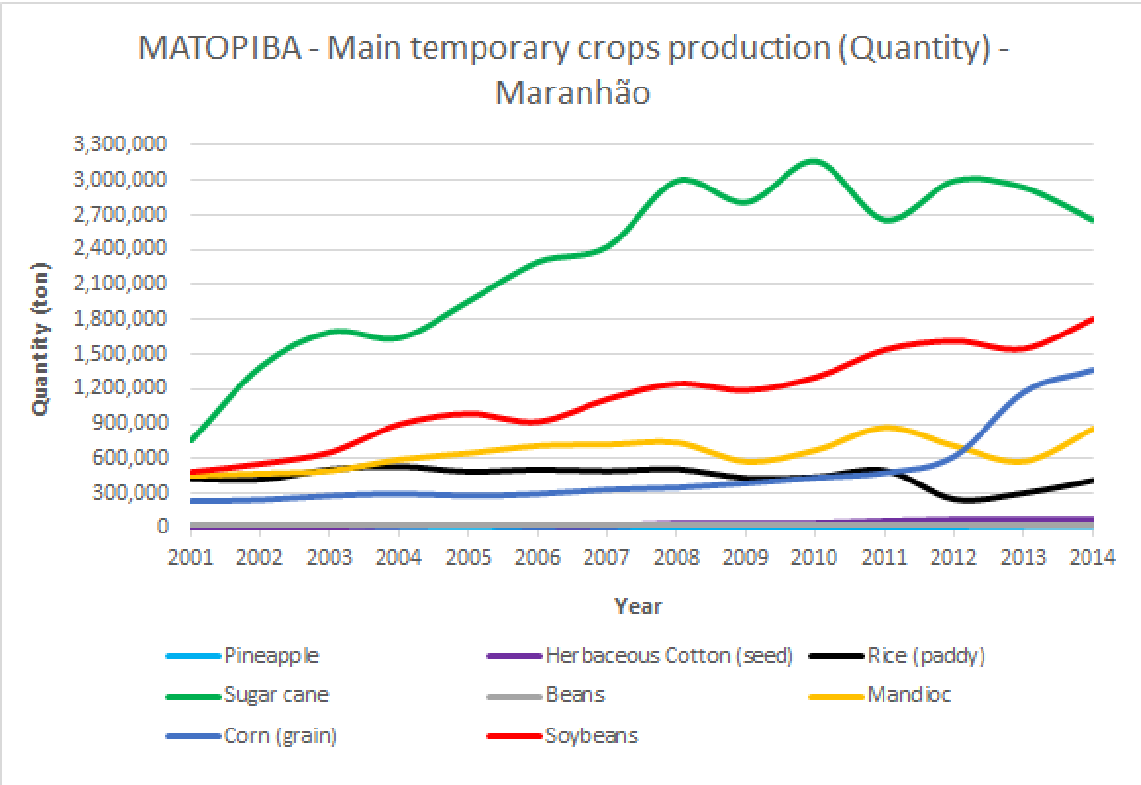

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Figure 23: Value (R$ 1,000) main temporary crops (MARANHÃO). Soybeans generate more revenues than any other crop in Maranhão. Despite a reducing trend in sugar cane production in recent years its value has increased since 2013 and it was the second most valuable crop in the state in 2014. All crops show an increasing trend since 2001

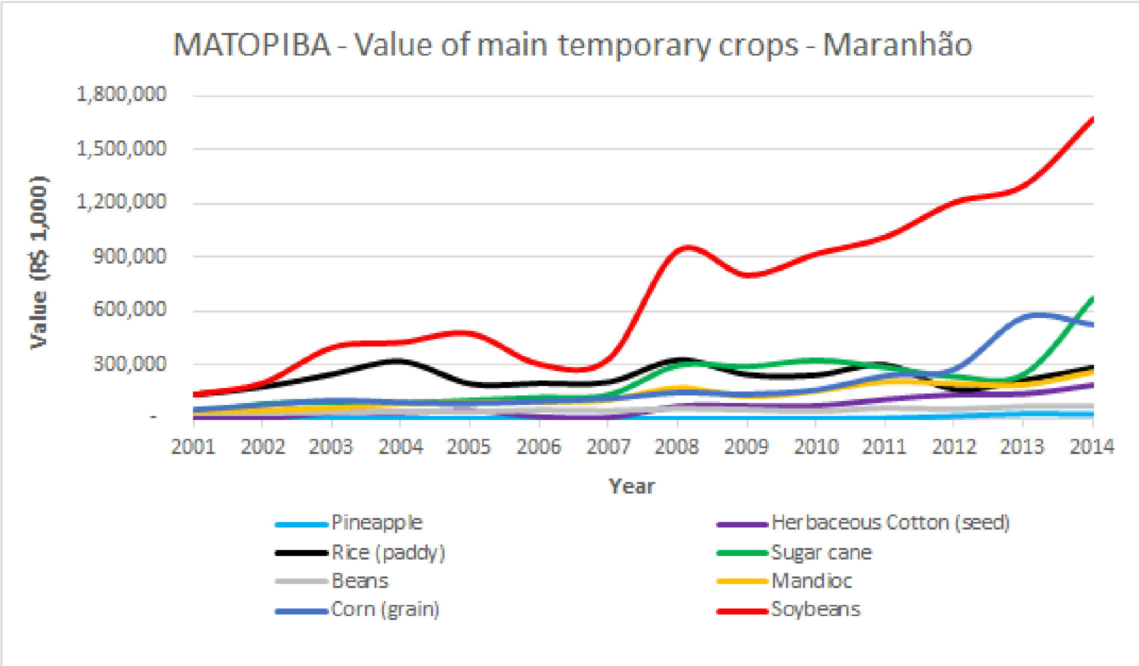

Figure 24: Average yields main temporary crops (MARANHÃO). Crops yields in Maranhão did not show a great variation in the period, with the exception of pineapple (increasing trend over time but with a reduction since 2012)

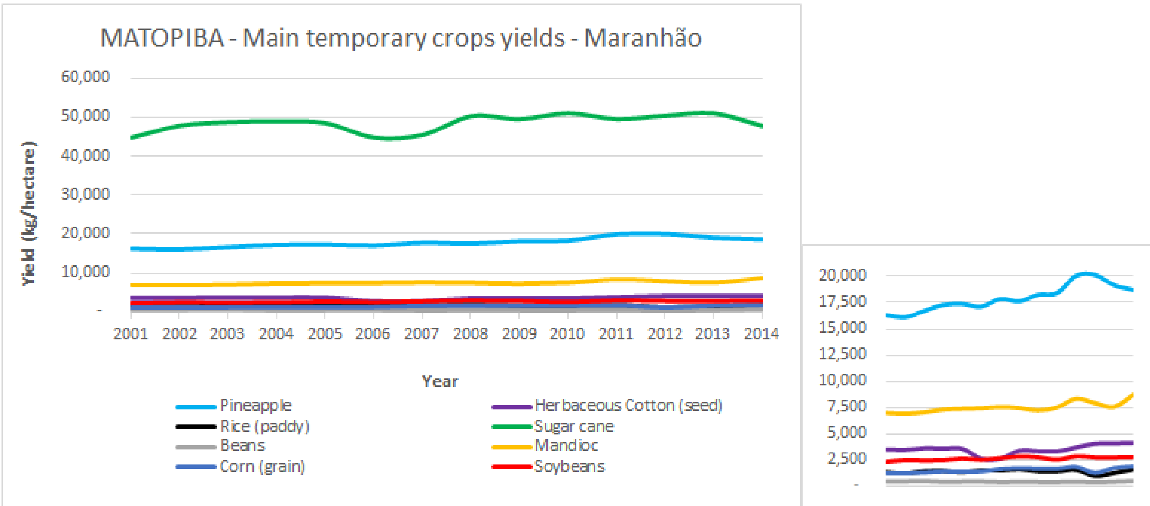

Figure 25: Quantity (ton) main temporary crops (PIAUÍ). Soybeans and corn are positively correlated in Piauí and quantities produced are significantly larger than other crops

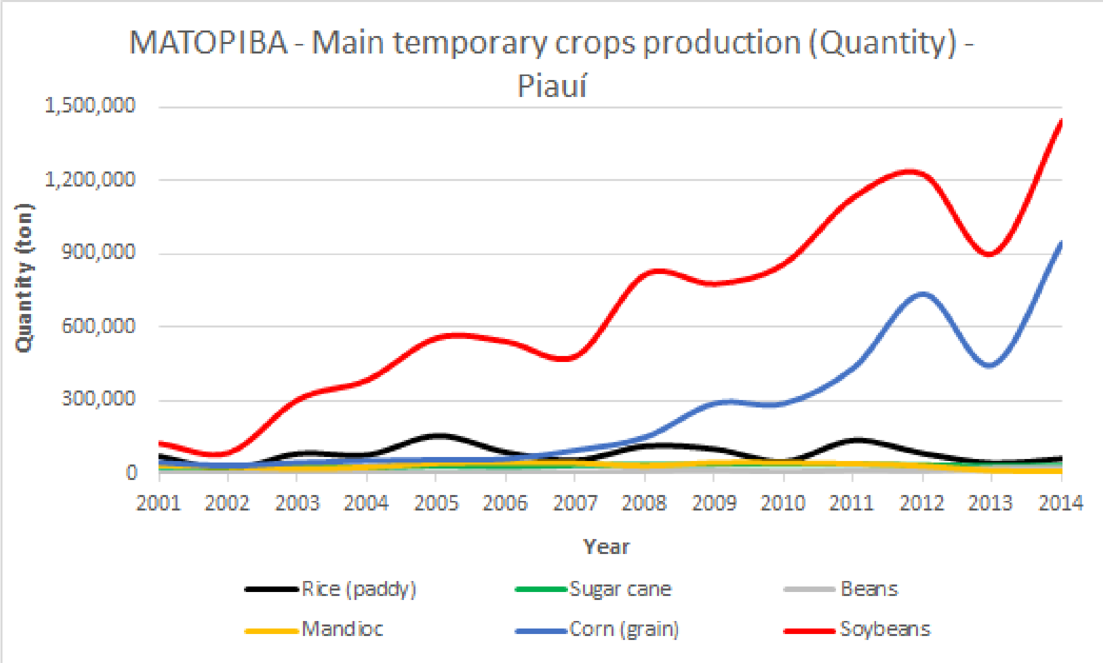

Figure 26: Value (R$ 1,000) main temporary crops (PIAUÍ). Other crops revenues in Piauí are significantly lower than soybeans and corn. In 2014 soybeans generated more than double the value of all other crops combined.

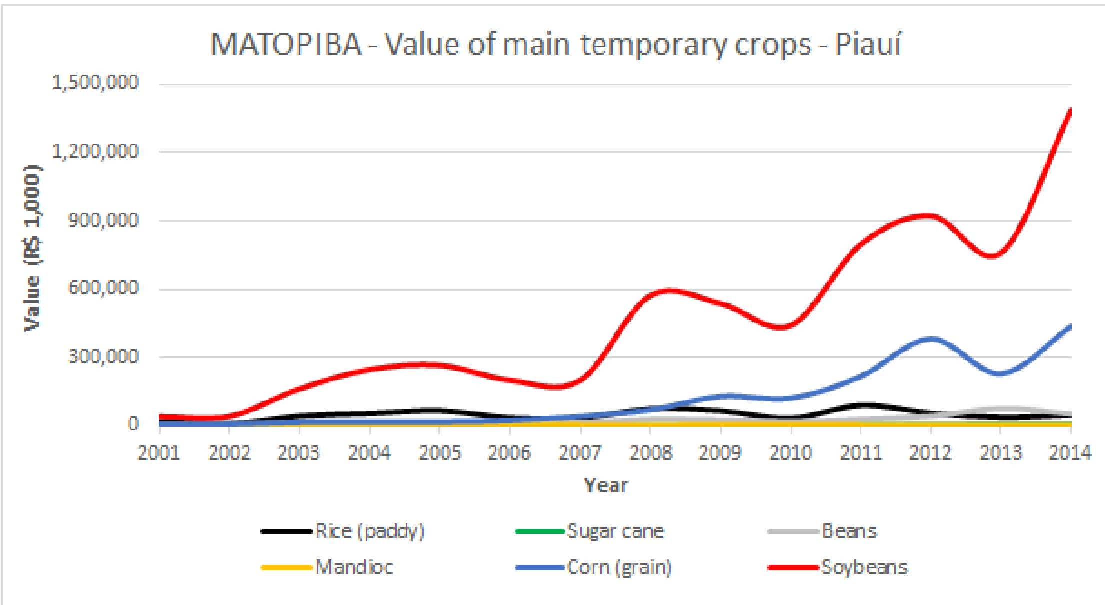

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Figure 27: Average yields main temporary crops (PIAUÍ). Only corn yield has increased over time in Piauí. Beans and soybeans yields varied but are about the same level as of 2001. Manioc yield lowered significantly between 2011 and 2013.

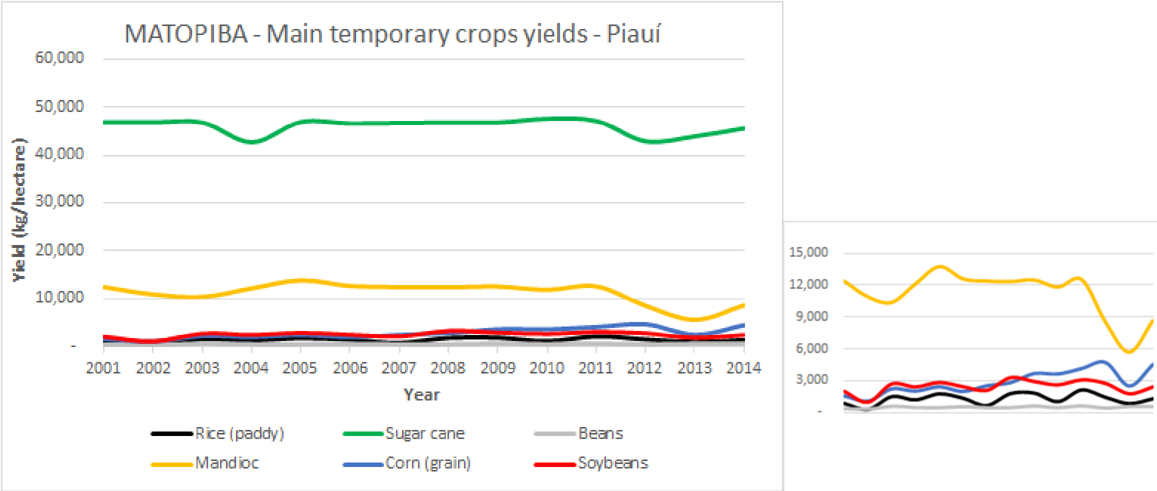

Figure 28: Quantity (ton) main temporary crops (TOCANTINS). The quantity of sugar cane produced surpassed that of soybeans in 2011 but this difference was higher in that year than later in 2014. This is partially explained by much higher yields (kg/ha) for this crop than soybeans. Only corn apart from sugar cane and soybeans have shown an overall increasing trend in the period. Watermelon is becoming more important since 2012.

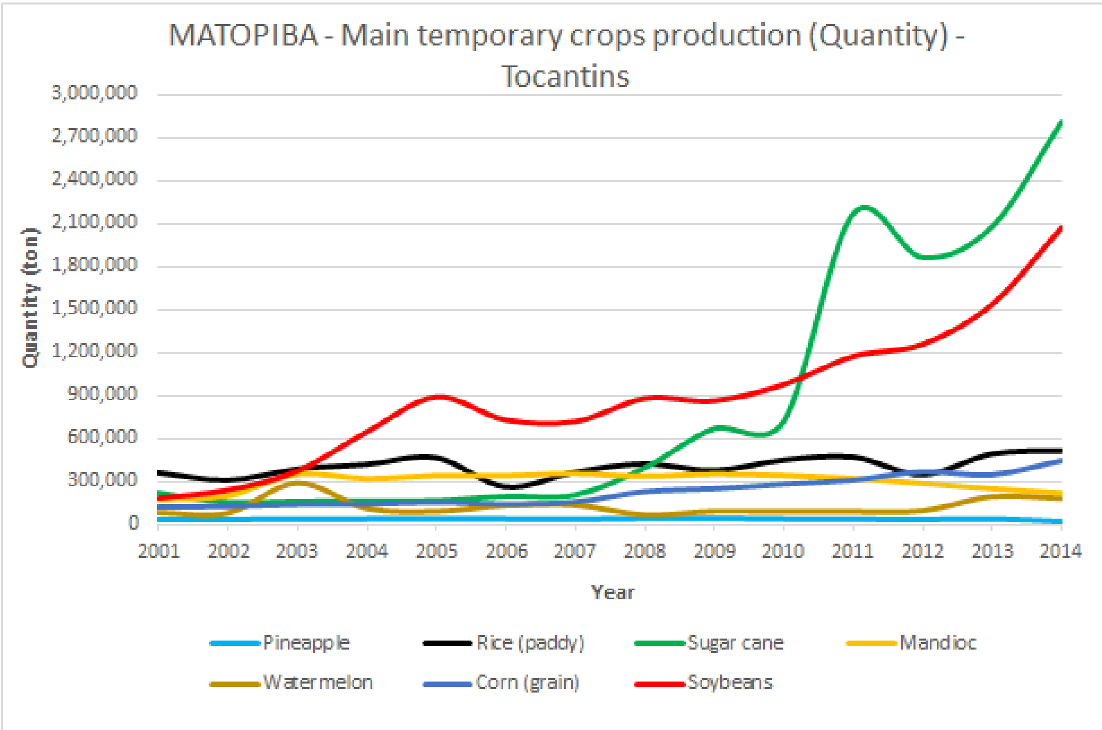

Figure 29: Value (R$ 1,000) main temporary crops (TOCANTINS). Soybean is by far the leading crop in revenues in Tocantins (despite being second in total quantity produced). Rice paddy is second, corn is third and sugar cane is fourth

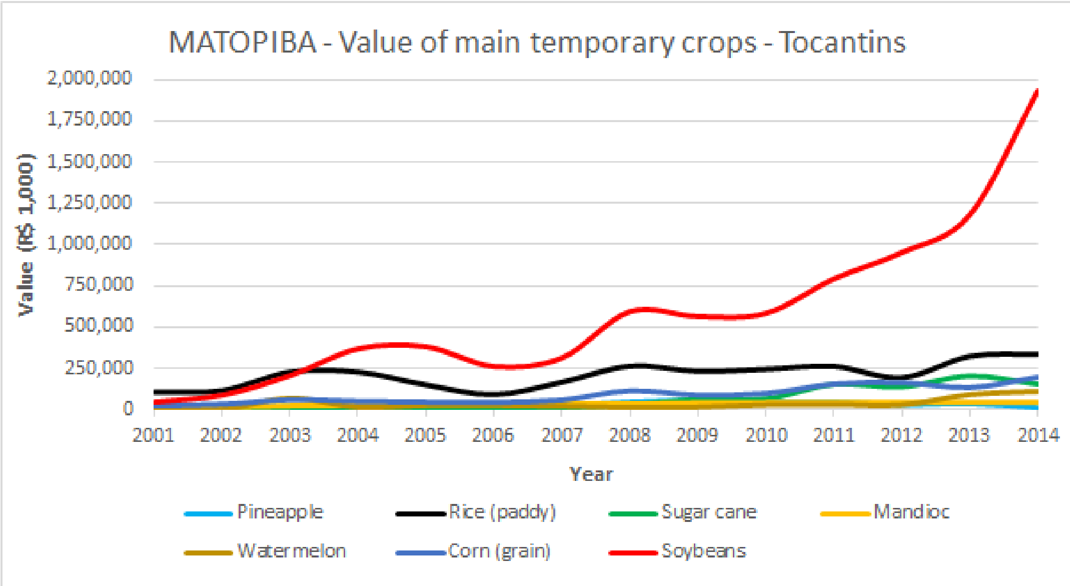

Figure 30: Average yields main temporary crops (TOCANTINS). Yields for rice paddy, corn and soybeans have seen a general increase since 2001. Productivity of corn surpassed that of soybeans in 2013

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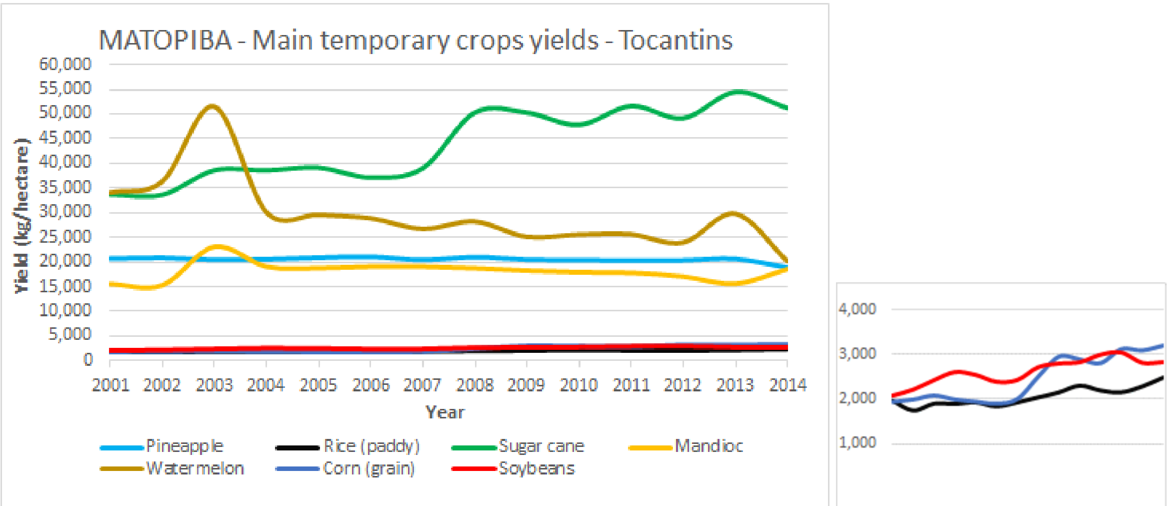


The boxplots for each selected crop (as per the ranking) by state, area category and TCL ratio category are shown in Figures 31-33. Each point refers to the municipality total production in the period. These are useful to identify outliers and variation in and between different categories.

