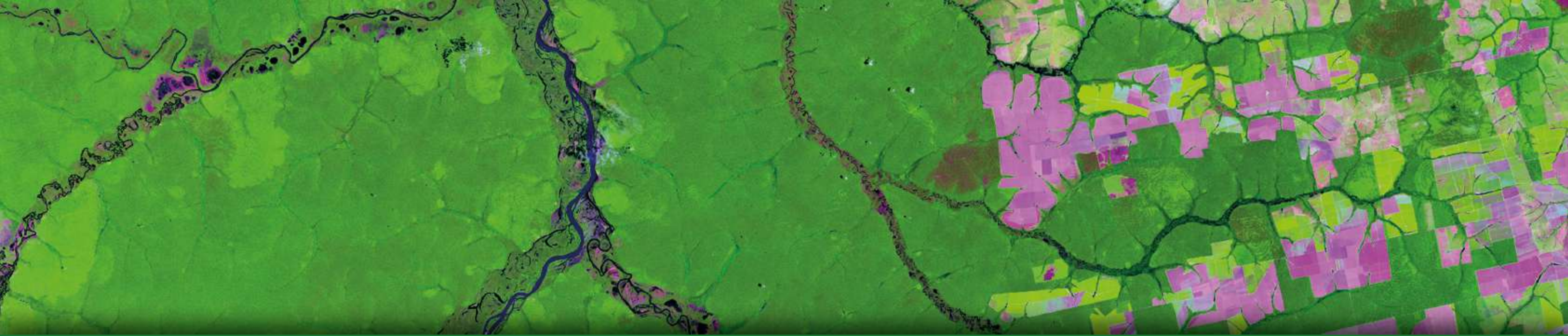

GEOSPATIAL ANALYSIS OF

SOY EXPANSION

ASSOCIATED LAND USE AND LAND COVER CHANGE, AND AGRICULTURAL SUITABILITY IN THE BRAZILIAN

AMAZON BIOME

2000 2017

Funding

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

agrosatélite

GEOSPATIAL ANALYSIS OF SOY EXPANSION, ASSOCIATED LAND USE AND LAND COVER CHANGE, AND AGRICULTURAL SUITABILITY IN THE BRAZILIAN AMAZON BIOME – 2000 TO 2017

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Geospatial analysis of soy expansion, associated land use and land cover change, and agricultural suitability in the Brazilian Amazon Biome: 2000 to 2017

Rudorff, B.; Risso, J. et al., 2018 - Florianópolis, Santa Catarina, Brazil, 2018.

ISBN: 978-85-54011-01-7

Funding Acknowledgement: This work was supported with funding from the Gibbs Land Use and Environment Lab (www.gibbs-lab.com) of the University of Wisconsin-Madison, USA.

CONTENTS

EXECUTIVE SUMMARY

The Amazon Biome covers an area of 4.18 million square kilometers corresponding to 50% of the Brazilian territory. Major deforestation started in the 1970s due to government incentives to integrate and develop this vast region of Brazil. At this time cattle raising was the most relevant activity while soy began to be relevant only in the early 2000s.

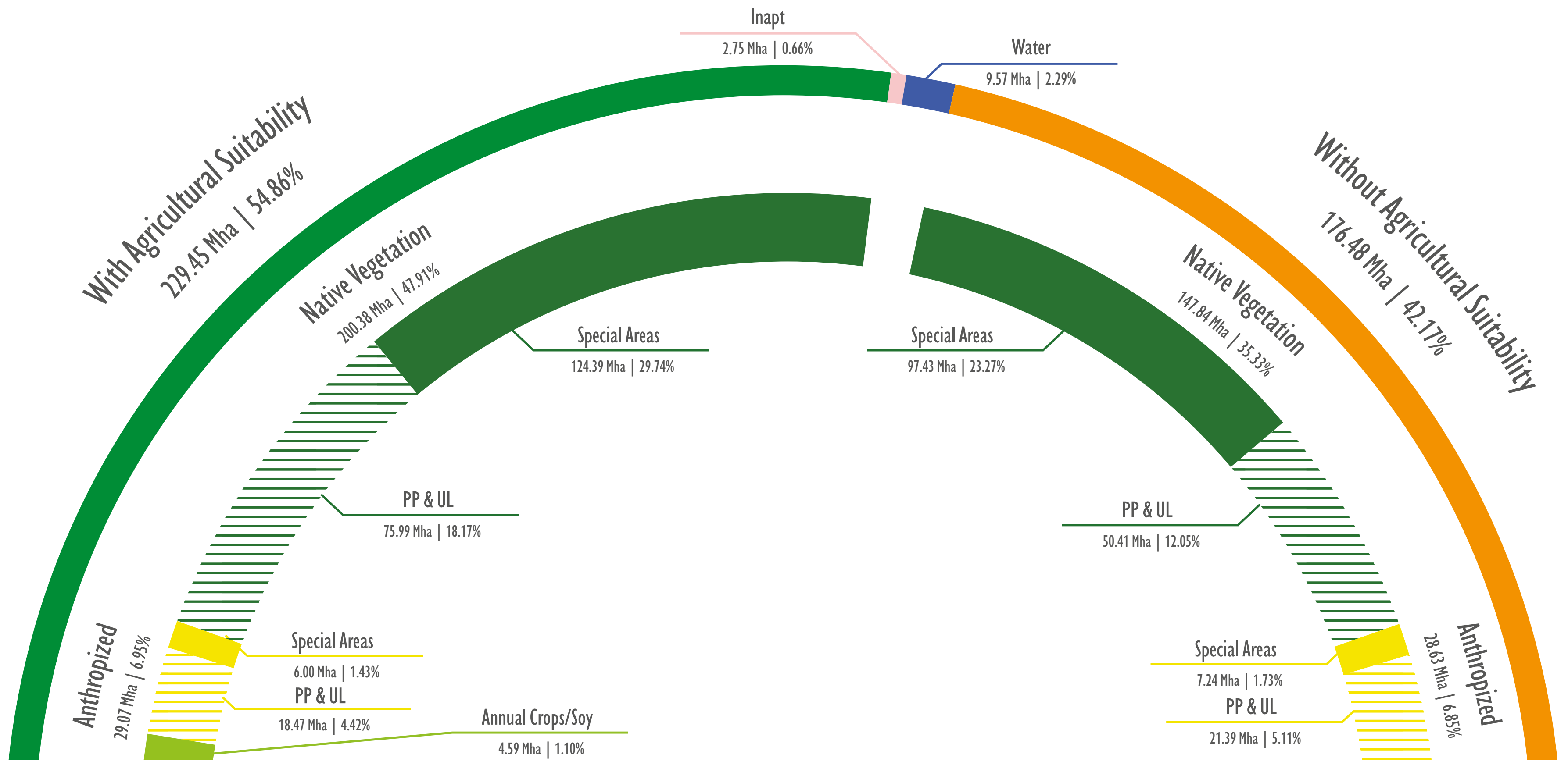
Since then, soy area went from 0.34 million hectares in crop year 2000/01 to 4.48 million hectares in 2016/17 a 13-fold increase at an average expansion rate of 260 thousand hectares per year. Current soy area of the Biome represents 13.4% of total Brazilian planted soy. From 2000 to 2006 the annual conversion rate of native vegetation (primary or secondary forest and native savanna) to soy was as high as 89 thousand hectares while from 2006 to 2014 it went down to 40 thousand hectares with a total conversion of 853 thousand hectares during the entire period 2000-2014 corresponding to 23% of the soy expansion. The remaining 2.82 million hectares of expansion (77%) was mainly on pasture. According to the Soy Moratorium the annual average conversion rate of primary native forest was 6 thousand hectares since the beginning of the Moratorium in July 2008 up to crop year 2016/17. This indicates that in recent years a significant portion of the soy expansion took place on secondary forest and non-forested native vegetation, not forgetting to mention the land use and land cover change associated to the 272 thousand hectares of soy in crop year 2016/17 that is inside a few settlements and not considered in the Soy Moratorium.

Agricultural suitability for soy (not restricted for soil, climate, slope and altitude) is favorable in more than half (54.9%; 229.45 million hectares) of the Amazon Biome. A considerable portion of 124.39 million hectares with agricultural suitability is covered with native vegetation inside "Special Areas" (Conservation Units, Settlements, Indigenous Lands and Quilombolas) being less vulnerable for conversion to soy. However, the 75.99 million hectares with agricultural suitability inside "Private Properties & Undesignated Land" are much more vulnerable to be converted to soy, particularly the areas in surplus of the Legal Reserve. Interesting to notice is that 18.47 million hectares with agricultural suitability are anthropized and mainly occupied with pasture. Using only 25% of this pasture land stock the current soy area could double with zero deforestation in the next two decades at the historical soy expansion rate of 260 thousand hectares per year.

The present study provides an enormous amount of detailed information from local to regional scale on agricultural suitability associated with current land use and land cover. It is recommended to further investigate the agricultural suitability and its associated land uses and land covers inside the private properties of the Amazon Biome.

AMAZON BIOME

LAND USE AND LAND COVER WITH & WITHOUT AGRICULTURAL SUITABILITY



The first level of the figure represents the areas "With Agricultural Suitability" and "Without Agricultural Suitability" for soy including the areas covered with "Water" and those that are "Inapt" (e.g. urban areas, rocky outcrops). The second level divides the Agricultural Suitability into two groups: "Anthropized" (mainly pasture), and "Native Vegetation" (primary forest, secondary forest and savanna). Each group is further divided into "Annual Crops" (mainly soy), "Special Areas" (Indigenous Lands, Conservation Units, Quilombola and Settlements), and "Private Properties & Undesignated Land". Attention should be given to the areas "With Agricultural Suitability" for soy that are "Anthropized" inside "Private Properties & Undesignated Land" once these are areas with opportunity for soy expansion free of deforestation. On the other hand, areas "With Agricultural Suitability" for soy that are with "Native Vegetation" inside "Private Properties & Undesignated Land" might be converted to soy, especially if in surplus of the Legal Reserve.

1. INTRODUCTION

The Amazon region spreads out over nine countries in South America, covering an area of 6.9 million square kilometres, of which 60% is in Brazil where it is known as Amazon Biome. A large part of this region started to be accessible only in the 1970s, when major deforestation was promoted by government incentives to integrate and develop this vast region of Brazil. At this time cattle raising was the most relevant activity, especially in the region bordering the Cerrado Biome known as "arc of deforestation". However, it was only at the start of this century that large-scale agriculture became relevant in the Amazon Biome due to its favourable climate and soil, as well as to the rapid development of Brazil's tropical agriculture.

It is estimated that the Amazon Biome has already lost 18% of its original forest cover, opening opportunities for agricultural activities where soy has a predominant role. To restrain the accelerated deforestation process in the Biome, preservationist steps were taken, such as establishing environmental protection areas, maintaining 80% of the native vegetation of the rural properties as Legal Reserve, restricting soy planting and pasture formation in areas deforested after 2008, implementing the PPCDAm (Action Plan for the Prevention and Control of Deforestation in the Legal Amazon), among others. These steps have been efficient in reducing annual deforestation rates to a mean of 5,260 km2 from 2009 to 2015. Since than, gradual increases have been observed reaching an annual rate of 10,666 km2 in 2019. Reconciling environmental preservation actions with a growing pressure to increase food production and economic development requires solid knowledge of the current spatial distribution of land use and land cover, and of the agricultural suitability of the land stocks, especially those that are already anthropized in order to halt the opening of new areas in the Amazon Biome.

The objective of this innovative study carried out by Agrosatélite, in partnership with the University of Wisconsin's Gibbs Land Use and Environment Lab (GLUE), with financing from the Gordon and Betty Moore Foundation, is to provide a detailed diagnostic of the dynamics of land use and land cover changes associated with the expansion of the large-scale agricultural grain production in the Amazon Biome since 2000. To do this, approximately 6,000 satellite images were analysed, and all the changes in land use and land cover caused by the expansion of soy, corn and cotton crops between 2000 and 2017 were identified and mapped, indicating where and when the expansion occurred, and whether the expansion was through land use intensification of previously opened areas or through the opening of new areas causing additional deforestation of native vegetation. The study also evaluated the amount of land stocks with agricultural suitability, both in previously opened areas, which should be prioritized for agricultural expansion, and in areas covered with native vegetation. In this way, relevant information was generated that can be used as a reference in analyses related to public policies, regulatory marks and sustainable development of the region.

2. MATERIALS AND METHODS

2.1 Study Area

The Amazon Biome comprises an area of 4,196,943 km2, corresponding to 49.3% of Brazil's territory. The states of Acre, Amapá, Amazonas, Pará and Roraima lie entirely within the Biome, along with almost all Rondônia state (98.8%) and part of the states of Mato Grosso (54%), Maranhão (34%) and Tocantins (9%). The study area spans the entire Biome, focused on the regions of large-scale agricultural production where the annual crops of interest and its associated land use changes were mapped based on remote sensing satellite images. These regions were defined with the support of information from IBGE (Brazilian Geographic & Statistical Institute) and the grid of the Worldwide Reference System of the Landsat scenes. A total of 81 Landsat scenes encompassed not only the municipalities indicated by IBGE as being soy, corn and cotton producers, but also the surrounding areas to ensure that all crops of interest were within the selected regions. In total, the mapping covered 201 municipalities, either totally or partially. Figure 1 illustrates the area covered by the 81 Landsat scenes where the annual crops and the corresponding land use changes were mapped, since outside this area no large-scale agricultural production is currently being practiced. The agricultural suitability evaluation comprised the entire Amazon Biome, irrespective of the presence of annual crops.

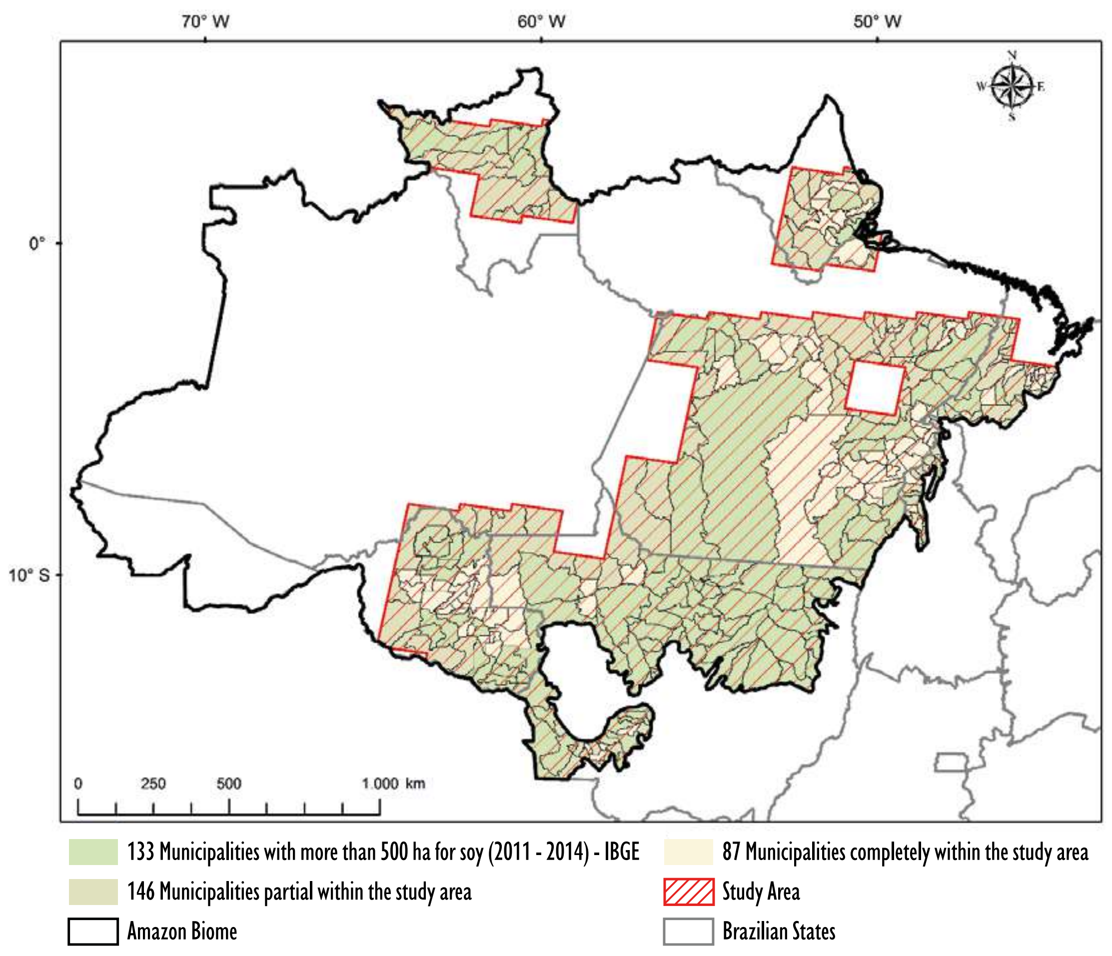


Figure 1 – Amazon Biome, highlighting the area covered by the 81 Landsat scenes to map the annual crops (soy, corn and cotton) and its associated land use and land cover change.

2.2 Mapping Annual Crops of First Harvest

It is a common agricultural practice to have more than one annual (seasonal) crop per crop year in the Amazon region due to favourable climate conditions. In the present study the annual crop mapping refers to the first-crop or first-harvest of either soy, corn or cotton that were mapped for the 2000/01, 2006/07, 2009/10, 2014/15 and 2016/17 crop years, using approximately 6,000 images acquired from different remote sensing satellites, as shown in Table 1. These images were submitted to a detailed visual interpretation, complemented by the analysis of MODIS time series, available on the SatVeg web application of EMBRAPA (Brazilian Agricultural Research Corporation; www.satveg.cnptia.embrapa.br), to take advantage of the best spatial, spectral and temporal resolutions of each satellite/sensor system to accurately identify and map the soy, corn and cotton crops in each of the evaluated crop years.

The large number of images used for mapping the annual crops is necessary for three main reasons:

1. The effective part of each image, free of clouds and shadows of clouds, used to identify and map annual crops is often restricted, especially in the rainy season that coincides with the crops' growth and development periods.

Table 1 – Number of images used from each satellite/sensor to map annual crops in each crop year, and the corresponding changes in land use and land cover change.

SATELLITE	SENSOR	BANDS (RGB)	CROP YEAR					TOTAL
			2000/01	2006/07	2009/10	2014/15	2016/17	
Landsat-5	TM	4-5-3	355	517	452	-	-	1,324
Landsat-7	ETM+	4-5-3	674	512	513	384	416	2,499
Landsat-8	OLI	5-6-4	-	-	-	630	616	1,246
Sentinel-2A	MSI	8A-11-4	-	-	-	-	800	800
Resourcesat-2	LISS	4-5-3	-	-	10	2	-	12
	AWIFS	4-5-3	-	-	43	23	-	66
TOTAL			1,029	1,029	1,018	1,039	1,832	5,947

The Landsat and Sentinel satellites images are available on https://glovis.usgs.gov.
The Resourcesat-2 satellite images are available on http://www.dgi.inpe.br/CDSR.

2. Annual crops have a very short growing cycle, for instance some soy varieties have a cycle of less than 100 days and can only be correctly identified on images taken during a relatively short period, from the growth stage where the crop significantly covers the land until beginning of plant senescence. Thus, any image minimally free of clouds during the crop's growth and development period becomes useful.

3. Annual crops are planted following agricultural calendars suitable for each region, with a temporal sowing window that generally lasts for two months. In this way, the selection of images in each region needs to consider the entire crop sowing window.

On countless occasions, crop identification uses a combination of both the trajectory of the EVI/MODIS time series and the Landsat-type images, as exemplified

in the next few figures allowing to perform a high-quality map of annual crops. Thus, operating with a constellation of satellites with multiple sensors increases the probability of getting cloud free or partially cloud free images and, therefore, making this type of study technologically possible.

Furthermore, the interpreter's knowledge of the growth and development dynamics of agricultural crops, in addition to the corresponding regional agricultural calendars in the Amazon's main agricultural production zone, are relevant aspects to be considered to ensure that the extracted information from the images is accurate enough to reflect the reality.

To exemplify how agricultural crops are interpreted from satellite images, Figures 2 to 4 show the identification and mapping of soy, corn and cotton crops, respectively. It should be noted that identification of the type of crop in general requires at least three satellite images per season, as well as the support from the EVI/MODIS[1] time series. For example, Figure 2 illustrates the soy plots identified in Landsat images in the municipality of Tabaporã in Mato Grosso state. Figure 2a shows a false-colour image from 5th November 2016, when the crop had recently been sowed and is shown in green due to the prevalence of bare soil. In contrast, in the image from 7th January 2017 (Figure 2b) when the crop is vibrant and fully covers the soil's surface, it appears in yellow in this false-colour composition which is typical of soy. Figure 2c presents an image from 17th February 2017 soon after crop harvest when the soil is mainly bare and covered with some straw, indicating that the crop cycle was very short. This crop cycle dynamic can also be seen in Figure 2d, through the temporal trajectory of the vegetation index depicted in the EVI/MODIS time series.

Figure 3 shows a corn field in the municipality of Santa Luzia in Maranhão state, identified through satellite images acquired by Sentinel and Landsat. In this region, the agricultural calendar starts later, and the corn was probably sown between the end of December 2016 and the beginning of January 2017 because there is little crop development in the image taken on 28th January 2017, which predominantly shows bare soil (Figure 3a). In the image taken on 9th March 2017, shown in Figure 3b, the corn crop covers the soil so that the green leaves of the corn crop are prevalent, showing up as orange in this false-colour image. Later, on 22nd June 2017 (Figure 3c), the corn crop was recently harvested, and the bare soil shows up again. In the lower left portion of Figure 3b one can also notice the presence of some soy fields that appear in yellow in this false-colour composite. The difference in colouration between soy (yellow) and corn (orange) in this false-colour composite image is due to the architecture of the plants which tend to have erect leaves for corn and planiform leaves for soy. Another subtle difference between these two crops is the crop cycle duration which is slightly longer for corn (Figure 3d) when compared to soy (Figure 2d).

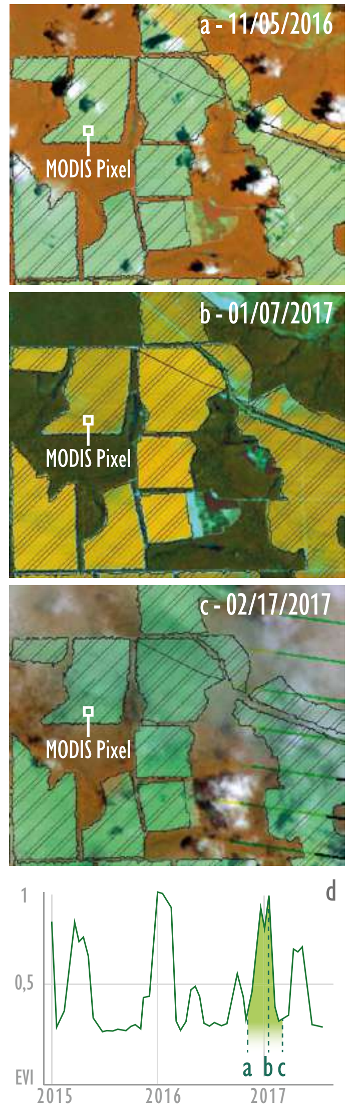


Figure 2 – Example of the identification and mapping of soy based on satellite images in the municipality of Tabaporã in Mato Grosso state: a) OLI/Landsat-8 image from 5th November 2016, showing a prevalence of bare soil in an intense agricultural production region; b) OLI/Landsat-8 image from 7th January 2017, showing the presence of fully developed soy crop in yellow; c) ETM/Landsat-7 image from 17th February 2017 soon after soy harvest; and d) temporal trajectory of the vegetation index for soy crops, shown in the SATVeg EVI/MODIS time series.

1 The EVI (Enhanced Vegetation Index) of the MODIS sensor is a vegetation index proposed by Huete et al. (1997) and is widely used in studies analyzing the dynamics of land use, especially those associated with agriculture. It has some advantages over the NDVI (Normalized Difference Vegetation Index) as it uses some correction factors for atmospheric and soil effects. Furthermore, it saturates less in conditions of high biomass (Risso et al., 2012).

Figure 4 highlights cotton crop fields in the municipality of Paranatinga in Mato Grosso state that were identified through Landsat satellite images. On 9th January 2017, bare soil is prevalent, indicating that the crop is at an initial growth stage (Figure 4a). In the 15th April 2017 image, the crop is fully developed and covering the ground (Figure 4b). By 18th June 2017, the cotton had already been harvested (Figure 4c). As can be seen, the colouration of the cotton crop in the false-colour images is very similar to soy. In this case, they can be differentiated by the duration of the growth cycle which, for cotton, ranges from 150 to 180 days and, for soy, from 90 to 130 days. The temporal trajectory of the vegetation index in the EVI/MODIS time series is essential to differentiate between cotton and soy, as shown for crop year 2016/17 in Figures 4d and 2d, respectively.

Figure 3 – Example of the identification and mapping of corn crop in the municipality of Santa Luzia in Maranhão state from Sentinel and Landsat satellite images: a) MSI/Sentinel-2A image from 28th January 2017 during the initial growth cycle of corn; b) MSI/Sentinel-2A image from 9th March 2017, showing the corn field in full development; c) OLI/Landsat-8 image from 22nd June 2017 soon after the corn harvest; and d) temporal trajectory of the vegetation index for corn crop depicted in the SATVeg EVI/MODIS time series.

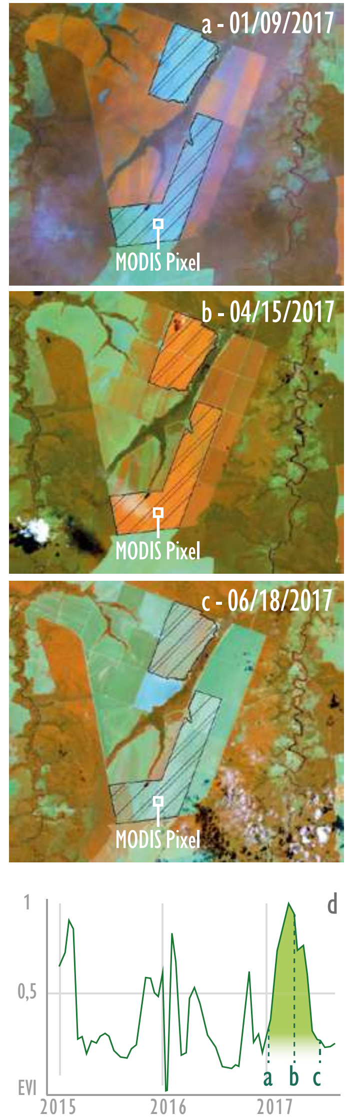


Figure 4 – Example of the identification and mapping of cotton in the municipality of Paranatinga in Mato Grosso state from Landsat satellite images: a) OLI/Landsat-8 image from 9th January 2017, showing cotton fields in its initial growth stage; b) OLI/Landsat-8 image from 15th April 2017, identifying fully developed cotton fields; c) OLI/Landsat-8 image from 18th June 2017, when the cotton fields had already been harvested; and d) temporal trajectory of the vegetation index for cotton crop, shown in the SATVeg EVI/MODIS time series.

2.2.1 Image Classification Procedure

The examples presented above illustrate the careful and detailed procedure carried out by the interpreters to classify the targets of interest. There are several alternatives to carry out a thematic classification of satellite images with each having advantages and disadvantages in terms of time consuming, subjectivity, cost, quality etc. In the present study we prioritized quality. Therefore, visual interpretation is the best method to assure highest mapping quality - if performed by a well-trained team of interpreters. Agrosatélite's team has a long history of producing high quality maps based on visual interpretation such as: the yearly sugarcane mapping in Brazil (Rudorff et al., 2010) form 2003 to date; the annual crops mapping in the Cerrado Biome from 2000 to 2016 (Rudorff et al. 2015 and 2018; https://agrosatelite.com.br/en/cases/#expansao-agricola); the update of the land use and land cover change (LULCC) maps for the entire Brazilian territory from 2010 to 2016 for Brazil's inventory of greenhouse gas emissions due to LULCC; the monitoring of soy plantations in recent deforestations in the Amazon Biome within the context of the Soy Moratorium initiative carried out every year since 2009 (Rudorff et al. 2011; http://www.abiove.org.br), among others (https://agrosatelite.com.br/en/cases/#expansao-agricola).

The visual interpretation procedure is strongly supported by computational facilities. It starts with the download of Landsat and Sentinel images at https://glovis.usgs.gov or Resourcesat-2 images from INPE's website at http://www.dgi.inpe.br/CDSR. Crop year 2014/15 was selected as baseline map for the other four crop maps (2000/01, 2006/07, 2009/10 and 2016/17). To produce the baseline map, cloud free Landsat image from year 2015 were segmented using the algorithm "Feature Extraction Workflow" available in the ENVI FX software that was developed based on a patented technology invented by Jin (2012). Segmentation is the process of partitioning an image into objects by grouping neighbouring pixels with common values. The objects in the image ideally correspond to real-world features (e.g. crop field) that have its boundaries defined by the segmentation process which in turn reduces the work of the analysts by avoiding him/her to draw "by hand" the features that were correctly delineated though an automated process. The "Scale" and "Merge" levels were selected at scene-by-scene considering regional agricultural characteristics to perform a more efficient segmentation. The Crop Enhancement Index (CEI, Rizzi at al., 2010), slope and altitude were used as ancillary data to pre-classify the segments. The segments were then exported to shapefile format and visually analyzed and classified in a GIS.

The visual classification of soy, corn and cotton is based on a multiple set of satellite images that cover the crops growing cycles according to the planting windows within each of the analysed regions. The associated land use and land cover change was evaluated based on images acquired at the beginning of each analysed period as described in more details in the next section. In a first stage the image classification is carried out by a team of interpreters whose results are reviewed in a second stage, by one or two highly experienced interpreters, to correct casual miss classifications. The classification procedure began with the mapping of crop year 2014/15 and moved both backwards up to the first mapping year (2000/01) and to the most recent one (2016/17). It is worth mentioning that every year Agrosatélite participates in the field campaigns organized by Agroconsult (Rally da Safra www.rallydasafra.com.br and Rally da Pecuária www.rallydapecuaria.com.br) to acquire a large field sample data set that is useful to exercise the interpreters in getting confidence in the classification decision process of annual crops and pastures.

The quality evaluation of the soybean mapping in the Amazon biome for crop year 2016/17 was performed using a stratified, two-stage cluster sampling design, also known as area sampling frame (Song et al., 2017). Two strata were considered in the first sampling stage: soybean and no-soybean. In the soybean stratum eight blocks of 20 x 20 km were randomly selected. In the second sampling stage 20 random points were allocated in each of the eight blocks (160 points) that were field visited to verify if the points were with or without soy. The field data were acquired by the group of Dr. Mathew Hansen from the University of Maryland at College Park, Maryland, USA. Dr. Hansen's group also performed the statistical analyses.