Figure 31: Boxplots main crops by state. Soybeans, corn, sugar cane and manioc were present in all states. Beans and rice paddy were located in three states. Cotton and pineapple were found in two and watermelon only in Tocantins (*n* BA = 28; *n* MA = 135; *n* PI = 33; *n* TO = 137)

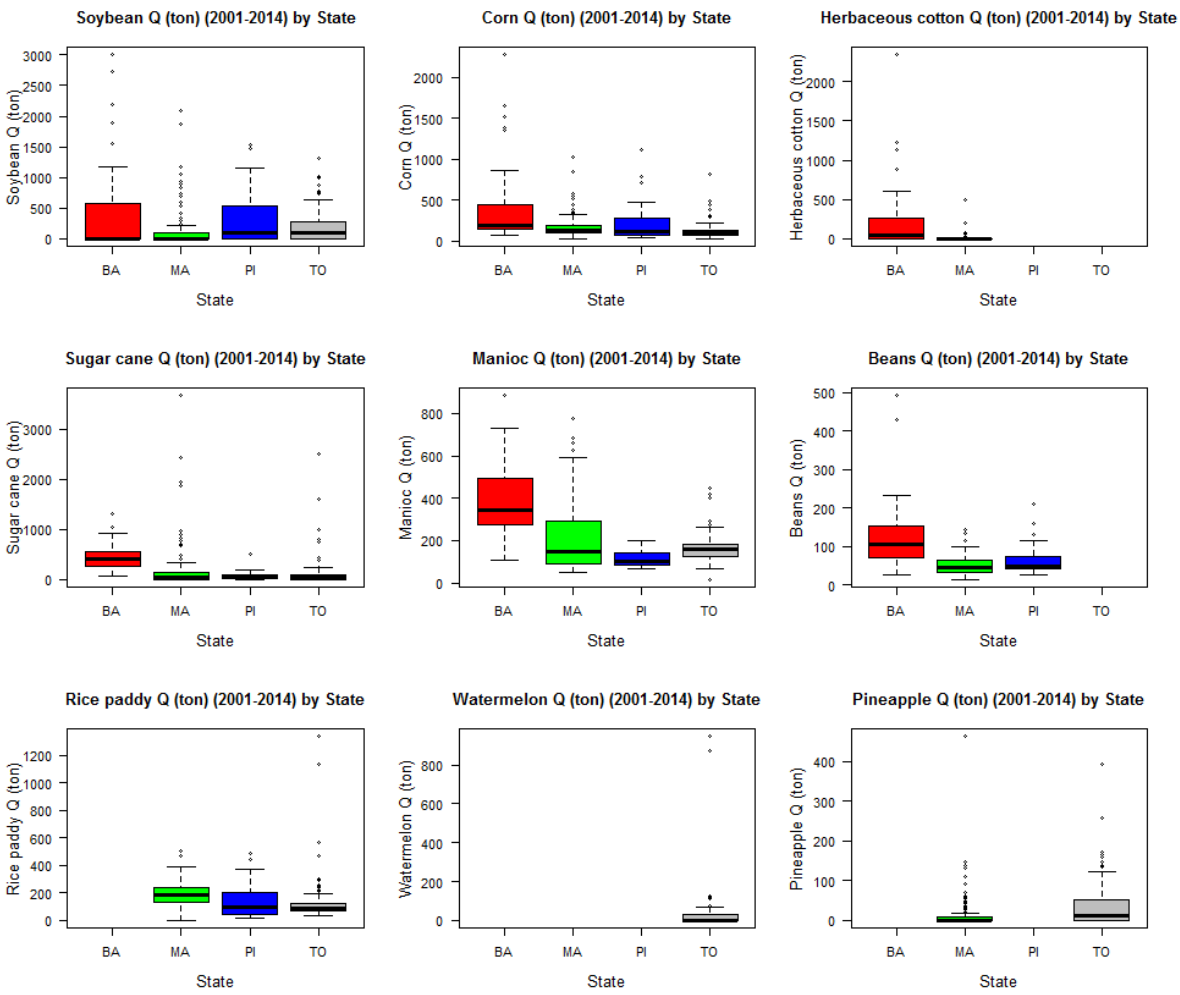


Figure 32: Boxplots main crops by municipality area size category. All selected crops are present in each area size category (n SMALL = 121, n MEDIUM = 177, n LARGE = 35)

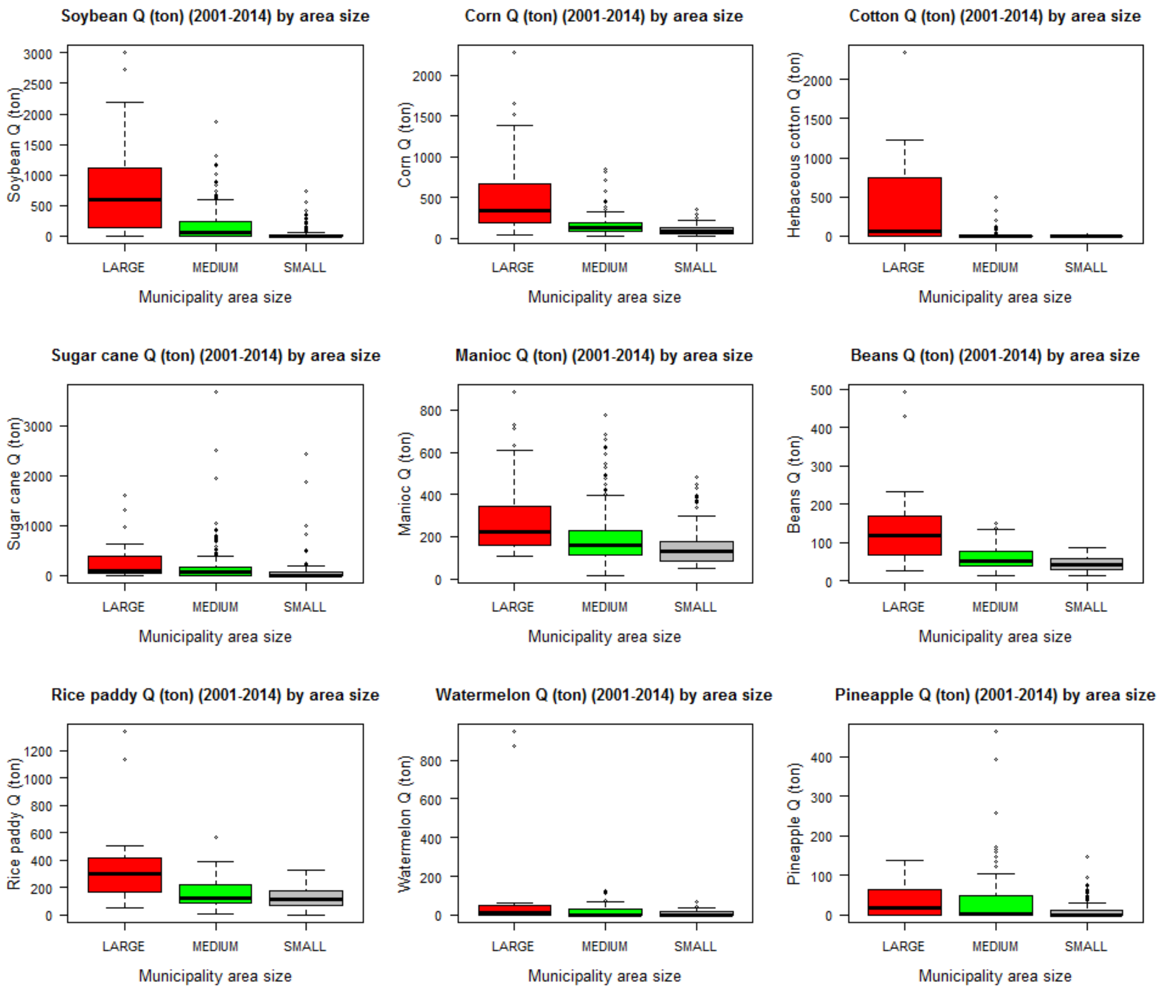
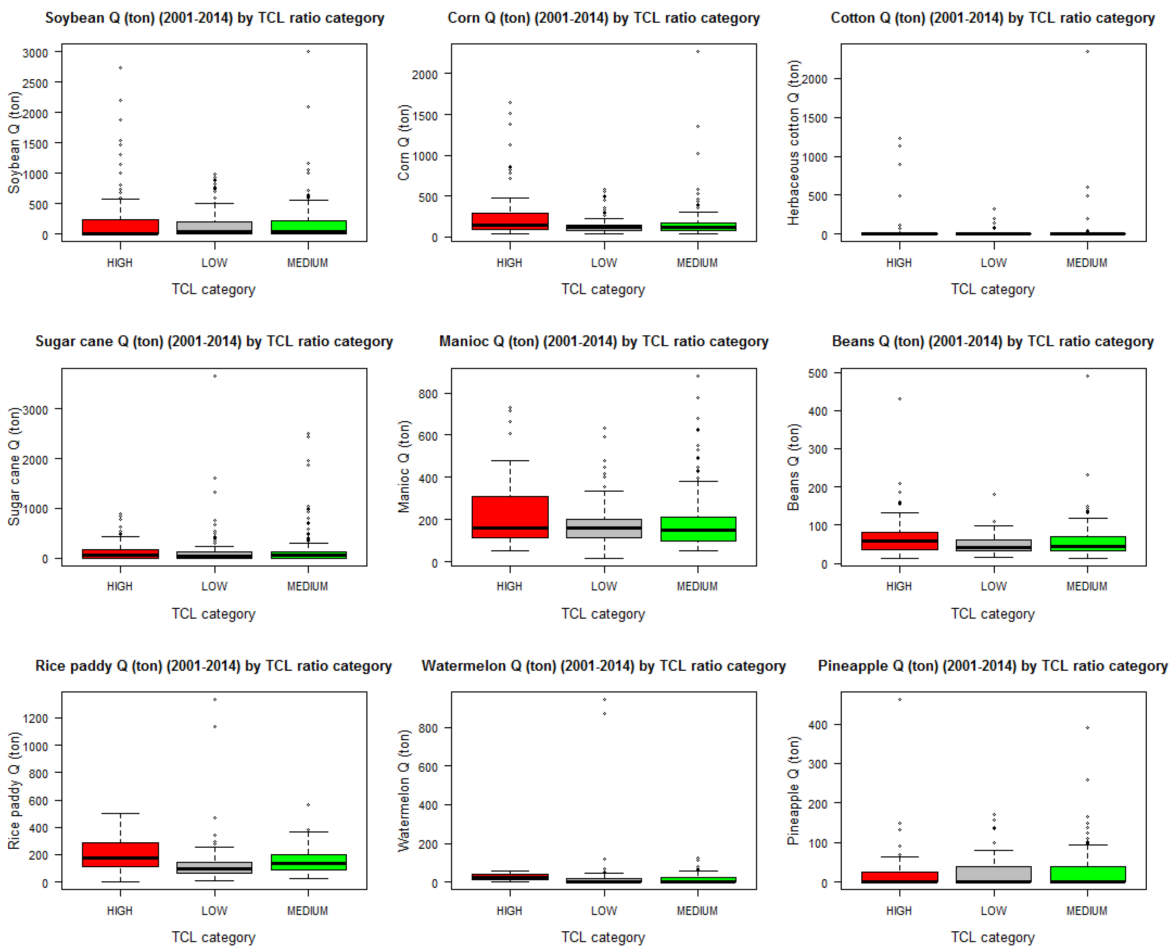


Figure 33: Boxplots main crops by TCL ratio category. Crops are present in all categories of TCL ratio. Thinner boxplots and/or no outliers shown indicate less variance between levels of municipalities' production for a given category (e.g. rice paddy quantities in municipalities with high TCL ratio vary less among themselves than soybean quantities originated from municipalities with high TCL ratio, where many outliers are present) (*n* LOW = 103, *n* MEDIUM = 142, *n* HIGH = 88)



The analysis also attempted to relate each crop's level of production between 2001-2014 with the sum of yearly TCL in the period. The objective was to find an explicit and significant relationship in a linear model with "sum TCL" (ha) as dependent variable and individual main temporary crops (largest yearly area planted (ha) in the period for each municipality) as explanatory variables. Table 14 presents the results for crops that passed the assumptions for a linear model analysis done at the state level.

Table 14: Crops with assumptions met for linear model explaining TCL, by state. Crops were attempted individually and values in red indicate lack of significance

State	Coefficient and significance	R^2	p-value	Shapiro-Wilk p-value	Bartlett p-value
BA	Log [Beans_a] 0.5403 **	0.2797	0.0038 26 DF	0.3615	0.9121
BA	Log [Sugarcane_a] 0.04493	0.0019	0.8257 26 DF	0.4569	0.8748
BA	Log [Corn_a] 0.71 ***	0.5864	2.047e-06 26 DF	0.6805	0.697
BA	Log [Manioc_a] 0.5831 **	0.2481	0.006992 26 DF	0.6223	0.4181
PI	Sqrt [Soybean_a] 0.74782 ***	0.8797	8.399e-16 31 DF	0.6201	0.2055
PI	Log [Corn_a] 0.95192 ***	0.76	4.008e-11 31 DF	0.1258	0.6217
PI	Log [Rice_paddy_a] 0.767 ***	0.6331	3.121e-08 31 DF	0.4558	0.8367
PI	Log [Sugarcane_a] 0.1969	0.06833	0.1417 31 DF	0.9466	0.1144
PI	Log [Beans_a] 1.1124 ***	0.631	3.426e-08 31 DF	0.8273	0.06109
MA	Log [Corn_a] 0.56564 ***	0.3441	7.633e-14 133 DF	0.7248	0.6736
MA	Log [Beans_a] 0.49159 ***	0.205	3.524e-08 133 DF	0.5338	0.3417

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

A similar attempt was made trying to relate any crop to TCL by area size category of the municipality (Table 15).

Table 15: Crops with assumptions met for linear model explaining TCL, by area size category. Value in red indicates lack of significance

Area size CAT	Coefficient and significance	R^2	p-value	Shapiro-Wilk p-value	Bartlett p-value
LARGE	Log [Beans_a] 0.3658 **	0.2718	0.00899 22 DF	0.2076	0.1607
LARGE	Sqrt [Herbaceous_Cotton_a] 0.5698 **	0.4462	0.001288 18 DF	0.6744	0.3686
LARGE	Sqrt [Corn_a] 1.0603 ***	0.5967	5.439e-08 33 DF	0.5414	0.069
LARGE	Log [Rice_paddy_a] 0.4208 **	0.3157	0.00229 25 DF	0.07205	0.2126
LARGE	Log [Manioc_a] 0.3352 **	0.2095	0.005693 33 DF	0.5333	0.0736
SMALL	Log [Herbaceous_Cotton_a] 0.08374	0.0086	0.443 68 DF	0.4215	0.7399

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Regarding the livestock in the region, bovines were selected for initial analysis. Other livestock in the region but they were not analysed. Five micro regions in MATOPIBA represent more than 46% of total number of bovine herds in 2014 (Figure 34) and six out of the first ten micro regions with largest shares are located in Tocantins (three in Maranhão and one in Bahia) (Table 16). The author opted not to include the bovine livestock in the regression analysis previously presented due to time limitation.

Figure 34: Livestock (Bovines) in MATOPIBA (2014). Ten municipalities represent more than 70% of total number of herd in 2014

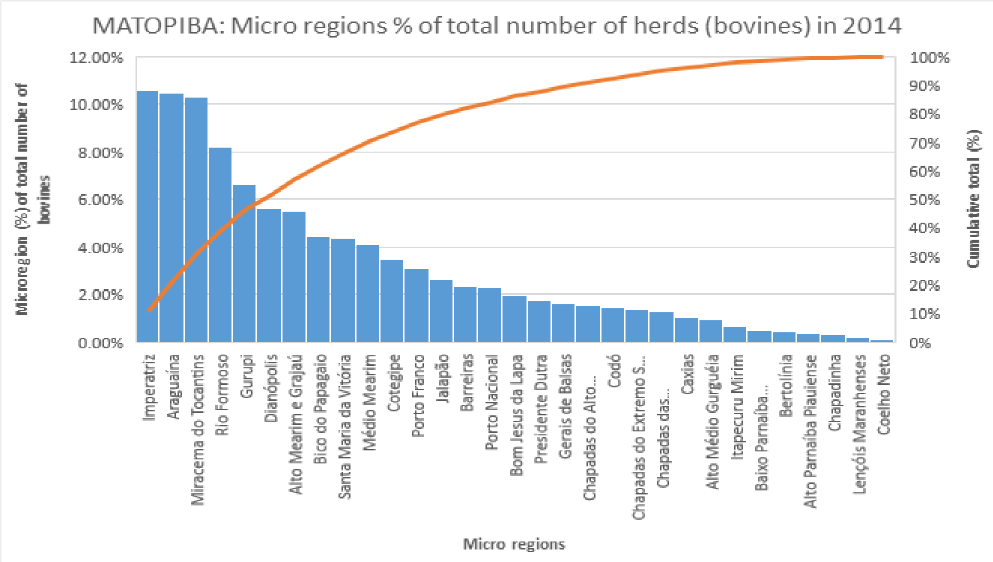


Table 16: Bovines per micro region. Bovines are more present in Tocantins and less present in Piauí. Only in two micro regions the number of herds decreased in the period (one in Piauí, one in Maranhão)

#	Micro region	State	% of Total # number effective herds (2014)	% variation (2014 x 2001)
1	Imperatriz	MA	10.61%	58.26%
2	Araguaína	TO	10.46%	23.29%
3	Miracema do Tocantins	TO	10.30%	17.94%
4	Rio Formoso	TO	8.21%	25.05%
5	Gurupi	TO	6.64%	23.76%
6	Dianópolis	TO	5.60%	33.01%
7	Alto Mearim e Grajaú	MA	5.51%	122.63%
8	Bico do Papagaio	TO	4.46%	13.72%
9	Santa Maria da Vitória	BA	4.37%	53.51%
10	Médio Mearim	MA	4.13%	56.46%
11	Cotegipe	BA	3.47%	62.86%
12	Porto Franco	MA	3.10%	99.47%
13	Jalapão	TO	2.67%	52.41%
14	Barreiras	BA	2.34%	34.36%
15	Porto Nacional	TO	2.29%	2.65%
16	Bom Jesus da Lapa	BA	1.97%	37.28%
17	Presidente Dutra	MA	1.76%	92.04%
18	Gerais de Balsas	MA	1.64%	35.45%
19	Chapadas do Alto Itapecuru	MA	1.58%	51.76%
20	Codó	MA	1.44%	65.94%
21	Chapadas do Extremo Sul Piauiense	PI	1.40%	28.30%
22	Chapadas das Mangabeiras	MA	1.31%	47.78%
23	Caxias	MA	1.04%	28.57%
24	Alto Médio Gurguéia	PI	0.93%	23.22%
25	Itapecuru Mirim	MA	0.70%	49.42%
26	Baixo Parnaíba Maranhense	MA	0.53%	100.33%
27	Bertolínia	PI	0.43%	-2.38%
28	Alto Parnaíba Piauiense	PI	0.38%	22.29%
29	Chapadinha	MA	0.36%	4.64%
30	Lençóis Maranhenses	MA	0.25%	76.08%
31	Coelho Neto	MA	0.10%	-24.26%

4.3 Other analysis: demographics *versus* TCL in the period

In municipalities with settlements there is a slight positive correlation between the number of settlement families and TCL ratio (%) in the period (Figure 35). Values for main summary statistics were higher for municipalities with settlements (Table 17). Medians were higher in municipalities with settlements in all area size categories (Figure 36). The TCL ratio (%) in each municipality was also compared against the population, illiteracy rate and Human Development Index (2010 Census data) and GDP per capita (2011 data) (Figures 37-40).

Figure 35: TCL ratio (%) by number settlement families (log). In municipalities with settlements TCL is positively correlated with the number of families established in settlements

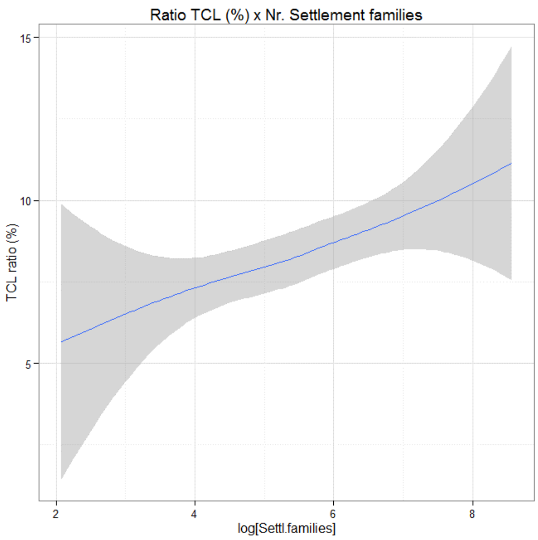


Table 17: Summary statistics TCL and settlements

	Min	1st Q	Median	Mean	3rd Q	Max
Municipalities with settlements (*n* = 197)	812	5,390	9,842	19,516	20,166	244,458
Municipalities with no settlements (*n* = 136)	397	3,470	6,547	12,557	12,684	156,258

Figure 36: Boxplots settlements families, TCL ratio (%) and area size

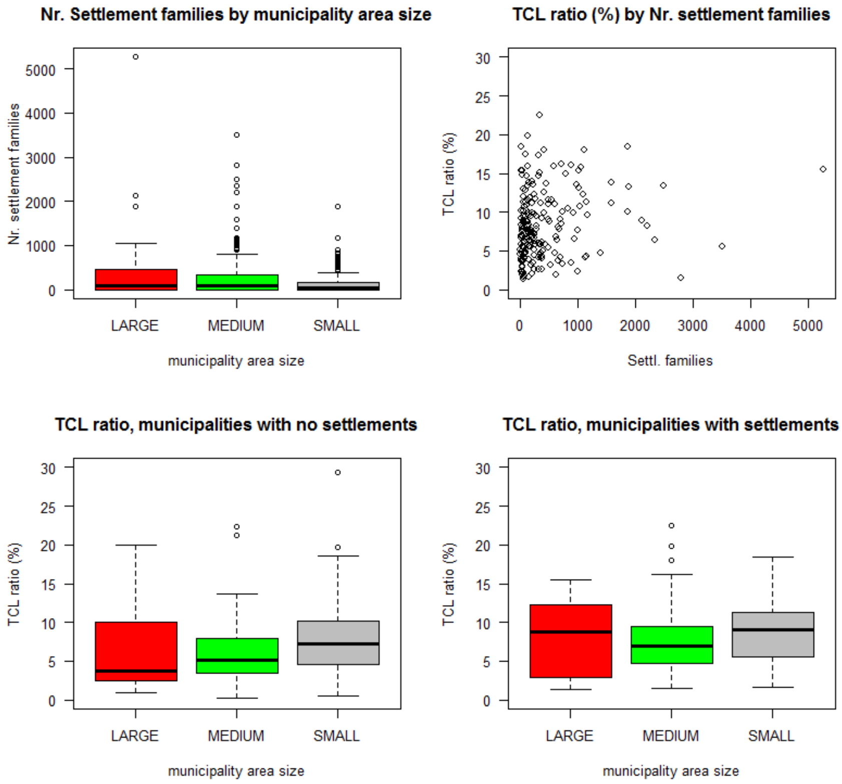


Figure 37: Ratio TCL (%) and population (sq. root). Positive correlation in municipalities with less than 60,000 inhabitants

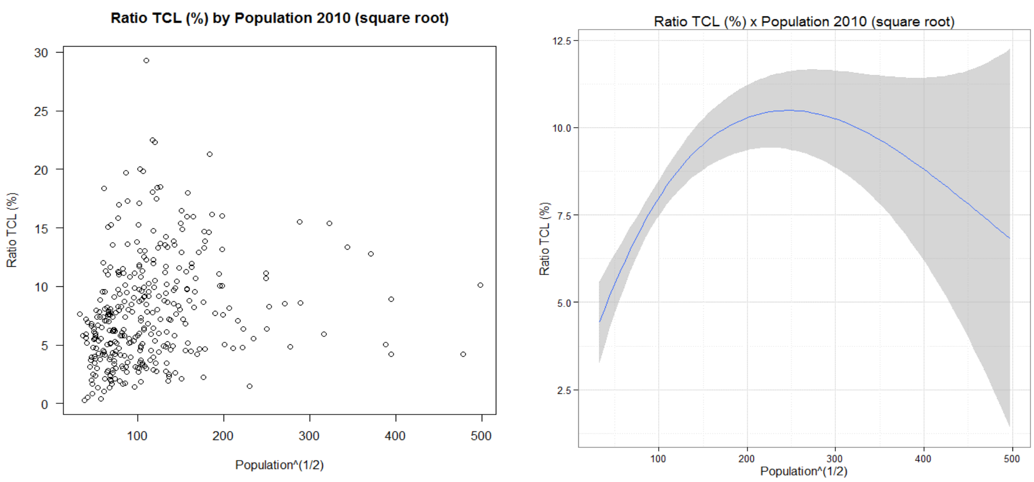


Figure 38: TCL ratio (%) and GDP/capita (2011). Negative correlation that turns positive as GDP/capita (per year) is higher than R$ 10,000

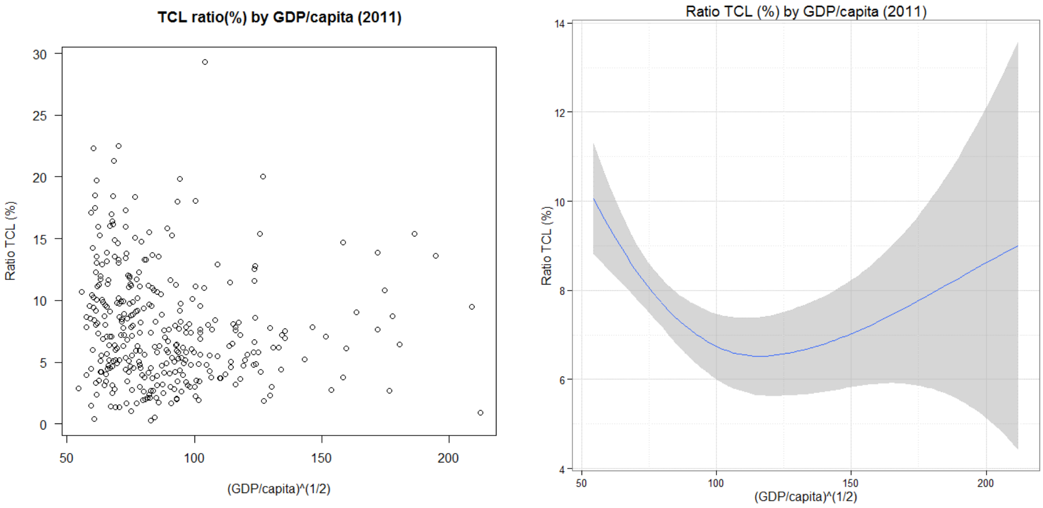


Figure 39: Ratio TCL (%) by illiteracy rate (2010)

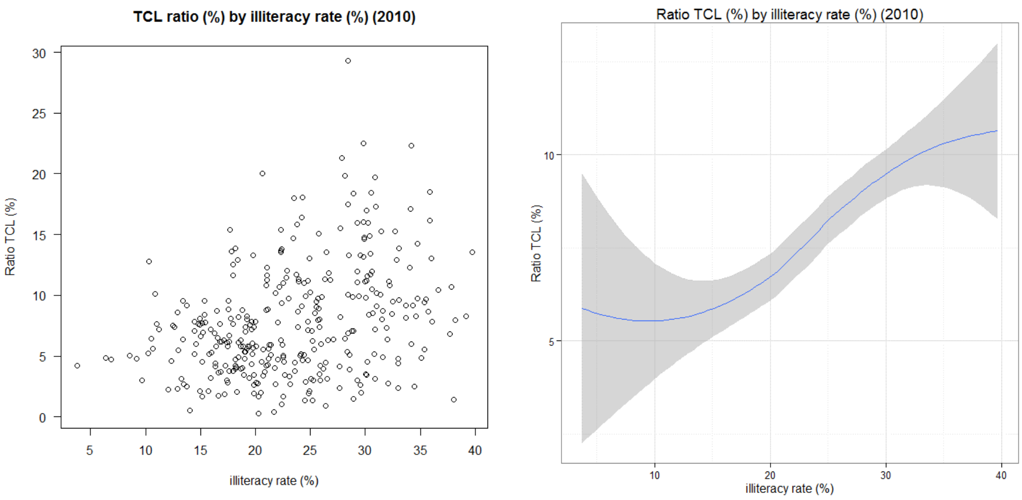
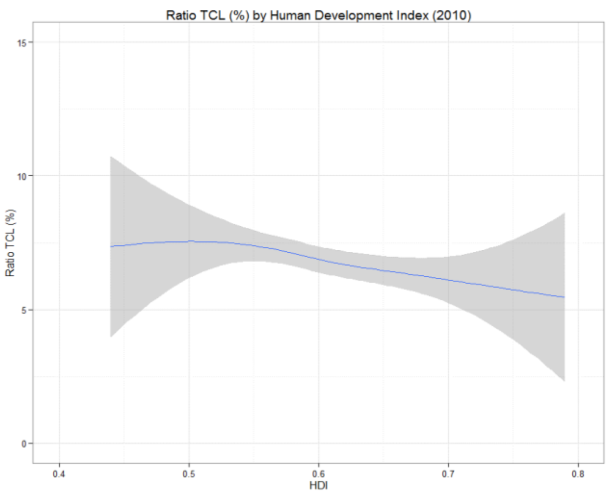


Figure 40: Ratio TCL (%) and HDI (2010)



4.4 Tree Cover Loss and Soybeans *Moratorium*

4.4.1 Soybeans in MATOPIBA

Only municipalities with at least one year of production in the period 2001-2014 were considered, 179 municipalities in total (13 in BA, 50 in MA, 21 in PI and 95 in TO). Five municipalities (four in BA and one in MA) were responsible for over 40% of total production in the period (Figures 41 and 42). Bahia is the main producer (Figures 42 and 43).