2.3 Land Use and Land Cover Change Mapping

The land use and land cover change (LULCC) mapping refer to the transitions observed in the Amazon Biome in response to the expansion of annual crops in the following periods: 2000/01 to 2006/07; 2006/07 to 2009/10; and 2009/10 to 2014/15. The LULCC evaluation consisted in identifying the land use and land cover at the beginning of each analysed period for those areas that were mapped as annual crops at the end of each period. For example, to evaluate the period 2009/10 to 2014/15, the annual crop fields in 2014/15 (end of the period) had its land use and land cover evaluated through images from 2009/10 (beginning of the period).

In the Amazon, it is common practice to introduce grassland into deforested areas with the initial purpose of developing cattle ranching that might change later to annual crops. However, if the pastures are not well managed, they will become degraded with the appearance of invasive plants, forming areas of dirty pasture or of native vegetation regeneration with pasture, though they are still used for cattle ranching. To better understand the LULCC from pasture to agriculture, the pastures were broken up in three types: clean pastures, dirty pastures and native vegetation regeneration with pastures. The other LULCC classes evaluated were: native vegetation, cleared (areas recently cleared of native vegetation), other agriculture (rice, beans, fallow, etc.), sugarcane and planted forest.

The land use and land cover changes were mapped through careful visual interpretation of Landsat-type images (Table 1), as well as extensive use of the EVI/MODIS time series that provide highly relevant information since it is similar to a "movie" that indirectly depicts the variation in biomass over time as a function of different land uses and vegetation covers. Following are some examples of the identification and mapping of the main classes of land use and land cover converted to annual crops. These examples illustrate that a combination of the adequate use of satellite images, field knowledge and experience in photointerpretation are key elements to obtain high quality maps.

Figure 5 shows an area mapped as an annual crop in the 2014/15 crop year (polygon with a black outline in Figure 5b), which expanded into a "clean pasture" area in 2009/10, as shown in the Landsat image of 12th September 2010 (Figure 5a). Clean pasture areas are well managed, with well-defined pickets, low presence of invasive grassy plants and the absence of individual trees. The EVI/MODIS time series for this area shows that it remained as pasture up to 2013 and then was converted to annual crop in 2014/15 (Figure 5c).

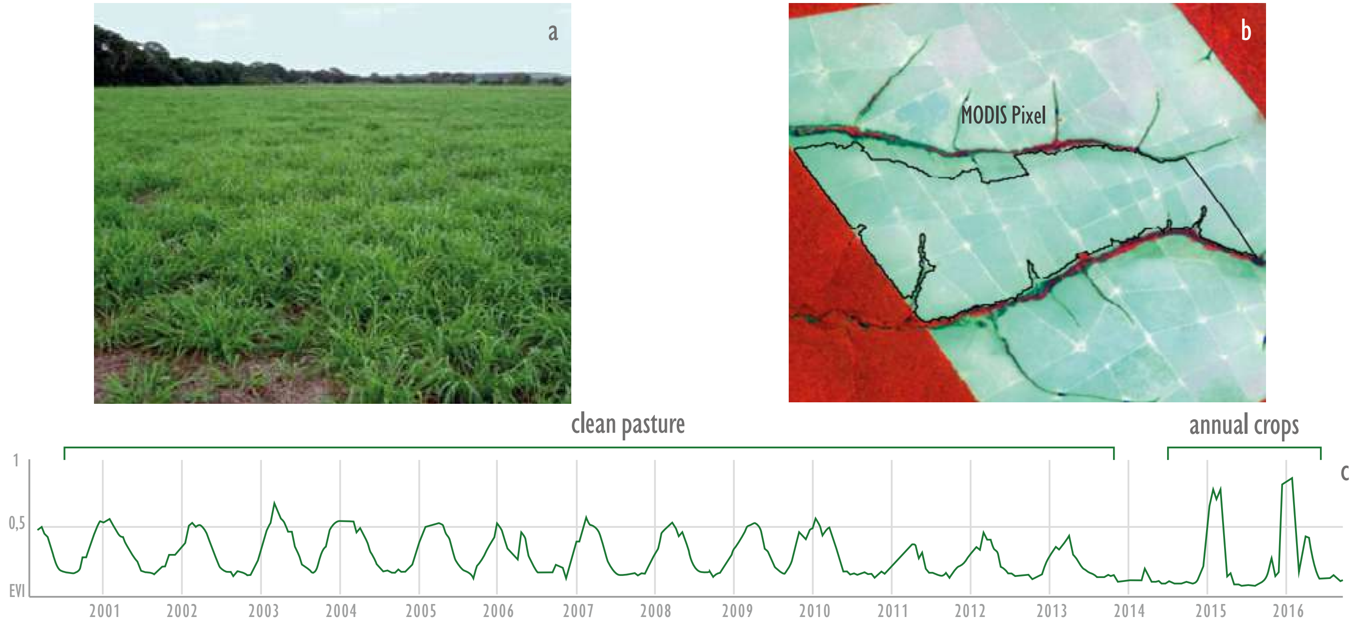


Figure 5 – Example of a LULCC of clean pasture into annual crop in the period 2009/10 to 2014/15: a) Photography taken elsewhere from a typical clean pasture; b) TM/Landsat-5 image from 12th September 2010, with the 2014/15 annual crop polygon boundary on the area identified as clean pasture; and c) EVI/MODIS time series showing the trajectory of the vegetation index from a clean pasture area up to 2013 to an annual crop in 2014/15.

Figure 6 shows the land use and land cover change of a "dirty pasture" area, illustrated in a Landsat image of 31st July 2010 (Figure 6b), into an annual crop in 2014/15. Dirty pasture areas show different stages of degradation, with a lesser or greater presence of invasive shrubs and trees (Figures 6a and 6b). The EVI/MODIS time series shows that the LULCC of the dirty pasture to an annual crop occurred in mid-2011 (Figure 6c).

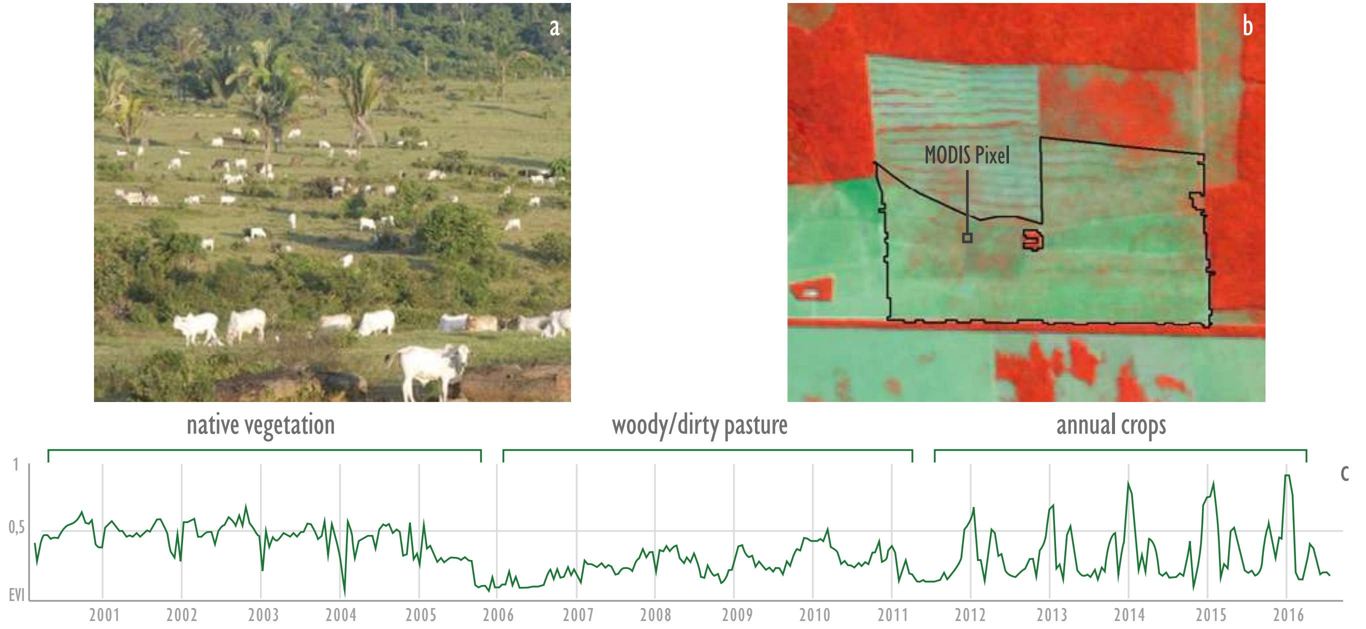


Figure 6 – Example of a LULCC of dirty pasture into annual crop in the period 2009/10 to 2014/15: a) Photography of a typical dirty pasture area, not from the same image area; b) TM/Landsat-5 image of 31st July 2010, with the 2014/15 annual crop polygon boundary on the area identified as dirty pasture; and c) The EVI/MODIS time series trajectory of the vegetation index shows the transitioning from dirty pasture up to 2011 to annual crop.

Figure 7 shows the land use and land cover change of an area of "regeneration with pasture", illustrated in the Landsat image of 24th July 2010 (Figure 7b), to an annual crop in 2014/15. Areas of regeneration with pasture are those which, after clear cutting the native vegetation, showed cattle ranching activity and which have begun the process of native vegetation regeneration. These areas are predominantly occupied by species of shrubs and trees (Figures 7a and 7b). The EVI/MODIS time series shows that the area was clear cut in 2003-2004, with cattle ranching activity supposedly beginning in 2004-2005 followed by a gradual regeneration of native vegetation, thus being classified as regeneration with pasture in 2009/10.

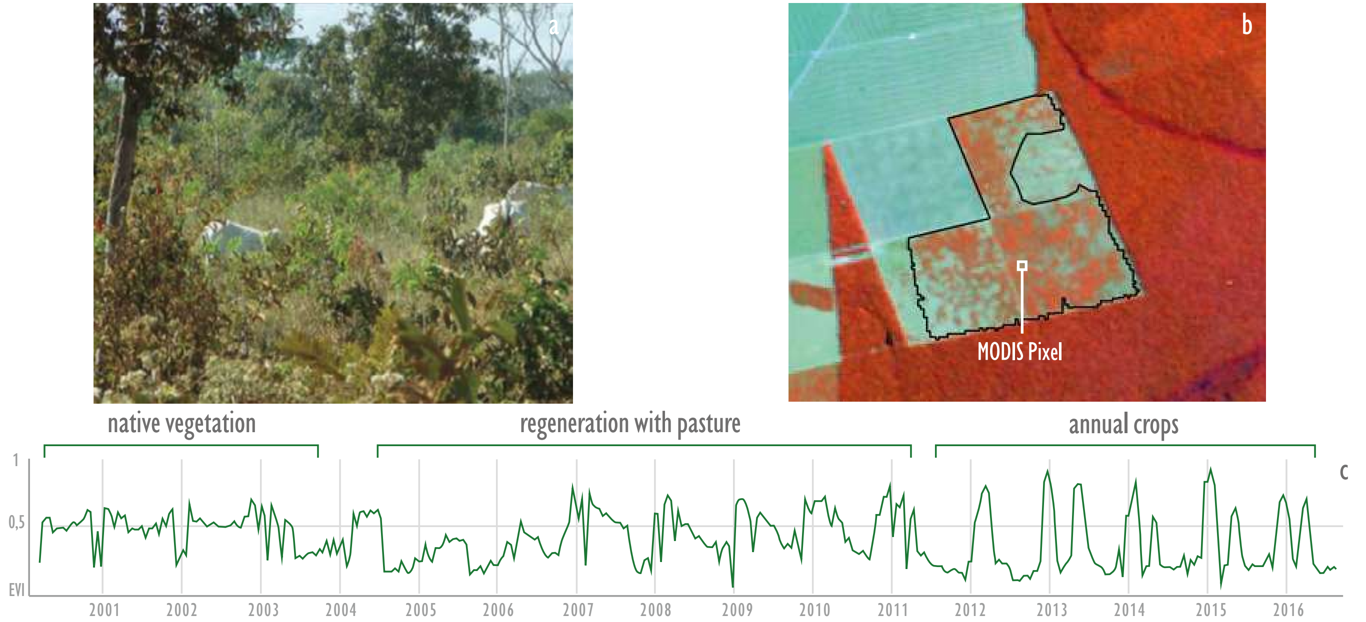


Figure 7 – Example of a LULCC of regeneration with pasture to annual crop in the period 2009/10 to 2014/15: a) Photography of a typical area of regeneration with pasture, not from the same image area; b) TM/Landsat-5 image from 24th July 2010, with the 2014/15 annual crop polygon boundary on the area identified as regeneration with pasture; and c) EVI/MODIS time series trajectory of the vegetation index showing the regeneration with pasture up to 2011 to annual crop.

Figure 8 shows the land use and land cover change of an area of primary native vegetation, shown in a Landsat image of 31st July 2010 (Figure 8b), to annual crop in 2014/15. The EVI/MODIS time series shows that, in 2009/10, this was an area of primary native vegetation (Figure 8c).

Figure 9 shows the land use and land cover change of an area of secondary native vegetation, shown in a Landsat image from 24th July 2010 (Figure 9b), to an annual crop in 2014/15. The EVI/MODIS time series shows that the area in question was clear cut in mid-2005, with later regeneration of native vegetation, thus becoming classified as an area of secondary native vegetation (Figure 9c). It should be noted that both primary native vegetation and secondary native vegetation make up a single class of land use and land cover change, namely native vegetation to annual crops.

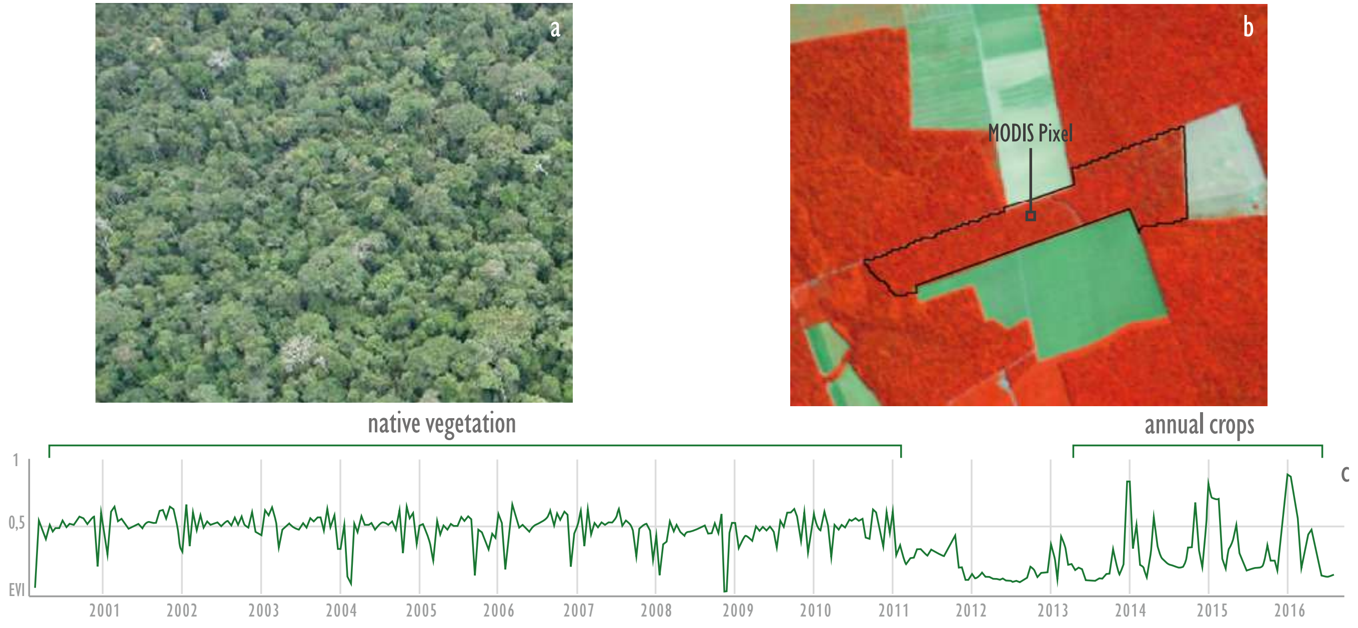


Figure 8 – Examples of a LULCC of primary native vegetation to annual crop in the period 2009/10 to 2014/2015: a) Photography of a typical area of native vegetation, not from the same image area; b) TM/Landsat-5 image from 31st July 2010, with the 2014/15 annual crop polygon boundary on the area identified as native vegetation in 2010; and c) The EVI/MODIS time series trajectory of the vegetation index from primary native vegetation up to 2011 to annual crop.

Figure 10 illustrates the land use and land cover change of an area recently cleared of native vegetation, shown in a Landsat image from 24th July 2010 (Figure 10b), to annual crop in 2014/15. Figure 10b shows the typical signs of a recently cleared area, with trace of fire and bare soil (Figure 10a). The clearing process is quite evident in the EVI/MODIS time series shown in Figure 10c, where in mid-2010 the trees were felled (abrupt fall in the vegetation index), followed by annual crop production.

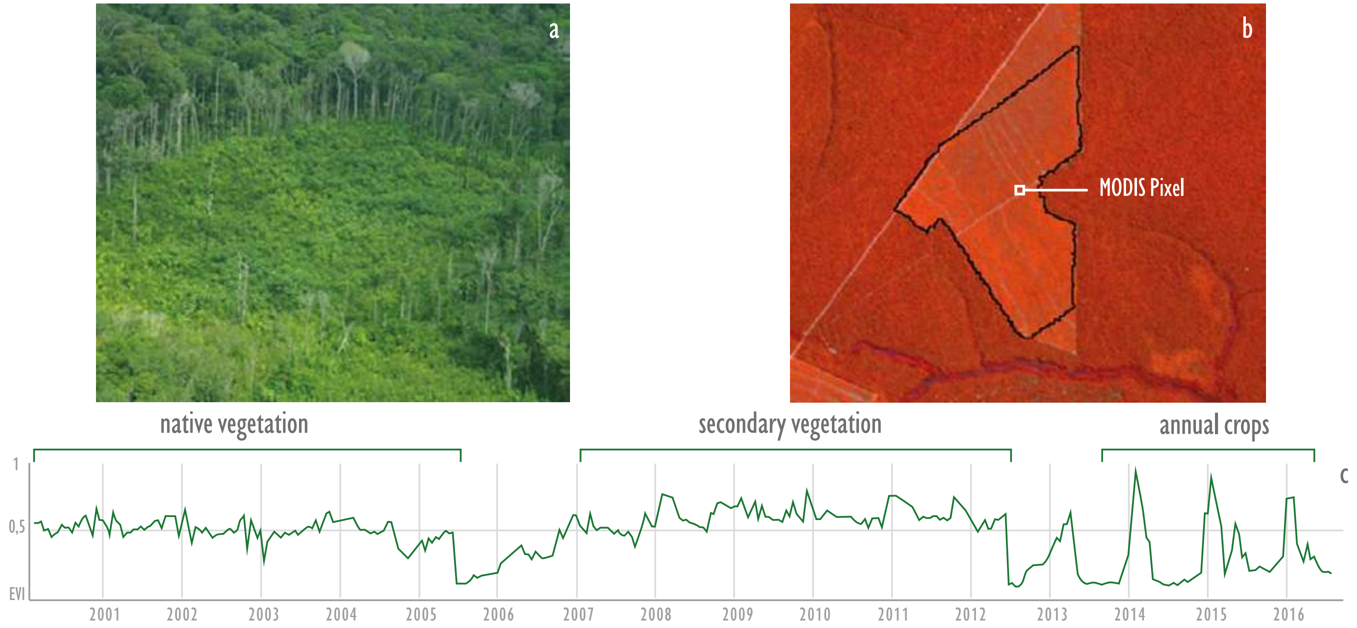


Figure 9 – Example of a LULCC of secondary native vegetation to annual crop in the period 2009/10 to 2014/15: a) Photography of atypical area of secondary native vegetation, not from the same image area; b) TM/Landsat-5 image from 24th July 2010, with the 2014/15 annual crop polygon boundary on the area identified as secondary native vegetation in 2010; and c) The EVI/MODIS time series trajectory of the vegetation index from secondary native vegetation up to 2012 to annual crop.

Figure 11 shows the land use and land cover change in the "other agriculture" class (rice), shown in the Landsat image from 6th February 2010 (Figure 11b), to an annual crop in 2014/15. The trajectory of the vegetation index from the EVI/MODIS time series indicates that, after clear cutting the native vegetation in 2003/04, there was a regeneration of vegetation and, in 2009, a new clearing followed by a rice crop in the 2009/10 crop year (Figure 11c).

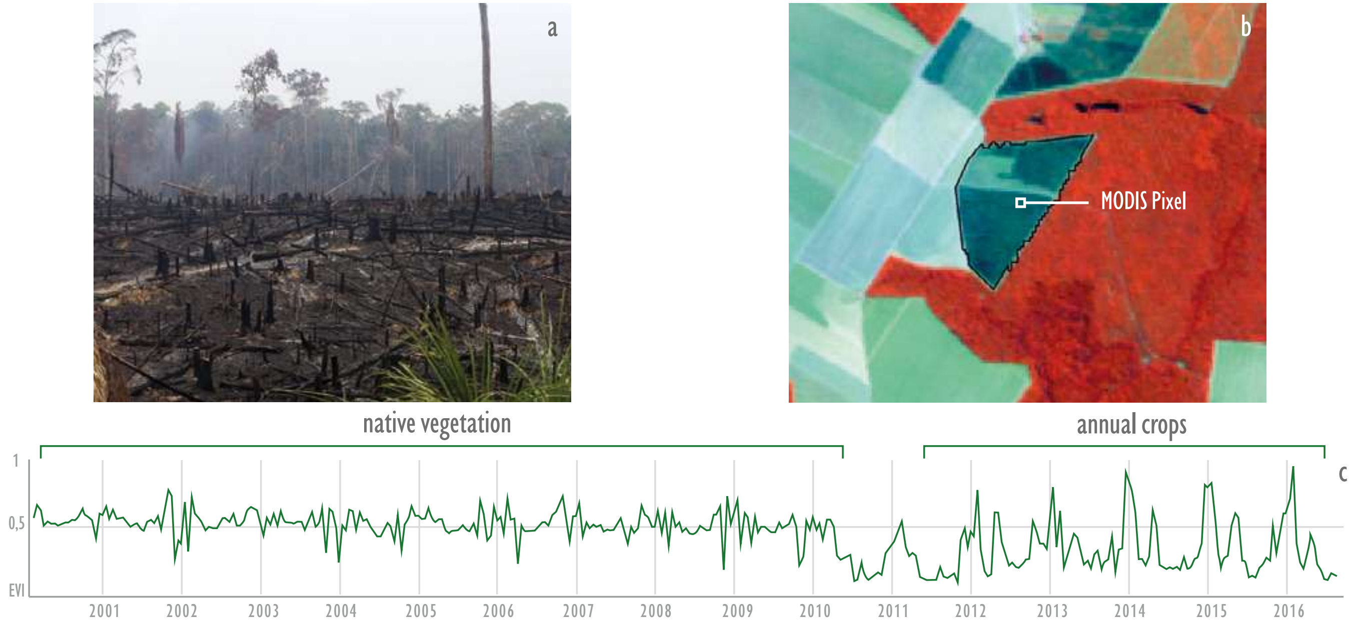


Figure 10 – Example of a LULCC of cleared native vegetation to annual crop in the period 2009/10 to 2014/15: a) Photography of an area in the process of clearing, not from the same area of the image; b) TM/Landsat-5 image from 24th July 2010, with the 2014/15 annual crop polygon boundary on the area cleared in 2010; and c) The EVI/MODIS time series trajectory of the vegetation index indicating the clearing of native vegetation in mid-2010, followed by annual crop.

Figure 12 also illustrates the land use and land cover change of "other agriculture" (fallow with cover crop), shown in

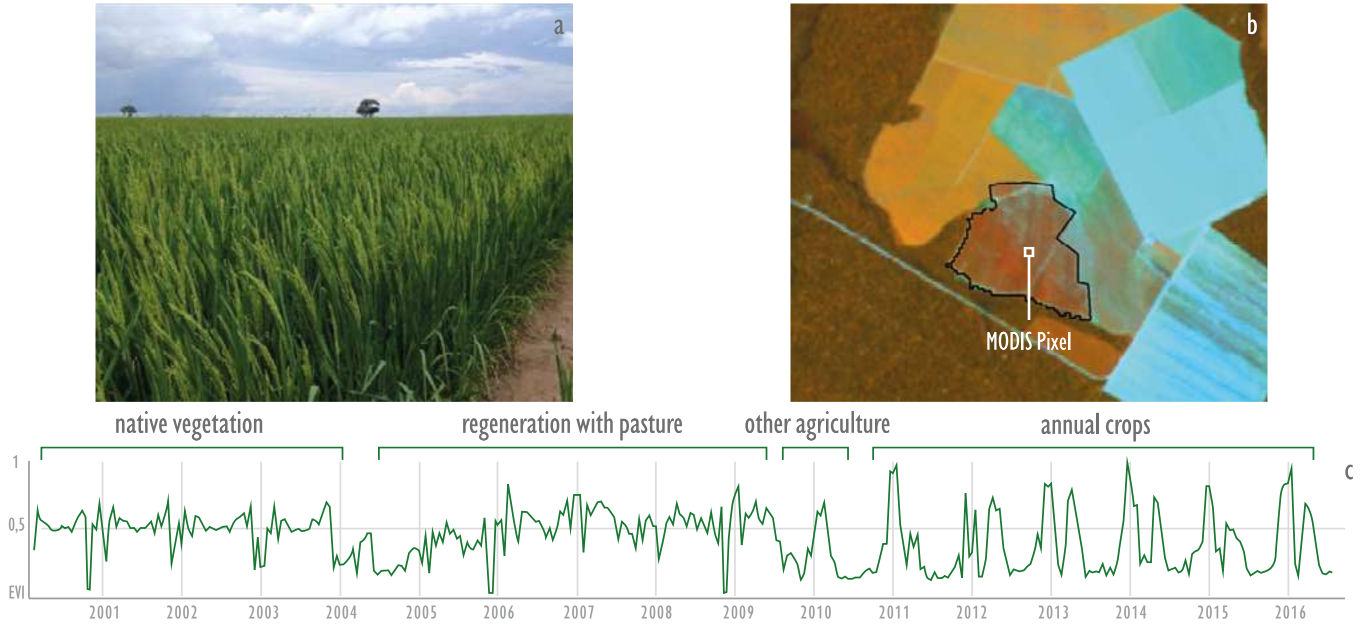


Figure 11 – Example of a LULCC of "other agriculture" class (rice) to annual crop in the period 2009/10 to 2014/15: a) Photography of an area with rice, not from the same area of the image; b) ETM/Landsat-7 image from 6th February 2010, with the 2014/15 annual crop polygon boundary on the area of other agriculture (rice) in 2010; and c) The EVI/MODIS time series trajectory of the vegetation index indicating other agriculture in the 2009/10 crop year.

the Landsat image from 31st January 2010 (Figure 12b), to annual crop in 2014/15. The trajectory of the vegetation index from the EVI/MODIS time series indicates that this area was used for pasturing up to 2004 and converted to annual crop in 2005. In the 2009/10 crop year, this area lay fallow (Figure 12c). It should be noted that all areas planted with crops other than soy, corn, cotton and sugarcane, as well as fallow areas, make up a single land use and land cover class named "other agriculture".

Figure 13 illustrates the land use and land cover change of the sugarcane class, shown in the Landsat image from 13th June 2010 (Figure 13b), to annual crop in 2014/15. Sugarcane crop has some typical characteristics that enable its identification in satellite images, such as the presence of roads that fully define the plots and the distance to the processing units that should not exceed 30 km. Renewal of sugarcane fields can be performed every 5-6 years in rotation with soy for one or two crop years. Figure 13c shows the trajectory of the vegetation index of the EVI/MODIS time series, showing that the 2009/10 sugarcane area is rotating with soy since crop year 2013/14.

The characteristics used to define the agricultural suitability for soy in the Amazon Biome were: 1)

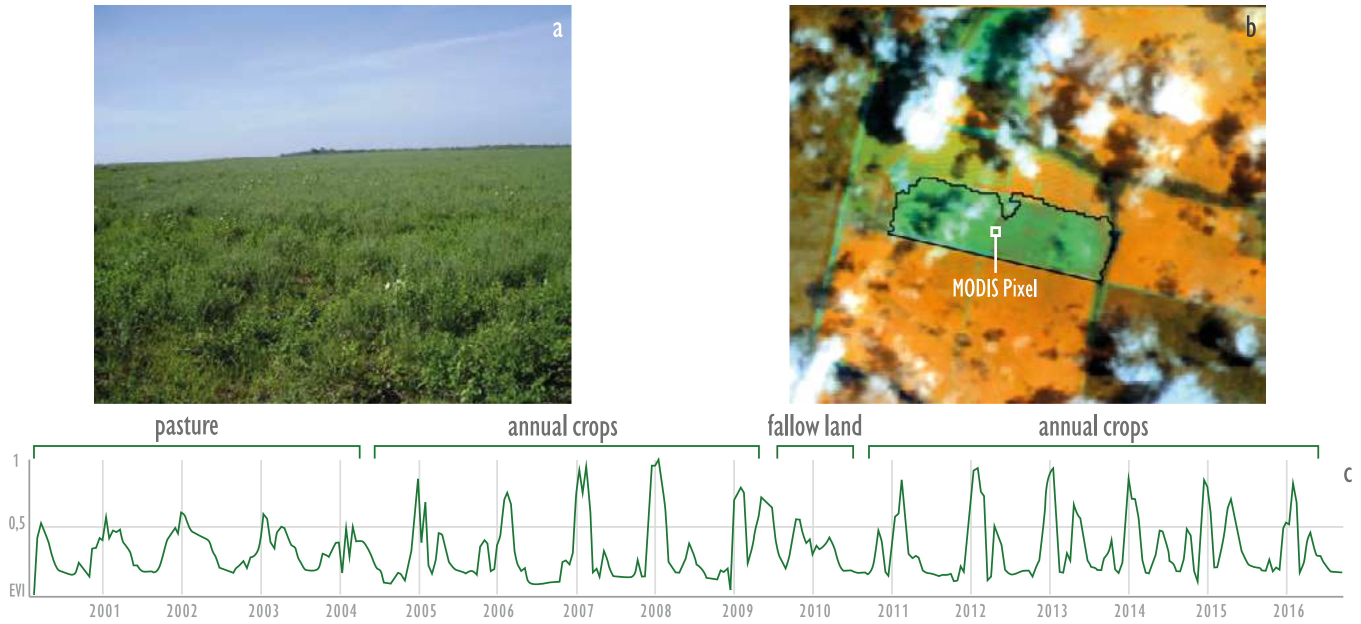


Figure 12 – Example of a LULCC of other agriculture (fallow/cover crop) to annual crop in the period 2009/10 to 2014/15: a) Photography of a fallow area with a cover crop, not from the same area of the image; b) ETM/Landsat-7 image from 31st January 2010, with the 2014/15 annual crop polygon boundary on the area of other agriculture (fallow) in 2010; and c) The EMI/MODIS time series trajectory of the vegetation index indicating the presence of other agriculture (fallow/cover crop) in the 2009/10.(fallow/cover crop) in the 2009/10.