Figure 41: MATOPIBA soybean production 2001-2014. A total of 67.941 million ton of soybeans was produced between 2001-2014. Bahia's municipalities were responsible for 29.355 million ton. In 2014 Bahia, Piauí, Maranhão and Tocantins produced, respectively, 2.768, 1.44, 1.817 and 2.094 million ton

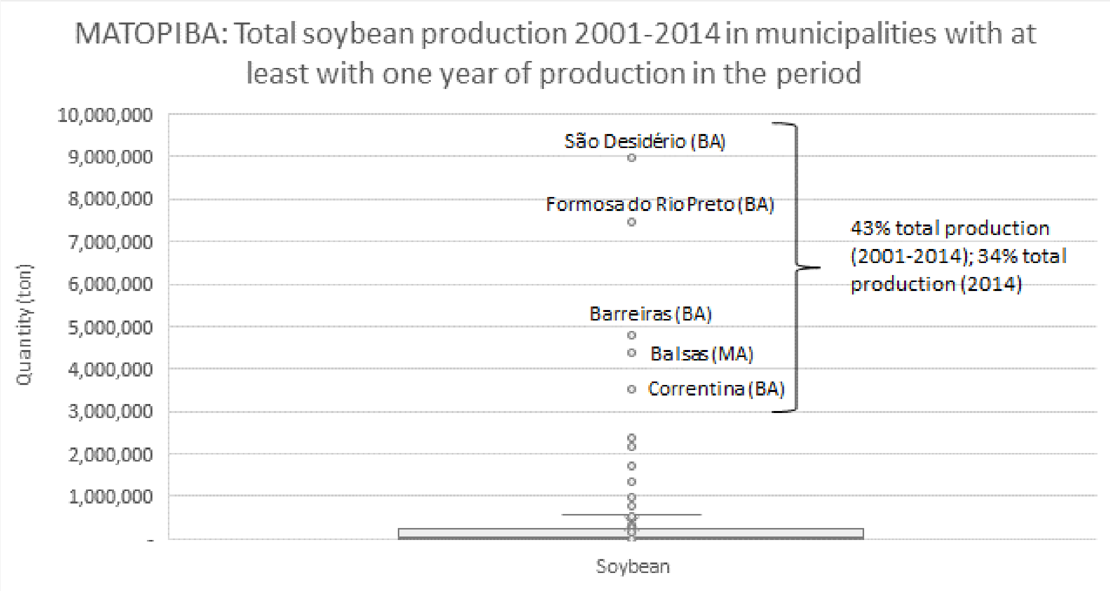


Figure 42: state % of total production. Municipalities not in Bahia are gaining importance in soybean production

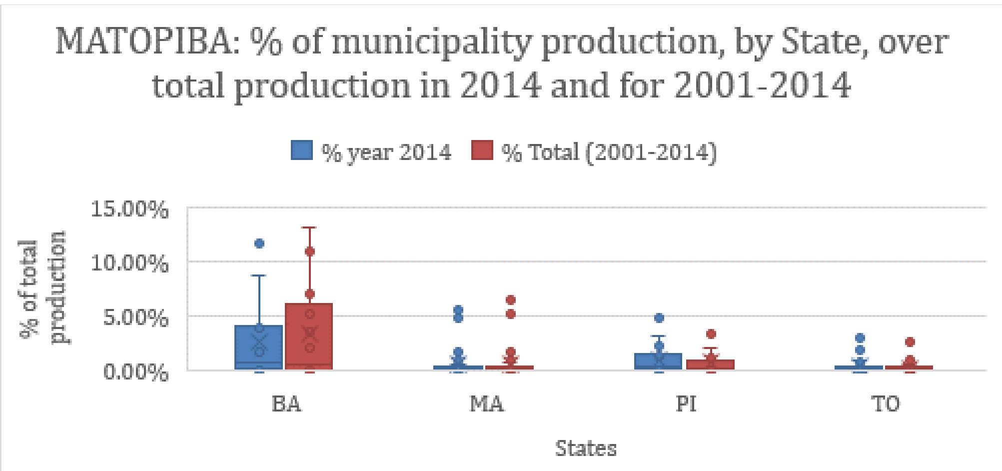
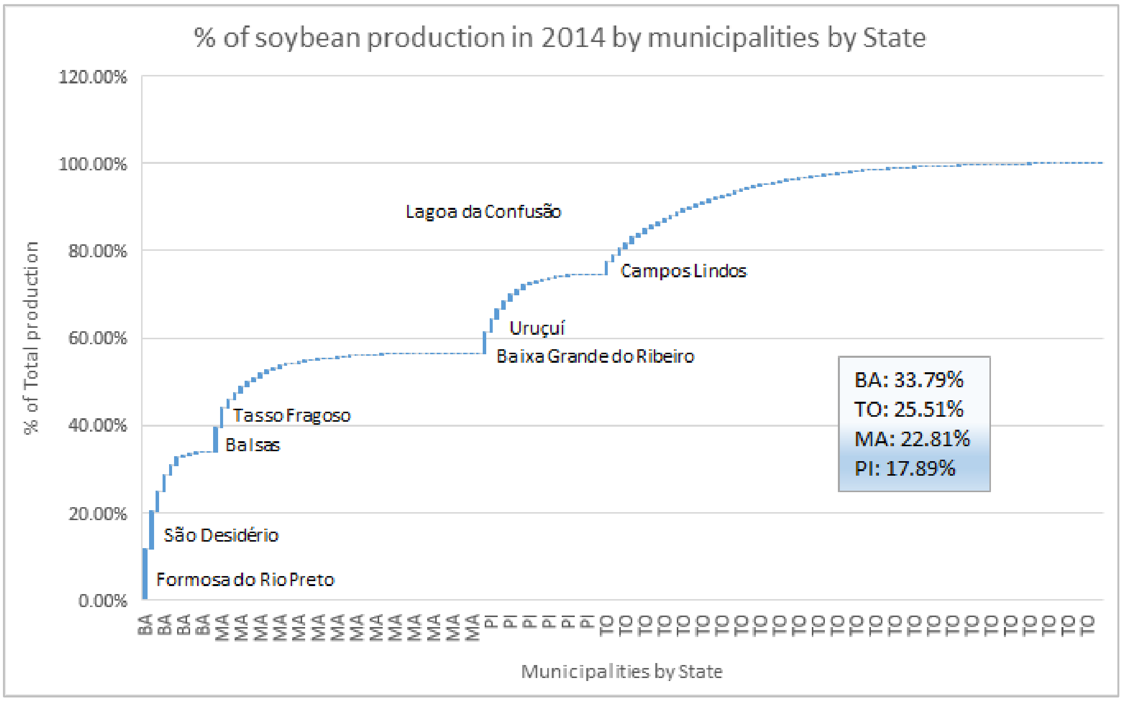


Figure 43: % of total production in 2014 by state. Eight municipalities (two from each State) were responsible for 43.41% of soybeans production (half was produced in Bahia)



The great variance in yields in the period (Figure 44) might be related with the expansion into new areas (69 municipalities planted soybeans in 2001; in 2014 there were 150) (Tables 18-19 and Figure 45).

10 **Figure 44: Soybean yields (2001-2014).** Despite its importance for the region there is a great variance in soybean yields among municipalities

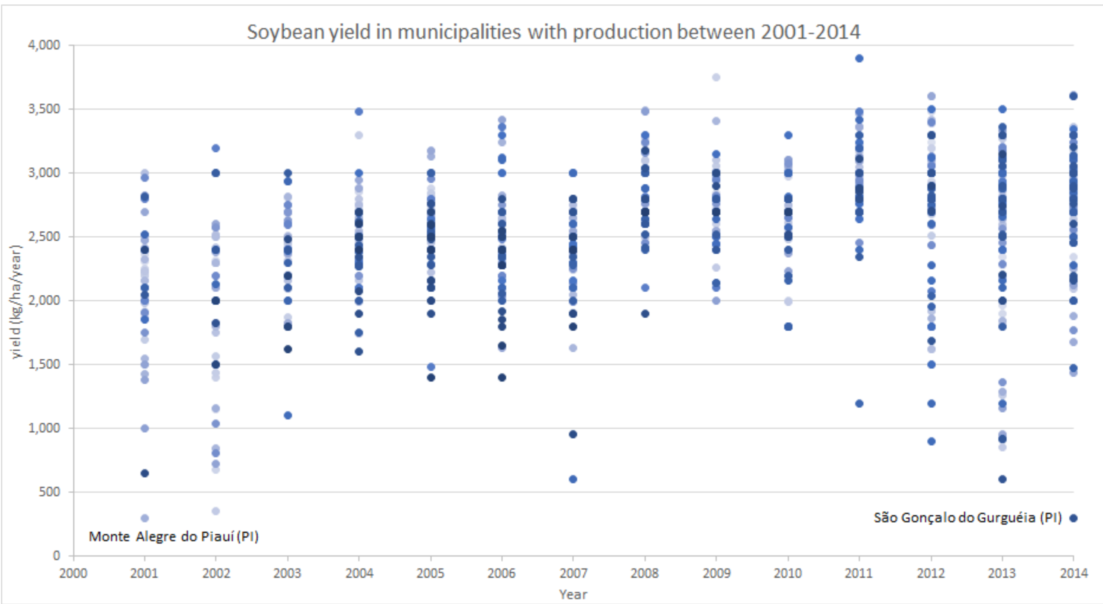


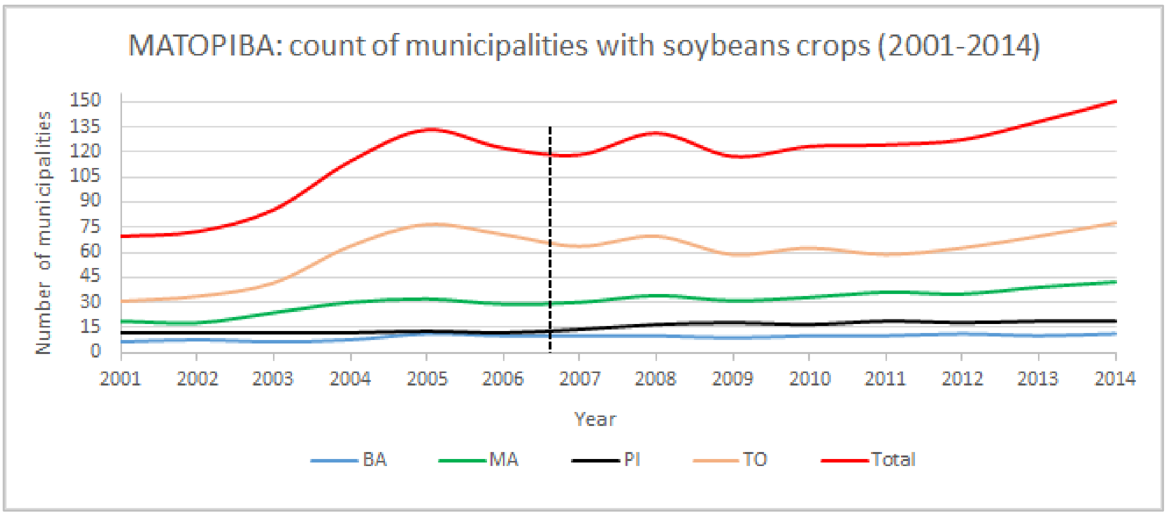
Table 18: Count of municipalities with soybean crops, per year

Year/State	BA	MA	PI	TO	Total
2001	7	19	12	31	69
2002	8	18	12	34	72
2003	7	24	12	42	85
2004	8	30	12	64	114
2005	11	32	13	77	133
2006	10	29	12	71	122
2007	10	30	14	64	118
2008	10	34	17	70	131
2009	9	31	18	59	117
2010	10	33	17	63	123
2011	10	36	19	59	124
2012	11	35	18	63	127
2013	10	39	19	70	138
2014	11	42	19	78	150

Table 19: Increase in number of municipalities before and after Soybeans Moratorium. In Piauí all additional soybeans crops appeared after the Soybeans *Moratorium*. In Maranhão the increase was also higher after 2006 (thirteen municipalities started producing soybeans) while it was much lower for Tocantins

	BA	MA	PI	TO	Total
Increase # municipalities 2001-2006	3	10	0	40	53
Increase # municipalities 2006-2014	1	13	7	7	28
Increase # municipalities 2001-2014	4	23	7	47	81
Increase ratio (%) 2001-2006	75%	43%	0%	85%	65%
Increase ratio (%) 2006-2014	25%	57%	100%	15%	35%
Total Increase (%) 2001-2014	57%	121%	58%	152%	117%

Figure 45: Count of municipalities trend in the period. Increase of soybeans crops was higher in Tocantins for the period (47 municipalities) but all states observed an increase in number of municipalities



A comparison of yields “before” and “after” the moratorium was done considering two periods (Figures 46-47). An increasing trend is observed but some municipalities presented very low yields, e.g. *Formosa do Rio Preto* (959,812 ton) and *São Desidério* (720,228 ton) presented low average yields in the period 2001-2006 (2,280 kg/ha and 2,268 kg/ha respectively).

Between 2001 and 2006, the same occurred in other states: in Piauí, *Baixa Grande do Ribeiro* (397,202 ton in 2014) and *Uruçuí* (250,718 ton in 2014) had low yields (2,347 kg/ha and 2,078 kg/ha respectively); in Maranhão, *Balsas* (457,760 ton in 2014) and *Tasso Fragoso* (394,556 ton in 2014) had low yields (2,468 kg/ha and 2,495 kg/ha); in Tocantins, *Campos Lindos* (232,140 ton in 2014) and *Lagoa da Confusão* (149,400 ton in 2014) had average yields of 2,490 kg/ha and 2,367 kg/ha, respectively. Despite the lowest yield in the period, *Corrente* produced only 674 ton in the period (its production increased to 22,263 ton in 2014).

Figure 46: Soybeans average yield (2001-2006). Despite the high yield, *Serra do Ramalho* is not relevant for the region as a whole (6,000 ton in 2014, only 0.22% of Bahia production). In brackets are the years of production between 2001-2006

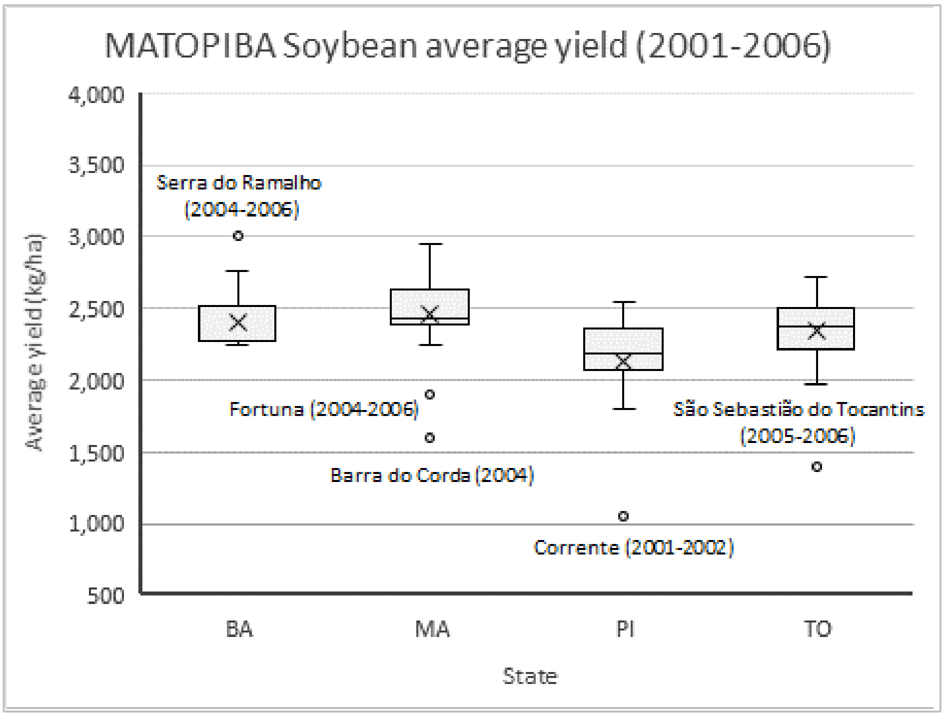
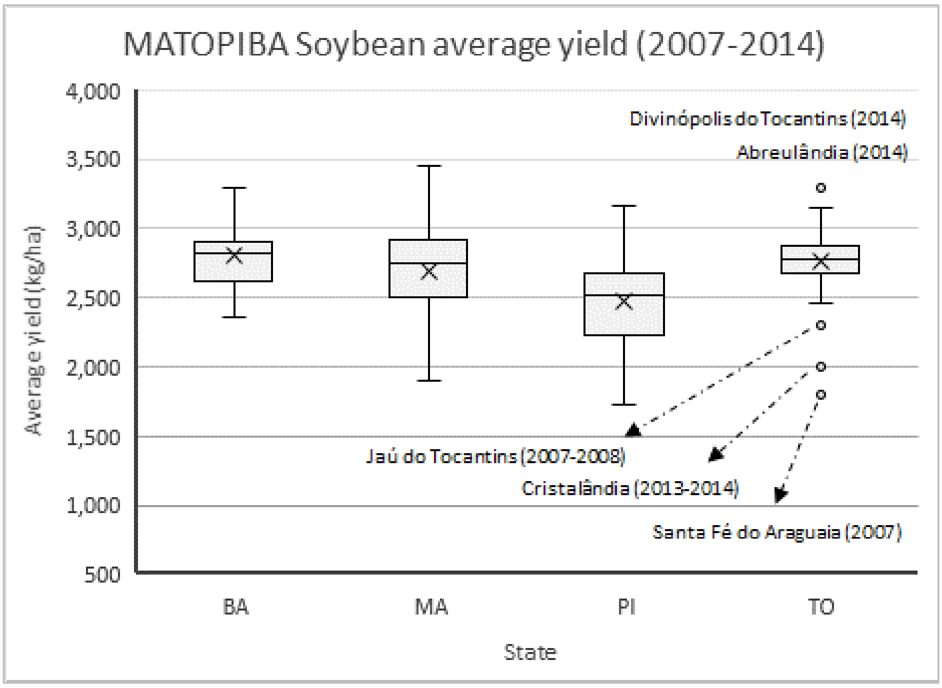


Figure 47: Soybeans average yield (2007-2014). Despite high yields, *Abreulândia* produced 924 ton and *Divinópolis do Tocantins* 2,079 ton in 2014 (respectively 0.04% and 0.1% of Tocantins production in that year). *Santa Fé do Araguaia* and *Jaú do Tocantins* have not produced soybeans since 2007 and 2008 respectively. In brackets are the years of production in the period



4.4.2 Soybeans and TCL relationship in MATOPIBA

For municipalities planting soybeans in the period, the TCL (ha) indicators ("average", "sum" and "median") were compared considering two periods, "before" and "after" the *Moratorium*: 2001-2007 and 2008-2014. The summary statistics are presented in Table 20. Plots by state are shown in Figure 48. It was also a matter of interest whether in the Legal Amazon these indicators increased or not (Figure 49).