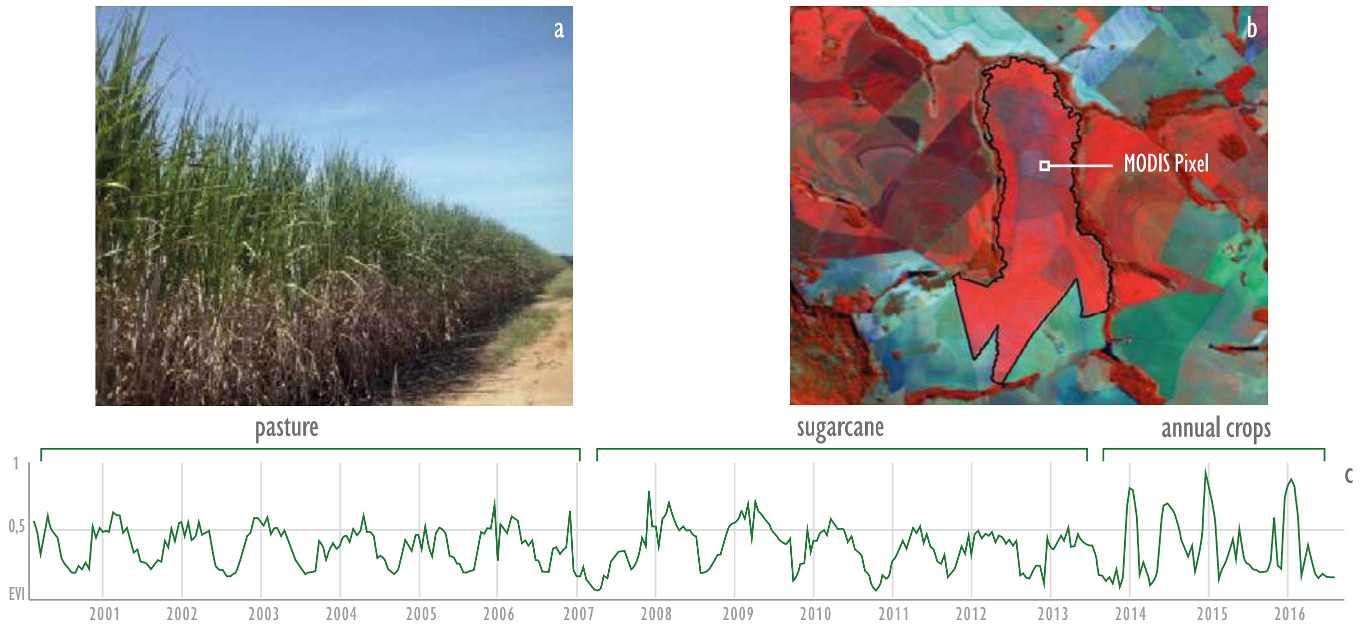


Figure 13 – Example of an LULCC of sugarcane in 2009/10 into an annual crop in 2014/15: a) Photograph of an area with a sugarcane crop, not from the same area of the image; b) TM/Landsat-5 from 13th June 2010, with the 2014/15 annual crop polygon boundary on an area of sugarcane in 2010; and c) The EVI/MODIS time series trajectory of the vegetation index indicating the presence of a sugarcane crop up to 2013.

2.4 Agricultural Suitability for Soy

edaphoclimatic suitability; 2) slope; and 3) altitude. Calculation of edaphoclimatic suitability was based on a methodology like the one adopted by ZARC (Agricultural Zoning for Climatic Risk) for soy crop. ZARC is established considering historic climate, water holding capacity of different soil types and the soy water demand during the most critical growth stages. In ZARC, the edaphoclimatic analysis evaluates the most appropriate planting window for the lowest risk of a water deficit during flowering and seed filling growth stages which are the most critical ones to determine the soy productive potential. For that, a comparative analysis is made between the crop evapotranspiration demand and the water availability in the soil, which in turn is determined based on rainfall and on the water holding capacity (WHC) of the soil. This evaluation considers a 30-year climatological normal, from 1980 to 2013 (Xavier et al., 2016). The soil map used in this study comes from the IBGE continuous base, at a scale of 1:250,000. Based on soil texture, they were classified in this study in four large groups, considering the average depth of soy's root system to be 50 cm: i) sandy soil texture (WHC = 40 mm); ii) medium soil texture (WHC = 50 mm); iii) clay soil texture (WHC = 75 mm); and iv) inadequate soils, urbanised areas, rocky outcrops (WHC not evaluated). In this study, four ZARC edaphoclimatic classes were established where the Water Requirement Satisfaction Index (WRSI) is the ratio of actual to potential evapotranspiration, which reflects the crop sensibility to water deficit:

1. High suitability: WRSI > 0.65, high offer of water in the critical crop growth period in 80% of the years;
2. Medium suitability: 0.55 < WRSI > 0.65, average offer of water in the critical crop growth period in 80% of the years;
3. Low suitability: WRSI < 0.55, low offer of water in the critical crop growth period in 80% of the years;
4. Inadequate: Urban areas, rocky outcrops and water.

This methodological approach is fully compatible with Rudorff et al. (2015), which made this same evaluation of agricultural suitability for soy in the Cerrado Biome, where water deficit is a serious crop growth limitation factor in several regions. However, for the Amazon Biome, where rainfall precipitation is adequate to supply the soy water requirements even in the most critical growth periods, conditions of low and medium water availability are not expected. Therefore, only the edaphoclimatic classes of "high suitability" and "inadequate" were considered.

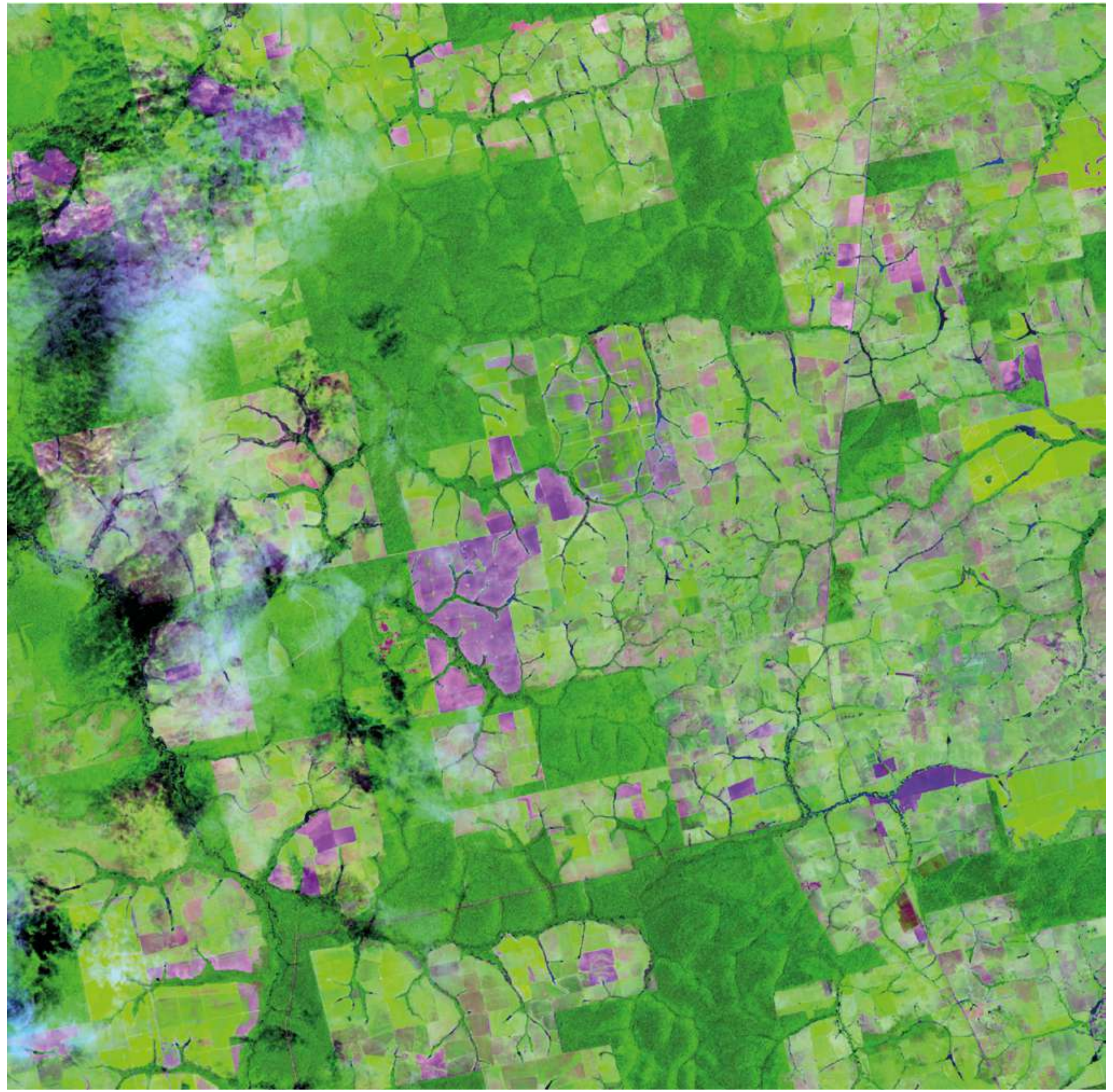
In addition to the edaphoclimatic evaluation, the land was classified in areas with and without restrictions as regards slope and altitude in accordance with the following approach:

1. Slope: areas with slope below 12% are without restriction as regards slope, while areas with a slope of more than 12% are restricted. Slope is calculated based on data from the Topodata digital elevation model, using data from the Shuttle Radar Topography Mission (dsr.inpe.br/topodata; Valeriano e Rossetti, 2011), and follows the same criterion established by Agrosatélite (2015). Slope is an important parameter that determines agricultural mechanisation which is a basic pre-requisite for soy planting. In Brazil, the maximum slope for mechanisation is generally set at 12%.

2. Altitude: areas with a restriction to altitude were defined by comparing the altitudes of two digital surfaces; the actual digital land surface; and a modelled digital surface named "crop surface". The crop surface connects the lower levels of each continuous area planted with either soy, corn or cotton in 2016/17 crop year, with the levels immediately above the areas that could potentially inundate every year in the Amazon Biome. This modelling creates a surface representing the minimum altitudes, above which annual agriculture is already practiced or could be practiced in the Amazon Biome, not being restricted to crop growth in terms of altitude. Conversely, areas below the crop surface are altitude-restricted with less potential for agricultural expansion at least while the stock of areas with no restriction to altitude are not run-out.

Therefore, based on edaphoclimatic conditions, slope and altitude, five classes of agricultural suitability were defined:

1. Agricultural suitability with no restrictions to slope and altitude (AS, NR);
2. Agricultural suitability with slope restriction (AS, SR);
3. Agricultural suitability with altitude restriction (AS, AR);
4. Agricultural suitability with restrictions to slope and altitude (AS, WR);
5. Inadequate due to edaphoclimatic deficiency, irrespective of slope and/or altitude (I).



2.5 Map of Land Use and Agricultural Suitability in the Amazon Biome | Crop year 2016/17

After performing the edaphoclimatic suitability evaluation for soybean in the Amazon Biome and considering the slope and altitude constraints, the land use classes were stratified according to its agricultural suitability. The classes of primary native vegetation (PNV) and anthropized (A) were obtained from INPE's PRODES project. However, for the areas of PNV of non-forested areas - that are not mapped by PRODES - such as savannas or grassland Agrosatélite used satellite images acquired in 2015 to visually classify the areas with sign of major human activity. These areas were then added to the anthropized class whereas the areas with no apparent disturbance were added to the PNV class. In addition, the secondary native vegetation (SNV) class was obtained from the available TerraClass Amazônia database of 2014 (Figure 25).

Thus, the agricultural suitability was assigned to the following land use classes as illustrated in Figure 26 for the Amazon Biome and in the Appendix (Table A1) for each state:

1. Annual Crops (AC) in crop year 2016/17 (Agrosatellite);
2. Anthropized (A) in 2015 (PRODES Amazon and Agrosatellite);
3. Primary Native Vegetation (PNV) in 2015 (PRODES Amazon and Agrosatellite); and
4. Secondary Native Vegetation (SNV) in 2014 (TerraClass Amazônia; INPE, 2016).

Based on this set of maps, the final land use and land cover map was prepared considering the following classes: annual crops for year 2016/17 (AC); primary native vegetation (PNV); secondary native vegetation (SNV); anthropized (A) which is the land other than AC and SNV; and water. This land use and land cover map was, in turn, overlaid on both:

1. agricultural suitability (AS) classes: i) AS-NR (AS with No Restrictions to slope and altitude); ii) AS-SR (AS with Slope Restriction; iii) AS-AR (AS with Altitude Restriction; iv) AS-WR (AS With Restrictions to slope and altitude); v) I (Inadequate, irrespective of slope or altitude), and
2. special areas: i) CU-IP (Conservation Units for Integral Protection; MMA, 2017); ii) CU-SU (Conservation Units for Sustainable Use; MMA, 2017); iii) SETT (Settlements; INCRA, 2017); iv) QUI (Quilombola communities; INCRA, 2017); and v) IL (Indigenous Lands; FUNAI, 2017). Everything else that was outside of the "special areas" was assigned to Private Properties and Undesignated Land (PP-UL). This procedure allowed to obtain the agricultural suitability for each land use and land cover class, inside and outside of the special areas as presented in Table A1, by State, for the Amazon Biome.

3. RESULTS AND DISCUSSIONS

3.1 Agricultural Dynamics 2000/01 to 2016/17

The area planted with first crop of soy, corn and cotton in the Amazon Biome in crop years 2000/01 (Table 2), 2006/07 (Table 3), 2009/10 (Table 4), 2014/15 (Table 5) and 2016/17 (Table 6) is illustrated in Figures 14 to 18, respectively. In the 2000/01 crop year, virtually 100% of the annual crops in the Amazon Biome were close to the Cerrado Biome border, more specifically along highways BR-163 (centre-north of Mato Grosso state) and the BR-158 (Araguaia Valley in Mato Grosso state), soy's main ports of entry to the Amazon (Figure 14). Over time, this new agricultural frontier expanded within the Amazon Biome, reaching the states of Rondônia, Pará, Amapá and Roraima in the 2006/07 crop year (Figure 15). However, the major soy expansion was observed from 2009/10 to 2014/15, with emphasis on the regions of the municipalities of São Félix do Araguaia in Mato Grosso state, Paragominas in Pará state, Macapá in Amapá state and Alto Alegre in Roraima state (Figures 16 and 17).

From 2000/01 to 2016/17, the area planted with first crop of soy, corn and cotton went from 0.37 million hectares to 4.59 million hectares, increasing more than twelvefold (by 4.22 million hectares, Figure 19). Furthermore, the expansion rate of annual crops was 0.18, 0.23, 0.39 and 0.26 million hectares/year in the periods 2000/01 to 2006/07, 2006/07 to 2009/10, 2009/10 to 2014/015 and 2014/15 to 2016/17, respectively (Figure 19). The slowdown expansion of soy in the last period can be attributed to several economic factors, such as the soy market prices, which have reduced investments in this sector. It should be noted that nearly all the expansion in annual crops between 2001 and 2017 is associated with soy, as the areas with corn and cotton are small and have remained relatively stable over the years (Tables 2 to 6). For example, in 2001, soy represented 92% of the total area for the three crops being evaluated, while in 2017 it was nearly 98%. As regards corn, it is important to highlight that Mato Grosso state is Brazil's largest producer, but in 2016/17 only 27,353 hectares were planted with first-crop corn in the Amazon Biome portion of this state (Table 6) because the major part of its corn production comes from the second-crop (the safrinha), which was not evaluated in this study. As regards first-crop cotton, this represents a very small part of the annual crop (199 hectares in the 2016/17 crop year, Table 6) and is getting smaller every year as a result of the development of a technological package that allows cotton being planted as a second-crop, such as for the second-crop of corn which is a very important strategy of land use intensification. It is worth noting that first-crop corn mapped by Agrosatélite represents the first-crop corn planted at large-scale such as for soybean. The very small corn areas planted as subsistence were not mapped.

The results also show that the soy area in the Amazon Biome jumped from 2.4% (0.34 million ha) in crop year 2000/01 to 13,2% (4.48 million ha) in crop year 2016/17, of Brazil's total soy area. In other words, while Brazil's total soy area increased 2.4 times (from 13.97 to 33.91 million ha) the Amazon's soy area increased 13.2 times (from 0.34 to 4.48 million ha) between 2000/01 and 2016/17 (Tables 2 and 6). Only the part of Mato Grosso state that lies within the Amazon Biome was responsible for 81.1% of soy expansion from 2000/01 to 2016/17 and, consequently, accounted for 82.1% (3.68 million hectares) of the soy area in this Biome in crop year 2016/17 (Table 6 and Figure 20).

Table A2 in the Appendix lists the 201 municipalities that are entirely or partially within the Amazon Biome and presented some annual crops area in at least one of the analysed years. The municipality of Querência in Mato Grosso state presented the largest soy area in crop year 2016/17 with 351,000 hectares. The fifteen municipalities with the largest soy areas account for over 50% of the Biome's soy area in 2016/17 and are all located in Mato Grosso state. In Pará state the municipality of Paragominas presented the largest soy are in 2016/17 with 101,521 hectares. Despite the Amazon Biome's vast territory, 90% of the 2016/17 soy area is concentrated in just 58 municipalities.

Paragominas is also the municipality that presents the largest first-crop corn area in Pará state with 13,000 hectares. Of the 201 municipalities listed in Table A2 only 50% (102 municipalities) presented first-crop corn in 2016/17 with just 8 municipalities concentrating 50% of the corn area. As already discussed, the first-crop of cotton is little grown in the Amazon Biome in recent years, due to excessive rains at harvest which harms the cotton fibre quality. In 2016/17 only one cotton area of 199 hectares was found in the municipality of Diamantino in Mato Grosso state.

The quality evaluation of the soybean mapping in the Amazon biome for crop year 2016/17 showed an overall accuracy of 98.8%, a producer accuracy (omission error) of 95.2%, and a user accuracy (commission error) of 95.2% (Table 7).

CROP YEAR 2000/01

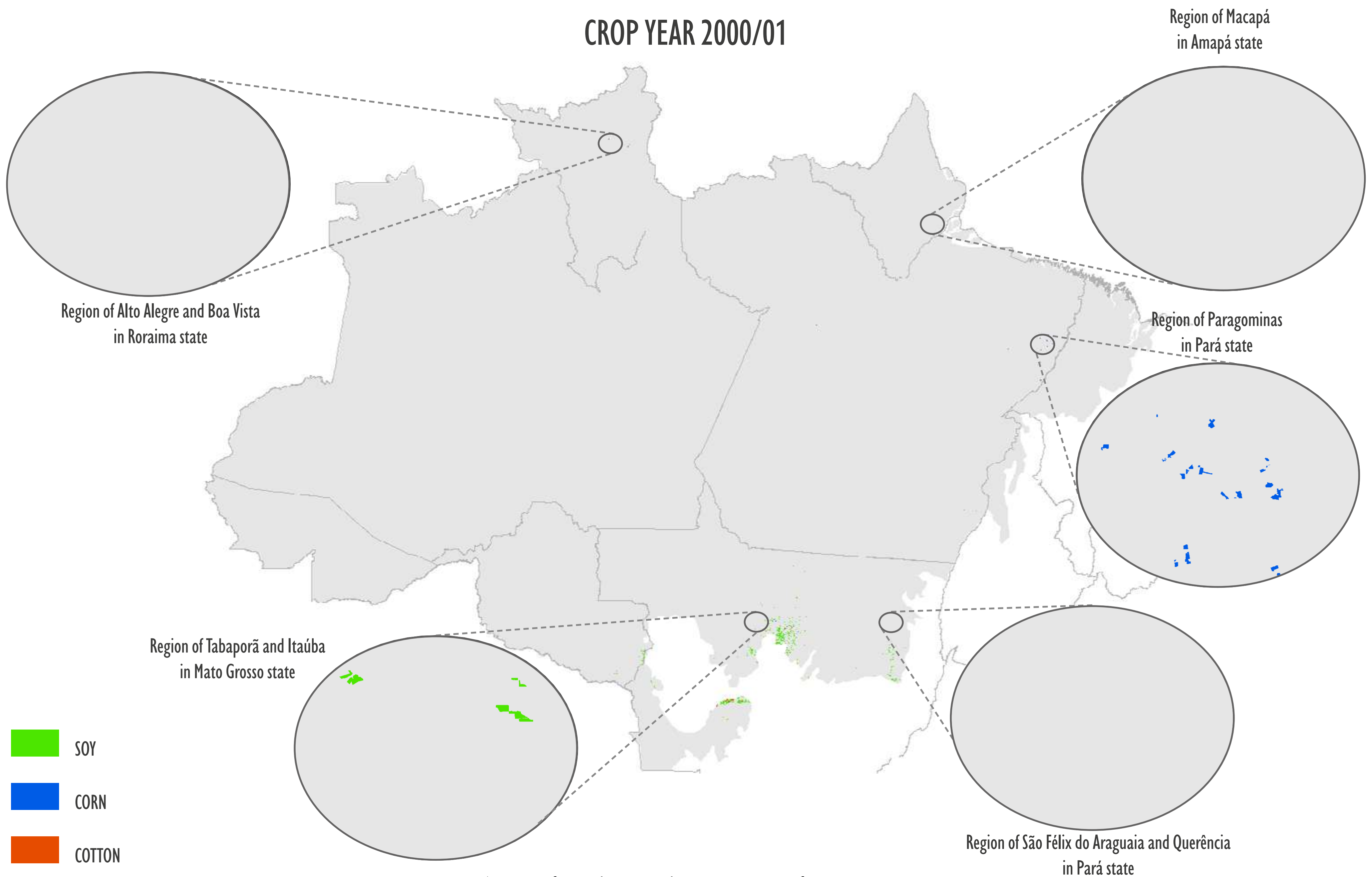


Figure 14 – Map of annual crops in the Amazon Biome for crop year 2000/01.

CROP YEAR 2006/07

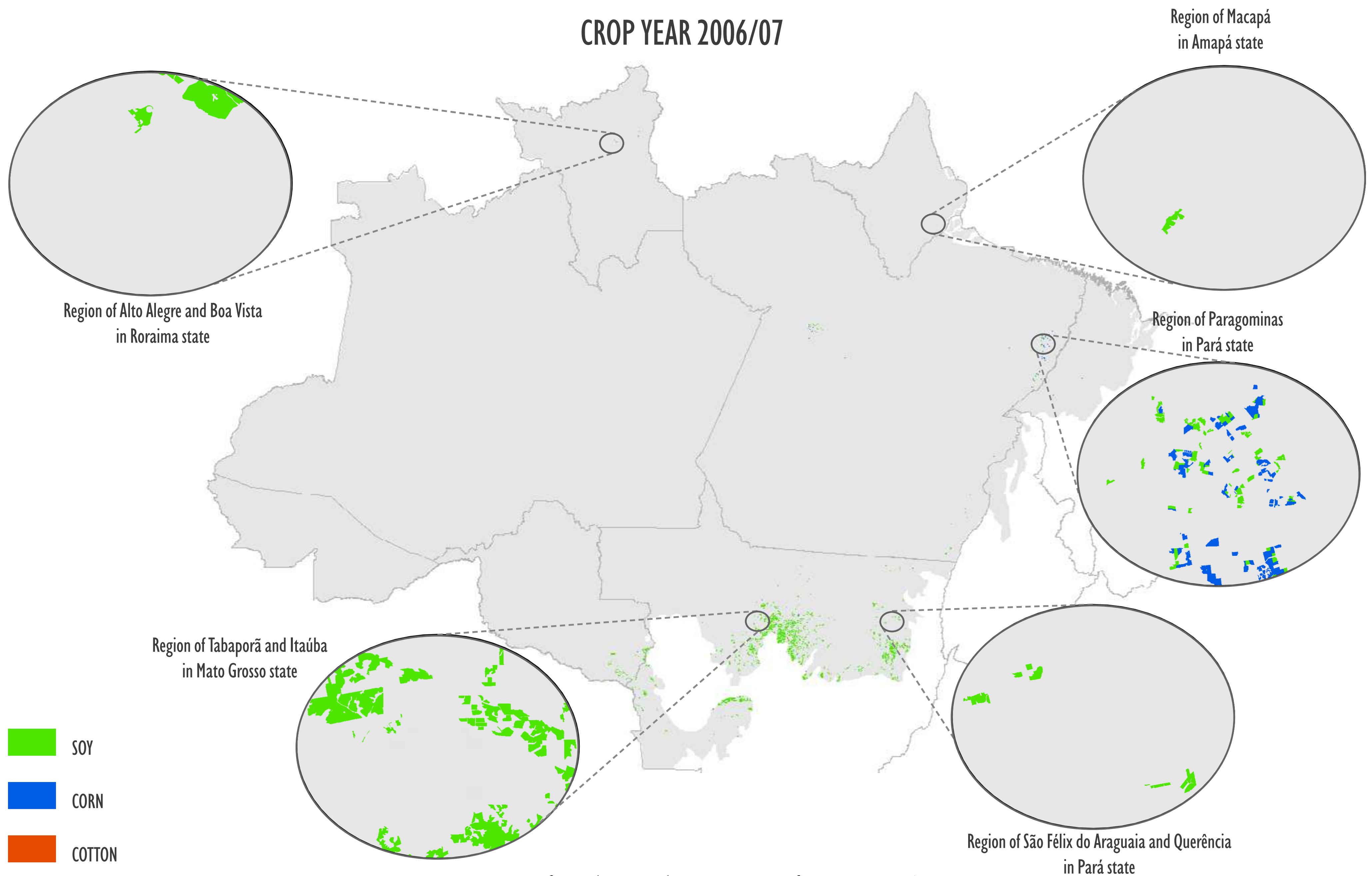


Figure 15 – Map of annual crops in the Amazon Biome for crop year 2006/07.

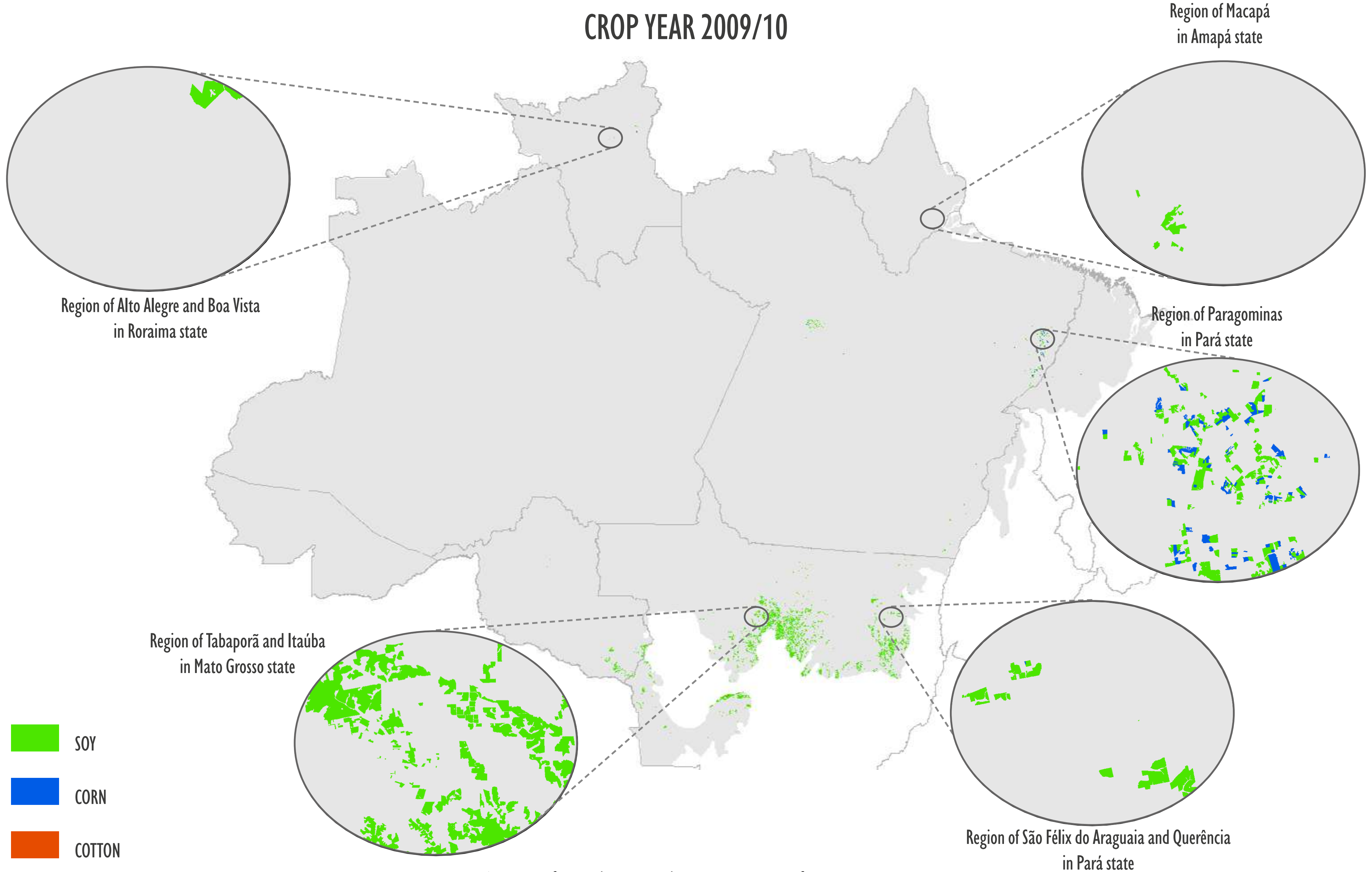


Figure 16 – Map of annual crops in the Amazon Biome for crop year 2009/10.

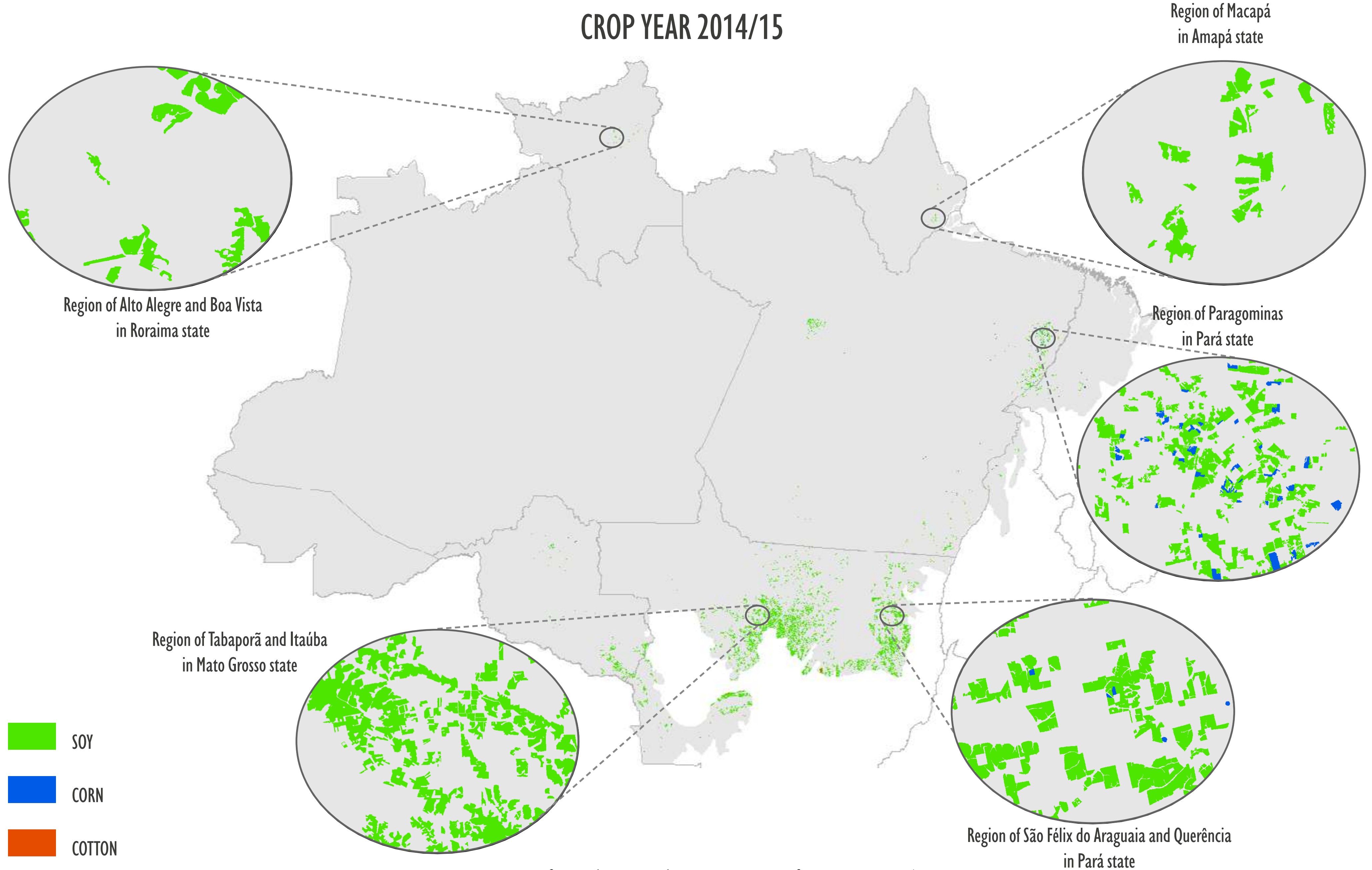


Figure 17 – Map of annual crops in the Amazon Biome for crop year 2014/15.

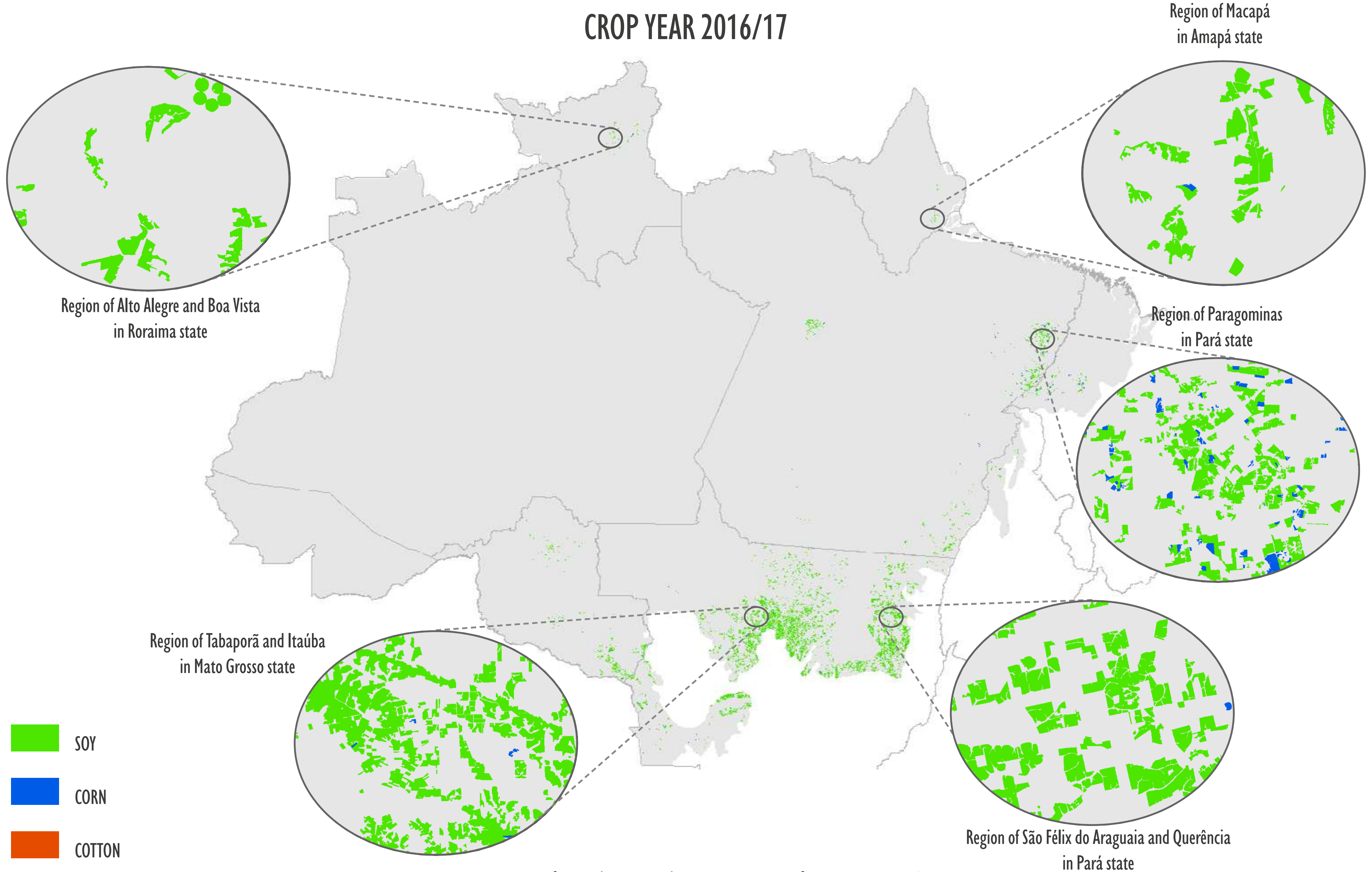


Figure 18 – Map of annual crops in the Amazon Biome for crop year 2016/17.

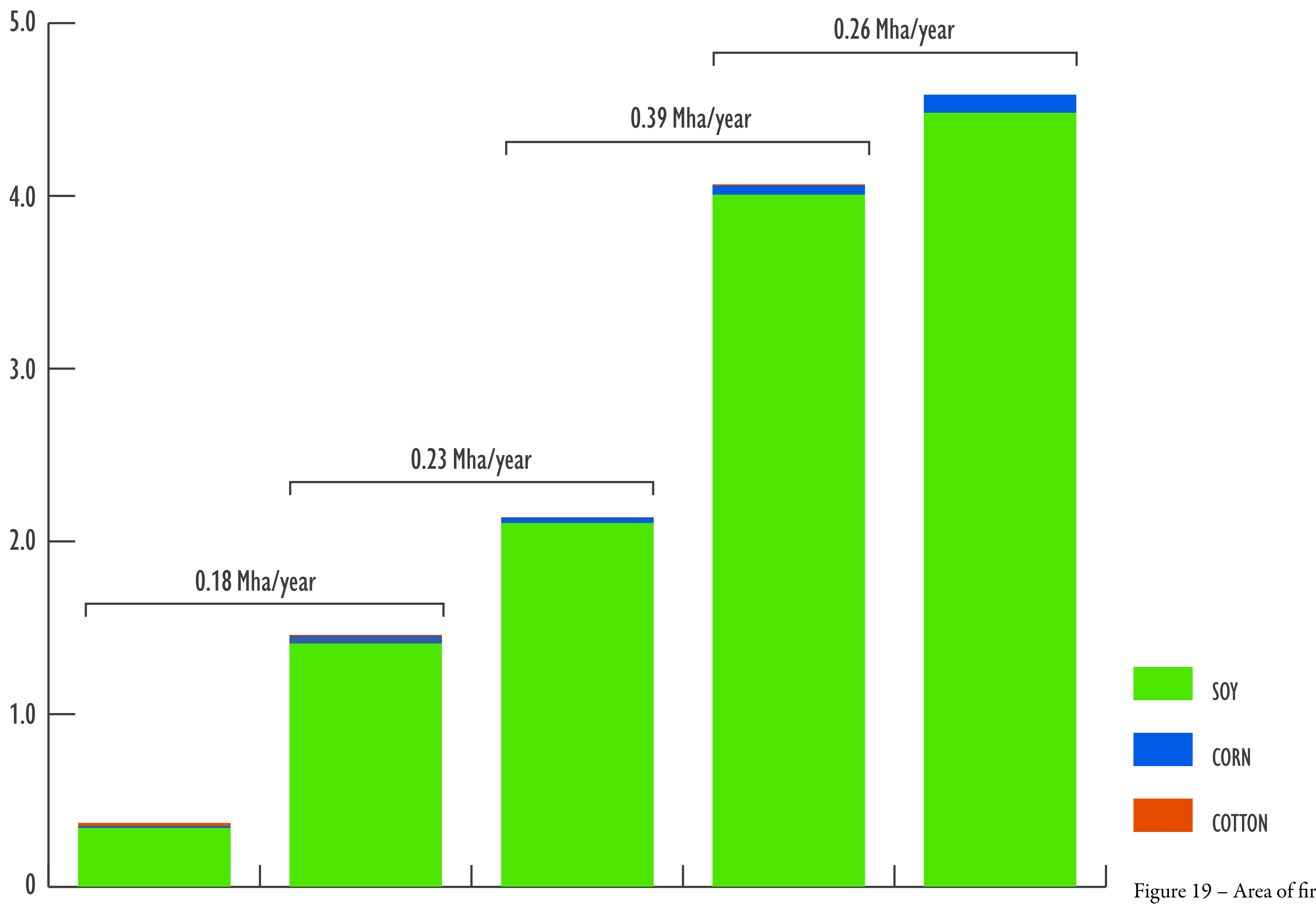


Figure 19 – Area of first-crop of soy, corn and cotton in the Amazon Biome for crop years 2000/01, 2006/07, 2009/10, 2014/15 and 2016/17, with the annual expansion rate for each analysed period.

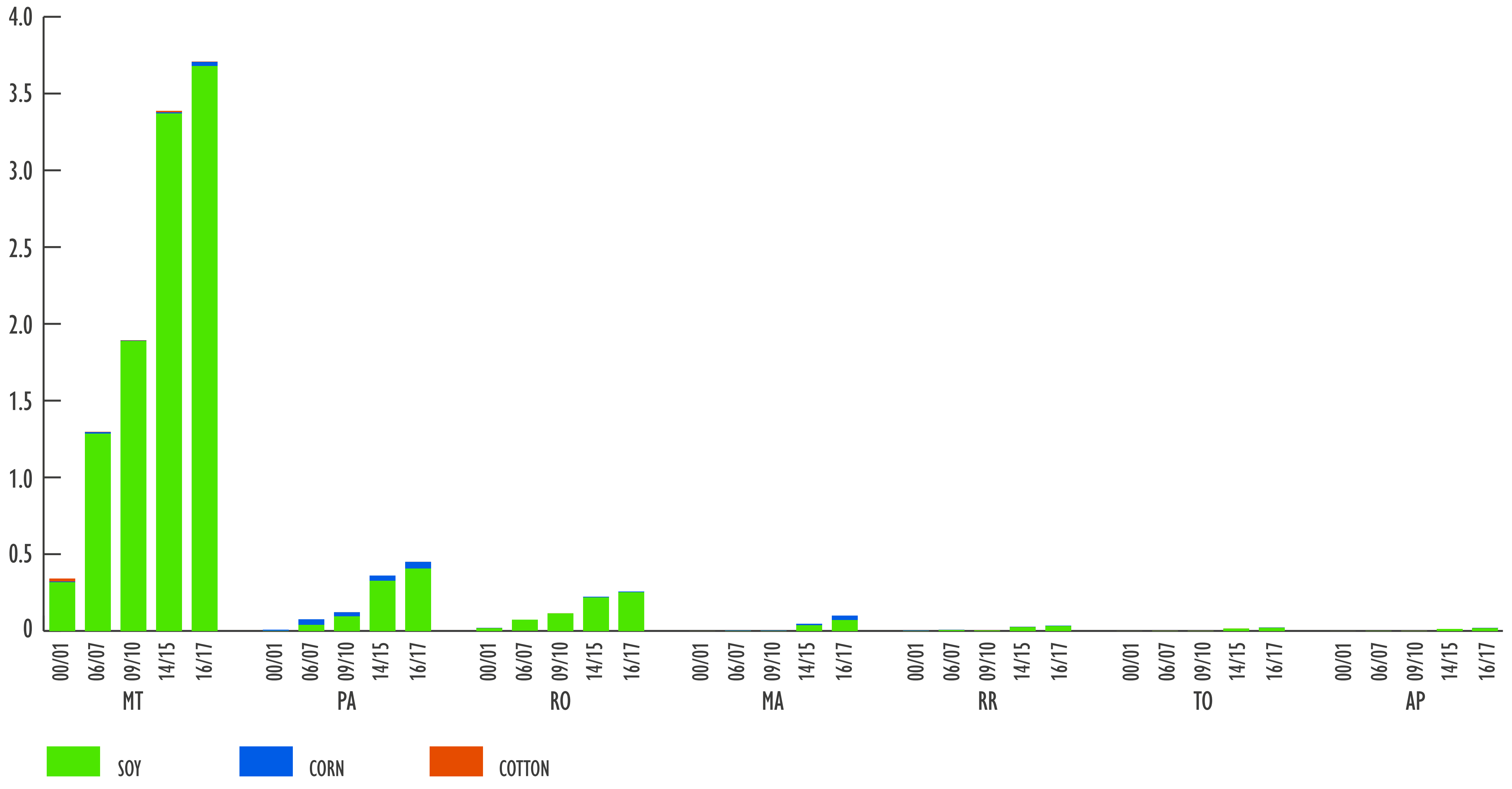


Figure 20 – Area of first-crop of soy, corn and cotton in the Amazon Biome, by state, for crop years 2000/01, 2006/07, 2009/10, 2014/15 and 2016/17 in the Amazon Biome.

Table 2 –Area of first-crop of soy, corn and cotton in the Amazon Biome, with their corresponding percentages, by state, for crop year 2000/01.

STATE	ANNUAL CROPS - 2000/01							
	SOY ha	%	CORN ha	%	COTTON ha	%	TOTAL ha	%
MT	318,.289	93.6	3,973	1.2	17,905	5.3	340,167	92.32
PA	876	12.2	6,315	87.8	0	0.0	7,191	1.95
RO	18,719	97.9	405	2.1	0	0.0	19,124	5.19
MA	0	0.0	0	0.0	0	0.0	0	0.0
RR	1,100	55.1	897	44.9	0	0.0	1,997	0.54
TO	0	0.0	0	0.0	0	0.0	0	0.0
AP	0	0.0	0	0.0	0	0.0	0	0.0
TOTAL	338,984	92.0	11,590	3.1	17,905	4.9	368,479	100.0

Table 3 – Area of first-crop of soy, corn and cotton in the Amazon Biome, with their corresponding percentages, by state, for crop year 2006/07.

STATE	ANNUAL CROPS - 2006/07							
	SOY ha	%	CORN ha	%	COTTON ha	%	TOTAL ha	%
MT	1,285,458	99.1	7,326	0.6	4,596	0.4	1,297,380	89.03
PA	40,132	53.0	35,651	47.0	0	0.0	75,783	5.20
RO	72,331	98.6	1,040	1.4	0	0.0	73,371	5.04
MA	177	7.9	2,076	92.1	0	0.0	2,253	0.15
RR	6,604	96.9	210	3.1	0	0.0	6,814	0.47
TO	1,190	100.0	0	0.0	0	0.0	1,190	0.08
AP	387	100.0	0	0.0	0	0.0	387	0.03
TOTAL	1,406,279	96.5	46,304	3.2	4,596	0.3	1,457,178	100.0

Table 4 – Area of first-crop of soy, corn and cotton in the Amazon Biome, with their corresponding percentages, by state, for crop year 2009/10.

STATE	ANNUAL CROPS - 2009/10							
	SOY ha	%	CORN ha	%	COTTON ha	%	TOTAL ha	%
MT	1,888,064	99.7	2,084	0.1	3,953	0.2	1,894,101	88.49
PA	94,867	77.7	27,264	22.3	0	0.0	122,131	5.71
RO	113,732	99.1	1,004	0.9	0	0.0	114,736	5.36
MA	1,466	65.8	760	34.2	0	0.0	2,226	0.10
RR	3,164	81.1	737	18.9	0	0.0	3,901	0.18
TO	1,461	100.0	0	0.0	0	0.0	1,461	0.07
AP	1,800	100.0	0	0.0	0	0.0	1,800	0.08
TOTAL	2,104,553	98.3	31,849	1.5	3,953	0.2	2,140,355	100.0

Table 5 – Area of first-crop of soy, corn and cotton in the Amazon Biome, with their corresponding percentages, by state, for crop year 2014/15.

STATE	ANNUAL CROPS - 2014/15							
	SOY ha	%	CORN ha	%	COTTON ha	%	TOTAL ha	%
MT	3,371,032	99.5	6,899	0.2	8,765	0.3	3,386,697	83.24
PA	327,391	91.0	32,522	9.0	0	0.0	359,914	8.85
RO	218,364	98.1	4,124	1.9	0	0.0	222,488	5.47
MA	37,212	82.9	7,699	17.1	0	0.0	44,911	1.10
RR	26,092	98.2	482	1.8	0	0.0	26,574	0.65
TO	14,919	94.7	833	5.3	0	0.0	15,752	0.39
AP	12,335	100.0	0	0.0	0	0.0	12,335	0.30
TOTAL	4,007,347	98.5	52,559	1.3	8,765	0.2	4,068,672	100.0

Table 6 – Area of first-crop of soy, corn and cotton in the Amazon Biome, with their corresponding percentages, by state, for crop year 2016/17.

STATE	ANNUAL CROPS - 2016/17							
	SOY ha	%	CORN ha	%	COTTON ha	%	TOTAL ha	%
MT	3,678,793	99.3	27,353	0.7	199	0.0	3,706,345	80.80
PA	407,041	90.4	43,241	9.6	0	0.0	450,282	9.82
RO	252,677	98.4	4,158	1.6	0	0.0	256,834	5.60
MA	71,362	72.5	27,051	27.5	0	0.0	98,413	2.15
RR	32,244	93.4	2,295	6.6	0	0.0	34,539	0.75
TO	21,386	98.5	323	1.5	0	0.0	21,709	0.47
AP	18,935	99.4	111	0.6	0	0.0	19,046	0.42
TOTAL	4,482,438	97.7	104,531	2.3	199	0.0	4,587,168	100.0

Table 7 – Statistics of the confusion matrix for the soy map of crop year 2016/17

		FIELD WORK				
		NOT SOY	SOY	TOTAL	UA	OA
SOY MAP	NOT SOY	0.233	0.002	0.224	99.3%	98.8%
	SOY	0.002	0.032	0.034	95.2%	-
	TOTAL	0.224	0.34	0.258	-	-
	PA	99.3%	95.2%	-	-	-

PA= Producer accuracy; UA= User accuracy; OA= Overall accuracy.

3.2 Land Use and Land Cover Change

The land use and land cover change (LULCC) analysis of the present study refers to the classes of clean pasture, dirty pasture, regeneration with pasture, native vegetation, cleared (areas recently cleared of native vegetation), other agriculture (rice, beans, fallow, etc.), sugarcane and planted forest, that were converted to annual crops in the following periods: 1) 2000/01 to 2006/07 (six crop year); 2) 2006/07 to 2009/10 (three crop years) and 3) 2009/10 to 2014/15 (five crop years).

As shown in Item 3.1, the planted area of first-crop soy, corn and cotton increased from 0.37 million hectares in 2000/01 to 4.07 million hectares in 2014/15, which was almost entirely due to soy as the area of corn and cotton remained relatively stable in this period. The expansion of 3.70 million hectares during that period resulted in a land use and land cover change of 3.90 million hectares[2], of which 1.14 million hectares were observed in the 2000/01-2006/07 period (Figure 21 and Table 8), 0.76 million hectares were observed in the 2006/07-2009/10 period (Figure 22 and Table 9) and 2.00 million hectares were observed in the 2009/10-2014/15 period (Figure 23 and Table 10). The LULCC observed for the classes of clean pasture, dirty pasture and regeneration with pasture accounted for 34%, 22% and 7%, respectively, of the area converted to annual crops during the period from 2000/01 to 2014/15 (Tables 8 to 10). The LULCC for the classes of native vegetation (native vegetation plus the cleared of native vegetation) accounted for 22% of the area converted to annual crops (Tables 8 to 10). The class of other agriculture accunted for 14%, while sugarcane and planted forest accounted for 1% of the observed LULCC in response to annual crops expansion (Tables 8 to 10).

Figure 21 shows the LULCC observed in the period 2000/01 to 2006/07, with the classes of clean pasture, dirty pasture and regeneration with pasture representing 23% (0.26 million hectares), 15% (0.17 million hectares) and 6% (0.07 million hectares), respectively, of the area converted to annual crops. The LULCC observed in the period from 2006/07 to 2009/10 (Figure 22) for the classes of clean pasture, dirty pasture and regeneration with pasture represented 21% (0.16 million hectares), 20% (0.15 million hectares) and 9% (0.07 million hectares), respectively, of the area converted to annual crops. While a reduction in pasture area converted to annual crops was observed from the first to the second analyzed period, there was a significant increase of pasture conversion to annual crops in the third period from 2009/10 to 2014/15. In this period the classes of clean pasture, dirty pasture and regeneration with pasture represented 44% (0.88 million hectares), 26% (0.53 million hectares) and 8% (0.16 million hectares), respectively (Figure 23), of the area converted to annual crops. The highest annual crops expansion rate was observed in this period (Figure 19) with almost 80% expanding on pasture (Figure 23).

The areas of "native vegetation" plus the areas of "cleared" native vegetation (recent deforestation), represent 47% (0.53 million hectares) of the land use and land cover change in the first period (2000/01 to 2006/07, Figure 21 and Table 8) and 14% (0.11 million hectares) in the second period (2006/07 to 2009/10, Figure 22 and Table 9). In the third period (2009/10 to 2014/15, Figure 23 and Table 10), this number was 11% (0.21 million hectares), even though, the highest annual crop expansion rates were observed in this latter period (0.39 million hectares/year; Figure 19). This relative reduction in deforestation associated with soy in the periods after 2007 is associated with, among other things, the effect of the Soy Moratorium that restricted the trading of soy originated in areas deforested after 2006[3] for those traders associated with ABIOVE (Brazilian Vegetable Oil Industries Association) and ANEC (National Grain Exporters Association). In absolute terms, the state of Mato Grosso heads by far the LULCC of native vegetation to annual crops, since the great majority of the annual crops expansion occurred in this state.

The state of Roraima (RR) and to some extend Amapá (AP) have some peculiarities compared to the other states because part of their territory is covered with natural vegetation formed predominantly by grasses and shrubs named "Lavrado" (similar to savannah). The expansion of annual crops, especially soy, is impelled in these areas in response to lower land price and low cost of the clearing process. Furthermore, the soy produced in this northern hemisphere region is coincident with the Brazilian intercrop period favouring better prices. The soy produced in these states also have the advantage of being relatively close to the northern shipping ports reducing freight cost, especially the soy areas in Amapá state that are just a few kilometres from the port of Santana.

Figure 24 shows the results of the expansion of annual crops, highlighting the expansion with and without deforestation in the Amazon for the three analyzed periods. It should be noted that deforestation associated with annual crops expansion in the period 2000/01 to 2006/07 was 0.09 million hectares/year, falling to 0.04 million hectares/year in the two following periods (2006/07 to 2009/10 and 2009/10 to 2013/14). This result does not agree with the recent soy expansion on deforested land reported by the Soy Moratorium initiative, which is about 0.01 million hectares/year. The reason for this disagreement is due to the fact that according to the Soy Moratorium rules only the soy expansion on primary native forested vegetation is considered. Therefore, soy expansion on native vegetation other than forest and on secondary native vegetation is not accounted in the Soy Moratorium, but was accounted in the present study. A small portion of this difference could also be explained by the conversion of native vegetation to corn or even to soy in those few municipalities that have less than 5,000 hectares of soy and, therefore, are not evaluated in the Soy Moratorium.

Although the largest expansion rates of annual crops were observed from the 2006/07 crop year on (Figure 19), it should be noted that the highest deforestation rates occurred up to 2004. Starting in this year, illegal deforestation diminished significantly as a result of the effective intervention by public authorities through implementation of the PPCDAm (Plan for Prevention & Control of Deforestation in Legal Amazon) in 2004. The Soy Moratorium that started on 22nd July 2006 (later changed to 22nd July 2008) has been an important regulatory mark to stop conversion of primary forested native vegetation to soy, promoting its expansion on anthropized land such as pasture or even secondary native vegetation.

Although deforestation rates associated with annual crops expansion have dropped since 2006/07, the expansion rates of annual crops continued to increase in the following years mainly on the classes of pasture and other agriculture. In the crop year of 2006/07 a general reduction in planted soy area, not only in the Amazon, but in nearly all of Brazil, due to an unfavourable economic scenario for soy resulted in a relatively large stock of the "other agriculture" class for soy expansion in the following crop years, particularly in the period 2006/07 to 2009/10 (Figures 22 and 24). However, the areas of retraction presented in Figure 24 are part of annual crop production dynamics and does not mean that an area has been abandoned, but rather that there is a floating stock of areas available for annual crops. Retractions occur mostly in two situations: i) land that is temporarily fallow, especially in the more peripheral areas or those not yet consolidated; and ii) rotation with other annual crops.

2 Among the evaluated crops, there were expansions as well as retractions (areas that ceased to grow soy, corn or cotton). Due to the retractions, the land use change is generally higher than the net expansion in agricultural crops in each period.

3 Originally, the Soy Moratorium reference date was 24th July 2006. In 2014, the reference date was changed to 22nd July 2008.

Table 8 – Main land use and land cover changes to annual crops in the states of the Amazon Biome for the period 2000/01 to 2006/07.

STATE	CHANGE IN LAND USE AND LAND COVER | 2000/01-2006/07									
	CLEAN PASTURE ha	DIRTY PASTURE ha	REGENERATION WITH PASTURE ha	NATIVE VEGETATION ha	CLEARED ha	OTHER AGRICULTURE ha	SUGARCANE ha	PLANTED FOREST ha	TOTAL ha	%
MT	225,128	140,107	58,888	368,346	117,600	87,168	3,957	0	1,001,193	87.8
PA	6,850	15,642	7,264	33,056	3,039	5,809	0.0	0	71,660	6.3
RO	29,147	14,868	2,934	5,280	854	3,957	0	0	57,039	5.0
MA	482	404	380	986	0	0	0	0	2,253	0.2
RR	1,150	924	50	3,858	213	283	0	0	6,479	0.6
TO	762	309	0	119	0	0	0	0	1,190	0.1
AP	0	0	0	387	0	0	0	0	387	0.0
TOTAL	263,520	172,255	69,515	412,032	121,706	97,217	3,957	0	1,140,201	100.0

Table 9 – Main land use and land cover changes to annual crops in the states of the Amazon Biome for the period 2006/07 to 2009/10.

STATE	CHANGE IN LAND USE AND LAND COVER | 2006/07-2009/10									
	CLEAN PASTURE ha	DIRTY PASTURE ha	REGENERATION WITH PASTURE ha	NATIVE VEGETATION ha	CLEARED ha	OTHER AGRICULTURE ha	SUGARCANE ha	PLANTED FOREST ha	TOTAL ha	%
MT	136,000	121,187	61,473	33,634	59,889	233,314	5,475	0	650,972	85.5
PA	7,881	14,540	3,582	5,500	5,706	21,667	0	0	58,875	7.7
RO	16,749	13,950	1,944	999	434	12,706	0	0	46,783	6.1
MA	312	548	84	195	16	108	0	0	1,263	0.2
RR	181	44	0	241	392	476	0	0	1,335	0.2
TO	225	28	148	41	8	221	0	0	671	0.1
AP	257	0	0	792	128	283	0	0	1,460	0.2
TOTAL	161,605	150,296	67,231	41,402	66,574	268,775	5,475	0	761,357	100.0

Table 10 – Main land use and land cover changes to annual crops in the states of the Amazon Biome for the period 2009/10 to 2014/15.