Table 20: Summary statistics for two periods (2001-2007 & 2008-2014)

	Min	1st Q	Median	Mean	3rd Q	Max
Average TCL (01-07)	32	153	728	1,353	1,440	15,460
Average TCL (08-14)	25	455	803	1,866	1,860	19,460
Sum TCL (01-07)	221	2,470	5,093	9,473	10,080	108,200
Sum TCL (08-14)	176	3,184	5,621	13,060	13,020	136,200

Figure 48: Boxplots TCL by state, two periods. In municipalities planting soybeans, the period 2007-2014 presented greater values and greater variance for average, sum, median and standard deviation of TCL (ha) in comparison with 2001-2007 (*n*: BA = 13, MA = 50, PI = 21, TO = 95)

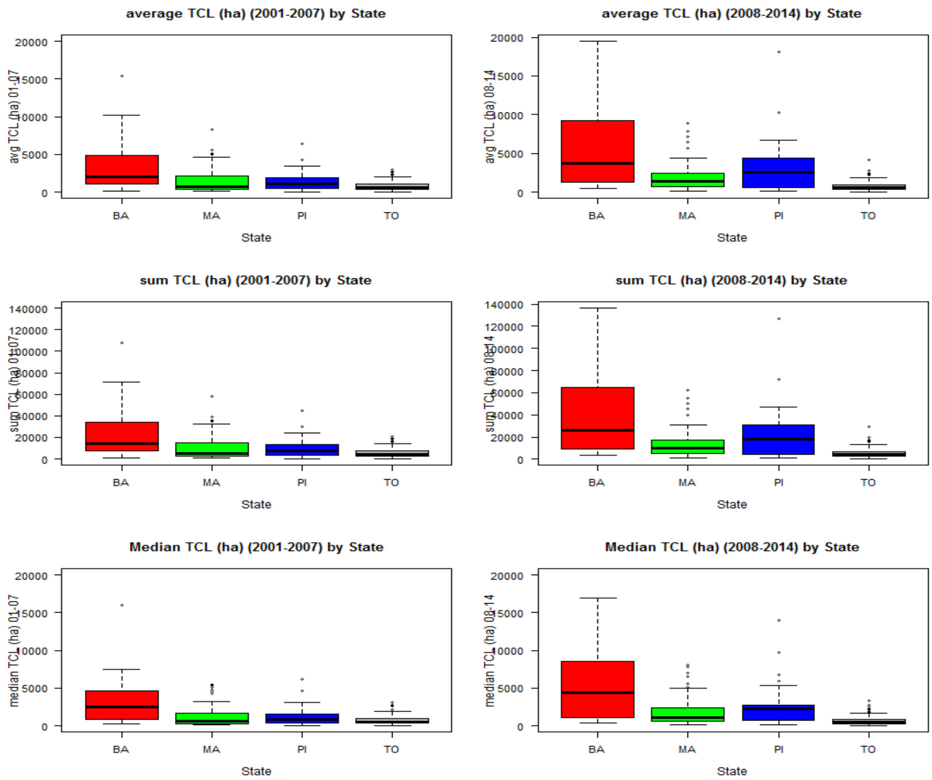
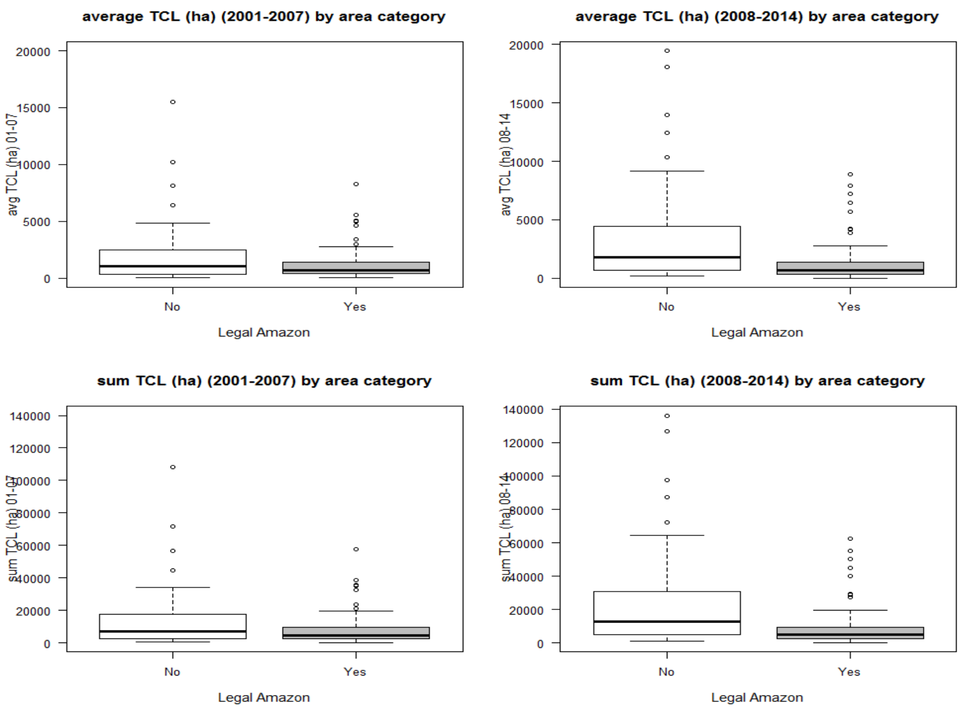


Figure 49: TCL and Legal Amazon, two periods. TCL (ha) after 2007 was higher only in areas outside the Legal Amazon but the number of outliers in Legal Amazon municipalities increased for both the average and sum of TCL (ha) (*n* Legal Amazon: BA = 0, MA = 34, PI = 0, TO = 95; *n* Non Legal Amazon: BA = 13, MA = 16, PI = 21 , TO = 0)



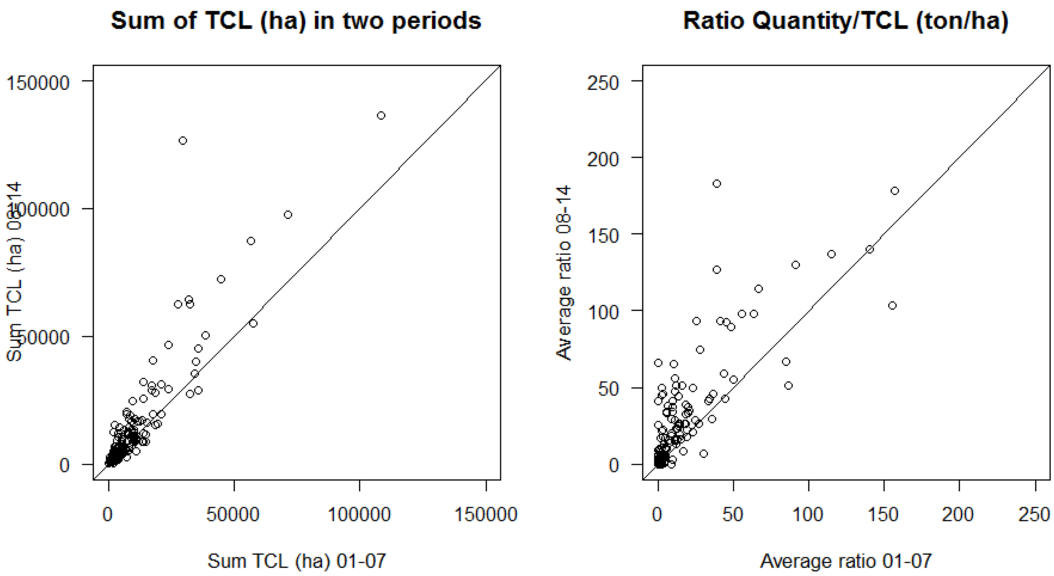
Test for significant difference (parametric t-test, paired) between the two periods was conducted for the “average of TCL” and “sum of TCL” of each municipality with soybean production between 2001-2014 for 2001-2007 and 2008-2014. Both series are normally distributed after log-transformation (Appendix VI – Figure 10). Results indicate a statistically significant difference between 2001-2007 and 2008-2014 for both the “average” and the “sum” of TCL (Table 21).

Table 21: Parametric t-test (paired), two periods. For municipalities that cultivated soybeans between 2001-2014 there is significant statistical difference between the “average” and “sum” of TCL before and after the *Moratorium*

	t	DF	*p*-value	95% CI	mean of differences
pair: Log[Average TCL (01-07)] ; Log[Average TCL (08-14)]	-5.2302	178	4.72E-07	[-0.2835838 : -0.1282110]	-0.2058974
pair: Log[Sum TCL (01-07)] ; Log[Sum TCL (08-14)]	-5.2355	178	4.60E-07	[-0.2836074 : -0.1283365]	-0.2059720

Despite the increase in average and sum of TCL after the *Moratorium*, more quantity of soybeans is being produced by TCL in each period (Figure 50) and that reflects the average increase in yield previously discussed. It also shows that not only soybeans drive TCL in the region, despite it being the major crop.

Figure 50: Pairing of two periods for Sum of TCL and ratio Q (ton)/TCL (ha). Line indicates a 1:1 ratio. Values above the line indicate that the y-axis (i.e period 2008-2014) had higher values when paired against the 2001-2007 period. Each point is a municipality



5. Discussion

This section will first discuss the results for TCL in the period (2001-2014) and the correlation with municipalities' official deforestation rates. Then there will be a discussion on (unexpected) findings with respect to how TCL was related to demographics in the region, including the presence of rural settlements. The discussion will then approach the agricultural development observed in the period, including the regression analysis attempted, the low yields observed and harvest losses in 2015/2016 and finally, whether there is evidence that the Soybeans *Moratorium* is creating "leakage" deforestation in MATOPIBA. Limitations in the methods and potential improvements are also discussed.

5.1 TCL, deforestation and other demographics

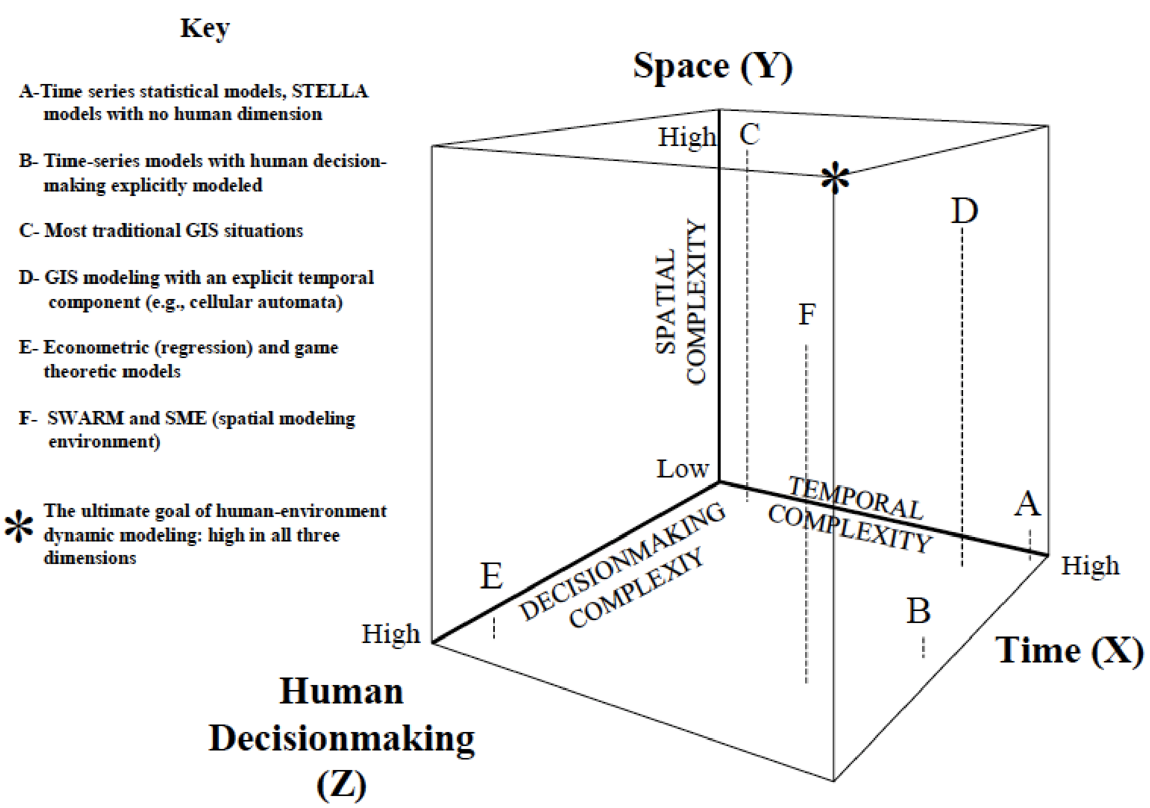
Extrapolating the TCL x deforestation model to MATOPIBA (Figure 12), deforestation between 2001-2014 would equal 6.366 million ha (TCL in the period was 5.56 million ha considering 334 municipalities). Because the total area of MATOPIBA is much larger than the largest area considered in the model (Appendix III; tables 7 - 9) predictions are limited. Nonetheless, the results show the scale of the potential deforestation (roughly 450,000 ha/year) that occurred between 2001-2014.

Total TCL (ha) was highest in Maranhão and lowest in Piauí, TCL ratio was highest in Bahia and lowest in Tocantins and TCL ratio (%) over total state area was highest in Piauí. (Table 3). In Bahia and Piauí, TCL was highest in 2012, in Maranhão in 2013 and in Tocantins in 2007 (more details in Appendix III; figures 1 – 4).

TCL for the period was highest in "medium" areas category (177 municipalities), about 2.733 million ha (more than 49% of total TCL observed in MATOPIBA). "Large" municipalities (35) experienced 2.243 million ha of TCL (~ 40.4% of total) and the remaining TCL occurred in "small" municipalities (121). Regarding the Legal Amazon domain, 237 municipalities experienced a total TCL of 3.031 million ha while 96 municipalities not in the Legal Amazon experienced 2.521 million ha in TCL. The discussion whether TCL was higher or not in areas within the "Legal Amazon" domain is relevant in the Cerrado context because the requirement for "Legal reserve" in those areas is higher than for areas not part of the "Legal Amazon" (35% instead of 20%), as per Brazilian Forest Code (FOREST CODE 2012).

The results show that some municipalities face higher land-use change pressures than others, leading to high TCL rates. A linear relationship of TCL and area size was present with different coefficients in each state and within each area size category but the assumptions of normality and homoscedasticity of residuals were not met. That shows that TCL (ha) is dependent on other factors in addition to area size. Some municipalities, either small or large, presented TCL values abnormally different in comparison with municipalities in the same state or in the same area size category. It is complex to estimate TCL based on a limited number of variables in simple linear models, such as the ones attempted and actual land-use change models take into account many other variables. They also rely on geo-reference coordinates to detect yearly changes in variables of interest (Andrade De Sá et al. 2012; Lapola et al. 2011; Assunção & Chiavari 2015; Agarwal et al. 2002). Agarwal et al. (2002) presents a dimensional framework in order to review and assess land-use change models (Figure 51). The ultimate goal in the modelling process is to achieve a high degree in all three dimensions.

Figure 51: Framework to assess land-use change models. Framework proposed in (Agarwal et al. 2002) to compare different land-use models. Illustration with some examples of model types (letters A-F) and how they rank in the three-dimension framework



In the case of the linear models attempted in this research and as per the framework proposed by Agarwal et al. (2002), the “Space” was limited to an individual point (municipality), the “Time” was limited to the analysis being conducted for the whole period of 2001-2014 and “Human decision-making” was limited to each individual crop and didn’t incorporate any other variables when trying to explain the level of TCL observed in the period.

Based on the framework, Agarwal et al. (2002) reviewed 19 land-use change models and argue that land-cover change is a significant and accelerating process, driven by human factors but that it also drives indirect changes that feedback to impact humans themselves. The best land-use change model will depend on specific goals, objectives, time and information available at the local or regional scale.

Espírito-Santo et al. (2016) explain that the intensity of land conversion and natural regeneration (e.g. in abandoned pastures) show great spatial and temporal variations and are influenced by many distinct variables including biophysical and human drivers, such as soil properties, density of paved roads and global demand for commodities. Another variable which impacts land-use change pattern is land price (Smith, Winograd, Gallopin, et al. 1998) and this may be the case of MATOPIBA, where land is cheaper than in more intensified and developed parts of *Cerrado* (e.g. Mato Grosso) (TERRACLASS/MMA (2015). Espírito-Santo et al. (2016) also argue that the impacts of land clearing in Cerrado on human wellbeing are likely to vary at local and regional scales and that land-use policies should not rely exclusively on socio-economic indicators.

Barretto et al. (2013) analysed the agricultural intensification in Brazil between 1975-2006 in a spatially explicit manner and findings suggest that the agricultural intensification (i.e. increase in yields and productivity) and availability of land interact in different manners in developed areas and frontier regions of agriculture. This is relevant for MATOPIBA as the results indicate that there is a great variance in yields and production levels among micro regions and objectives set forward need to take the local circumstances into account.

Other demographics' associations with TCL (ratio - %) were done for the 334 (municipalities) (Figures 37-40) and interesting trends appeared for all variables chosen, namely: HDI, illiteracy rate, GDP/capita, population and number of settlement families. All the trends that appeared deserve further exploration and it is not likely that these patterns appeared by chance. Each point is a pair of the TCL ratio (%) and an individual variable and the results show a pattern with respect to how TCL relates to changes in these variables across all 334 municipalities. As an illustration, the findings indicate that tackling high illiteracy rates may bring positive results if the objective is to reduce TCL ratio over time.

Or, in the same manner, implementing policies that eventually lead to increase in HDI over time may also bring positive results in TCL disturbance.

Regarding rural settlements, they are present in 197 municipalities, 144 of which are in the Legal Amazon (24 municipalities are “large” size category, 110 “medium” and 63 “small”). The positive correlation between the number of settled families part of the Agrarian Reform and TCL ratio (Figure 35) deserves further investigation because no test for significant difference was attempted to compare TCL in municipalities with settlements and those without. The summary statistics showed that values are higher for municipalities with settlements but this could be solely due to their number being higher (197) than municipalities without settlements (136). Nonetheless the issue is relevant as rural settlements could be driving TCL in MATOPIBA at higher or lower rates in comparison with other types of rural establishments.

As for TCL, when related to municipality area, the coefficient was highest in Piauí and lowest in Tocantins (Figure 15) and this could be related to the fact that Tocantins experienced and earlier agricultural development (including livestock pastures) (Barretto et al. 2013; Richards 2015; Lapola et al. 2014). If TCL is used as an indicator of land-use change pressure, the results show in an explicit manner that in Piauí such pressures seem to be higher than in other states. In terms of TCL ratio (%) over total municipality area, Maranhão was the state with highest observed rates but this is partially because “small” municipalities are more present in that state than any other (~ half of the municipalities in Maranhão are smaller than 100,000 ha).

Because Maranhão was also the state where more municipalities (~ 40% of municipalities) faced “high” TCL ratio the issues deserves further investigation as TCL pressure could be higher smaller areas (or smaller land properties) than in larger areas (or larger properties) (Appendix III, Figure 9). In a field survey it would be interesting to get stakeholders’ perceptions on incentives and barriers which may lead to higher (or lower) TCL rates at their land property.

5.2 Expansion of agriculture

The region has seen a great expansion of agriculture in the period analysed. A high level of specialization in certain crops was observed at the municipality level in the case of temporary crops. Crops that appeared in the rankings were not produced in many municipalities even within the same micro region in that state. Only corn, manioc and soybeans were present in all states. Only 179 municipalities out of 334 had at least one year of soybeans production between 2001-2014 and only 150 planted this crop in 2014. Soybean is the main crop in MATOPIBA and that illustrates further the specialization in place in the area.

As noted in Garagorry et al. (2015), there is a great concentration in the grains production in MATOPIBA and the analysis confirm that few micro regions drive production while many produce just a little. The results also show that the dynamics in the production (for municipalities and micro regions) can vary a lot from one year to another. Therefore if a strategic approach is to be adopted the production shall be monitored continuously (Luís Garagorry et al. 2014). While some municipalities appear with consolidated fields, others are still being shaped and as explained before, the TCL pressures will vary depending on the crops and level of production present.

The pressure on TCL from agricultural practices is different in each municipality and is dependent on a variety of factors, not only agriculture. Because the ranking was done at the micro region level, some municipalities did not have any production for some of the crops selected for each state. Appendix V (Tables 20 – 24) lists the municipalities (by state) that did not produce any of the crops in the period. For the temporary crops selected for regression analysis based on municipality data and considering the total quantity (ton) produced in the period:

- Pineapple was led by Maranhão and Tocantins;
- Herbaceous cotton seed was led mostly by Bahia (not relevant in Tocantins);
- Rice paddy was not relevant in the Bahia context and production was led by Maranhão, Tocantins and Piauí;
- Sugar cane was mostly led by Maranhão but in Tocantins and Bahia production was also high. In Piauí sugar cane is less relevant;
- Beans was led by Bahia, followed by Maranhão, Tocantins and Piauí;
- Manioc was mostly led by Maranhão but Bahia and Tocantins combined produced about the same. In Piauí it was not relevant. Manioc was present in all municipalities;
- Watermelon was led by Tocantins, with Maranhão in second. It was not relevant in Bahia and Piauí context;
- Bahia led corn production but the crop was relevant in all states. Maranhão follows Bahia (but less than half of Bahia's production). Corn was present in all municipalities;

- Soybeans were also relevant in all states, but mostly in Bahia, followed by Maranhão. In 2014 five municipalities (four in Bahia, one in Maranhão) produced more than 40% of total soybeans production in MATOPIBA. From 2001-2014 total soybeans production in MATOPIBA was about 8.5% of total national production in the period, with a clear increasing trend in recent years in all four states (specially in Tocantins and Piauí).

Livestock (bovines) seem to be more relevant in Tocantins, followed by Maranhão. It is important the note the opportunities that arise from vast areas of degraded pastures where increasing the (low) current yields and numbers of bovines heads/ha could play a major role in increasing beef production and recovering degraded areas at the same time. Agricultural intensification and integrated systems combining crops, livestock and forest have an important role to play in land-use strategies. Targets in place in Brazil for increasing food and meat production and reducing GHG emissions at the time present many opportunities in the agricultural sector (Carvalho et al. 2014; Carvalho et al. 2010; Buller et al. 2015; Lapola et al. 2014; Silva et al. 2016). Silva et al. (2016) modelled the GHG projections in Brazil in the livestock sector based on meat demand and production level and found that, if decoupled from deforestation, meat production increase may lead to sinks in pastures carbon stocks. The idea is that degraded and abandoned pastures are to be used to increase productivity, intensify the meat production and avoid further land clearing.

The regression analysis focused only on temporary crops because of their relevance in the agricultural context in the region. The objective to find an explicit and significant relationship in a linear model with “TCL (ha)” as dependent variable and individual main temporary crops (largest area planted, in hectare, in any given year in the period for each municipality) as explanatory variables was only partially accomplished. Most crops included in a linear model failed to pass the assumptions for linearity (normality and homoscedasticity of residuals). Nonetheless, the analysis shows in an explicit and quantitative manner that there is a great variance among municipalities (in a given state or in the same area size category) for most crops.

The results presented regarding the linear models attempted with each crop, and respective coefficients, should be read with caution. What they mean in practice is that there is statistical significant linearity between each of the crops (largest yearly area planted in the period) that passed the linearity assumptions in each state (or area size category) and sum of TCL in the period. Actual relationship of the combination of different crops in a given period with TCL (in the same period) certainly is far more complex than the basic linear models attempted (Andrade De Sá et al. 2012; Lapola et al. 2014; Assunção & Chiavari 2015; Agarwal et al. 2002; TERRACLASS/MMA 2015)

The attempts made at state and category areas size levels did not take into account that many municipalities in both approaches did not have any production (i.e no area planted) for a given crop in the period and that greatly affected the results, in particular the cases in which a linear relationship could not be verified (i.e. many municipalities with "zero" values for that particular crop).

Alternative future approaches to resolve this issue include: (a) focusing on the crops relationship with TCL regardless of state or area size category; (b) disregard "zero values"; or (c) differentiate the municipalities with more history in the crop production than those with more recent expansion.

A relevant discovery was made with respect to the yields in the crops for the study area. Many permanent and temporary crops have low yields in comparison to Brazil and in the case of soybean this was explored more deeply. Despite the agricultural development of the region in the past decade the disparities among municipalities' yields were surprising given their magnitude. For the selected temporary crops, nine in total (corn, manioc, beans, sugar cane, soybeans, herbaceous cotton seed, pineapple, watermelon and rice paddy) the only crops with higher yields than Brazil's average were herbaceous cotton and beans in Bahia, watermelon in Piauí and manioc and watermelon in Tocantins. Certainly there is a great space for improvement in crops yields. Grains, food and meat demand are expected to increase in the next decades creating yet more pressure for agricultural land (OECD/Food and Agriculture Organization of the United Nations 2015; TERRACLASS/MMA 2015).

Not only the demand will create further pressures to increase yields but also climate change (OECD/Food and Agriculture Organization of the United Nations 2015). This is already being observed to some extent in MATOPIBA. In 2015/2016 harvests, the National Supply Company reported significant harvest losses due to *"adverse effects of climate change"*, including increased temperatures and prolonged drought periods (dry-spells) (CONAB 2016). Further investigation on this issue could incorporate, for example, data on precipitation, and try to relate it to the low yields observed in particular areas. There are many meteorological stations in the region and data can be retrieved from reliable sources such as EMBRAPA and LAPIG (EMBRAPA - GITE 2015; LAPIG/IESA/UFG 2016)

5.3 Soybeans *Moratorium* impact on TCL in MATOPIBA

Another issue investigated in the research was whether TCL increased in MATOPIBA after the Soybeans Moratorium started in July 2006. There is evidence that the moratorium has been effective in tackling deforestation in the Amazon biome (AGROSATÉLITE/GTS 2016; Macedo et al. 2012; Rudorff et al. 2011) but if it leads to "leakage" to other biomes, in particular the Cerrado, then the strategy should take that into account in the way forward of the agreement (which was extended indefinitely in May 2016) (AGROSATÉLITE/GTS 2016).

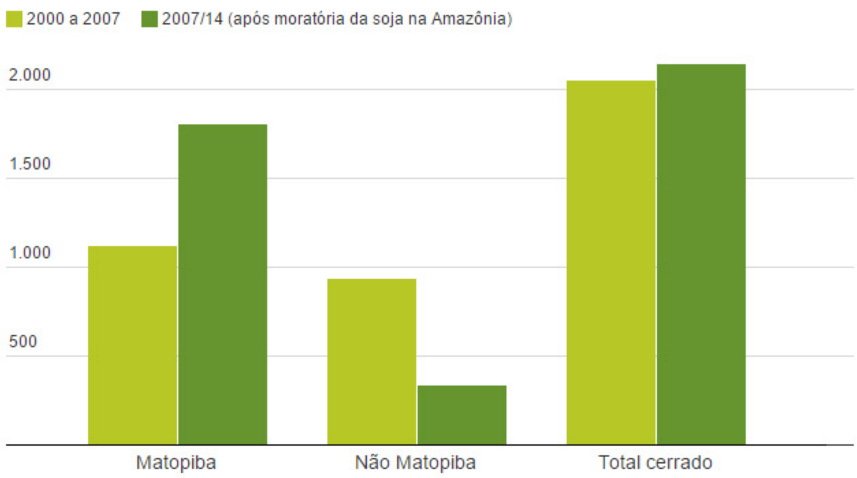
The first conclusion was that the soybeans production and number of municipalities planting it increased in the study area after the soybeans moratorium became effective (2007 was the year chosen to divide the fourteen years in two equal periods; 2001-2007 and 2008-2014). In Tocantins this trend was not observed and most soybean expansion occurred before 2007. But Tocantins is also the state that saw the greatest number of municipalities with soybeans plantation in the period assessed (there were 47 additional municipalities in 2014 in comparison to 2001). For the whole region, there were 150 municipalities planting soybeans in 2014 while this number was 118 in 2007 and 69 in 2001.