STATE	CHANGE IN LAND USE AND LAND COVER | 2009/10-2014/15									
	CLEAN PASTURE ha	DIRTY PASTURE ha	REGENERATION WITH PASTURE ha	NATIVE VEGETATION ha	CLEARED ha	OTHER AGRICULTURE ha	SUGARCANE ha	PLANTED FOREST ha	TOTAL ha	%
MT	764,481	369,402	113,384	79,514	48,542	150,836	19,766	63	1,545,989	77.3
PA	51,537	89,884	31,723	39,473	5,813	24,541	1,522	29	244,523	12.2
RO	45,049	49,887	3,870	3,124	1,354	14,241	0	0	117,526	5.9
MA	10,486	14,750	6,009	9,125	159	2,069	0	155	42,754	2.1
RR	3,562	2,379	185	15,080	206	2,556	0	178	24,146	1.2
TO	6,721	7,279	163	136	0	17	0	6	14,323	0.7
AP	2,591	58	0	8,224	0	0	0	0	10,873	0.5
TOTAL	884,427	533,640	155,335	154,677	56,074	194,261	21,288	432	2,000,133	100.0

LAND USE AND LAND COVER CHANGE: 2000/01-2006/07

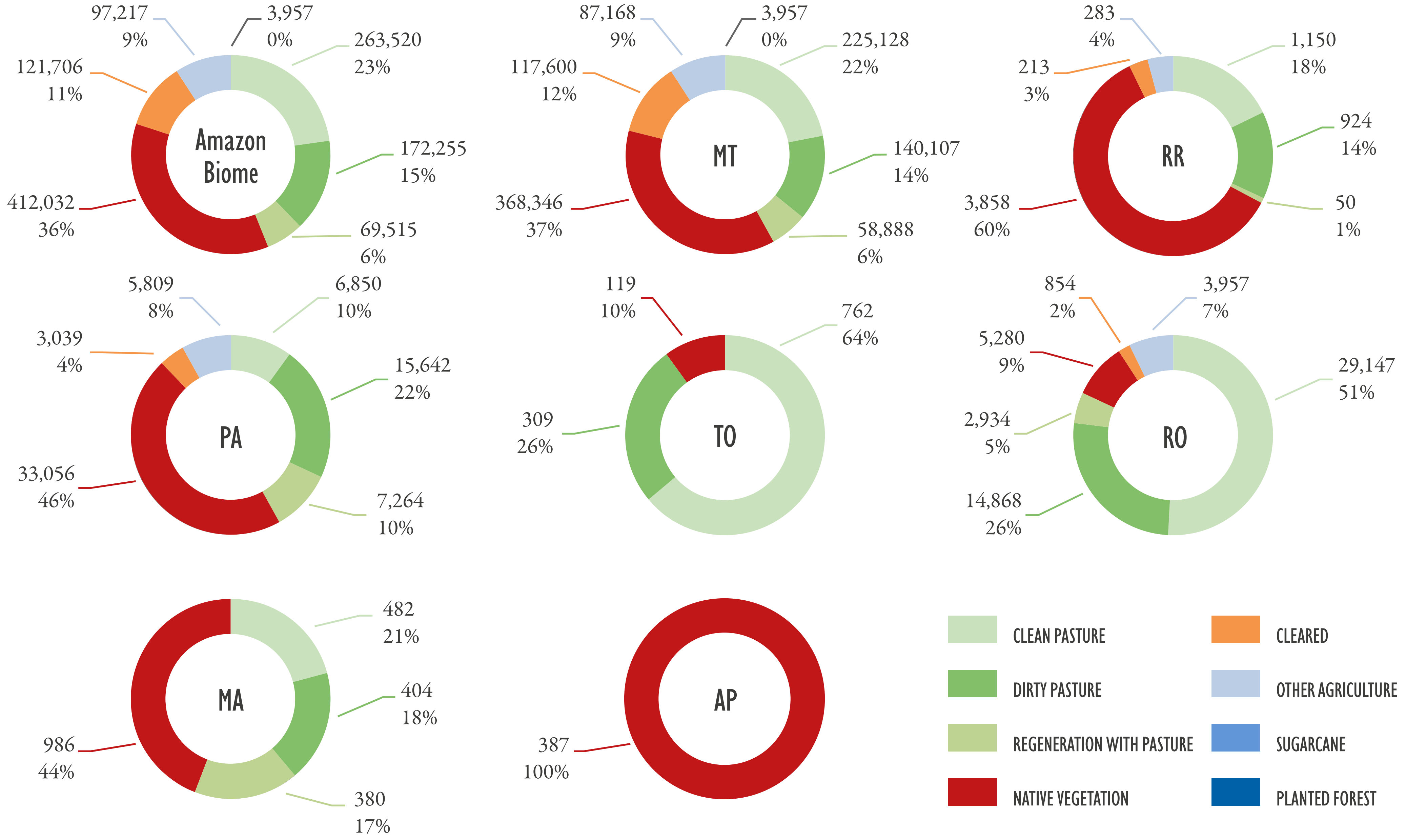


Figure 21 – Land use and land cover change in the Amazon Biome and by state for the period 2000/01-2006/07.

LAND USE AND LAND COVER CHANGE: 2006/07-2009/10

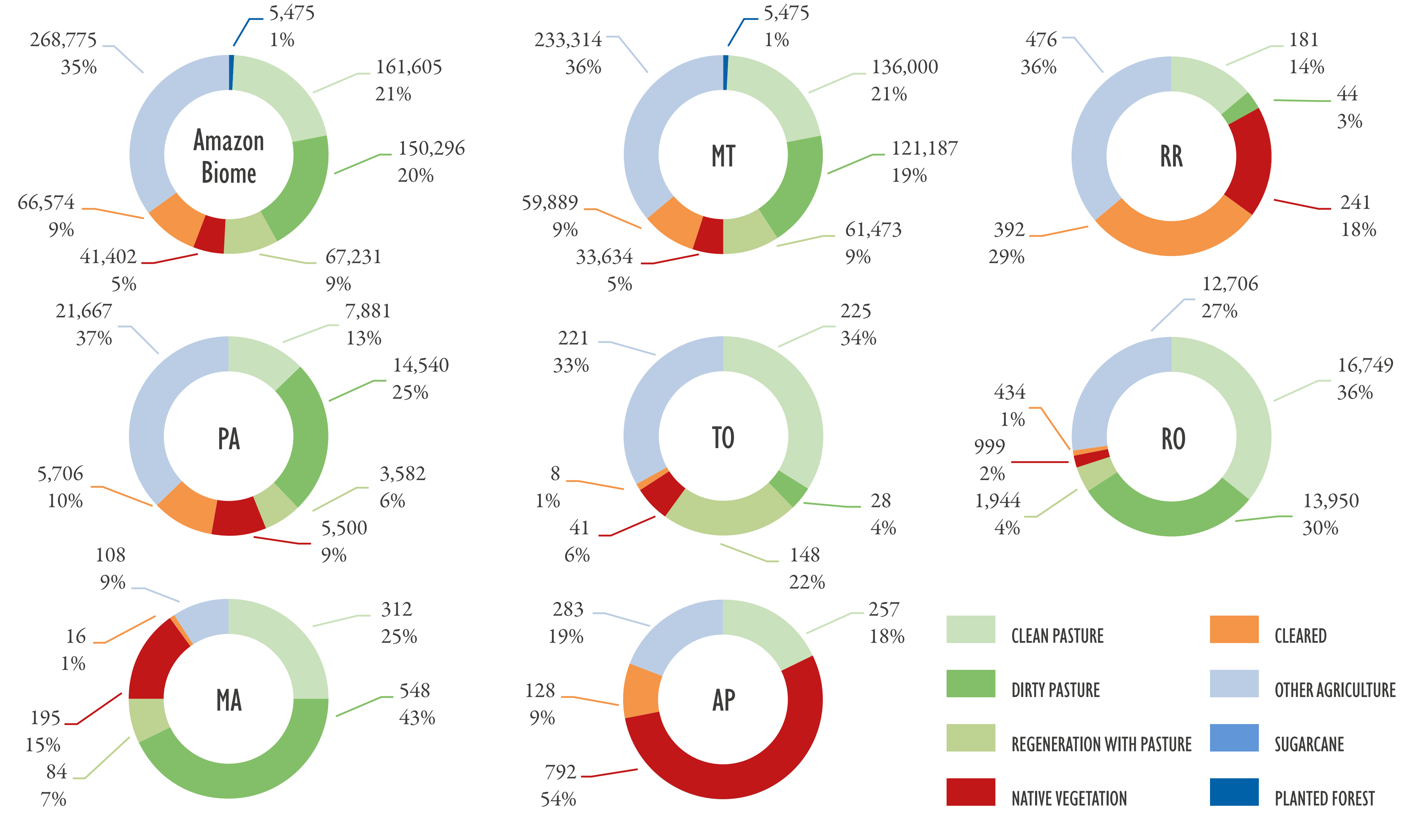


Figure 22 – Land use and land cover change in the Amazon Biome and by state for the period 2006/07-2009/10.

LAND USE AND LAND COVER CHANGE: 2009/10-2014/15

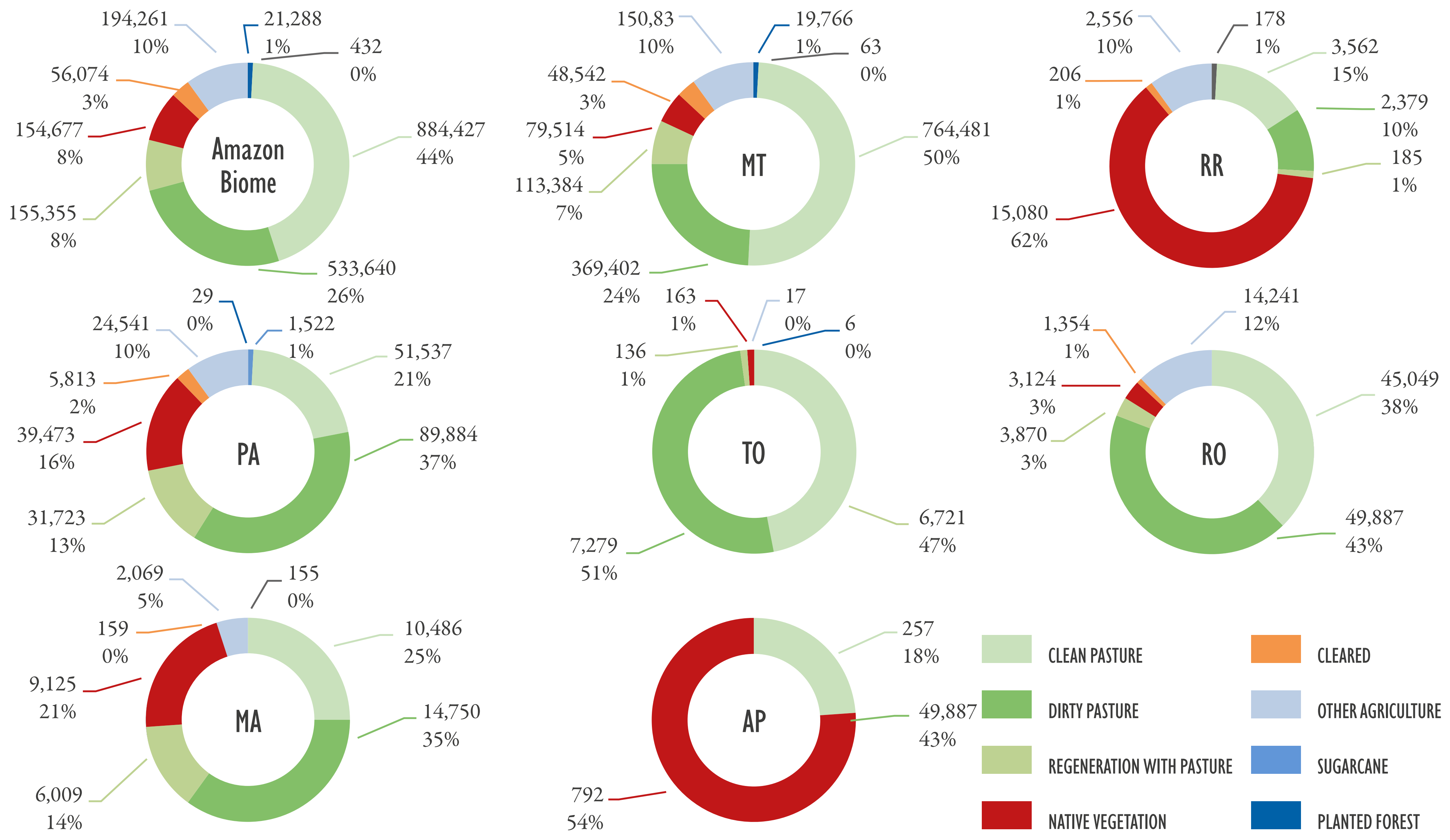


Figure 23 – Land use and land cover change in the Amazon Biome and by state for the period 2009/10-2014/15.

AREA OF FIRST-CROP OF SOYBEAN, CORN AND COTTON

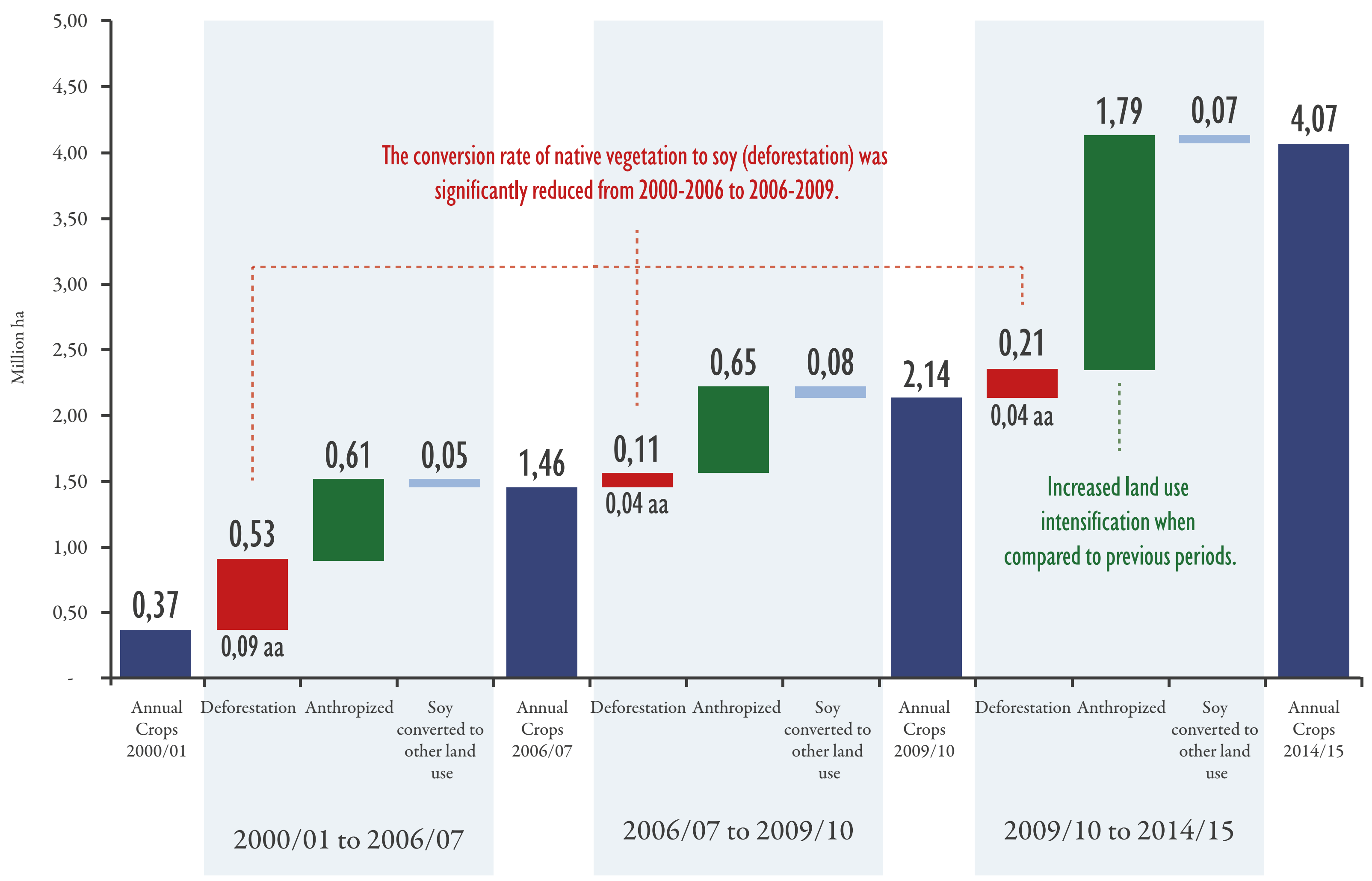


Figure 24 – Expansion of first-crop of soy, corn and cotton in the Amazon Biome, with deforestation (red) and without deforestation (green), in three periods: 2000/01-2006/07; 2006/07-2009/10; and 2009/10-2014/15 crop years.

3.3 Agricultural Suitability in the Amazon Biome

The map of land use and land cover in the Amazon Biome for the classes of annual crops (AC), primary native vegetation (PNV), anthropized (A), secondary native vegetation (SNV) and water is presented in Figure 25. According to this map 4.59 million hectares (7.0%) are used to produce annual crops (first-crop of soy, corn or cotton), 335.67 million hectares (80.3%) are covered with primary native vegetation, 53.30 million hectares (6.8%) are anthropized lands mainly used as pasture, 15.30 million hectares (3.6%) are covered with secondary native vegetation, and 9.57 million hectares (2.3%) are covered with water (rivers, lakes, etc.).

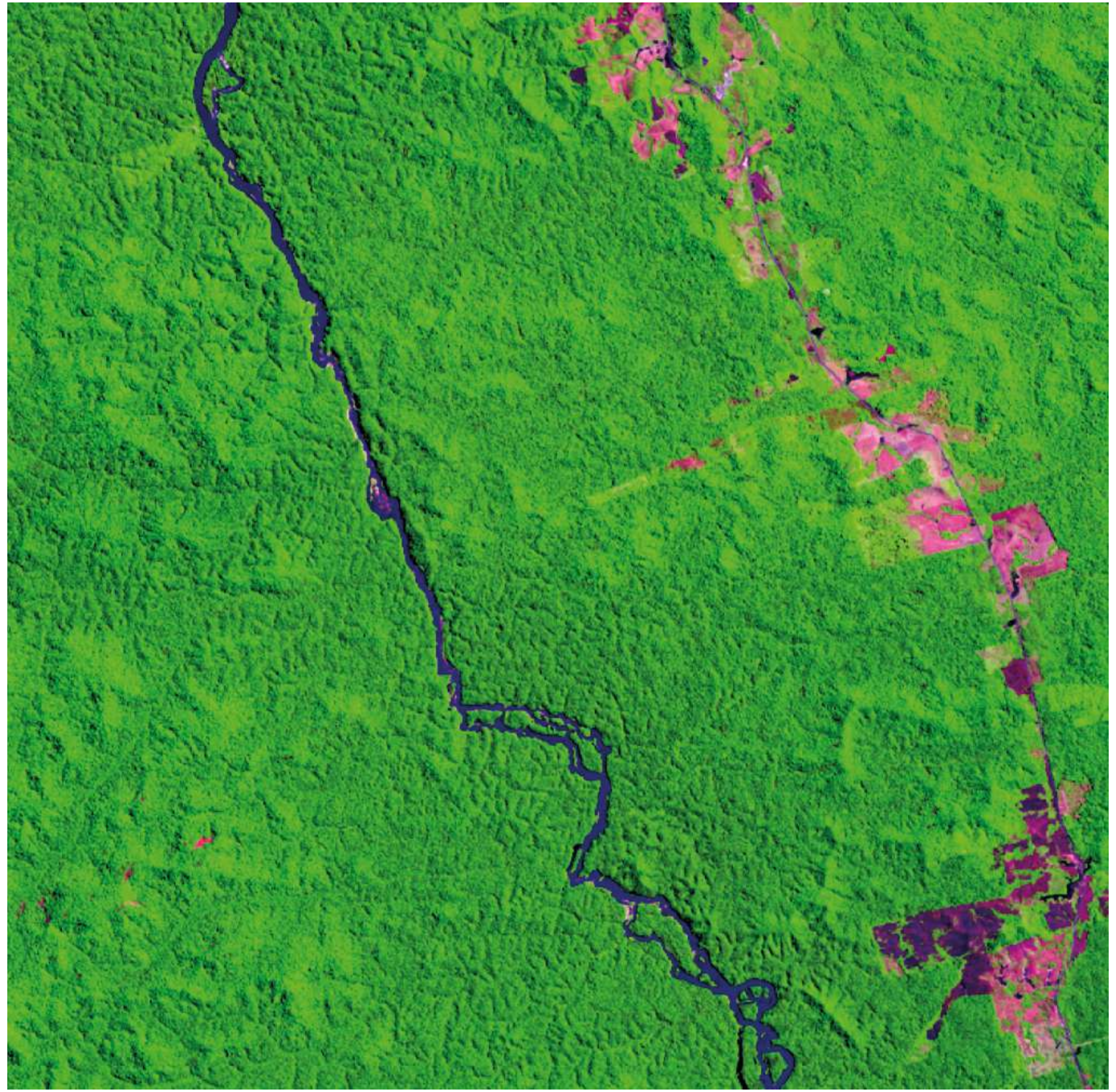
Figure 26 illustrates the agricultural suitability for each of the land use and land cover classes in the Amazon Biome. According to this analysis 194.19 million hectares (46.43%) of primary native vegetation (PNV) have high agricultural suitability without slope and altitude restrictions, of which 122.39 million hectares (63.03%) are within special areas (conservation units, settlements, indigenous lands or quilombolas), as shown in Table A1.

Although the 71,80 million hectares covered with primary native vegetation, inside private properties or undesignated land, have high agricultural suitability without slope and altitude restrictions they are largely restricted for annual crop expansion due to other conditions. For example, the Soy Moratorium restricts soy expansion in areas deforested after 22nd July 2008, and the Forest Code establishes a Legal Reserve of 80% in private properties leaving only 20% for other uses such as ranching or annual crops. In addition, a major part of this area is in regions that are practically inaccessible without the necessary logistics and infrastructure for annual crop expansion. Therefore, under the current scenario, the large reserves of primary native vegetation with agricultural suitability that could potentially be converted to soy are not that big. On the other hand, the 6.20 million hectares (1.5%) of secondary vegetation and the 24.48 million hectares (5.9%) of anthropized land, both with high agricultural suitability are potential stocks of land to be converted to annual crops. Figure 26 also shows that 176.48 million hectares (41.9%) is not suitable for annual crop expansion, and that 12.33 million hectares (2.95%) are inadequate for agricultural activity (rivers, lakes, marshes, etc.), whether they are or not protected.

The 18.47 million hectares of anthropized land (mainly pasture) and the 4,20 million hectares of secondary vegetation with agricultural suitability within private properties or undesignated land (Table A1 in Appendix) are considerable large stock of land for future crop expansion in the Amazon Biome. With only 20% of this area the current annual crop area of the Biome could be doubled. Considering that the ranching activity is less demanding in terms of agricultural suitability, the loss of pasture land with high agricultural suitability could be compensated by increasing the support capacity of pastures with lower agricultural capacity located elsewhere - in other words - intensifying the land use by increasing productivity. This land use intensification process has increased in recent years as shown in Figure 24, particularly for the 2009/10 -2014/15 period. Due to the constraints of converting native vegetation to annual crops the land use intensification process will probably continue or even increase to favour the crop expansion in the Biome.

The greatest stocks of anthropized land with agricultural suitability are placed in the states of Mato Grosso, Pará and Rondônia with 6.96, 8.32 and 4.27 million hectares, respectively, representing approximately 80% of that stock (Table A1 in Appendix). These same states are also responsible for 96% of the annual crop area in the Amazon Biome in 2016/17 presenting favourable infrastructure around the producing areas and, therefore, the best conditions for further expansion of annual crops on previously disturbed land.

Finally, this study supplies detailed information from local to regional scale on agricultural suitability associated not only with slope and altitude restrictions, but also with current land use and land cover. The information on agricultural suitability and on land use is shown for the special areas (Conservation Units for Integral Protection – CU-IP; Conservation Units for Sustainable Use – CU-SU; Settlements – SETT; Indigenous Lands – IL and Quilombolas – QUI) and, by difference, for Private Properties and Undesignated Land (PP-UL). Figures A1 to A18 in the Appendix show the maps for land use and land cover classes, and the maps of agricultural suitability for each state in the Biome. Table A1 of the Appendix synthesizes the values of each class of land use and the corresponding classes of agricultural suitability for the Biome and for each state within the Biome. The figures tables presented in the Appendix provide an enormous amount of information that has been only discussed superficially, but could be looked with more detail, according to the reader's interest.



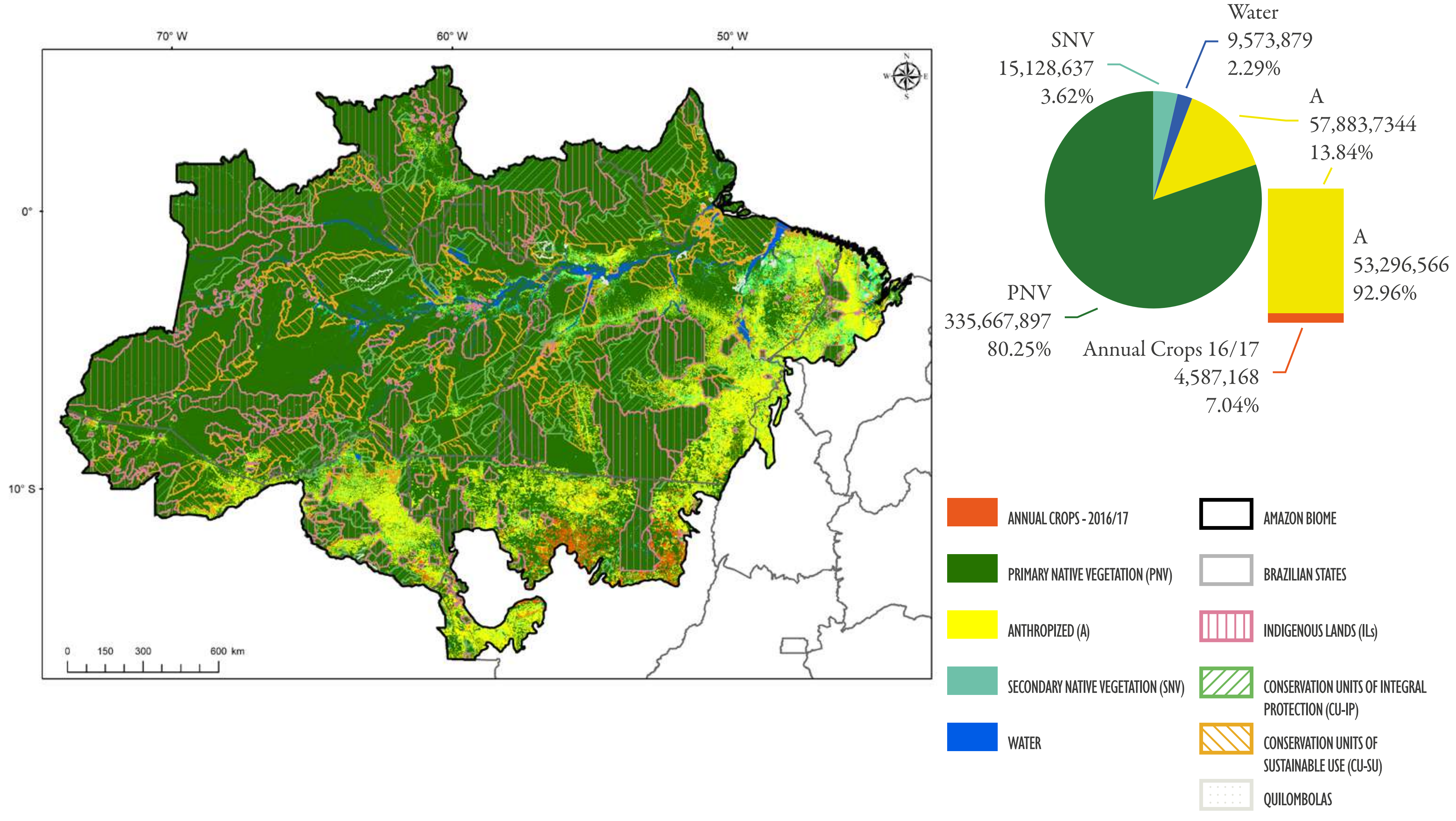
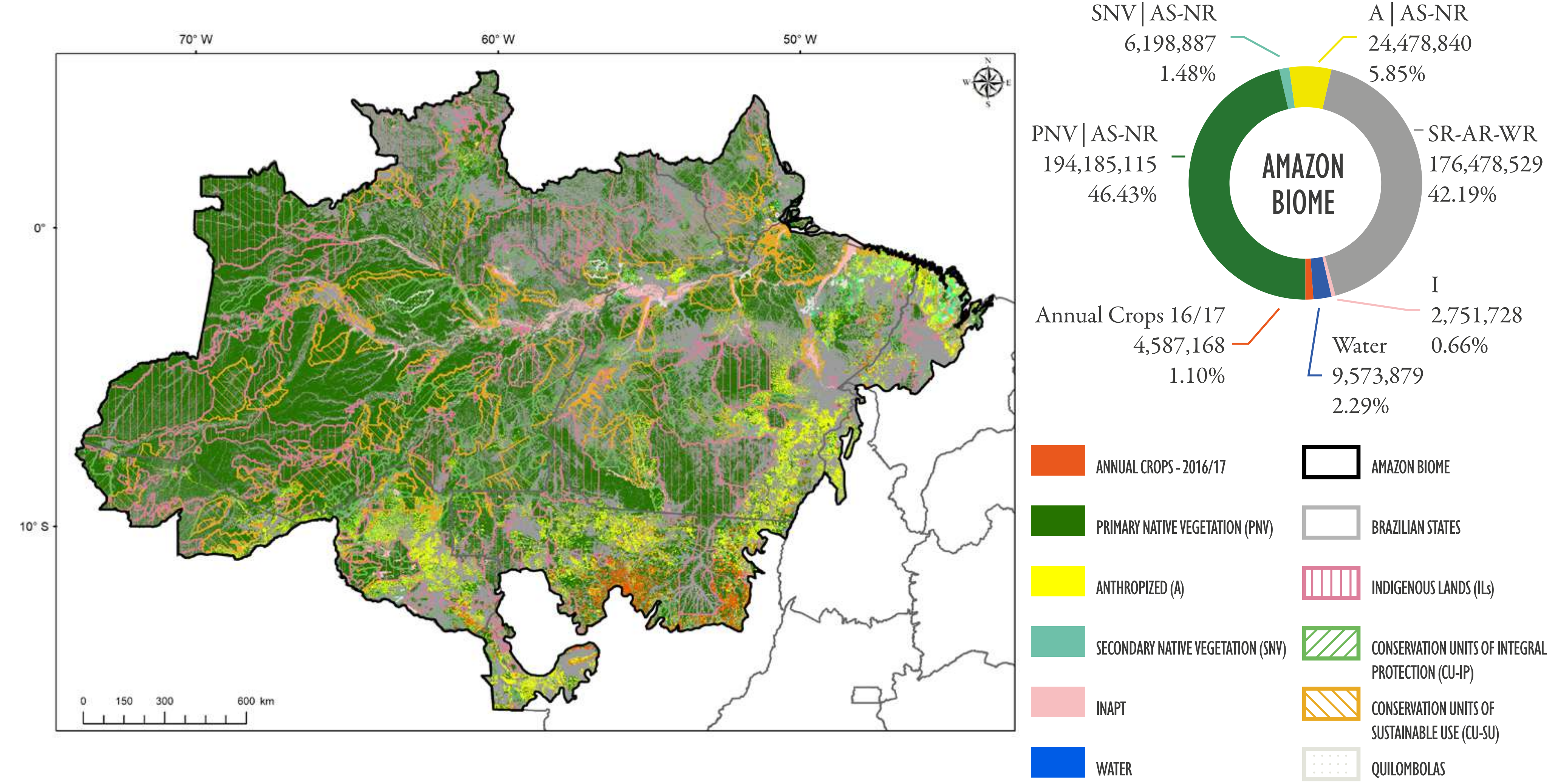


Figure 25 – Land use and land cover in the Amazon Biome in 2015.