Average yields were also higher for 2008 onwards than prior to 2007. Despite a general average yield increase since 2001, the variance among crops in different municipalities is still large and low yields were present even in more recent years. It should be investigated further whether the lower yields are found, for example, on a particular type of soil type, rural establishment size or if any observed change in precipitation regime because of climate change is an explanatory factor. The possibility that climate change is already affecting the yields cannot be ruled out (CONAB 2016) and should be investigated further with annual monitoring of crops performances in areas with lowest yields.

For TCL comparison analysis between the two periods (before and after the *Moratorium*) the summary statistics for "average" and "sum" of yearly values of TCL for municipalities planting soybeans between 2001-2014 show that TCL was higher in 2008-2014 than 2001-2007, in particular in municipalities not within the Legal Amazon. The results of the paired t-test show statistically significant difference between TCL in the two periods for the "average" and "sum" of yearly values. The difference cannot be entirely explained by the increase in soybean production and for such conclusion to be made the analysis should consider the variation in other crops cultivated in the period too. It seems that other crops also gained importance in many municipalities despite soybean becoming more important both in municipalities cultivating this crop longer and more recent ones.

The findings of a possible leakage deforestation effect towards the MATOPIBA as an indirect consequence of the Soybeans *Moratorium* are in agreement with AGROSATÉLITE report (AGROSATÉLITE 2015) (Figure 57), that highlights that TCL pressure in MATOPIBA is different than in other parts of *Cerrado* mostly because land is still available at cheaper prices. The report suggests that in MATOPIBA the agricultural expansion occurs at the expense of native vegetation, contrary to other parts of *Cerrado* that may be experiencing wood encroachment or expansion of agricultural fields on low productive pastures or formerly cleared land.

Figure 52: Deforestation rate (km^2/year) caused by soybeans corn and cotton in Cerrado (MATOPIBA and non-MATOPIBA), two periods. Period after the *Moratorium* is in dark green.



Source: (AGROSATÉLITE 2015; FOLHA 2015)

6. Conclusion

MATOPIBA consists of a complex agrarian structure and provides a variety of ecosystem services. It is crucial both for agriculture and biodiversity conservation strategies at a national scale. The research summarized and detailed the agricultural expansion in the region between 2001 and 2014 and analysed yearly data for Tree Cover Loss (TCL) (ha) in 334 municipalities. TCL was 5.56 million ha and increased in the period. There is significant correlation between TCL and official deforestation rates (p-value < 0.0001). The coefficient of TCL as function of municipality area was highest in Piauí (0.474; p-value < 0.0001) and lowest in Tocantins (0.155; p-value < 0.0001) but linearity assumptions were not met because of great variance in TCL among municipalities. TCL ratio (%) was higher in micro regions in Bahia and Maranhão. Interesting trends appeared when TCL in the period was plotted against HDI, illiteracy rate and GDP/capita. TCL was positively correlated with the number of settled families in municipalities with Agrarian Reform settlements. These patterns deserve further exploration.

Agricultural production is highly concentrated in few municipalities. Land-use change pressures from different agricultural practices are present at different scales even within one micro region. Soybean is the leading crop but showed great concentration. The same applies to sugar cane, cotton, rice paddy and beans. Manioc and corn were present in all municipalities. Pineapple and watermelon appeared in the ranking of Tocantins only. The correlation of TCL in the period with each main crop was limited due to a great variance in area planted and “zero values” from municipalities that didn’t plant certain crops. An alternative approach could focus on the crops instead of municipality location (state) or area size category and try more than one crop at once. Low yields in comparison with Brazil’s are present for nearly all crops (even soybean) and there is a great variance among municipalities. Severe harvest losses were reported in 2015/2016 and this could be related to adverse effects of climate change for Central/NE Brazil (e.g. prolonged drought periods). That exacerbates the challenge to increase yields and reduce the pressure on TCL (deforestation) in MATOPIBA.

The research found statistical significant difference between the “sum” and “average” TCL before and after the Soybeans Moratorium (July 2006). This raises concern if the pact creates “leakage” deforestation to Cerrado while protecting the Amazon. Over 60% of MATOPIBA consists of Legal Amazon. Soybeans production and number of municipalities planting the crop increased in MATOPIBA and findings suggest that the increase in TCL from 2007 onwards could be directly related with the soybeans expansion.

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Appendices

Appendix I: Interactions with supervisors to date (discussions & briefing on dissertation progress)

Dan Van der Horst (Geosciences), meetings on: 7/12/2015, 14/01/2106, 22/01/2016, 11/04/2016, 27/04/2016, 08/07/2016 (Skype), 02/08/2016

Rafael Silva and Dominic Moran, SRUC. Meetings on: 29/01/2016, 26/02/2016 24/06/2016

10

Appendix II: MATOPIBA municipalities

Appendix Table 1: Municipalities in Bahia

Angical	*Cocos*	*Luis Eduardo Magalhães*	*São Félix do Coribe*
Baianópolis	*Coribe*	*Mansidão*	*Serra do Ramalho*
Barreiras	*Correntina*	*Paratinga*	*Serra Dourada*
Bom Jesus da Lapa	*Cotegipe*	*Riachão das Neves*	*Sítio do Mato*
Brejolândia	*Cristópolis*	*Santa Maria da Vitória*	*Tabocas do Brejo Velho*
Canápolis	*Feira da Mata*	*Santa Rita de Cássia*	*Wanderley*
Carinhanha	*Formosa do Rio Preto*	*Santana*	
Catolândia	*Jaborandi*	*São Desidério*	
		Total	***30***

Appendix Table 2: Municipalities in Piauí

Alvorada do Gurguéia	*Cristalândia do Piauí*	*Marcos Parente*	*Santa Filomena*
Antônio Almeida	*Cristino Castro*	*Monte Alegre do Piauí*	*Santa Luz*
Avelino Lopes	*Curimatá*	*Morro Cabeça no Tempo*	*São Gonçalo do Gurguéia*
Baixa Grande do Ribeiro	*Currais*	*Palmeira do Piauí*	*Sebastião Barros*
Barreiras do Piauí	*Eliseu Martins*	*Parnaguá*	*Sebastião Leal*
Bertolínia	*Gilbués*	*Porto Alegre do Piauí*	*Uruçuí*
Bom Jesus	*Júlio Borges*	*Redenção do Gurguéia*	
Colônia do Gurguéia	*Landri Sales*	*Riacho Frio*	
Corrente	*Manoel Emídio*	*Ribeiro Gonçalves*	
		Total	***33***

Appendix Table 3: Municipalities in Maranhão

Açailândia	Davinópolis	Magalhães de Almeida	São Benedito do Rio Preto
Afonso Cunha	Dom Pedro	Mata Roma	São Bernardo
Água Doce do Maranhão	Duque Bacelar	Matões	São Domingos do Azeitão
Aldeias Altas	Esperantinópolis	Matões do Norte	São Domingos do Maranhão
Alto Alegre do Maranhão	Estreito	Milagres do Maranhão	São Félix de Balsas
Alto Parnaíba	Feira Nova do Maranhão	Mirador	São Francisco do Brejão
Amarante do Maranhão	Fernando Falcão	Miranda do Norte	São Francisco do Maranhão
Anapurus	Formosa da Serra Negra	Montes Altos	São João do Paraíso
Araioses	Fortaleza dos Nogueiras	Nina Rodrigues	São João do Soter
Arame	Fortuna	Nova Colinas	São João dos Patos
Bacabal	Gonçalves Dias	Nova Iorque	São José dos Basílios
Balsas	Governador Archer	Olho d'Água das Cunhãs	São Luís Gonzaga do Maranhão
Barão de Grajaú	Governador Edison Lobão	Paraibano	São Mateus do Maranhão
Barra do Corda	Governador Eugênio Barros	Parnarama	São Pedro da Água Branca
Barreirinhas	Governador Luiz Rocha	Passagem Franca	São Pedro dos Crentes
Belágua	Graça Aranha	Pastos Bons	São Raimundo das Mangabeiras
Benedito Leite	Grajaú	Paulino Neves	São Raimundo do Doca Bezerra
Bernardo do Mearim	Humberto de Campos	Pedreiras	São Roberto
Bom Lugar	Igarapé Grande	Peritoró	Satubinha
Brejo	Imperatriz	Pio XII	Senador Alexandre Costa
Buriti	Itaipava do Grajaú	Pirapemas	Senador La Rocque
Buriti Bravo	Itapecuru Mirim	Poção de Pedras	Sítio Novo
Buritirana	Itinga do Maranhão	Porto Franco	Sucupira do Norte
Campestre do Maranhão	Jatobá	Presidente Dutra	Sucupira do Riachão
Cantanhede	Jenipapo dos Vieiras	Presidente Vargas	Tasso Fragoso
Capinzal do Norte	João Lisboa	Primeira Cruz	Timbiras
Carolina	Joselândia	Riachão	Timon
Caxias	Lago do Junco	Ribamar Fiquene	Trizidela do Vale
Chapadinha	Lago dos Rodrigues	Sambaíba	Tuntum
Cidelândia	Lago Verde	Santa Filomena do Maranhão	Tutóia
Codó	Lagoa do Mato	Santa Quitéria do Maranhão	Urbano Santos
Coelho Neto	Lajeado Novo	Santana do Maranhão	Vargem Grande
Colinas	Lima Campos	Santo Amaro do Maranhão	Vila Nova dos Martírios
Coroatá	Loreto	Santo Antônio dos Lopes	
		Total	135

Appendix Table 4: Municipalities in Tocantins

Abreulândia	*Chapada da Natividade*	*Lizarda*	*Praia Norte*
Aguiarnópolis	*Chapada de Areia*	*Luzinópolis*	*Presidente Kennedy*
Aliança do Tocantins	*Colinas do Tocantins*	*Marianópolis do Tocantins*	*Pugmil*
Almas	*Colméia*	*Mateiros*	*Recursolândia*
Alvorada	*Combinado*	*Maurilândia do Tocantins*	*Riachinho*
Ananás	*Conceição do Tocantins*	*Miracema do Tocantins*	*Rio da Conceição*
Angico	*Couto Magalhães*	*Miranorte*	*Rio dos Bois*
Aparecida do Rio Negro	*Cristalândia*	*Monte do Carmo*	*Rio Sono*
Aragominas	*Crixás do Tocantins*	*Monte Santo do Tocantins*	*Sampaio*
Araguacema	*Darcinópolis*	*Muricilândia*	*Sandolândia*
Araguaçu	*Dianópolis*	*Natividade*	*Santa Fé do Araguaia*
Araguaína	*Divinópolis do Tocantins*	*Nazaré*	*Santa Maria do Tocantins*
Araguanã	*Dois Irmãos do Tocantins*	*Nova Olinda*	*Santa Rita do Tocantins*
Araguatins	*Dueré*	*Nova Rosalândia*	*Santa Rosa do Tocantins*
Arapoema	*Esperantina*	*Novo Acordo*	*Santa Tereza do Tocantins*
Arraias	*Fátima*	*Novo Alegre*	*Santa Terezinha do Tocantins*
Augustinópolis	*Figueirópolis*	*Novo Jardim*	*São Bento do Tocantins*
Aurora do Tocantins	*Filadélfia*	*Oliveira de Fátima*	*São Félix do Tocantins*
Axixá do Tocantins	*Formoso do Araguaia*	*Palmas*	*São Miguel do Tocantins*
Babaçulândia	*Fortaleza do Tabocão*	*Palmeirante*	*São Salvador do Tocantins*
Bandeirantes do Tocantins	*Goianorte*	*Palmeiras do Tocantins*	*São Sebastião do Tocantins*
Barra do Ouro	*Goiatins*	*Palmeirópolis*	*São Valério da Natividade*
Barrolândia	*Guaraí*	*Paraíso do Tocantins*	*Silvanópolis*
Bernardo Sayão	*Gurupi*	*Paranã*	*Sítio Novo do Tocantins*
Bom Jesus do Tocantins	*Ipueiras*	*Pau D'Arco*	*Sucupira*
Brasilândia do Tocantins	*Itacajá*	*Pedro Afonso*	*Taguatinga*
Brejinho de Nazaré	*Itaguatins*	*Peixe*	*Taipas do Tocantins*
Buriti do Tocantins	*Itapiratins*	*Pequizeiro*	*Talismã*
Cachoeirinha	*Itaporã do Tocantins*	*Pindorama do Tocantins*	*Tocantínia*
Campos Lindos	*Jaú do Tocantins*	*Piraquê*	*Tocantinópolis*
Cariri do Tocantins	*Juarina*	*Pium*	*Tupirama*
Carmolândia	*Lagoa da Confusão*	*Ponte Alta do Bom Jesus*	*Tupiratins*
Carrasco Bonito	*Lagoa do Tocantins*	*Ponte Alta do Tocantins*	*Wanderlândia*
Caseara	*Lajeado*	*Porto Alegre do Tocantins*	*Xambioá*
Centenário	*Lavandeira*	*Porto Nacional*	
		Total	***139***

Appendix III: Additional information on Tree Cover Loss (TCL) data

Appendix Table 5: Micro regions areas as per official IBGE data

Microregion	State	Area (ha)*	Area (ha)**	# Municipalities**	# Municipalities not found in GFW	Area not found in GFW (ha)	(Area**) / (Area*)
Alto Mearim e Grajaú	MA	3,707,008	3,662,581	11	0		99%
Alto Médio Gurguéia	PI	2,760,896	2,760,896	11	0		100%
Alto Parnaíba Piauiense	PI	2,548,521	2,548,523	4	0		100%
Araguaína	TO	2,643,960	2,643,961	17	0		100%
Baixo Parnaíba Maranhense	MA	651,554	603,285	6	0		93%
Barreiras	BA	5,291,931	5,282,149	7	1	424,505	100%
Bertolínia	PI	1,109,817	1,109,817	9	0		100%
Bico do Papagaio	TO	1,576,796	1,576,796	25	1	74,790	100%
Bom Jesus da Lapa	BA	1,553,042	1,441,512	6	0		93%
Caxias	MA	1,532,990	1,532,990	6	0		100%
Chapadas das Mangabeiras	MA	1,677,952	1,696,920	8	0		101%
Chapadas do Alto Itapecuru	MA	2,494,633	2,501,657	13	0		100%
Chapadas do Extremo Sul Piauiense	PI	1,785,354	1,785,354	9	0		100%
Chapadinha	MA	1,022,596	1,079,662	9	0		106%
Codó	MA	991,026	991,026	6	0		100%
Coelho Neto	MA	360,692	360,692	4	0		100%
Cotegipe	BA	2,300,238	2,263,094	8	1	292,068	98%
Dianópolis	TO	4,718,099	4,718,100	20	0		100%
Gerais de Balsas	MA	3,650,332	3,650,332	5	0		100%
Gurupi	TO	2,744,543	2,744,542	14	0		100%
Imperatriz	MA	2,924,461	2,924,466	16	0		100%
Itapecuru Mirim	MA	705,859	705,859	8	0		100%
Jalapão	TO	5,350,661	5,350,680	15	0		100%
Lençóis Maranhenses	MA	1,084,293	1,075,496	6	0		99%
Médio Mearim	MA	1,100,536	1,100,536	20	0		100%
Miracema do Tocantins	TO	3,477,611	3,477,611	24	0		100%
Porto Franco	MA	1,422,693	1,422,693	6	0		100%
Porto Nacional	TO	2,119,811	2,119,838	11	0		100%
Presidente Dutra	MA	655,721	654,776	11	0		100%
Rio Formoso	TO	5,140,572	5,140,556	13	0		100%
Santa Maria da Vitória	BA	4,069,287	4,198,551	9	0		103%
			Total	***337***	***3***	***791,362***	

* as per Table 1 in Miranda et al. 2014

** as per IBGE official data

Appendix Table 6: Area of forest plantations in MATOPIBA in 2014.

Municipality	*Eucalyptus and Pinus* managed forests (ha)	% of municipality area	Equivalent area harvested (ha) in 2001-2014*	Municipality	*Eucalyptus and Pinus* managed forests (ha)	% of municipality area	Equivalent area harvested (ha) in 2001-2014*
Grajaú	30,142	3.40%	8,612	Porto Franco	744	0.52%	213
Açailândia	28,106	4.84%	8,030	Carolina	733	0.11%	209
Barra do Corda	21,130	4.07%	6,037	São Benedito do Rio Preto	712	0.76%	203
Brejinho de Nazaré	18,421	10.68%	5,263	Taguatinga	681	0.28%	195
São Bento do Tocantins	16,980	15.35%	4,851	Barão de Grajaú	650	0.29%	186
Vila Nova dos Martírios	12,594	10.59%	3,598	Miracema do Tocantins	650	0.24%	186
Itinga do Maranhão	10,823	3.02%	3,092	Natividade	640	0.20%	183
Urbano Santos	9,432	5.52%	2,695	Mata Roma	580	1.06%	166
Parnarama	9,279	2.86%	2,651	São Félix do Tocantins	568	0.30%	162
Araguaína	9,236	2.31%	2,639	Bom Jesus do Tocantins	550	0.41%	157
Goiatins	9,128	1.42%	2,608	Baixa Grande do Ribeiro	545	0.07%	156
Santa Quitéria do Maranhão	9,010	6.28%	2,574	Dois Irmãos do Tocantins	534	0.14%	153
Crixás do Tocantins	7,415	7.52%	2,119	Monte do Carmo	525	0.15%	150
Imperatriz	7,324	5.35%	2,093	Figueirópolis	524	0.27%	150
Estreito	7,178	2.64%	2,051	Campos Lindos	488	0.15%	139
Ananás	7,160	4.54%	2,046	Ponte Alta do Bom Jesus	470	0.26%	134
Palmeirante	6,364	2.41%	1,818	Nazaré	426	1.08%	122
Wanderlândia	5,754	4.19%	1,644	Guaraí	400	0.18%	114
Sítio Novo	5,188	1.67%	1,482	Dianópolis	400	0.12%	114
Dueré	5,000	1.46%	1,429	Almas	400	0.10%	114
Anapurus	4,826	7.93%	1,379	Filadélfia	380	0.19%	109
Aliança do Tocantins	4,649	2.94%	1,328	Nova Olinda	324	0.21%	93
Uruçuí	4,471	0.53%	1,277	Jaú do Tocantins	320	0.15%	91
Darcinópolis	4,146	2.53%	1,185	Arraias	320	0.06%	91
Babaçulândia	3,842	2.15%	1,098	Governador Edison Lobão	311	0.50%	89
Ponte Alta do Tocantins	3,700	0.57%	1,057	Milagres do Maranhão	300	0.47%	86
São João do Paraíso	3,581	1.74%	1,023	Araguaçu	300	0.06%	86
São Pedro dos Crentes	3,275	3.34%	936	Miranorte	290	0.28%	83
Araguatins	3,132	1.19%	895	Taipas do Tocantins	275	0.25%	79
Antônio Almeida	3,020	4.68%	863	Rio Sono	250	0.04%	71
Peixe	2,550	0.48%	729	Ribamar Fiquene	236	0.31%	67
Conceição do Tocantins	2,440	0.98%	697	Xambioá	200	0.17%	57
Feira Nova do Maranhão	2,400	1.63%	686	Brejo	185	0.17%	53
Angico	2,218	4.91%	634	Paranã	160	0.01%	46
Tasso Fragoso	2,100	0.48%	600	Ribeiro Gonçalves	155	0.04%	44
São Francisco do Brejão	2,088	2.80%	597	Lagoa do Tocantins	150	0.16%	43
Jaborandi	2,000	0.20%	571	Alvorada do Gurguéia	150	0.07%	43
Centenário	1,840	0.94%	526	Lizarda	150	0.03%	43
Chapadinha	1,809	0.56%	517	João Lisboa	100	0.09%	29
Cidelândia	1,612	1.10%	461	Palmeira do Piauí	100	0.05%	29
Riachão	1,600	0.25%	457	São Félix de Balsas	100	0.05%	29
Sambaíba	1,500	0.61%	429	Amarante do Maranhão	86	0.01%	25
Alto Parnaíba	1,500	0.13%	429	Couto Magalhães	65	0.04%	19
Palmeiras do Tocantins	1,481	NA	423	Porto Alegre do Tocantins	57	0.11%	16
Sucupira	1,450	1.41%	414	Tupirama	50	0.07%	14
Loreto	1,350	0.38%	386	Santa Maria do Tocantins	50	0.04%	14
Barra do Ouro	1,231	1.11%	352	Piraquê	43	0.03%	12
Caxias	1,124	0.22%	321	Tocantinópolis	40	0.04%	11
Matões	1,047	0.50%	299	São Salvador do Tocantins	40	0.03%	11
São Pedro da Água Branca	1,023	1.42%	292	Silvanópolis	26	0.02%	7
São Valério da Natividade	997	0.40%	285	Campestre do Maranhão	24	0.04%	7
Novo Acordo	904	0.34%	258	Sebastião Leal	23	0.01%	7
Pugmil	900	2.24%	257	Santa Fé do Araguaia	15	0.01%	4
Tupiratins	900	1.01%	257	Nova Iorque	8	0.01%	2
Riachinho	891	1.72%	255	Palmas	2	0.00%	1
Buritirana	850	1.04%	243	* assuming one harvest every seven years			
Codó	830	0.19%	237				
Alvorada	800	0.66%	229				
Formoso do Araguaia	800	0.06%	229				

Appendix Table 7: Municipalities in MATOPIBA and deforestation. Periods considered are 2002-2008, 2010 and 2011. Correspondent TCL data for the municipality was compiled. Source of deforestation data are the reports published by the Ministry of Environment in Brazil

Municipality	State	TCL 2002-2008 (ha)	TCL 2010 (ha)	TCL 2011 (ha)	Deforestation 2002-2008 (ha)	Deforestation 2009-2010 (ha)	Deforestation 2010-2011 (ha)
Alto Parnaíba	MA	35,412	-	-	31,451	-	-
Amarante do Maranhão	MA	38,408	-	-	37,022	-	-
Araguaçu	TO	20,278	-	-	32,744	-	-
Baixa Grande do Ribeiro	PI	38,356	27,543	11,596	66,181	39,429	34,861
Balsas	MA	67,360	8,893	-	86,205	8,524	-
Barra do Corda	MA	40,865	-	-	87,441	-	-
Barreiras	BA	33,058	3,831	-	61,575	8,839	-
Bom Jesus	PI	28,401	-	-	41,527	-	-
Campos Lindos	TO	19,572	-	-	28,572	-	-
Carolina	MA	14,011	-	-	46,784	-	-
Caxias	MA	-	3,069	-	-	4,585	-
Chapadinha	MA	-	2,071	-	-	5,835	-
Codó	MA	24,179	4,374	-	38,591	6,991	-
Coroatá	MA	-	2,264	-	-	5,163	-
Correntina	BA	78,698	-	13,096	128,439	-	11,077
Currais	PI	-	-	5,802	-	-	8,727
Dois Irmãos do Tocantins	TO	12,705	-	-	42,250	-	-
Formosa da Serra Negra	MA	10,882	-	-	33,664	-	-
Formosa do Rio Preto	BA	118,802	9,642	18,765	200,313	14,392	19,540
Gilbués	PI	-	-	9,033	-	-	15,448
Goiatins	TO	9,152	-	-	43,466	-	-
Grajaú	MA	36,285	7,925	-	60,814	6,880	-
Jaborandi	BA	31,647	-	7,549	72,428	-	8,588
Manoel Emídio	PI	-	-	5,192	-	-	10,429
Mateiros	TO	-	1,153	-	-	9,306	-
Palmeira do Piauí	PI	-	3,060	-	-	6,434	-
Pium	TO	15,103	-	-	29,952	-	-
Riachão	MA	19,028	-	-	41,399	-	-
Riachão das Neves	BA	34,823	3,355	-	54,555	6,881	-
Santa Filomena	PI	21,399	-	-	31,871	-	-
Santa Quitéria do Maranh	MA	-	3,160	-	-	7,388	-
Santa Rita de Cássia	BA	30,459	-	-	29,081	-	-
São Desidério	BA	67,750	8,791	21,015	132,938	11,985	14,962
Sítio Novo	MA	11,377	-	-	34,919	-	-
Tasso Fragoso	MA	34,354	-	-	39,243	-	-
Tuntum	MA	23,674	-	-	30,368	-	-
Uruçuí	PI	45,684	18,236	11,551	54,814	20,348	20,956

10

Appendix Table 8: Outliers deleted TCL x deforestation

TCL (ha)	Deforestation (ha)	Action
1,153	9,306	outlier deleted
9,152	43,466	outlier deleted
13,096	11,077	outlier deleted
14,011	46,784	outlier deleted
21,015	14,962	outlier deleted
18,236	20,348	outlier deleted
18,765	19,540	outlier deleted
30,459	29,081	outlier deleted
35,412	31,451	outlier deleted
38,408	37,022	outlier deleted
45,684	54,814	outlier deleted
31,647	72,428	outlier deleted

Appendix Table 9: Points considered in the linear model. Log [deforestation] = *a**Log [TCL] + *b*

#	TCL (ha)	Deforestation (ha)	#	TCL (ha)	Deforestation (ha)
1	2,071	5,835	21	12,705	42,250
2	2,264	5,163	22	15,103	29,952
3	3,060	6,434	23	19,028	41,399
4	3,069	4,585	24	19,572	28,572
5	3,160	7,388	25	20,278	32,744
6	3,355	6,881	26	21,399	31,871
7	3,831	8,839	27	23,674	30,368
8	4,374	6,991	28	24,179	38,591
9	5,192	10,429	29	27,543	39,429
10	5,802	8,727	30	28,401	41,527
11	7,549	8,588	31	33,058	61,575
12	7,925	6,880	32	34,354	39,243
13	8,791	11,985	33	34,823	54,555
14	8,893	8,524	34	36,285	60,814
15	9,033	15,448	35	38,356	66,181
16	9,642	14,392	36	40,865	87,441
17	10,882	33,664	37	67,360	86,205
18	11,377	34,919	38	67,750	132,938
19	11,551	20,956	39	78,698	128,439
20	11,596	34,861	40	118,802	200,313

Appendix Table 10: Validation of area in the analysis

State	Area (ha)	# of Municipalities
TO	27,772,052	139
MA	23,982,346	135
PI	8,204,588	33
BA	13,214,499	30
IBGE/EMBRAPA (1)	**73,173,485**	**337**
analysis	***72,333,588***	***334***
(2) / (1)	*98.85%*	
Area not found in GFW (ha)	*791,362*	
(1) - (2)	*839,897*	

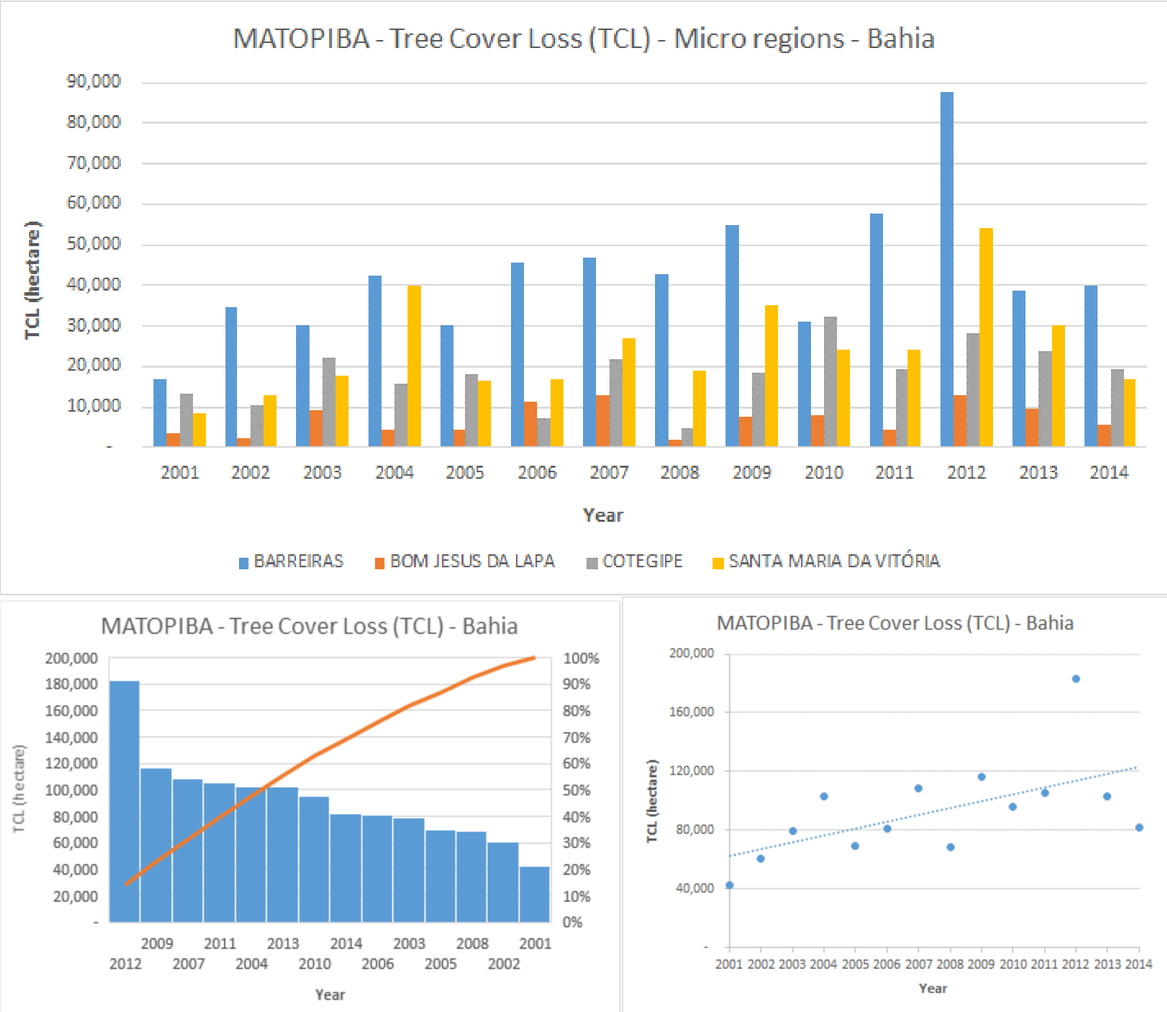
10

Appendix Table 11: TCL ratio (%) per micro region (2001-2014). Seven out of ten micro regions with highest TCL ratio over total area are located in Maranhão. Micro regions in Tocantins, as a whole, experienced lower rates of TCL.

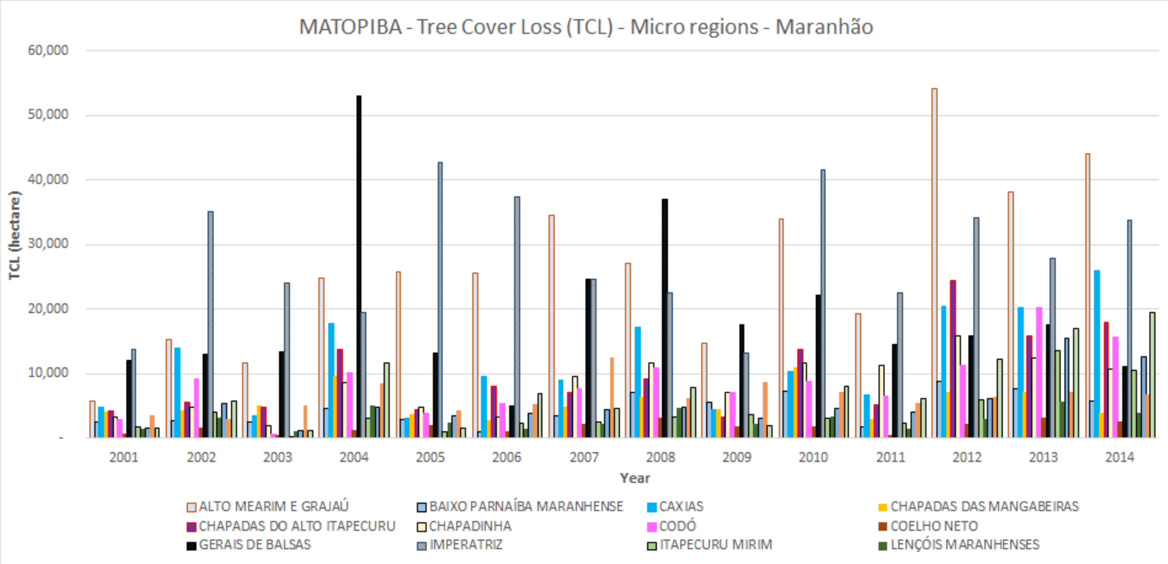
#	Micro region	State	TCL % (Micro region area)
1	PRESIDENTE DUTRA	MA	16.25%
2	ALTO PARNAÍBA PIAUIENSE	PI	14.79%
3	IMPERATRIZ	MA	13.43%
4	COTEGIPE*	BA	12.99%
5	BARREIRAS*	BA	12.34%
6	CODÓ	MA	12.17%
7	CAXIAS	MA	10.92%
8	CHAPADINHA	MA	10.91%
9	BAIXO PARNAÍBA MARANHENSE	MA	10.70%
10	ALTO MEARIM E GRAJAÚ	MA	10.24%
11	ALTO MÉDIO GURGUÉIA	PI	8.98%
12	BICO DO PAPAGAIO*	TO	8.67%
13	ITAPECURU MIRIM	MA	8.22%
14	SANTA MARIA DA VITÓRIA	BA	8.17%
15	GERAIS DE BALSAS	MA	7.42%
16	COELHO NETO	MA	7.08%
17	MÉDIO MEARIM	MA	6.92%
18	BOM JESUS DA LAPA	BA	6.85%
19	GURUPI	TO	6.42%
20	PORTO FRANCO	MA	6.37%
21	CHAPADAS DO EXTREMO SUL PIAUIENSE	PI	6.18%
22	MIRACEMA DO TOCANTINS	TO	6.04%
23	BERTOLÍNIA	PI	5.99%
24	CHAPADAS DO ALTO ITAPECURU	MA	5.51%
25	PORTO NACIONAL	TO	5.22%
26	ARAGUAÍNA	TO	5.13%
27	CHAPADAS DAS MANGABEIRAS	MA	4.64%
28	DIANÓPOLIS	TO	4.45%
29	RIO FORMOSO	TO	4.16%
30	LENÇÓIS MARANHENSES	MA	3.91%
31	JALAPÃO	TO	2.80%
	% of Total MATOPIBA Area	-	*7.69%*

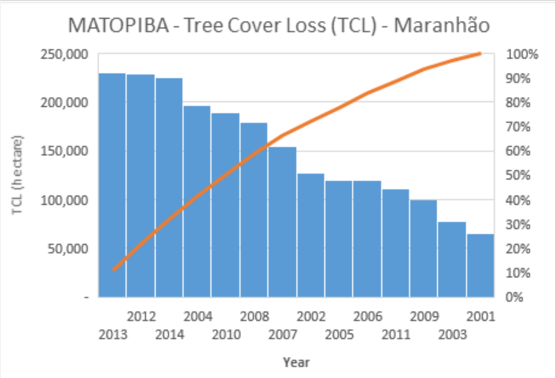
* One municipality in the micro region not found in GFW database

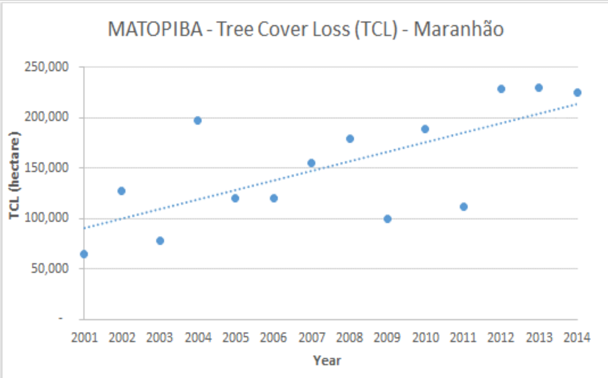
Appendix Figure 1: TCL in micro regions (BAHIA)



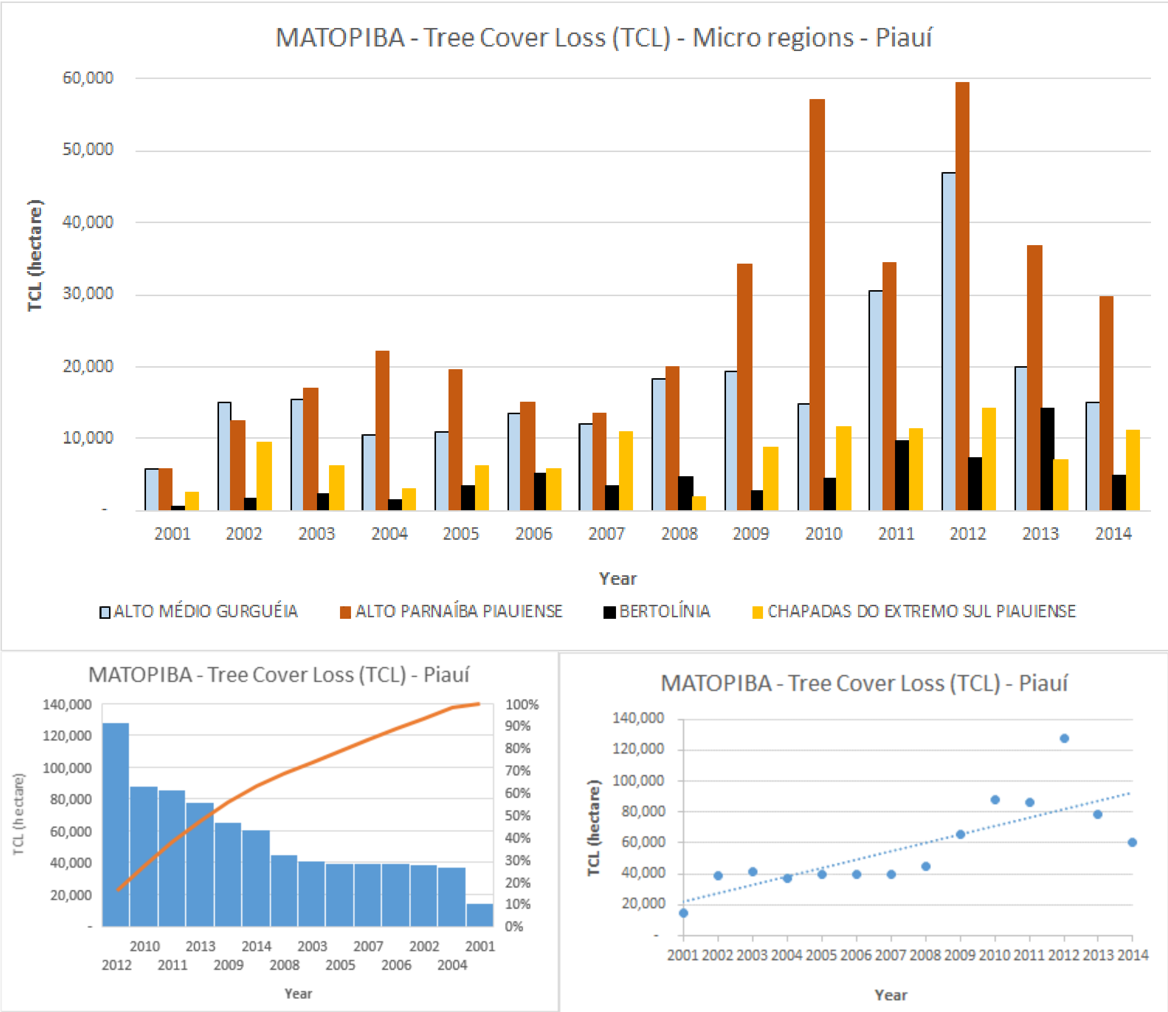
Appendix Figure 2: TCL in micro regions (MARANHÃO)





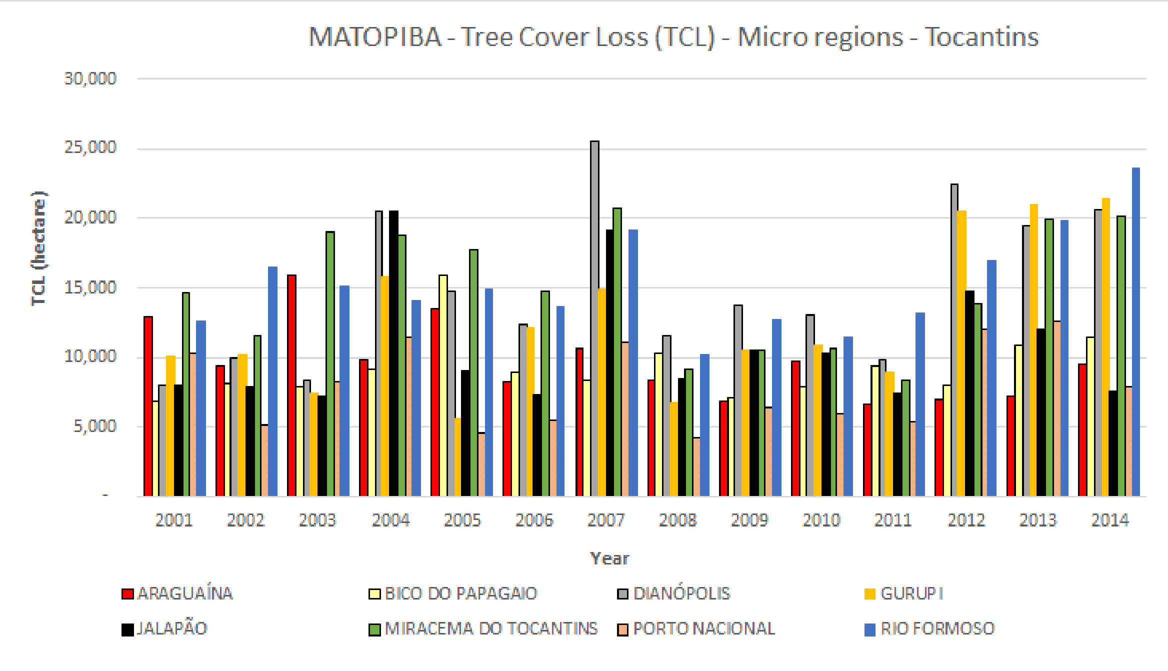


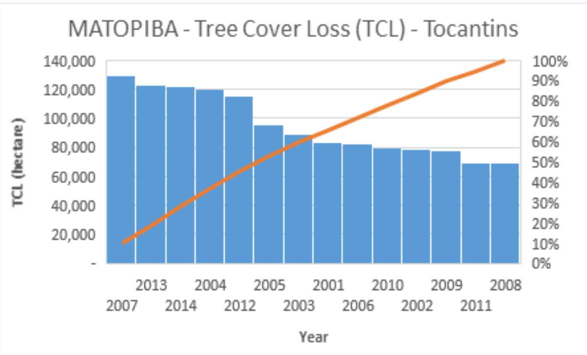
Appendix Figure 3: TCL in micro regions (PIAUÍ)

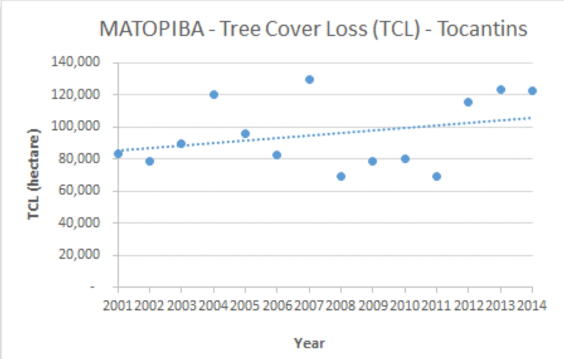


10

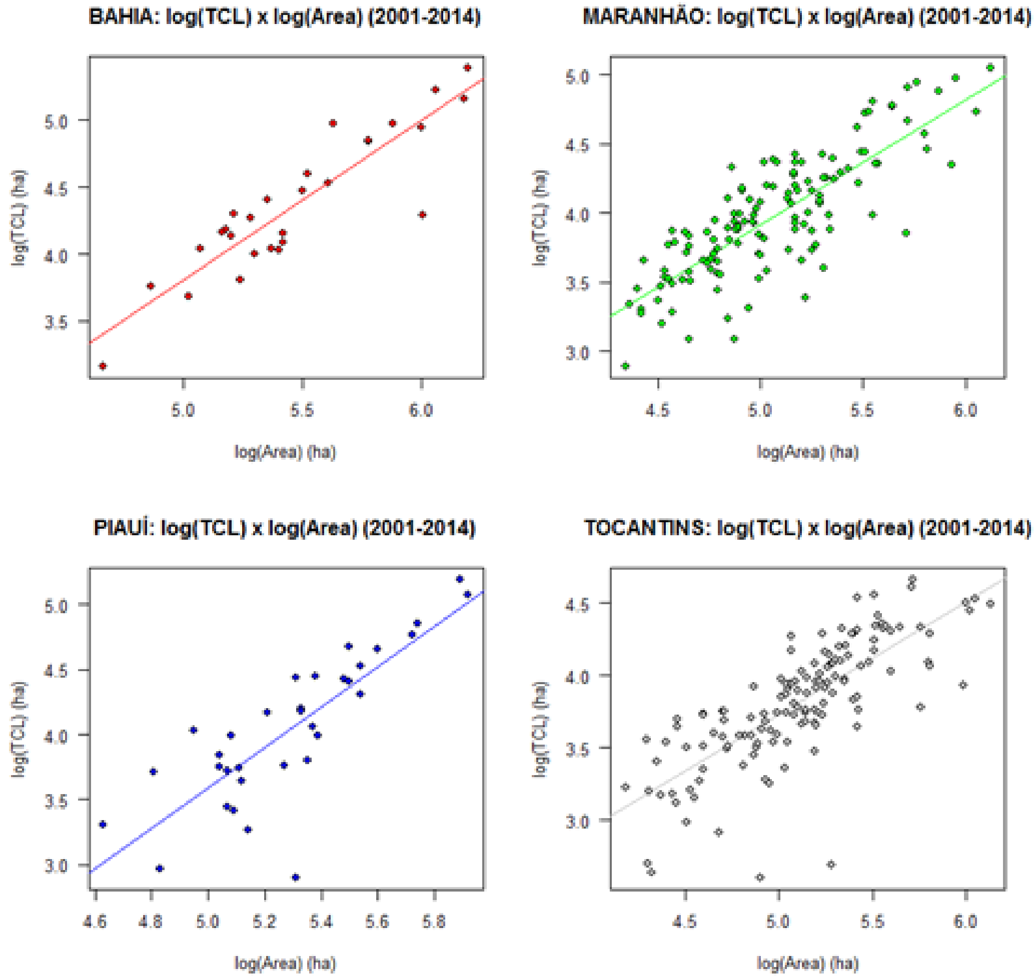
Appendix Figure 4: TCL in micro regions (TOCANTINS)





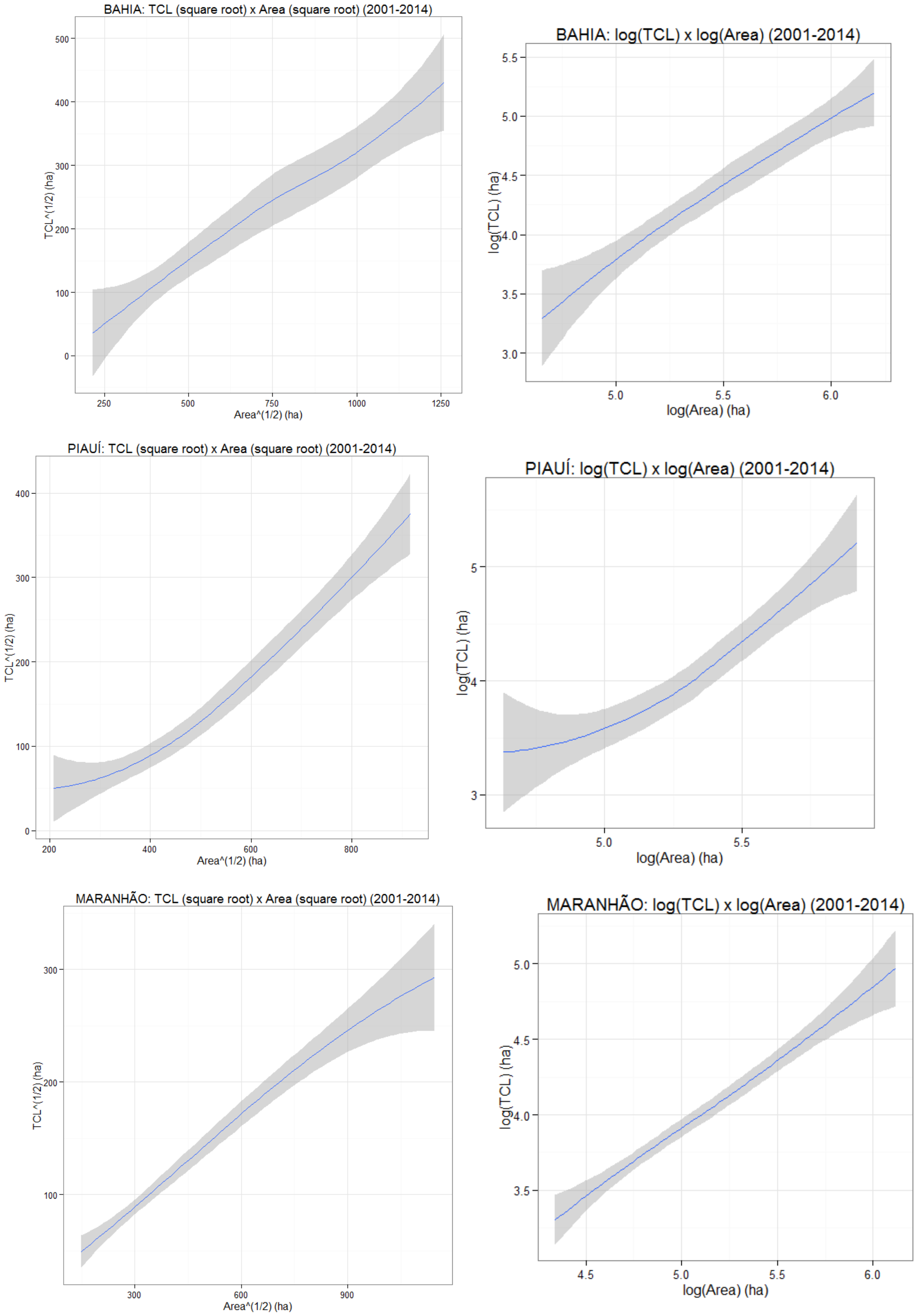


Appendix Figure 5: TCL (log) by Area (log)