Observation:
PNV | AS-NR: Primary Native Vegetation (PNV) with Agricultural Suitability (AS) and No Restrictions to slope and altitude (NR);
A | AS-NR: Anthropized (A) with Agricultural Suitability (AS) and No Restrictions to slope and altitude (NR);
SNV | AS-NR: Secondary Native Vegetation (SNV) with Agricultural Suitability (AS) and No Restrictions to slope and altitude (NR);
SR-AR-WR: Without Agricultural Suitability due to Slope Restriction (SR), Altitude Restriction (AR), and slope and altitude restrictions (WR);
I: Inapt (e.g. urban areas, rocky outcrops etc.);
Water

Figure 26 – Agricultural suitability in the Amazon Biome in 2015.

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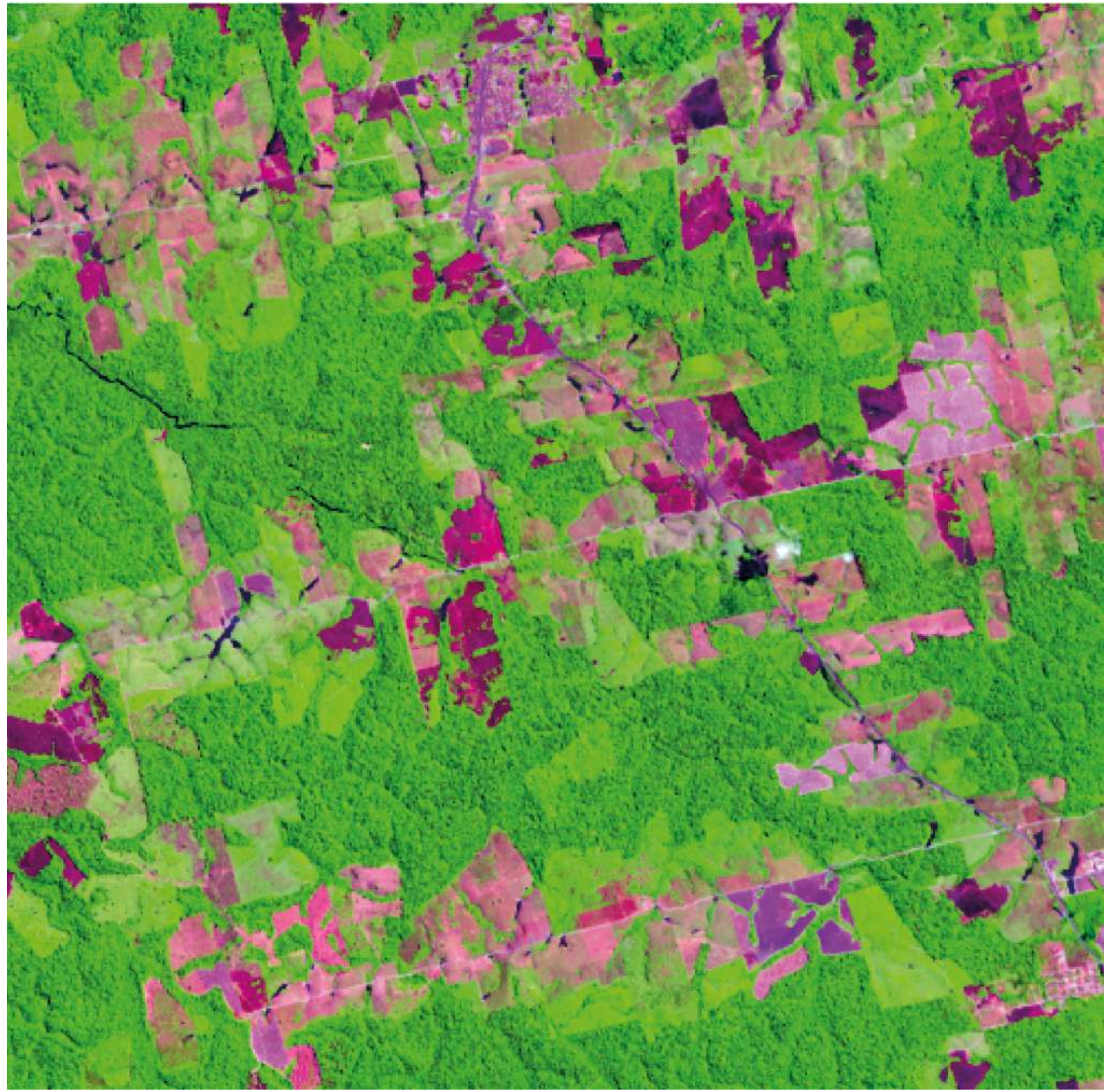
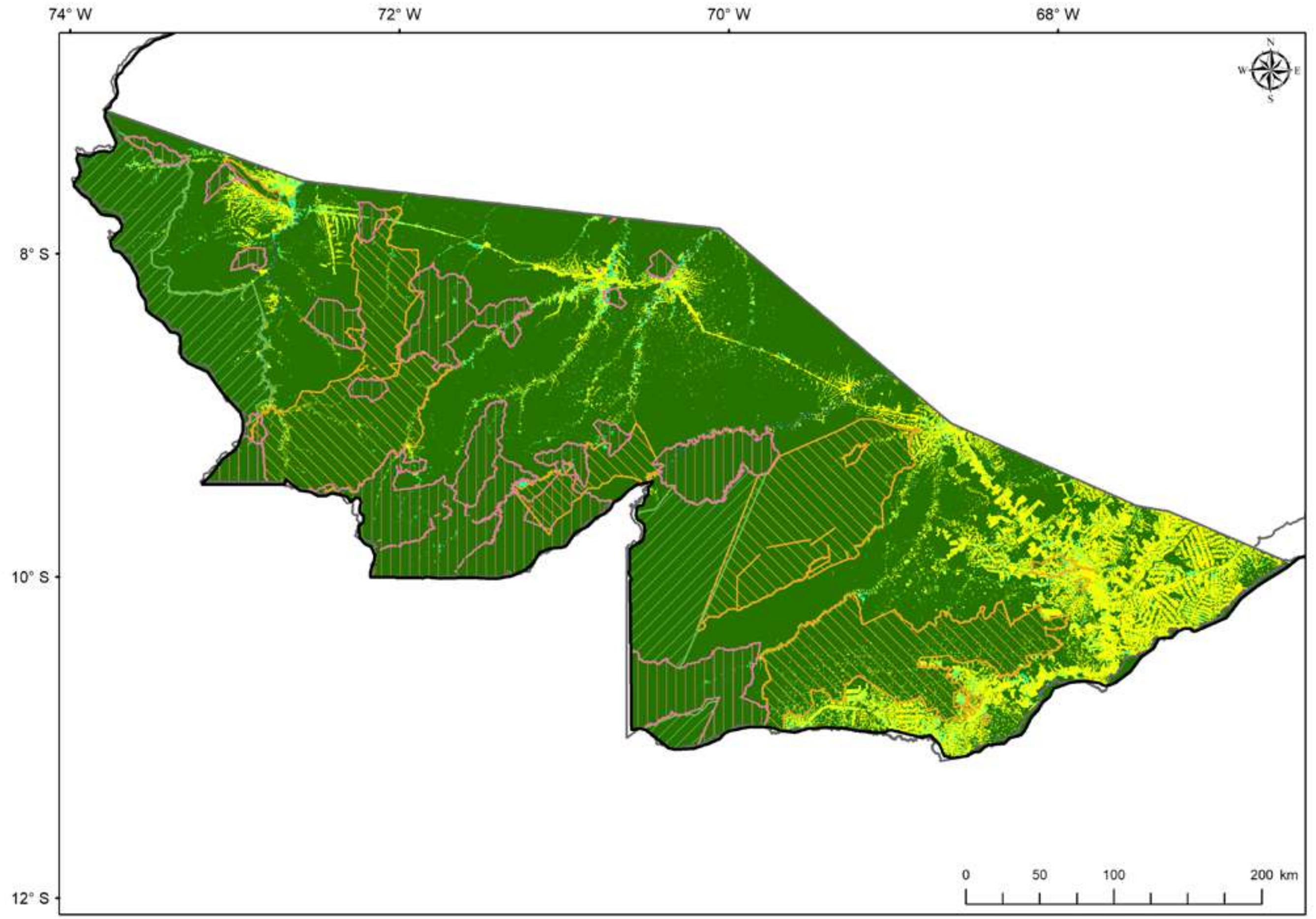


APPENDIX



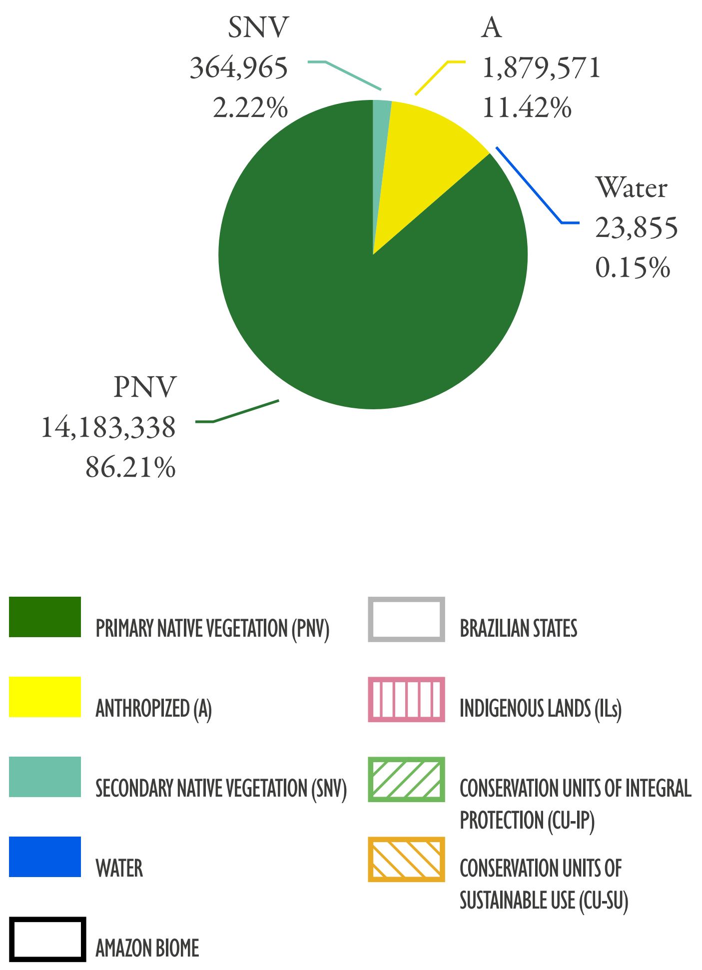
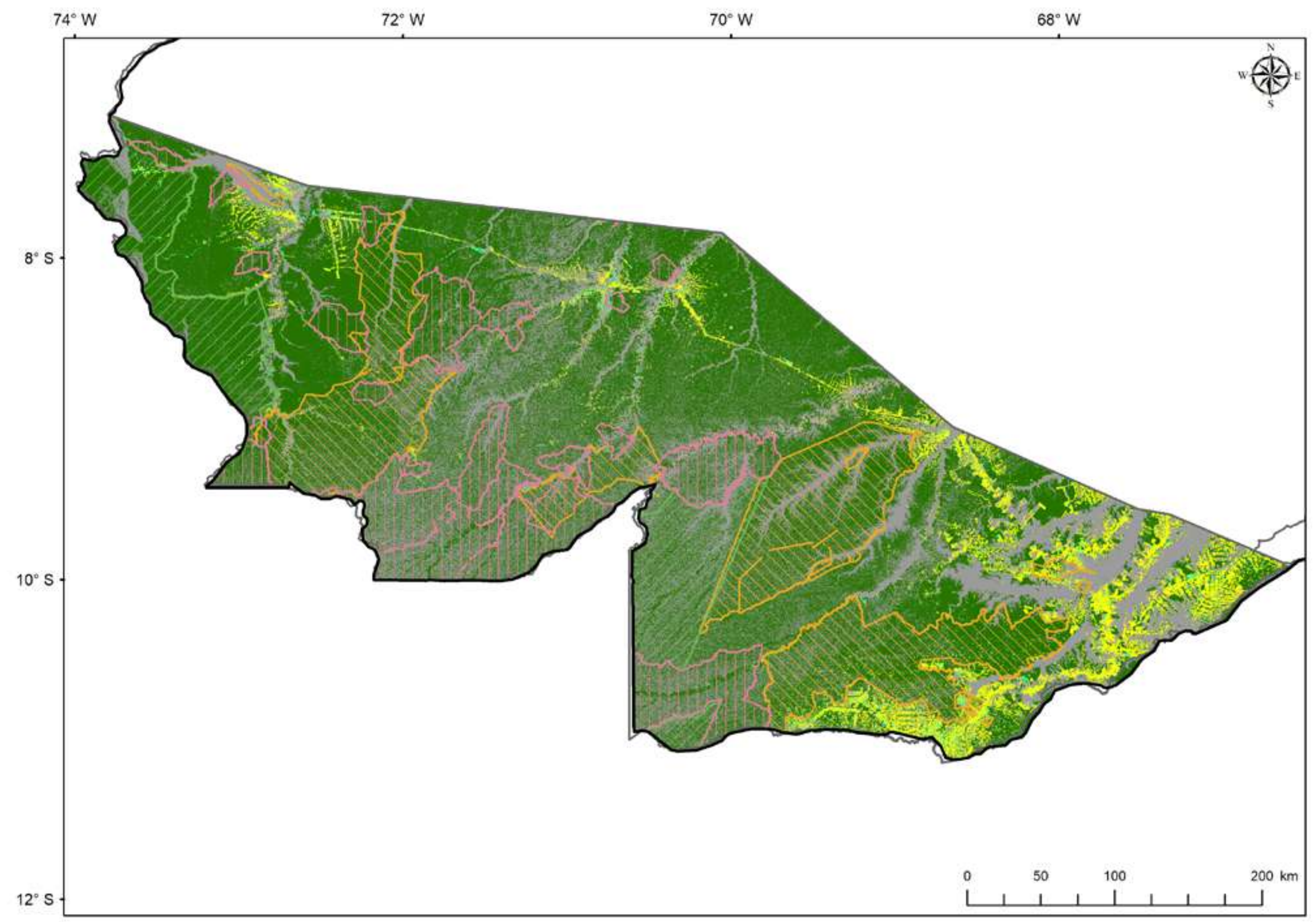
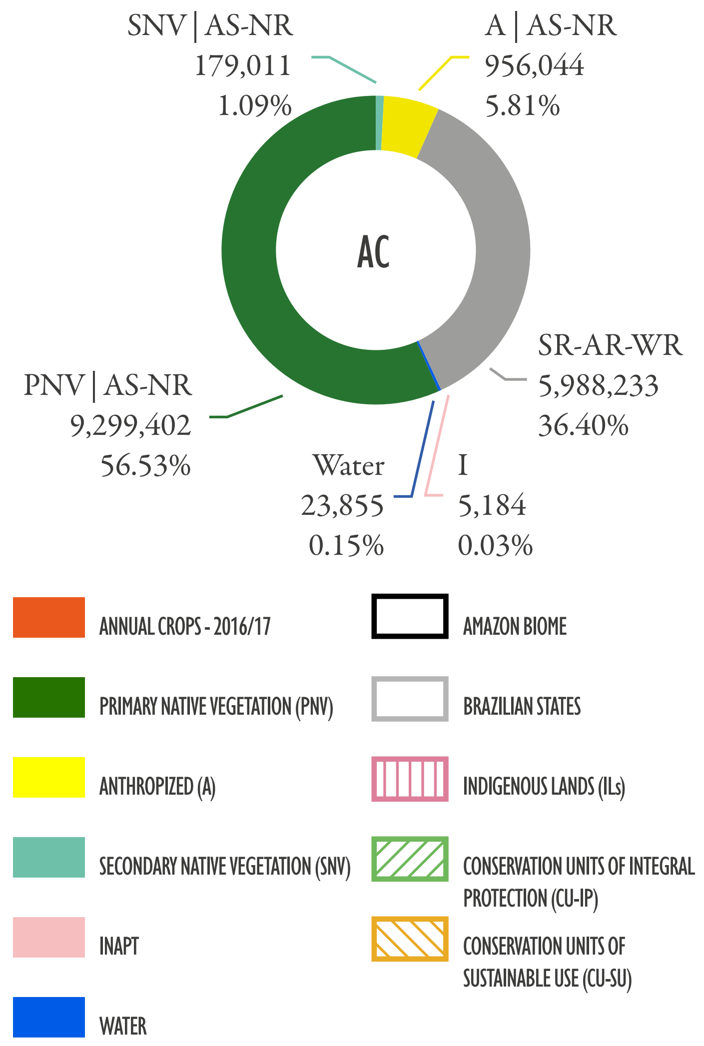


Figure A1 – Land use and land cover in the state of Acre in 2015.





Observation:
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I: Inapt (e.g. urban areas, rocky outcrops etc.);
Water

Figure A2 – Agricultural suitability in the state of Acre in 2015.

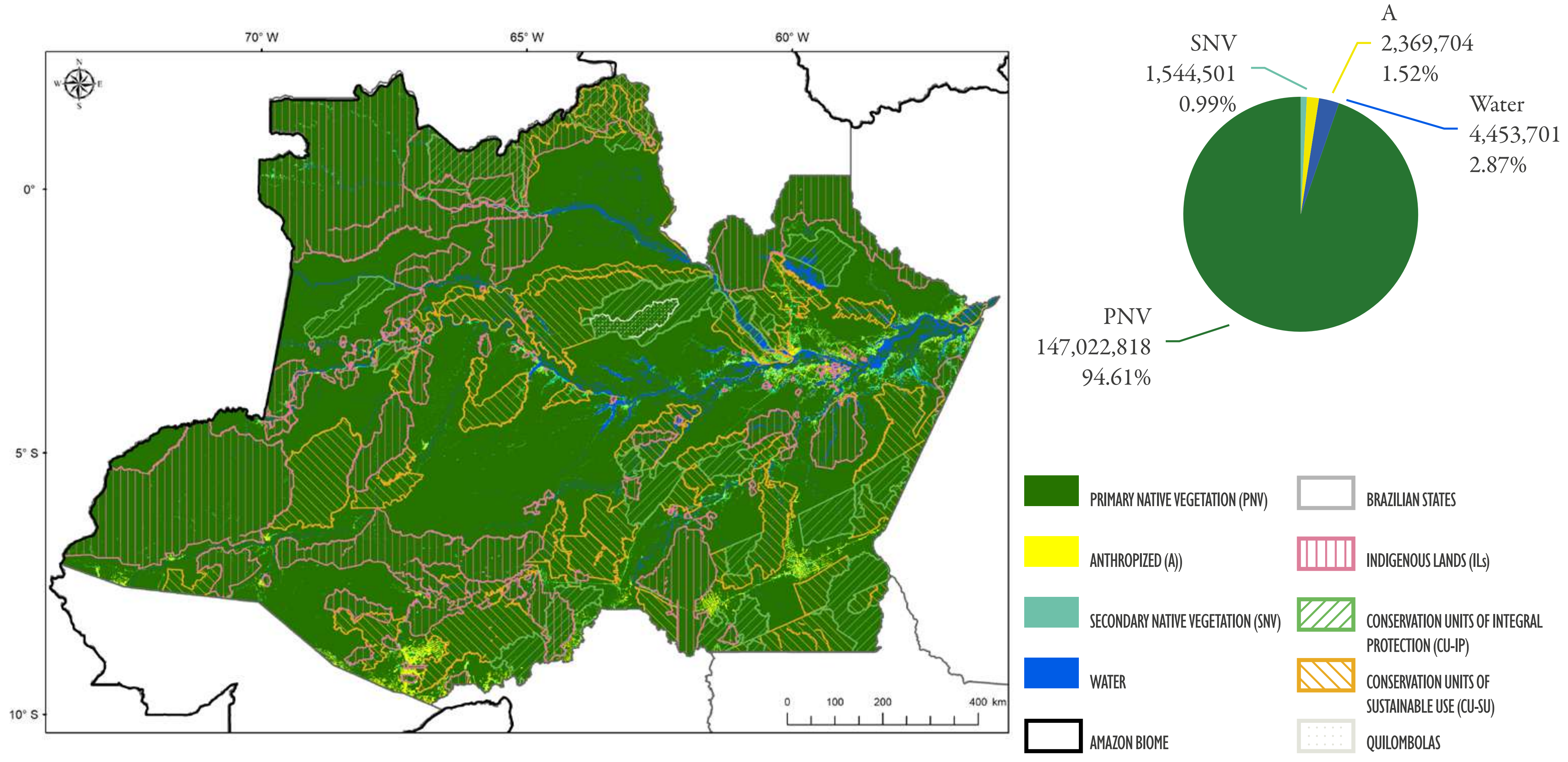
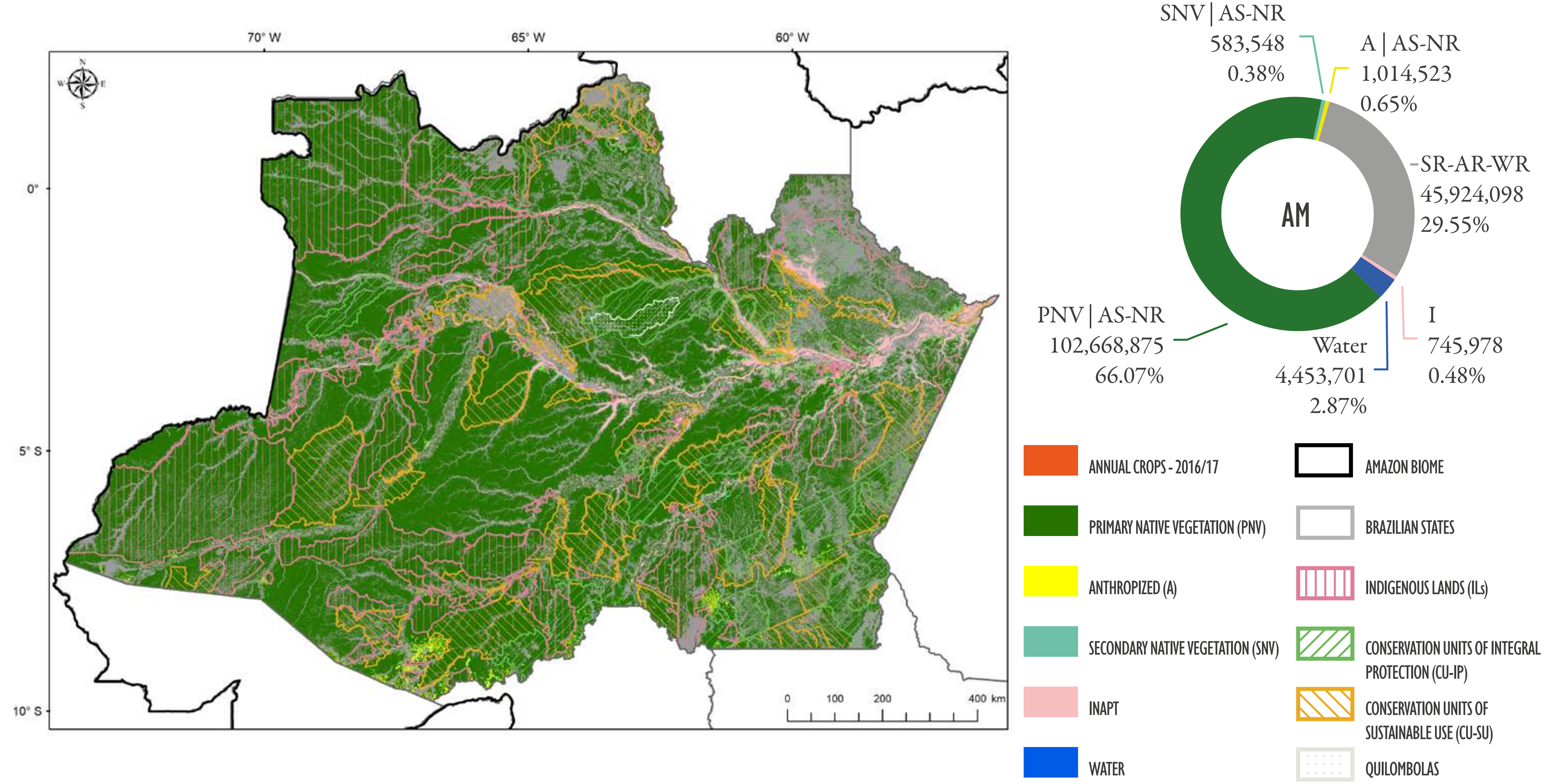


Figure A3 – Land use and land cover in the state of Amazonas in 2015.



Observation:
PNV | AS-NR: Primary Native Vegetation (PNV) with Agricultural Suitability (AS) and No Restrictions to slope and altitude (NR);
A | AS-NR: Anthropized (A) with Agricultural Suitability (AS) and No Restrictions to slope and altitude (NR);
SNV | AS-NR: Secondary Native Vegetation (SNV) with Agricultural Suitability (AS) and No Restrictions to slope and altitude (NR);
SR-AR-WR: Without Agricultural Suitability due to Slope Restriction (SR), Altitude Restriction (AR), and slope and altitude restrictions (WR);
I: Inapt (e.g. urban areas, rocky outcrops etc.);
Water

Figure A4 – Agricultural suitability in the state of Amazonas in 2015.

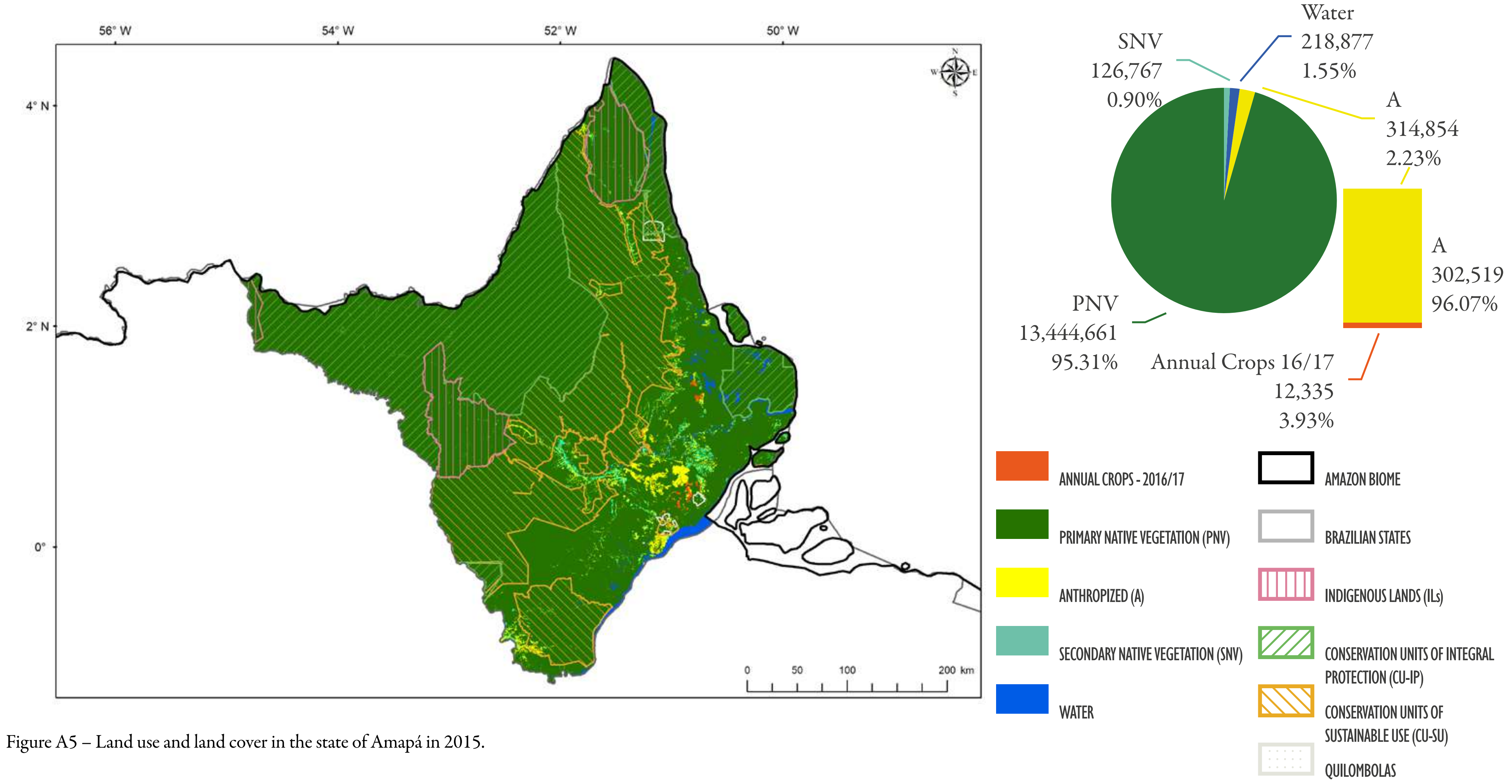
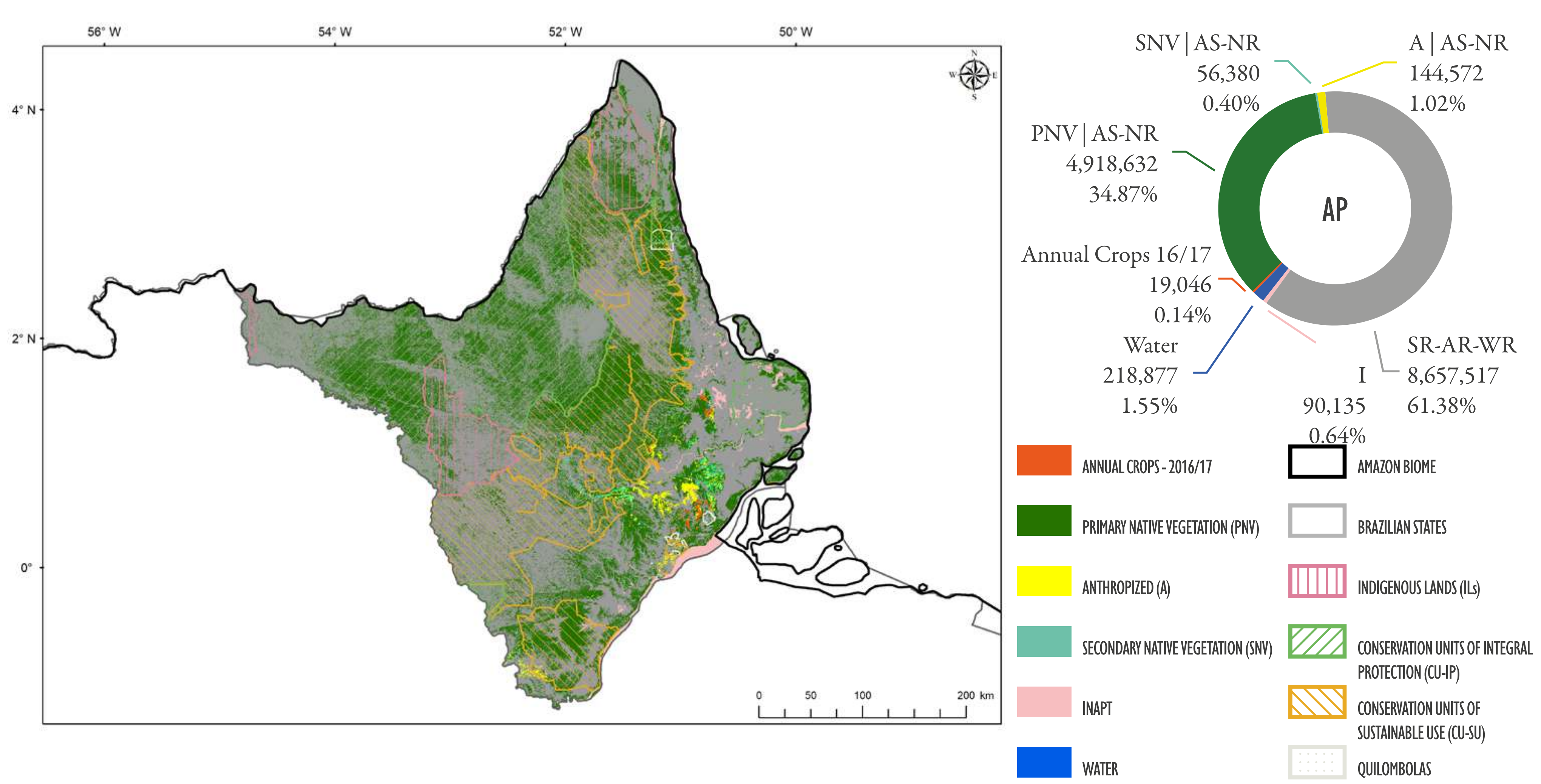


Figure A5 – Land use and land cover in the state of Amapá in 2015.