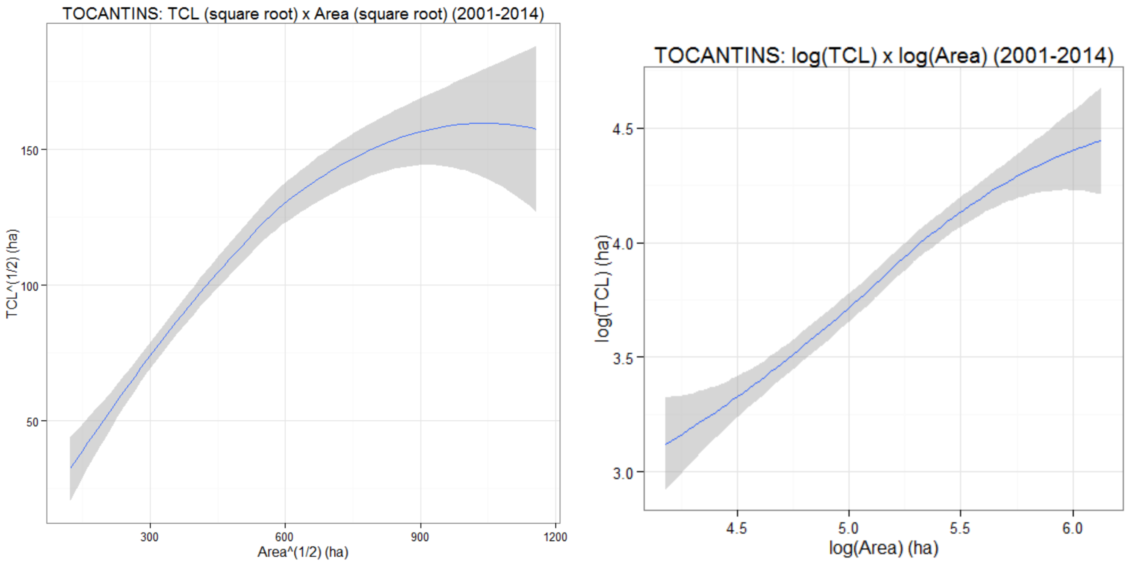


10

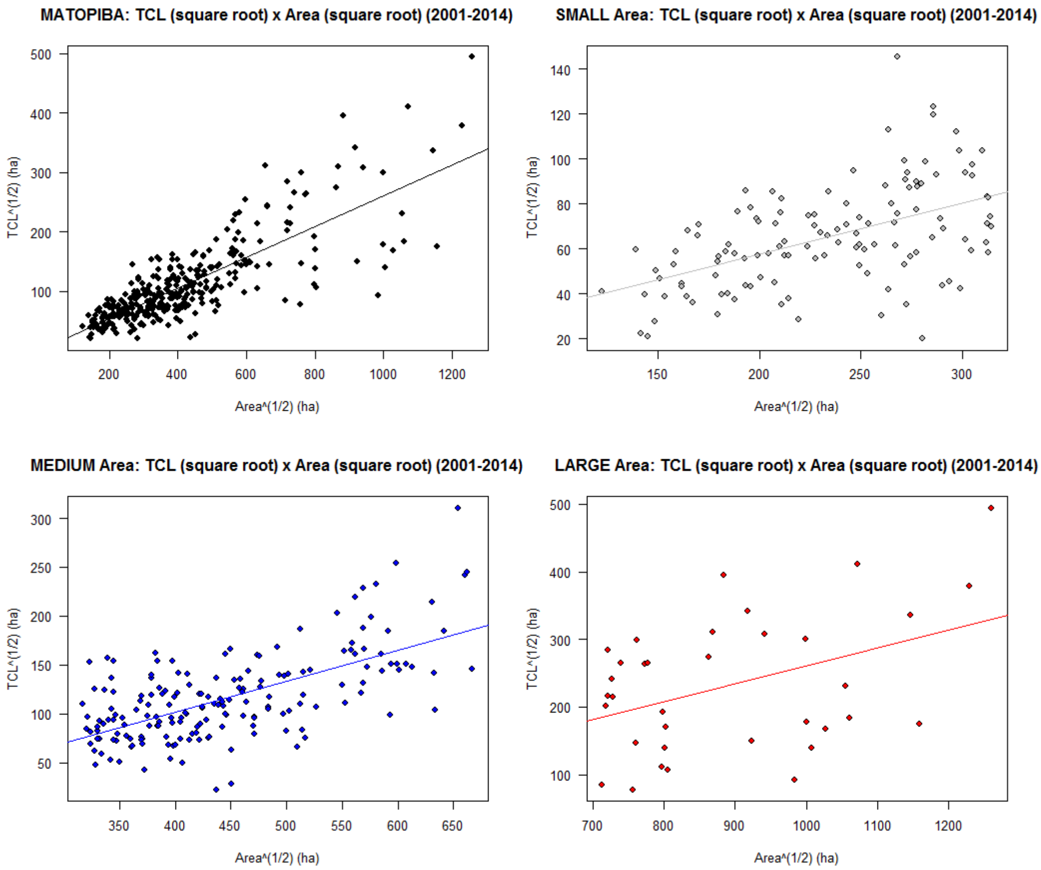
Appendix Figure 6: Smooth lines[3] and CI (0.95) for TCL (ha) by area size (ha) with different transformations, by state



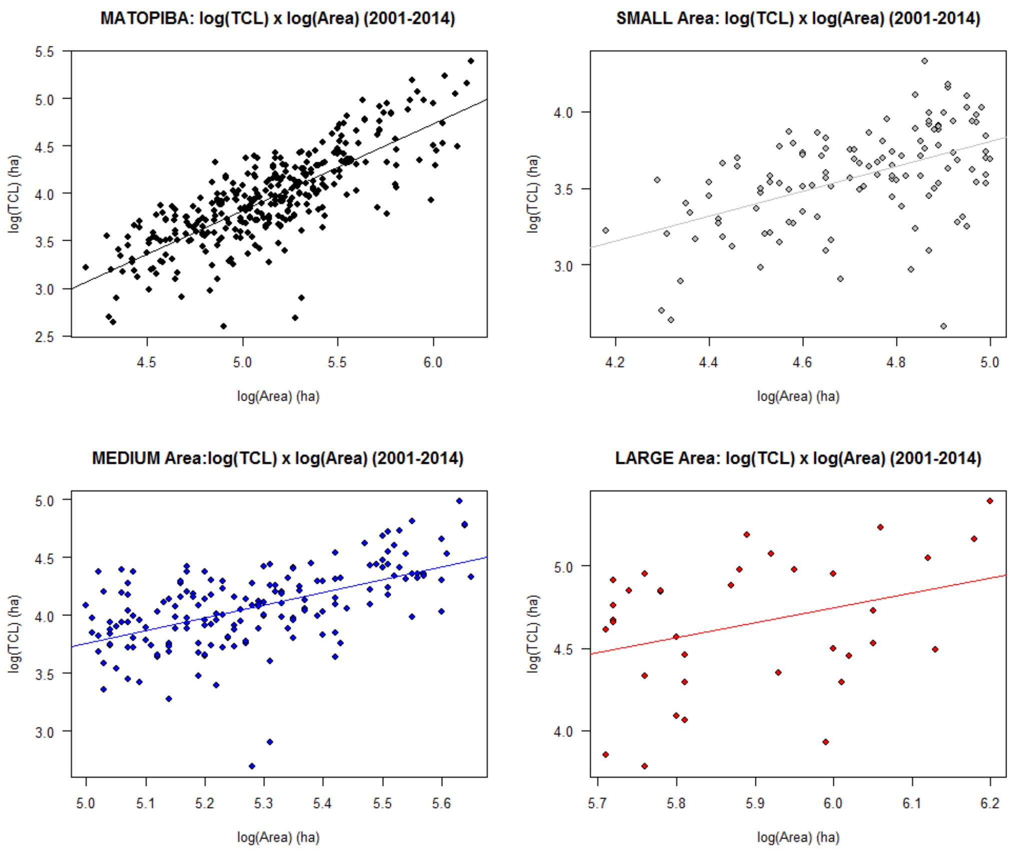
[3] Using “ggplot2” package in “R” software



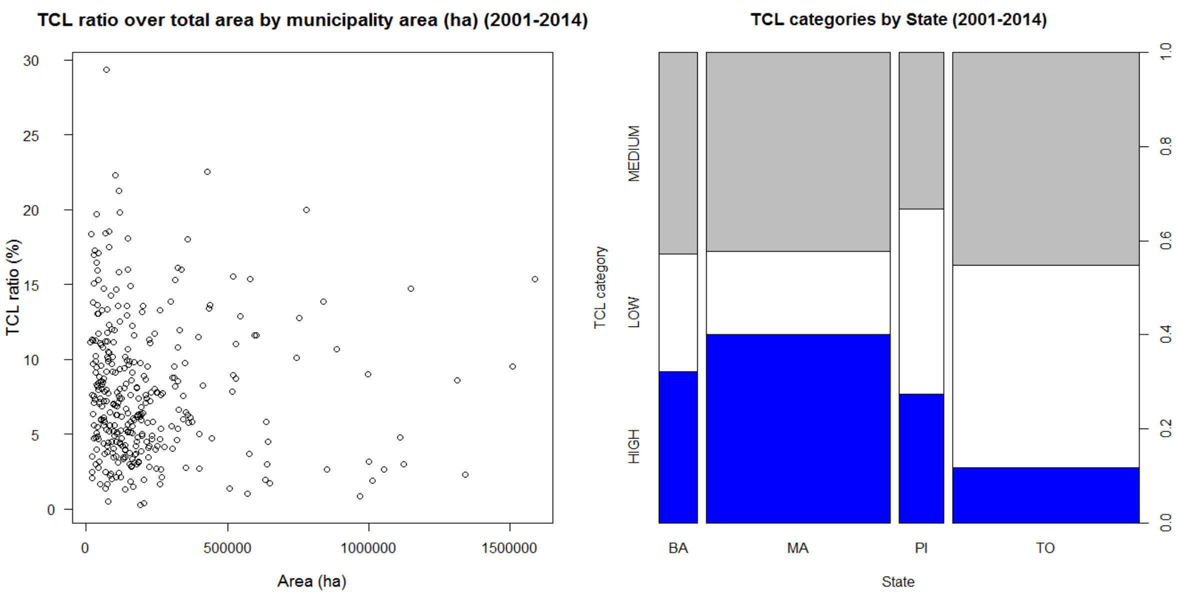
Appendix Figure 7: Sqrt TCL x Sqrt area by municipality area size category



Appendix Figure 8: Log TCL x Log Area by municipality area size category



Appendix Figure 9: TCL ratio (%) by area and TCL categories by state



Appendix IV: Additional information on agricultural crops

Appendix Table 12: Ranking temporary crops by micro region (BAHIA)

MATOPIBA - BAHIA	#	RANK Quantity	RANK Value
Barreiras	1	Soybeans	Soybeans
	2	Corn (grain)	Herbaceous Cotton (seed)
	3	Herbaceous Cotton (seed)	Corn (grain)
Bom Jesus da Lapa	1	Manioc	Manioc
	2	Sugar cane	Herbaceous Cotton (seed)
	3	Corn (grain)	Beans (grain)
Cotegipe	1	Sugar cane	Manioc
	2	Manioc	Corn (grain)
	3	Corn (grain)	Sugar cane
Santa Maria da Vitoria	1	Sugar cane	Soybeans
	2	Soybeans	Herbaceous Cotton (seed)
	3	Corn (grain)	Corn (grain)

Appendix Table 13: Ranking temporary crops by micro region (PIAUÍ)

MATOPIBA - PIAUÍ	#	RANK :: Quantity/year	RANK :: Value/year
Alto Médio Gurguéia	1	Soybeans	Soybeans
	2	Corn (grain)	Corn (grain)
	3	Sugar cane	Rice (paddy)
Alto Parnaíba Piauiense	1	Soybeans	Soybeans
	2	Corn (grain)	Corn (grain)
	3	Rice (paddy)	Rice (paddy)
Bertolínia	1	Soybeans	Soybeans
	2	Corn (grain)	Corn (grain)
	3	Rice (paddy)	Rice (paddy)
Chapadas do Extremo Sul Piauiense	1	Manioc	Beans (grain)
	2	Corn (grain)	Corn (grain)
	3	Sugar cane	Rice (paddy)

Appendix Table 14: Ranking temporary crops by micro region (MARANHÃO)

MATOPIBA - MARANHÃO	#	RANK :: Quantity/year	RANK :: Value/year
Alto Mearim e Grajaú	1	Rice (paddy)	Rice (paddy)
	2	Sugar cane	Corn (grain)
	3	Manioc	Manioc
Baixo Parnaíba Maranhense	1	Manioc	Manioc
	2	Rice (paddy)	Rice (paddy)
	3	Sugar cane	Beans (grain)
Caxias	1	Sugar cane	Rice (paddy)
	2	Rice (paddy)	Sugar cane
	3	Manioc	Corn (grain)
Chapadas das Mangabeiras	1	Sugar cane	Soybeans
	2	Soybeans	Sugar cane
	3	Corn (grain)	Corn (grain)
Chapadas do Alto Itapecuru	1	Rice (paddy)	Rice (paddy)
	2	Sugar cane	Soybeans
	3	Corn (grain)	Corn (grain)
Chapadinha	1	Manioc	Soybeans
	2	Soybeans	Manioc
	3	Rice (paddy)	Rice (paddy)
Codó	1	Sugar cane	Rice (paddy)
	2	Manioc	Sugar cane
	3	Rice (paddy)	Corn (grain)
Coelho Neto	1	Sugar cane	Sugar cane
	2	Rice (paddy)	Rice (paddy)
	3	Manioc	Corn (grain)
Gerais de Balsas	1	Soybeans	Soybeans
	2	Corn (grain)	Herbaceous Cotton (seed)
	3	Herbaceous Cotton (seed)	Corn (grain)
Imperatriz	1	Sugar cane	Rice (paddy)
	2	Corn (grain)	Corn (grain)
	3	Rice (paddy)	Sugar cane
Itapecuru Mirim	1	Manioc	Manioc
	2	Rice (paddy)	Rice (paddy)
	3	Corn (grain)	Corn (grain)
Lençóis Maranhenses	1	Manioc	Manioc
	2	Rice (paddy)	Rice (paddy)
	3	Corn (grain)	Beans (grain)
Médio Mearim	1	Manioc	Rice (paddy)
	2	Rice (paddy)	Manioc
	3	Corn (grain)	Corn (grain)
Porto Franco	1	Sugar cane	Soybeans
	2	Soybeans	Sugar cane
	3	Corn (grain)	Corn (grain)
Presidente Dutra	1	Rice (paddy)	Rice (paddy)
	2	Corn (grain)	Corn (grain)
	3	Manioc	Pineapple

Appendix Table 15: Ranking temporary crops by micro region (TOCANTINS)

MATOPIBA - TOCANTINS	#	RANK :: Quantity/year	RANK :: Value/year
Araguaína	1	Manioc	Soybeans
	2	Soybeans	Manioc
	3	Corn (grain)	Rice (paddy)
Bico do Papagaio	1	Manioc	Rice (paddy)
	2	Corn (grain)	Corn (grain)
	3	Rice (paddy)	Manioc
Dianópolis	1	Sugar cane	Soybeans
	2	Soybeans	Corn (grain)
	3	Corn (grain)	Sugar cane
Gurupi	1	Soybeans	Soybeans
	2	Sugar cane	Rice (paddy)
	3	Manioc	Corn (grain)
Jalapão	1	Soybeans	Soybeans
	2	Corn (grain)	Corn (grain)
	3	Manioc	Rice (paddy)
Miracema do Tocantins	1	Soybeans	Soybeans
	2	Sugar cane	Pineapple
	3	Manioc	Rice (paddy)
Porto Nacional	1	Sugar cane	Soybeans
	2	Soybeans	Sugar cane
	3	Manioc	Rice (paddy)
Rio Formoso	1	Rice (paddy)	Rice (paddy)
	2	Watermelon	Soybeans
	3	Soybeans	Watermelon

Appendix Table 16: Ranking permanent crops by micro region (BAHIA)

BAHIA		RANK Quantity	RANK Value
Barreiras	1	Papaya	Coffee (beans)
	2	Coffee (beans)	Papaya
	3	Banana (bunch)	Banana (bunch)
Bom Jesus da Lapa	1	Banana (bunch)	Banana (bunch)
	2	Papaya	Papaya
	3	Mango	Mango
Cotegipe	1	Banana (bunch)	Banana (bunch)
	2	-	-
	3	-	-
Santa Maria da Vitoria	1	Papaya	Papaya
	2	Mango	Coffee (beans)
	3	Coffee (beans)	Mango

Appendix Table 17: Ranking permanent crops by micro region (PIAUÍ)

PIAUÍ		RANK :: Quantity/year	RANK :: Value/year
Alto Médio Gurguéia	1	Banana (bunch)	Banana (bunch)
	2	Coconut	Cashew nut
	3	Mango	Coconut
Alto Parnaíba Piauiense	1	Banana (bunch)	Cashew nut
	2	Cashew nut	Banana (bunch)
	3	Orange	Orange
Bertolínia	1	Banana (bunch)	Cashew nut
	2	Cashew nut	Banana (bunch)
	3	Orange	Orange
Chapadas do Extremo Sul Piauiense	1	Mango	Banana (bunch)
	2	Banana (bunch)	Mango
	3	Orange	Orange

Appendix Table 18: Ranking permanent crops by micro region (TOCANTINS)

TOCANTINS		RANK :: Quantity/year	RANK :: Value/year
Araguaína	1	Banana (bunch)	Banana (bunch)
	2	Coconut	Coconut
	3	Orange	Orange
Bico do Papagaio	1	Banana (bunch)	Banana (bunch)
	2	-	-
	3	-	-
Dianópolis	1	Banana (bunch)	Banana (bunch)
	2	-	-
	3	-	-
Gurupi	1	Banana (bunch)	Banana (bunch)
	2	Rubber (coagulated latex)	Rubber (coagulated latex)
	3	-	-
Jalapão	1	Banana (bunch)	Banana (bunch)
	2	-	-
	3	-	-
Miracema do Tocantins	1	Banana (bunch)	Banana (bunch)
	2	-	-
	3	-	-
Porto Nacional	1	Banana (bunch)	Banana (bunch)
	2	Coconut	Coconut
	3	-	-
Rio Formoso	1	Banana (bunch)	Banana (bunch)
	2	-	-
	3	-	-

Appendix Table 19: Ranking permanent crops by micro region (MARANHÃO)

MARANHÃO		RANK :: Quantity/year	RANK :: Value/year
Alto Mearim e Grajaú	1	Banana (bunch)	Banana (bunch)
	2	Orange	Cashew nut
	3	Cashew nut	Orange
Baixo Parnaíba Maranhense	1	Banana (bunch)	Banana (bunch)
	2	Cashew nut	Cashew nut
	3	Coconut	Coconut
Caxias	1	Banana (bunch)	Cashew nut
	2	Cashew nut	Banana (bunch)
	3	Mango	Orange
Chapadas das Mangobeiras	1	Banana (bunch)	Banana (bunch)
	2	Orange	Orange
	3	-	-
Chapadas do Alto Itapecuru	1	Banana (bunch)	Banana (bunch)
	2	Orange	Orange
	3	Cashew nut	Cashew nut
Chapadinha	1	Banana (bunch)	Banana (bunch)
	2	Orange	Orange
	3	Coconut	Coconut
Codó	1	Banana (bunch)	Banana (bunch)
	2	Orange	Orange
	3	Coconut	Coconut
Coelho Neto	1	Banana (bunch)	Banana (bunch)
	2	Orange	Orange
	3	Mango	Mango
Gerais de Balsas	1	Banana (bunch)	Banana (bunch)
	2	Orange	Orange
	3	Coconut	Coconut
Imperatriz	1	Banana (bunch)	Banana (bunch)
	2	Rubber (coagulated latex)	Rubber (coagulated latex)
	3	Papaya	Black pepper
Itapecuru Mirim	1	Banana (bunch)	Banana (bunch)
	2	Orange	Orange
	3	-	-
Lençóis Maranhenses	1	Cashew nut	Cashew nut
	2	Coconut	Coconut
	3	Banana (bunch)	Banana (bunch)
Médio Mearim	1	Banana (bunch)	Banana (bunch)
	2	Orange	Orange
	3	Coconut	Coconut
Porto Franco	1	Banana (bunch)	Banana (bunch)
	2	Orange	Orange
	3	-	-
Presidente Dutra	1	Banana (bunch)	Banana (bunch)
	2	Orange	Orange
	3	Cashew nut	Cashew nut

Appendix V: Crops that did not impact TCL between 2001-2014

Appendix Table 20: Municipalities where ranked cotton was not planted

Herbaceous Cotton seed			
Municipality	**State**	**Municipality**	**State**
Angical	BA	Lago Verde	MA
Brejolândia	BA	Lajeado Novo	MA
Canápolis	BA	Lima Campos	MA
Catolândia	BA	Loreto	MA
Cotegipe	BA	Magalhães de Almeida	MA
Cristópolis	BA	Mata Roma	MA
Mansidão	BA	Matões	MA
Santa Maria da Vitória	BA	Matões do Norte	MA
Santa Rita de Cássia	BA	Milagres do Maranhão	MA
Tabocas do Brejo Velho	BA	Miranda do Norte	MA
Açaílândia	MA	Montes Altos	MA
Afonso Cunha	MA	Nina Rodrigues	MA
Água Doce do Maranhão	MA	Nova Colinas	MA
Aldeias Altas	MA	Olho D'Água das Cunhãs	MA
Alto Alegre do Maranhão	MA	Parnarama	MA
Amarante do Maranhão	MA	Paulino Neves	MA
Anapurus	MA	Pedreiras	MA
Araioses	MA	Pio XII	MA
Arame	MA	Pirapemas	MA
Bacabal	MA	Poção de Pedras	MA
Barão de Grajaú	MA	Porto Franco	MA
Barra do Corda	MA	Presidente Dutra	MA
Barreirinhas	MA	Presidente Vargas	MA
Belágua	MA	Primeira Cruz	MA
Benedito Leite	MA	Ribamar Fiquene	MA
Bernardo do Mearim	MA	Sambaíba	MA
Bom Lugar	MA	Santa Filomena do Maranhão	MA
Brejo	MA	Santa Quitéria do Maranhão	MA
Buriti	MA	Santana do Maranhão	MA
Buritirana	MA	Santo Amaro do Maranhão	MA
Campestre do Maranhão	MA	Santo Antônio dos Lopes	MA
Cantanhede	MA	São Benedito do Rio Preto	MA
Carolina	MA	São Bernardo	MA
Caxias	MA	São Domingos do Maranhão	MA
Chapadinha	MA	São Francisco do Brejão	MA
Cidelândia	MA	São Francisco do Maranhão	MA
Coelho Neto	MA	São João do Paraíso	MA
Coroatá	MA	São João do Soter	MA
Davinópolis	MA	São José dos Basílios	MA
Dom Pedro	MA	São Luís Gonzaga do Maranhão	MA
Duque Bacelar	MA	São Mateus do Maranhão	MA
Esperantinópolis	MA	São Pedro da Água Branca	MA
Feira Nova do Maranhão	MA	São Pedro dos Crentes	MA
Fernando Falcão	MA	São Raimundo das Mangabeiras	MA
Formosa da Serra Negra	MA	São Raimundo do Doca Bezerra	MA
Fortaleza dos Nogueiras	MA	São Roberto	MA
Fortuna	MA	Satubinha	MA
Gonçalves Dias	MA	Senador Alexandre Costa	MA
Governador Archer	MA	Senador La Rocque	MA
Governador Edison Lobão	MA	Sítio Novo	MA
Governador Eugênio Barros	MA	Sucupira do Norte	MA
Governador Luiz Rocha	MA	Timon	MA
Graça Aranha	MA	Trizidela do Vale	MA
Humberto de Campos	MA	Tuntum	MA
Igarapé Grande	MA	Tutóia	MA
Imperatriz	MA	Urbano Santos	MA
Itaipava do Grajaú	MA	Vargem Grande	MA
Itapecuru Mirim	MA	Vila Nova dos Martírios	MA
Itinga do Maranhão	MA	Dois Irmãos do Tocantins	TO
Jenipapo dos Vieiras	MA	Guaraí	TO
João Lisboa	MA	Lajeado	TO
Joselândia	MA	Palmas	TO
Lago do Junco	MA	Ponte Alta do Tocantins	TO
Lago dos Rodrigues	MA	**Total**	**127**