Observation:
PNV | AS-NR: Primary Native Vegetation (PNV) with Agricultural Suitability (AS) and No Restrictions to slope and altitude (NR);
A | AS-NR: Anthropized (A) with Agricultural Suitability (AS) and No Restrictions to slope and altitude (NR);
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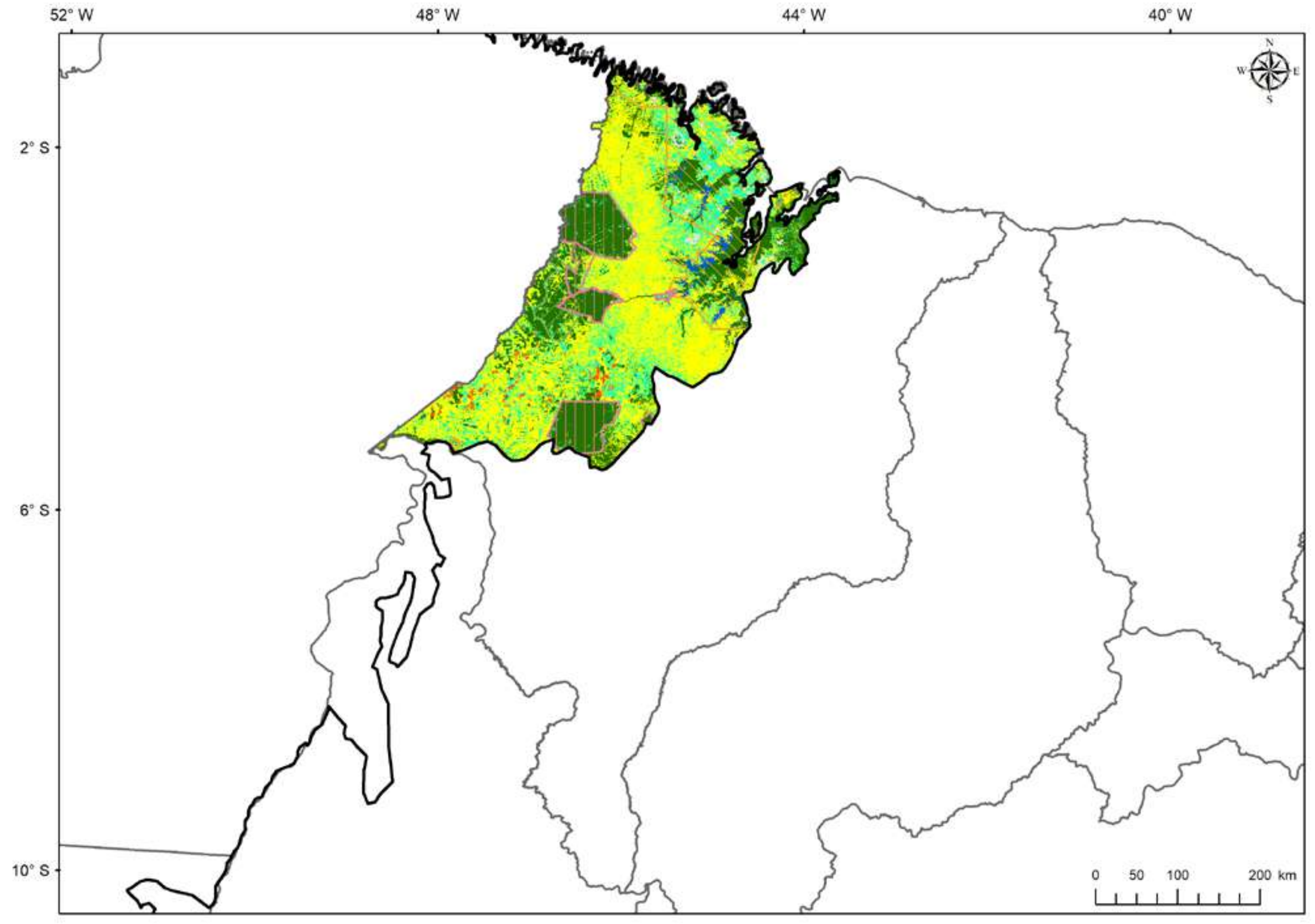
Water

Figure A6 – Agricultural suitability in the state of Amapá in 2015.



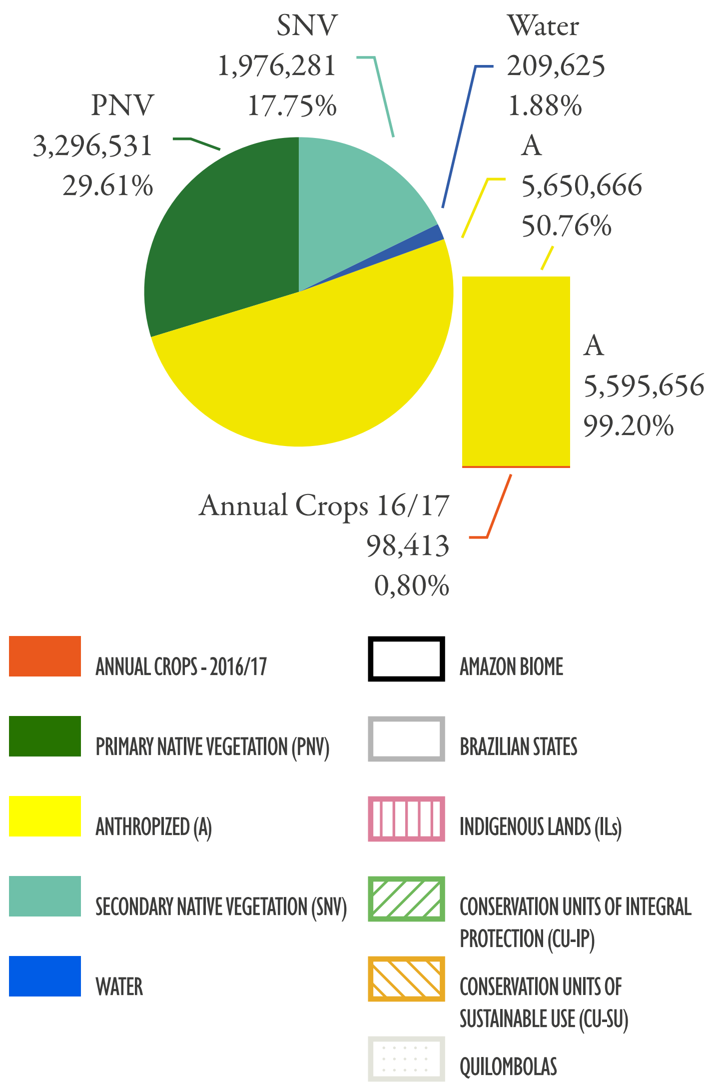
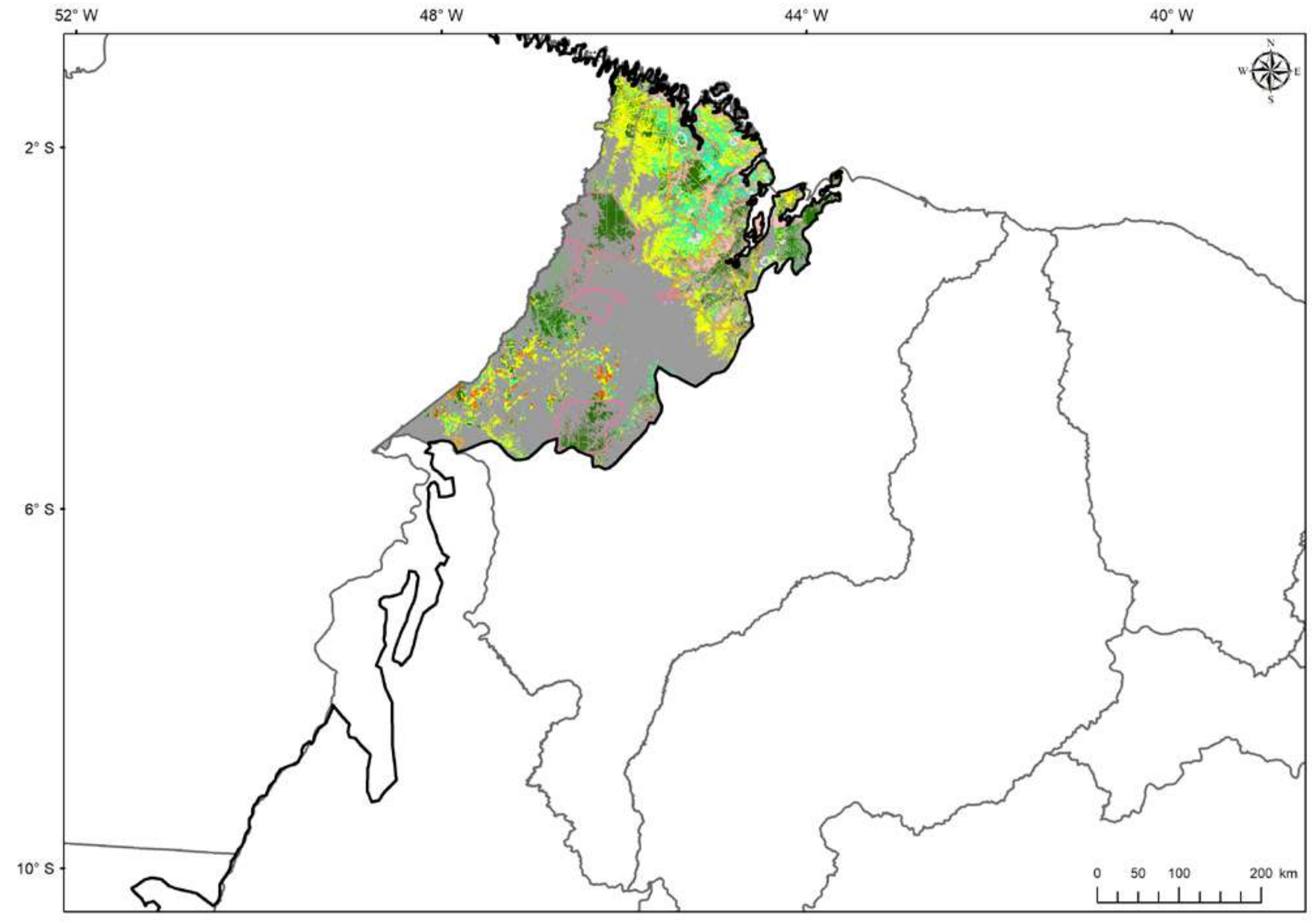
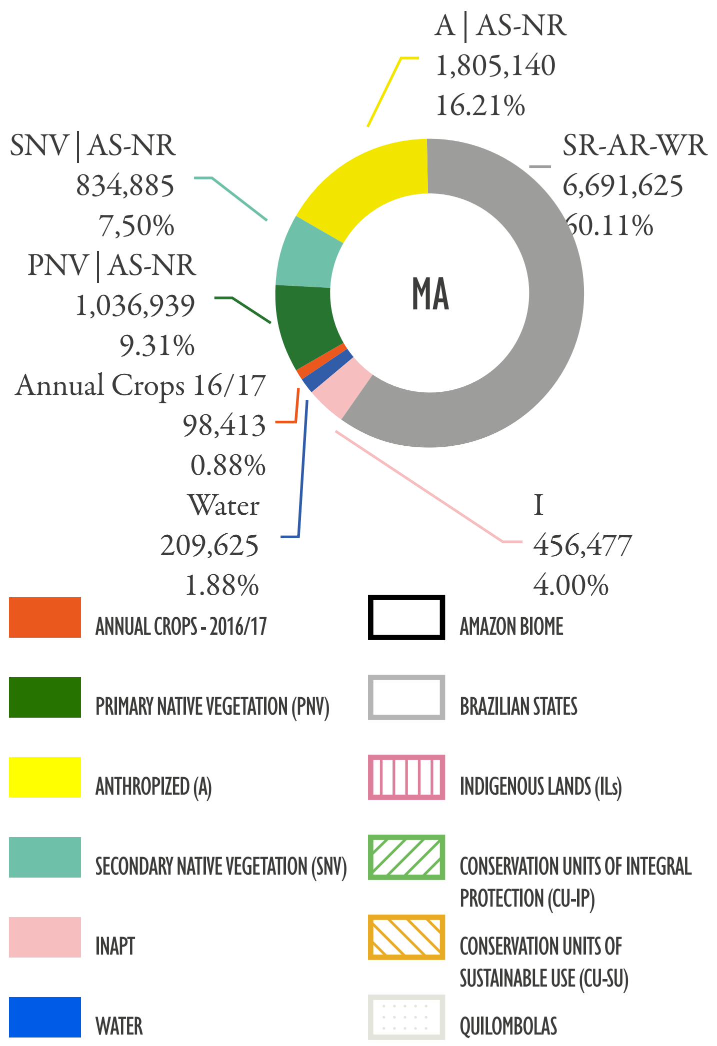


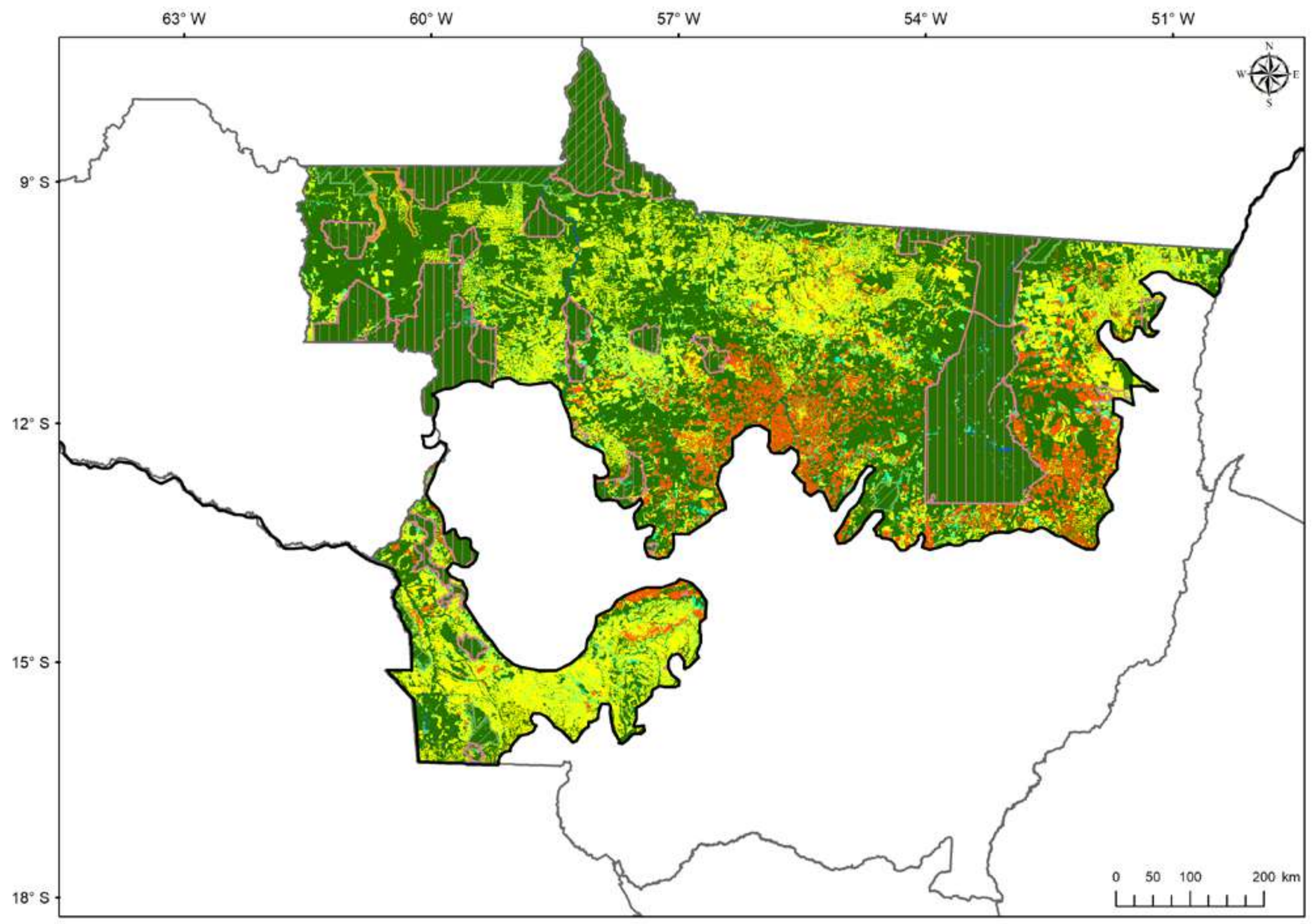
Figure A7 – Land use and land cover in the state of Maranhão (Amazon Biome portion) in 2015.





Observation:
PNV | AS-NR: Primary Native Vegetation (PNV) with Agricultural Suitability (AS) and No Restrictions to slope and altitude (NR);
A | AS-NR: Anthropized (A) with Agricultural Suitability (AS) and No Restrictions to slope and altitude (NR);
SNV | AS-NR: Secondary Native Vegetation (SNV) with Agricultural Suitability (AS) and No Restrictions to slope and altitude (NR);
SR-AR-WR: Without Agricultural Suitability due to Slope Restriction (SR), Altitude Restriction (AR), and slope and altitude restrictions (WR);
I: Inapt (e.g. urban areas, rocky outcrops etc.);
Water

Figure A8 – Agricultural suitability in the state of Maranhão (Amazon Biome portion) in 2015.



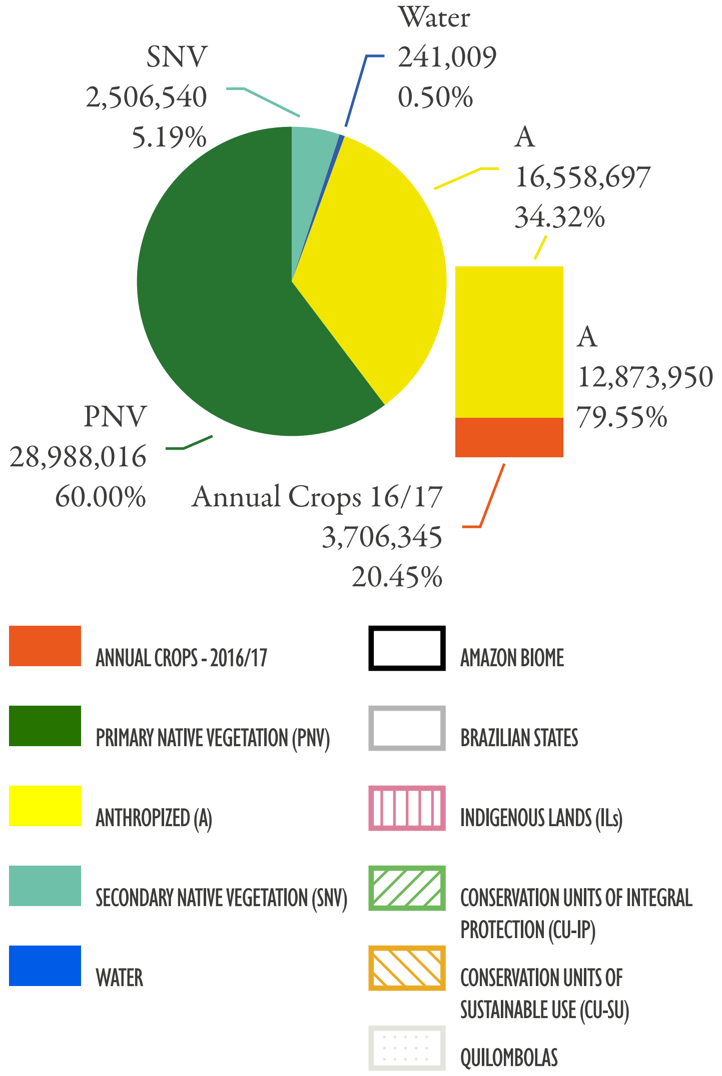
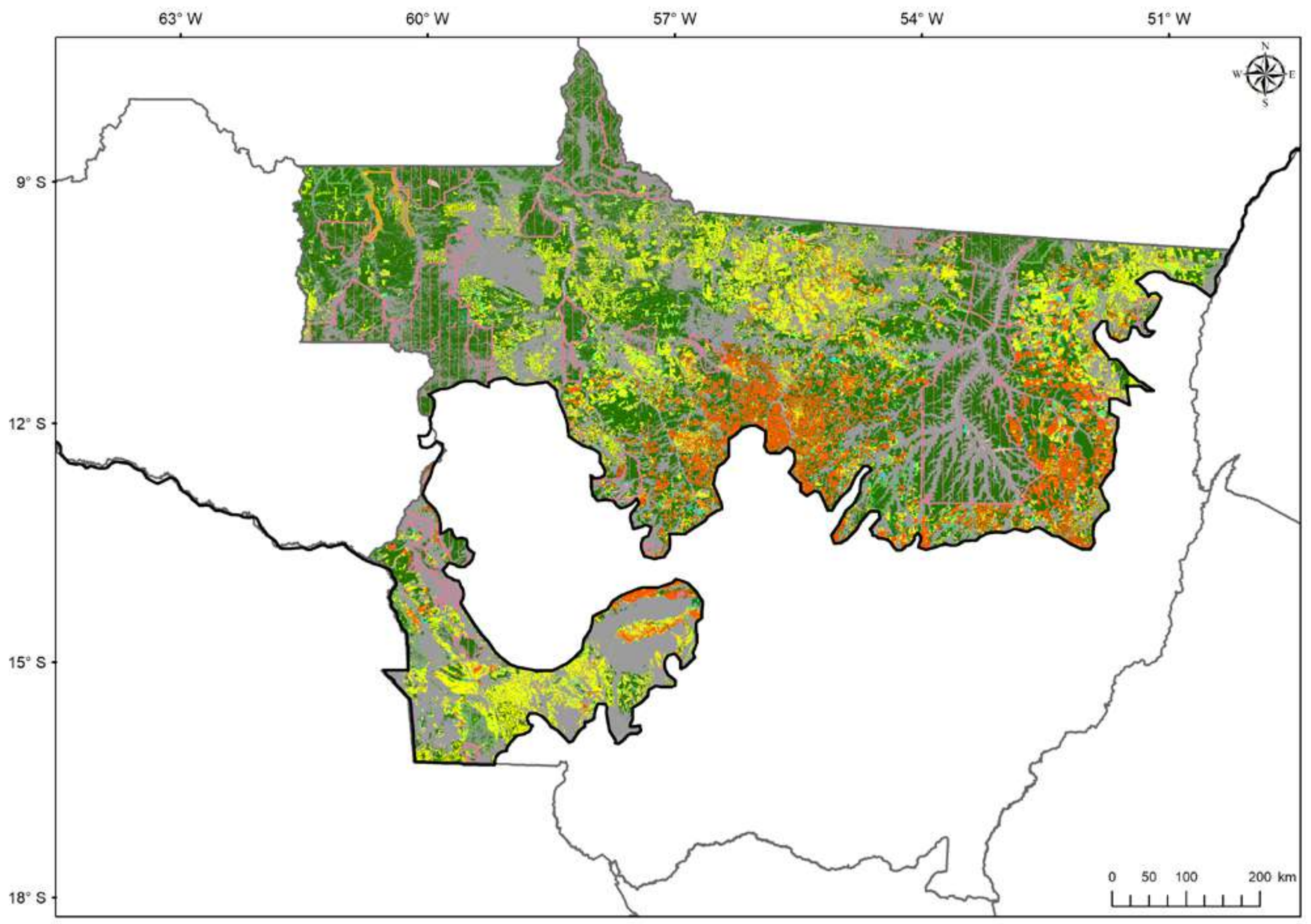
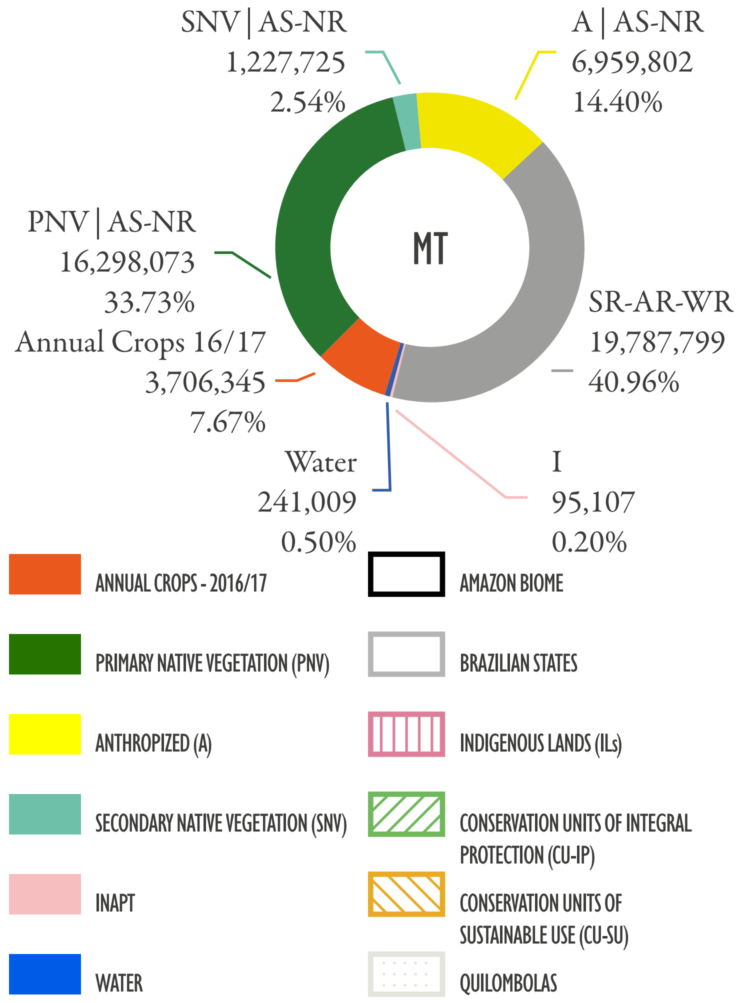


Figure A9 – Land use and land cover in the state of Mato Grosso (Amazon Biome portion) in 2015.





Observation:
PNV | AS-NR: Primary Native Vegetation (PNV) with Agricultural Suitability (AS) and No Restrictions to slope and altitude (NR);
A | AS-NR: Anthropized (A) with Agricultural Suitability (AS) and No Restrictions to slope and altitude (NR);
SNV | AS-NR: Secondary Native Vegetation (SNV) with Agricultural Suitability (AS) and No Restrictions to slope and altitude (NR);
SR-AR-WR: Without Agricultural Suitability due to Slope Restriction (SR), Altitude Restriction (AR), and slope and altitude restrictions (WR);
I: Inapt (e.g. urban areas, rocky outcrops etc.);
Water

Figure A10 – Agricultural suitability in the state of Mato Grosso (Amazon Biome portion) in 2015.