Appendix Table 21: Municipalities where ranked watermelon was not planted

Watermelon			
Municipality	State	Municipality	State
Abreulândia	TO	Monte do Carmo	TO
Aguiarnópolis	TO	Monte Santo do Tocantins	TO
Almas	TO	Muricilândia	TO
Aragominas	TO	Natividade	TO
Arapoema	TO	Nova Rosalândia	TO
Arraias	TO	Novo Alegre	TO
Aurora do Tocantins	TO	Novo Jardim	TO
Bandeirantes do Tocantins	TO	Oliveira de Fátima	TO
Bernardo Sayão	TO	Paranã	TO
Brasilândia do Tocantins	TO	Pau D'Arco	TO
Brejinho de Nazaré	TO	Pedro Afonso	TO
Cachoeirinha	TO	Pequizeiro	TO
Carmolândia	TO	Piraquê	TO
Centenário	TO	Ponte Alta do Bom Jesus	TO
Chapada da Natividade	TO	Ponte Alta do Tocantins	TO
Chapada de Areia	TO	Porto Alegre do Tocantins	TO
Colinas do Tocantins	TO	Presidente Kennedy	TO
Combinado	TO	Recursolândia	TO
Conceição do Tocantins	TO	Rio da Conceição	TO
Couto Magalhães	TO	Rio dos Bois	TO
Darcinópolis	TO	Rio Sono	TO
Fátima	TO	Sandolândia	TO
Fortaleza do Tabocão	TO	Santa Maria do Tocantins	TO
Goianorte	TO	Santa Rita do Tocantins	TO
Guaraí	TO	Santa Rosa do Tocantins	TO
Ipueiras	TO	São Félix do Tocantins	TO
Itaporã do Tocantins	TO	São Salvador do Tocantins	TO
Jaú do Tocantins	TO	Silvanópolis	TO
Juarina	TO	Taguatinga	TO
Lajeado	TO	Taipas do Tocantins	TO
Lavandeira	TO	Talismã	TO
Lizarda	TO	Tocantínia	TO
Mateiros	TO	Tocantinópolis	TO
Miracema do Tocantins	TO	Tupirama	TO
Miranorte	TO	**Total**	**69**

Sugar cane			
Municipality	**State**	**Municipality**	**State**
Açailândia	MA	Augustinópolis	TO
Alto Alegre do Maranhão	MA	Axixá do Tocantins	TO
Arame	MA	Bandeirantes do Tocantins	TO
Benedito Leite	MA	Barra do Ouro	TO
Bernardo do Mearim	MA	Barrolândia	TO
Bom Lugar	MA	Bernardo Sayão	TO
Buritirana	MA	Brasilândia do Tocantins	TO
Cantanhede	MA	Buriti do Tocantins	TO
Carolina	MA	Cachoeirinha	TO
Davinópolis	MA	Cariri do Tocantins	TO
Governador Eugênio Barros	MA	Carmolândia	TO
Governador Luiz Rocha	MA	Carrasco Bonito	TO
Humberto de Campos	MA	Centenário	TO
Igarapé Grande	MA	Colinas do Tocantins	TO
Itinga do Maranhão	MA	Couto Magalhães	TO
Jatobá	MA	Crixás do Tocantins	TO
Joselândia	MA	Divinópolis do Tocantins	TO
Lago Verde	MA	Esperantina	TO
Lajeado Novo	MA	Fátima	TO
Magalhães de Almeida	MA	Goianorte	TO
Matões do Norte	MA	Guaraí	TO
Miranda do Norte	MA	Itacajá	TO
Nina Rodrigues	MA	Itaguatins	TO
Nova Iorque	MA	Itapiratins	TO
Olho D'Água das Cunhãs	MA	Itaporã do Tocantins	TO
Paulino Neves	MA	Juarina	TO
Pirapemas	MA	Lajeado	TO
Primeira Cruz	MA	Lizarda	TO
Santa Filomena do Maranhão	MA	Luzinópolis	TO
Santana do Maranhão	MA	Marianópolis do Tocantins	TO
Santo Amaro do Maranhão	MA	Mateiros	TO
São Domingos do Maranhão	MA	Maurilândia do Tocantins	TO
São Francisco do Brejão	MA	Monte Santo do Tocantins	TO
São Luís Gonzaga do Maranhão	MA	Muricilândia	TO
São Pedro da Água Branca	MA	Nova Olinda	TO
São Pedro dos Crentes	MA	Palmeirante	TO
Satubinha	MA	Pau D'Arco	TO
Senador Alexandre Costa	MA	Pequizeiro	TO
Senador La Rocque	MA	Piraquê	TO
Tasso Fragoso	MA	Praia Norte	TO
Tutóia	MA	Presidente Kennedy	TO
Vila Nova dos Martírios	MA	Recursolândia	TO
Bertolínia	PI	Riachinho	TO
Curimatá	PI	Sampaio	TO
Eliseu Martins	PI	Santa Maria do Tocantins	TO
Gilbués	PI	Santa Tereza do Tocantins	TO
Porto Alegre do Piauí	PI	Santa Terezinha do Tocantins	TO
Sebastião Barros	PI	São Bento do Tocantins	TO
Abreulândia	TO	São Félix do Tocantins	TO
Aguiarnópolis	TO	São Miguel do Tocantins	TO
Aliança do Tocantins	TO	São Sebastião do Tocantins	TO
Ananás	TO	Sítio Novo do Tocantins	TO
Aparecida do Rio Negro	TO	Tocantínia	TO
Araguanã	TO	Tocantinópolis	TO
Araguatins	TO	Tupiratins	TO
Arapoema	TO	**Total**	**111**

Appendix Table 22: Municipalities where ranked pineapple was not planted

Pineapple			
Municipality	State	Municipality	State
Afonso Cunha	MA	São José dos Basílios	MA
Água Doce do Maranhão	MA	São Luís Gonzaga do Maranhão	MA
Aldeias Altas	MA	São Mateus do Maranhão	MA
Alto Alegre do Maranhão	MA	São Pedro da Água Branca	MA
Alto Parnaíba	MA	São Pedro dos Crentes	MA
Amarante do Maranhão	MA	São Raimundo das Mangabeiras	MA
Anapurus	MA	São Roberto	MA
Araioses	MA	Satubinha	MA
Arame	MA	Senador Alexandre Costa	MA
Barão de Grajaú	MA	Senador La Rocque	MA
Barreirinhas	MA	Sucupira do Norte	MA
Belágua	MA	Sucupira do Riachão	MA
Benedito Leite	MA	Tasso Fragoso	MA
Bernardo do Mearim	MA	Timbiras	MA
Bom Lugar	MA	Timon	MA
Brejo	MA	Trizidela do Vale	MA
Buriti	MA	Tutóia	MA
Buriti Bravo	MA	Urbano Santos	MA
Buritirana	MA	Vargem Grande	MA
Campestre do Maranhão	MA	Vila Nova dos Martírios	MA
Cantanhede	MA	Aguiarnópolis	TO
Capinzal do Norte	MA	Almas	TO
Carolina	MA	Augustinópolis	TO
Chapadinha	MA	Aurora do Tocantins	TO
Cidelândia	MA	Brasilândia do Tocantins	TO
Coelho Neto	MA	Buriti do Tocantins	TO
Coroatá	MA	Cachoeirinha	TO
Davinópolis	MA	Carmolândia	TO
Duque Bacelar	MA	Carrasco Bonito	TO
Esperantinópolis	MA	Centenário	TO
Feira Nova do Maranhão	MA	Combinado	TO
Formosa da Serra Negra	MA	Conceição do Tocantins	TO
Fortaleza dos Nogueiras	MA	Esperantina	TO
Gonçalves Dias	MA	Fortaleza do Tabocão	TO
Igarapé Grande	MA	Goianorte	TO
Itapecuru Mirim	MA	Guaraí	TO
Itinga do Maranhão	MA	Ipueiras	TO
João Lisboa	MA	Itacajá	TO
Joselândia	MA	Itapiratins	TO
Lagoa do Mato	MA	Itaporã do Tocantins	TO
Lajeado Novo	MA	Jaú do Tocantins	TO
Lima Campos	MA	Juarina	TO
Loreto	MA	Lagoa da Confusão	TO
Magalhães de Almeida	MA	Lagoa do Tocantins	TO
Mata Roma	MA	Lajeado	TO
Matões	MA	Lavandeira	TO
Matões do Norte	MA	Lizarda	TO
Milagres do Maranhão	MA	Luzinópolis	TO
Miranda do Norte	MA	Mateiros	TO
Nina Rodrigues	MA	Nova Olinda	TO
Nova Colinas	MA	Nova Rosalândia	TO
Nova Iorque	MA	Novo Acordo	TO
Olho D'Água das Cunhãs	MA	Novo Alegre	TO
Paraibano	MA	Novo Jardim	TO
Parnarama	MA	Paranã	TO
Passagem Franca	MA	Peixe	TO
Pastos Bons	MA	Pequizeiro	TO
Paulino Neves	MA	Pindorama do Tocantins	TO
Pedreiras	MA	Ponte Alta do Tocantins	TO
Peritoró	MA	Porto Alegre do Tocantins	TO
Pirapemas	MA	Presidente Kennedy	TO
Porto Franco	MA	Recursolândia	TO
Presidente Vargas	MA	Rio da Conceição	TO
Primeira Cruz	MA	Sampaio	TO
Ribamar Fiquene	MA	Sandolândia	TO
Sambaíba	MA	Santa Maria do Tocantins	TO
Santa Filomena do Maranhão	MA	Santa Rita do Tocantins	TO
Santa Quitéria do Maranhão	MA	Santa Rosa do Tocantins	TO
Santana do Maranhão	MA	Santa Terezinha do Tocantins	TO
Santo Amaro do Maranhão	MA	São Félix do Tocantins	TO
Santo Antônio dos Lopes	MA	São Salvador do Tocantins	TO
São Benedito do Rio Preto	MA	São Sebastião do Tocantins	TO
São Bernardo	MA	Taguatinga	TO
São Domingos do Azeitão	MA	Taipas do Tocantins	TO
São Félix de Balsas	MA	Tocantinópolis	TO
São Francisco do Maranhão	MA	Tupirama	TO
São João do Paraíso	MA	Tupiratins	TO
São João do Soter	MA	**Total**	**155**

Appendix Table 23: Municipalities where ranked soybean was not planted

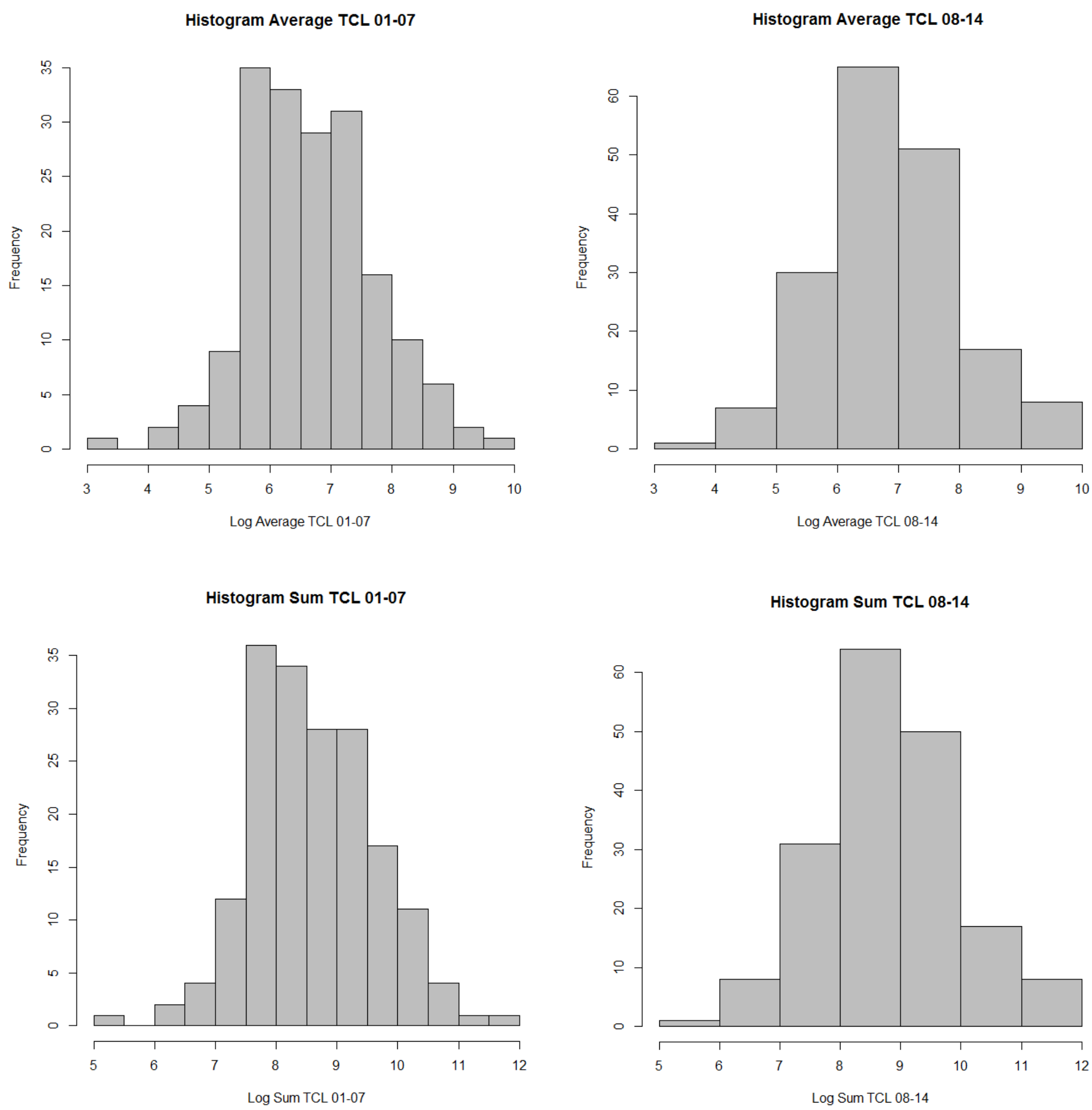
Soybeans			
Municipality	**State**	**Municipality**	**State**
Angical	BA	Santo Amaro do Maranhão	MA
Bom Jesus da Lapa	BA	Santo Antônio dos Lopes	MA
Brejolândia	BA	São Bernardo	MA
Canápolis	BA	São Domingos do Maranhão	MA
Carinhanha	BA	São Francisco do Brejão	MA
Catolândia	BA	São João do Paraíso	MA
Coribe	BA	São João do Soter	MA
Cotegipe	BA	São José dos Basílios	MA
Feira da Mata	BA	São Luís Gonzaga do Maranhão	MA
Mansidão	BA	São Mateus do Maranhão	MA
Paratinga	BA	São Pedro da Água Branca	MA
Santa Maria da Vitória	BA	São Raimundo do Doca Bezerra	MA
Santa Rita de Cássia	BA	São Roberto	MA
Serra Dourada	BA	Satubinha	MA
Tabocas do Brejo Velho	BA	Senador La Rocque	MA
Água Doce do Maranhão	MA	Sítio Novo	MA
Aldeias Altas	MA	Sucupira do Riachão	MA
Alto Alegre do Maranhão	MA	Timbiras	MA
Araioses	MA	Timon	MA
Arame	MA	Trizidela do Vale	MA
Bacabal	MA	Tuntum	MA
Barão de Grajaú	MA	Tutóia	MA
Barreirinhas	MA	Vargem Grande	MA
Belágua	MA	Avelino Lopes	PI
Bernardo do Mearim	MA	Barreiras do Piauí	PI
Bom Lugar	MA	Bertolínia	PI
Buriti Bravo	MA	Colônia do Gurguéia	PI
Buritirana	MA	Cristino Castro	PI
Campestre do Maranhão	MA	Curimatá	PI
Cantanhede	MA	Eliseu Martins	PI
Capinzal do Norte	MA	Júlio Borges	PI
Codó	MA	Marcos Parente	PI
Coelho Neto	MA	Morro Cabeça no Tempo	PI
Coroatá	MA	Riacho Frio	PI
Dom Pedro	MA	Santa Luz	PI
Duque Bacelar	MA	Aguiarnópolis	TO
Esperantinópolis	MA	Ananás	TO
Gonçalves Dias	MA	Angico	TO
Governador Archer	MA	Aragominas	TO
Governador Edison Lobão	MA	Araguanã	TO
Governador Luiz Rocha	MA	Araguatins	TO
Graça Aranha	MA	Arraias	TO
Humberto de Campos	MA	Augustinópolis	TO
Igarapé Grande	MA	Aurora do Tocantins	TO
Imperatriz	MA	Axixá do Tocantins	TO
Itaipava do Grajaú	MA	Bernardo Sayão	TO
Itapecuru Mirim	MA	Buriti do Tocantins	TO
Jatobá	MA	Cachoeirinha	TO
Jenipapo dos Vieiras	MA	Carmolândia	TO
João Lisboa	MA	Carrasco Bonito	TO
Joselândia	MA	Chapada de Areia	TO
Lago do Junco	MA	Combinado	TO
Lago dos Rodrigues	MA	Conceição do Tocantins	TO
Lago Verde	MA	Esperantina	TO
Lagoa do Mato	MA	Filadélfia	TO
Lajeado Novo	MA	Itaguatins	TO
Lima Campos	MA	Itaporã do Tocantins	TO
Matões	MA	Juarina	TO
Matões do Norte	MA	Lajeado	TO
Miranda do Norte	MA	Luzinópolis	TO
Montes Altos	MA	Maurilândia do Tocantins	TO
Nina Rodrigues	MA	Muricilândia	TO
Nova Iorque	MA	Nazaré	TO
Olho D'Água das Cunhãs	MA	Novo Alegre	TO
Paraibano	MA	Pindorama do Tocantins	TO
Paulino Neves	MA	Praia Norte	TO
Pedreiras	MA	Riachinho	TO
Peritoró	MA	Sampaio	TO
Pio XII	MA	Santa Tereza do Tocantins	TO
Pirapemas	MA	Santa Terezinha do Tocantins	TO
Poção de Pedras	MA	São Félix do Tocantins	TO
Presidente Dutra	MA	São Miguel do Tocantins	TO
Presidente Vargas	MA	São Salvador do Tocantins	TO
Primeira Cruz	MA	Sítio Novo do Tocantins	TO
Ribamar Fiquene	MA	Taipas do Tocantins	TO
Santa Filomena do Maranhão	MA	Tocantinópolis	TO
Santana do Maranhão	MA	Xambioá	TO

Appendix Table 24: Municipalities where ranked rice paddy was not planted

Rice Paddy	
Municipality	**State**
Água Doce do Maranhão	MA

Appendix VI: Additional information on TCL before and after the Soybeans *Moratorium*

Appendix Figure 10: Frequency distribution after log-transformation. The "average" and "sum" of TCL data series for the two periods are normally distributed after log-transformation



10

Appendix VII: Spreadsheets generated as part of the research (also saved in the CD-ROM enclosed to the dissertation)

Appendix table 25: Spreadsheets used

File name	Description/Comments	Source of data
"area municipalities IBGE.xls"	Data on municipality area from GFW online database was corrected based on official area sourced from IBGE	**IBGE** ftp://geoftp.ibge.gov.br/organizacao_do_territorio/estrutura_territorial/areas_territoriais/2015/AR_BR_RG_UF_MUN_2015.xls
"forestry-SIDRA-IBGE.xls"	Data on forest plantations (Pine and Eucalyptus) in MATOPIBA as of 31/12/2014	**SIDRA/IBGE** http://www.sidra.ibge.gov.br/bda/tabela/listabl.asp?c=5930&z=p&o=30
"MATOPIBA - Summary TCL.xls"	Yearly Tree Cover Loss (TCL) data downloaded for 334 municipalities in MATOPIBA for the period 2001-2014, canopy density > 30%. Spreadsheet presents annual and total TCL for micro regions for the period, summary, graphs, validation of TCL data with deforestation official data and how municipalities with inconsistencies in names OR which were not found in the online database were treated	**GFW / Hansen / UMD / Google / USGS / NASA** http://commodities.globalforestwatch.org/#v=map&x=-51.42&y=-9.63&l=4&lyrs=tcc%2Closs&wiz=open
"municipios_da_amazonia_legal_2014.xls"	Municipalities in the "Legal Amazon", as per official IBGE data	**IBGE** ftp://geoftp.ibge.gov.br/cartas_e_mapas/mapas_regionais/sociedade_e_economia/amazonia_legal/lista_de_municipios_da_amazonia_legal_2014.xls
"MATOPIBA - Summary Agriculture.xls"	Official data for micro regions in MATOPIBA (planted area, quantity produced, value of production and yields) on temporary and permanent crops between 2001-2014. Livestock (bovines = number of effective herds) from 2001-2014. Selection and ranking of crops, summary per micro region, summary for temporary and permanent crops in MATOPIBA in the period.	**SIDRA/IBGE** temporary crops: http://www.sidra.ibge.gov.br/bda/tabela/listabl.asp?c=1612&z=p&o=29 permanent crops: http://www.sidra.ibge.gov.br/bda/tabela/listabl.asp?c=1613&z=p&o=29 livestock (bovines): http://www.sidra.ibge.gov.br/bda/tabela/listabl.asp?c=3939&z=p&o=28
"SIDRA_IBGE_PMA_temporary crops_municipalitiesMATOPIBA.xls"	Official data for municipalities in MATOPIBA (planted area, quantity produced, value of production and yields) on temporary crops between 2001 and 2014. Crops downloaded for each state are based on the ranking /selection of crops at the micro region level. The spreadsheet also presents some data analysis (including the assessment of soybeans production for RQ 2) and crops that were part of state ranking but were not produced in certain municipalities (therefore not affecting TCL in those municipalities between 2001-2014)	**SIDRA/IBGE** temporary crops: http://www.sidra.ibge.gov.br/bda/tabela/listabl.asp?c=1612&z=p&o=29
"demographics.xls"	Official data on GDP/capita (2011), population (2010 Census), HDI (2010) and illiteracy rate (2010 Census) for municipalities	**IBGE:** GDP/capita: ftp://ftp.ibge.gov.br/Pib_Municipios/2011/xls/Pib_Municipal_2007_2011_xls.zip population: ftp://ftp.ibge.gov.br/Censos/Censo_Demografico_2010/indicadores_sociais_municipais/Brasil.zip illiteracy rate: http://www.ibge.gov.br/home/estatistica/populacao/censo2010/indicadores_sociais_municipais/default_indicadores_sociais_municipais.shtm **ATLAS BRASIL:** http://www.atlasbrasil.org.br/2013/data/rawData/atlas2013_dadosbrutos_pt.xlsx
"TCL_tempcrops_municipalities_sum_sqrt_log.csv"	Spreadsheet prepared with data downloaded from different sources, to be used in R software for plots, boxplots and regression analysis. 334 municipalities. TCL value refers to the sum in the period 2001-2014. Area planted is the largest area planted for a given crop in the period 2001-2014. Columns are: Municipality, Microregion, state, Legal Amazon, Area, TCL, Area_log, TCL_log, Area_sqrt, TCL_sqrt, Ratio TCL, Cat_Area, Cat_TCL, settlements, nr_settl_families, settl_families_sqrt, population 2010, population 2010_sqrt, GDBP_per_capita 2011, GDBP_per_capita_sqrt 2011, illiteracy rate_2010, HDI 2010, Bovines_avg, Bovines_avg_sqrt, Bovines_avg_log, Beans_a, Corn_a, Manioc_a, Sugarcane_a, Soybeans_a, Rice paddy_a, Herbaceous cotton_a, pineapple_a, watermelon_a and log transformation of these areas	All sections above
"TCL_municipalities_twoperiods.csv"	Spreadsheet prepared to be used in R software to assess the TCL in two periods, before and after the Soybeans Moratorium. 179 municipalities, columns are the "min", max", "avg", "median" and "sum" of TCL in each municipality, considering two periods, 2001-2007 and 2008-2014	All sections above