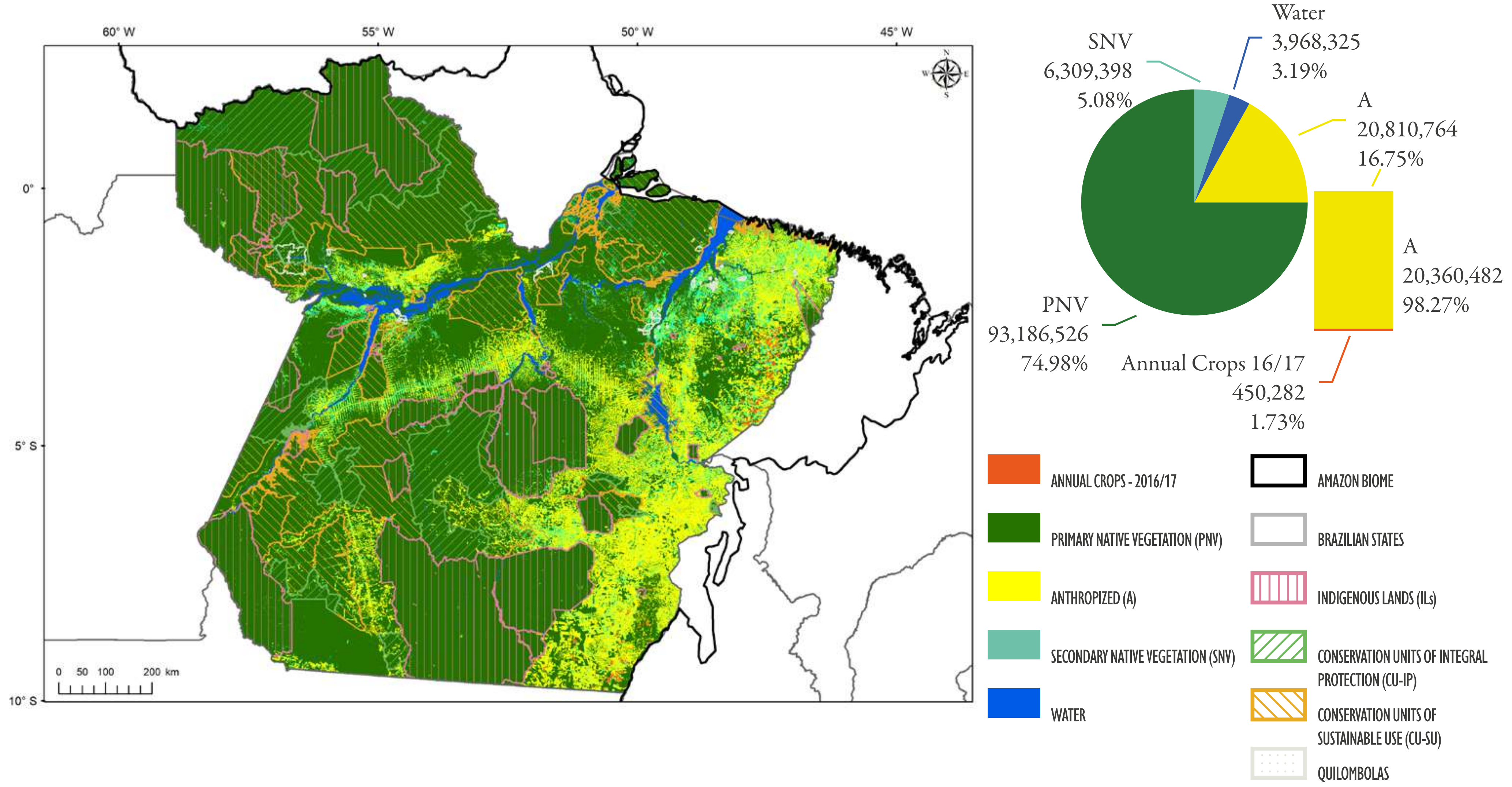
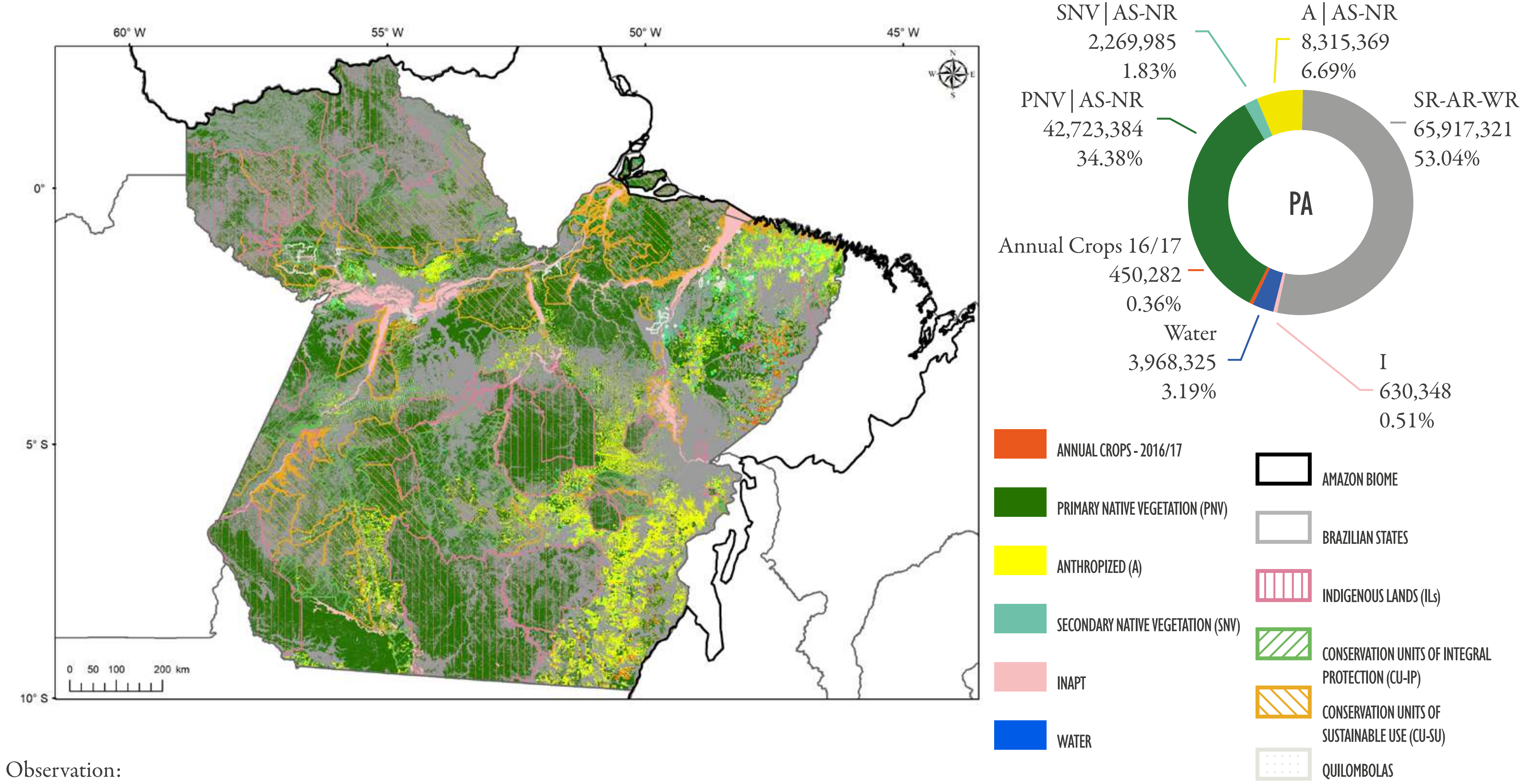
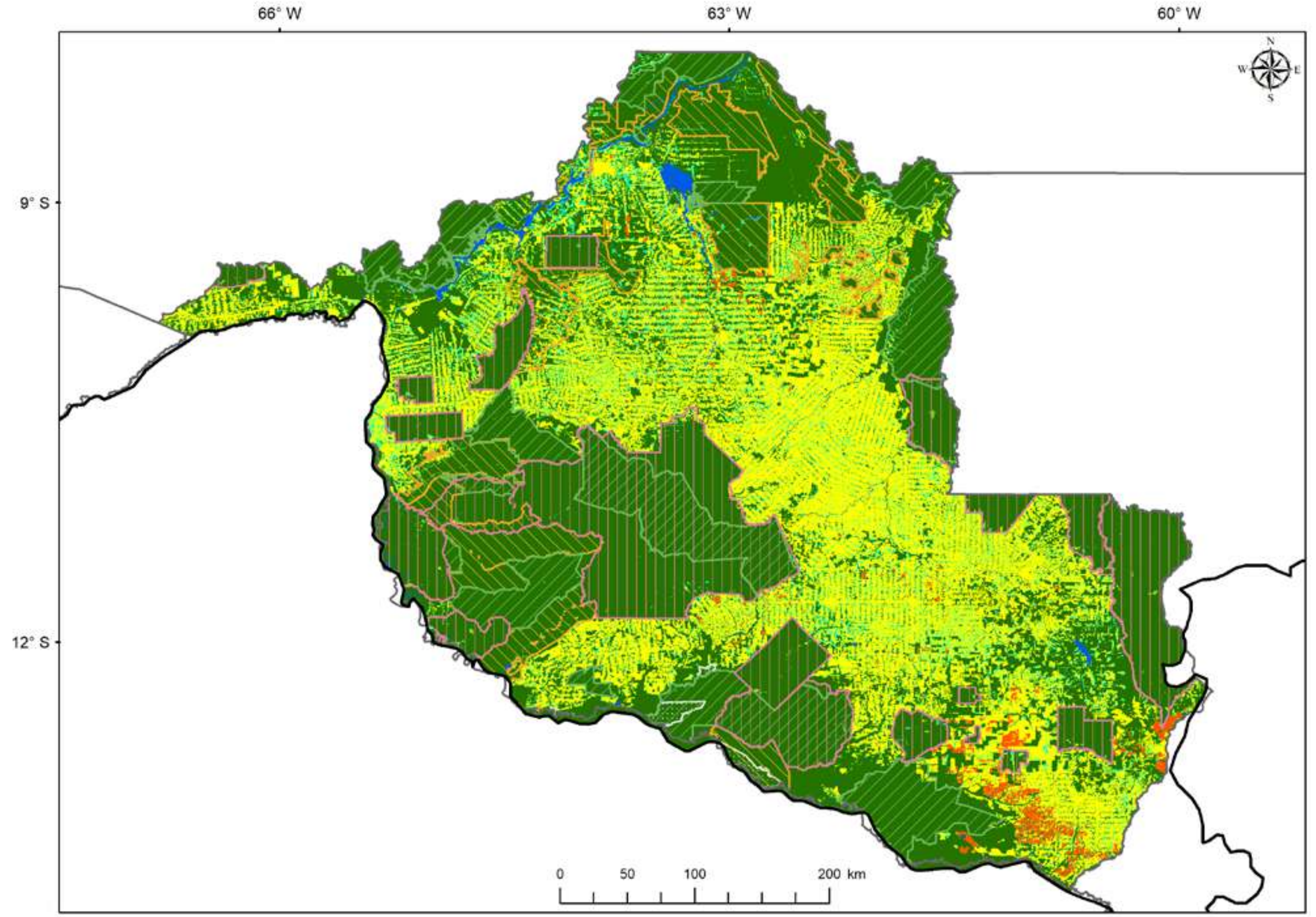


Figure A11 – Land use and land cover in the state of Pará in 2015.



Observation:
PNV | AS-NR: Primary Native Vegetation (PNV) with Agricultural Suitability (AS) and No Restrictions to slope and altitude (NR);
A | AS-NR: Anthropized (A) with Agricultural Suitability (AS) and No Restrictions to slope and altitude (NR);
SNV | AS-NR: Secondary Native Vegetation (SNV) with Agricultural Suitability (AS) and No Restrictions to slope and altitude (NR);
SR-AR-WR: Without Agricultural Suitability due to Slope Restriction (SR), Altitude Restriction (AR), and slope and altitude restrictions (WR);
I: Inapt (e.g. urban areas, rocky outcrops etc.);
Water

Figure A12 – Agricultural suitability in the state of Pará in 2015.



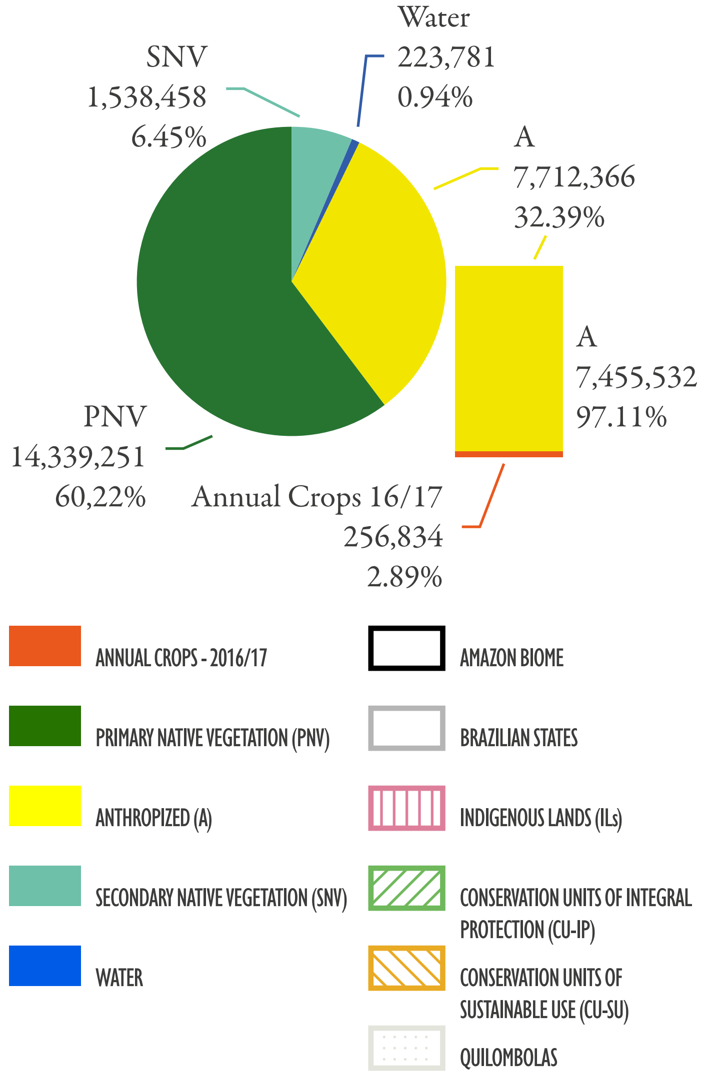
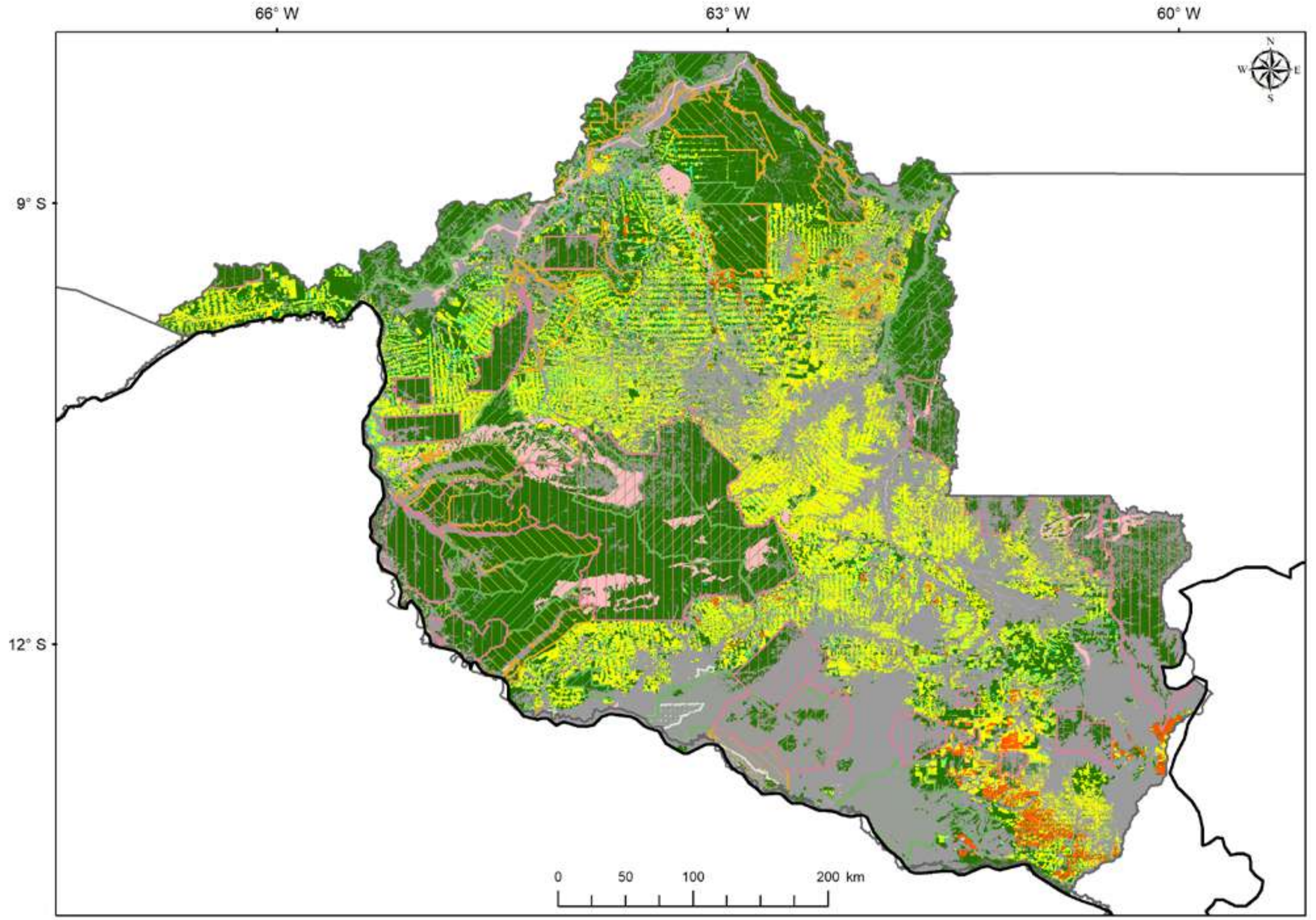
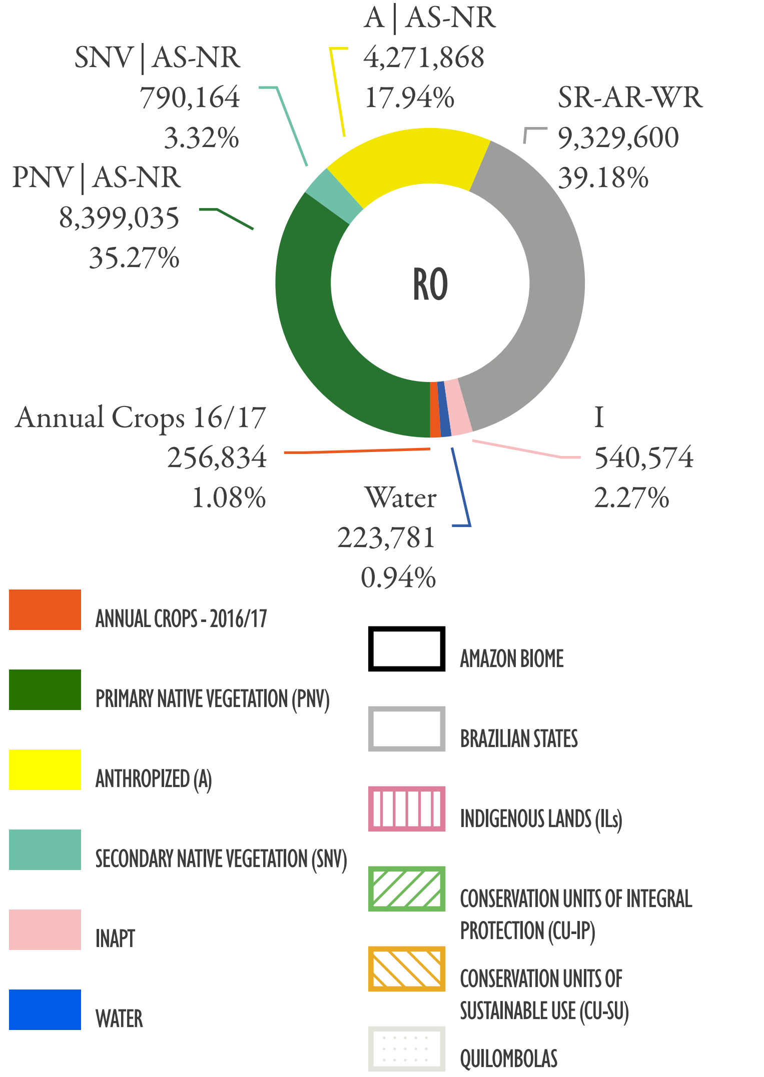


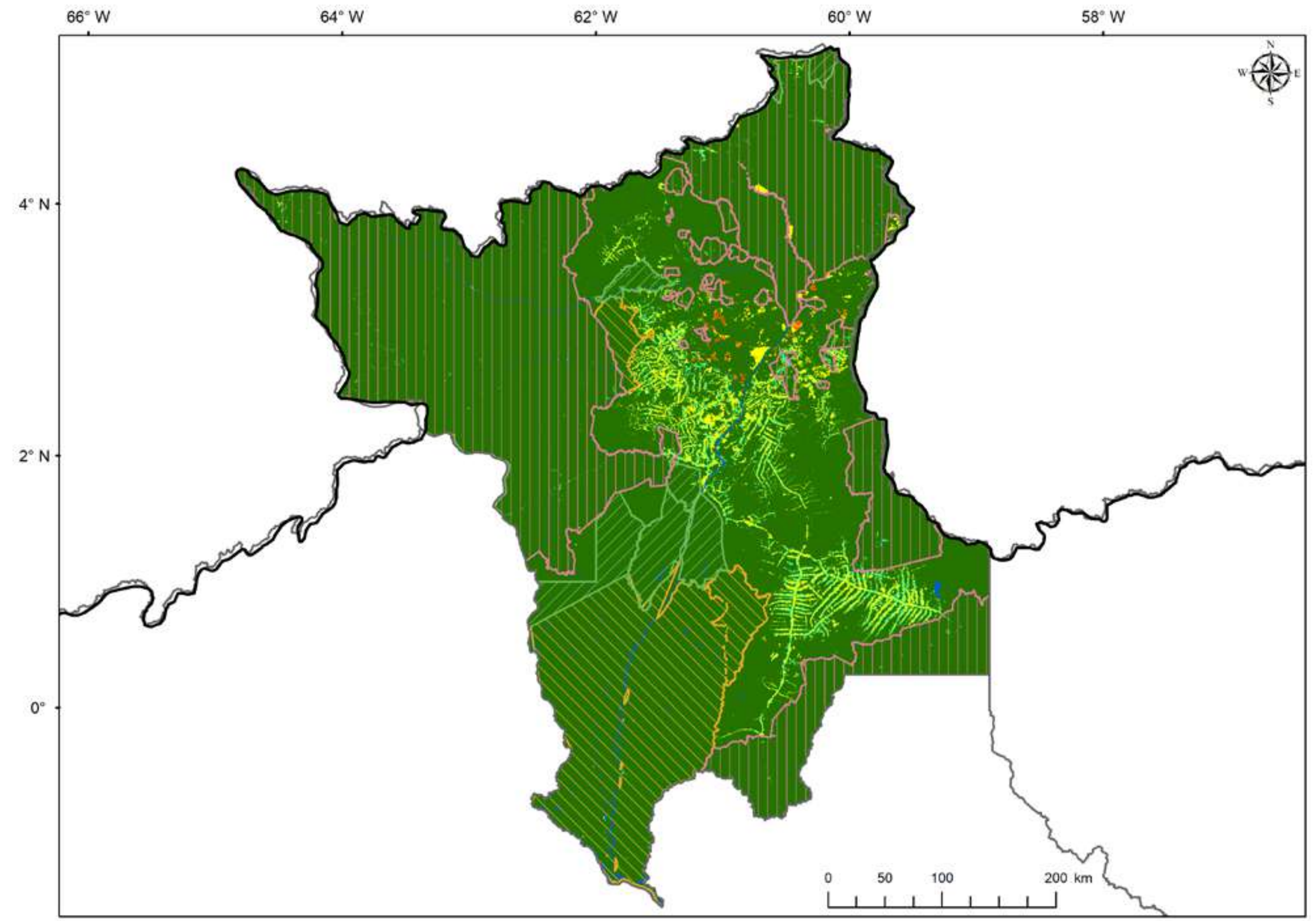
Figure A13 – Land use and land cover in the state of Rondônia in 2015.





Observation:
PNV | AS-NR: Primary Native Vegetation (PNV) with Agricultural Suitability (AS) and No Restrictions to slope and altitude (NR);
A | AS-NR: Anthropized (A) with Agricultural Suitability (AS) and No Restrictions to slope and altitude (NR);
SNV | AS-NR: Secondary Native Vegetation (SNV) with Agricultural Suitability (AS) and No Restrictions to slope and altitude (NR);
SR-AR-WR: Without Agricultural Suitability due to Slope Restriction (SR), Altitude Restriction (AR), and slope and altitude restrictions (WR);
I: Inapt (e.g. urban areas, rocky outcrops etc.);
Water

Figure A14 – Agricultural suitability in the state of Rondônia in 2015.



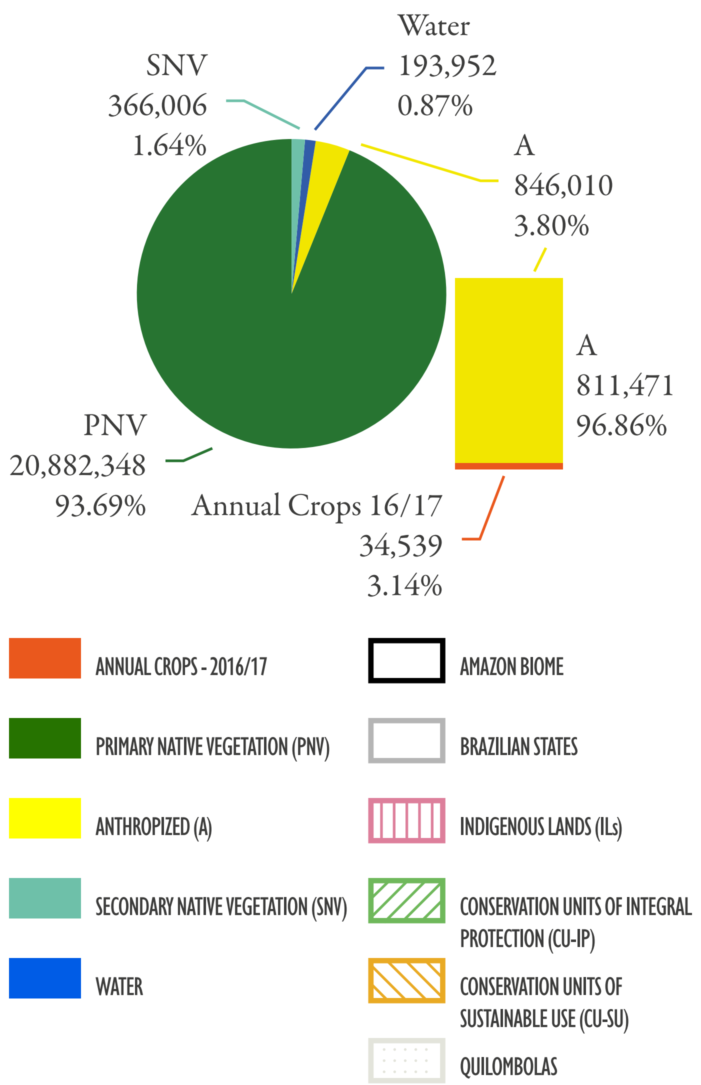
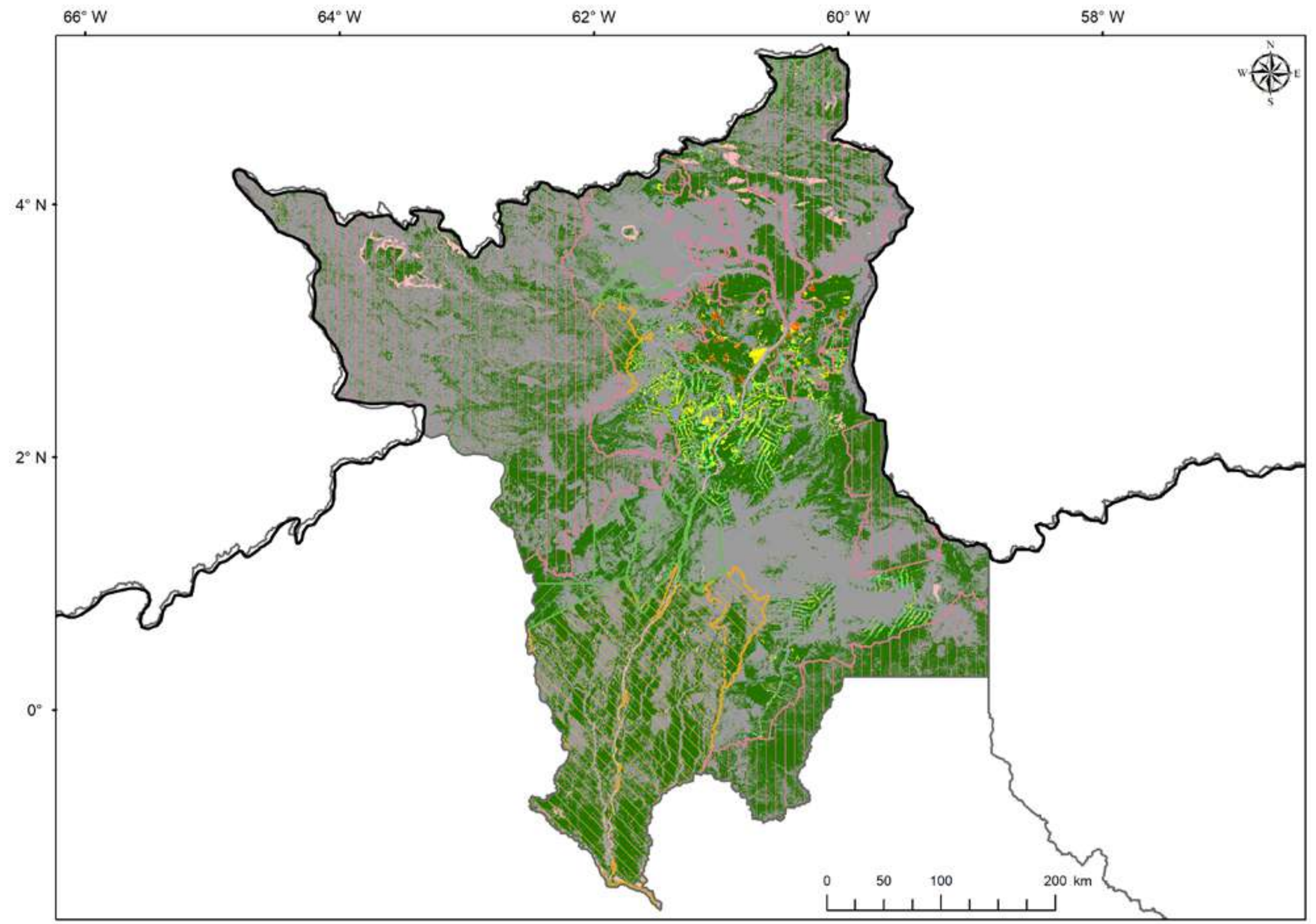
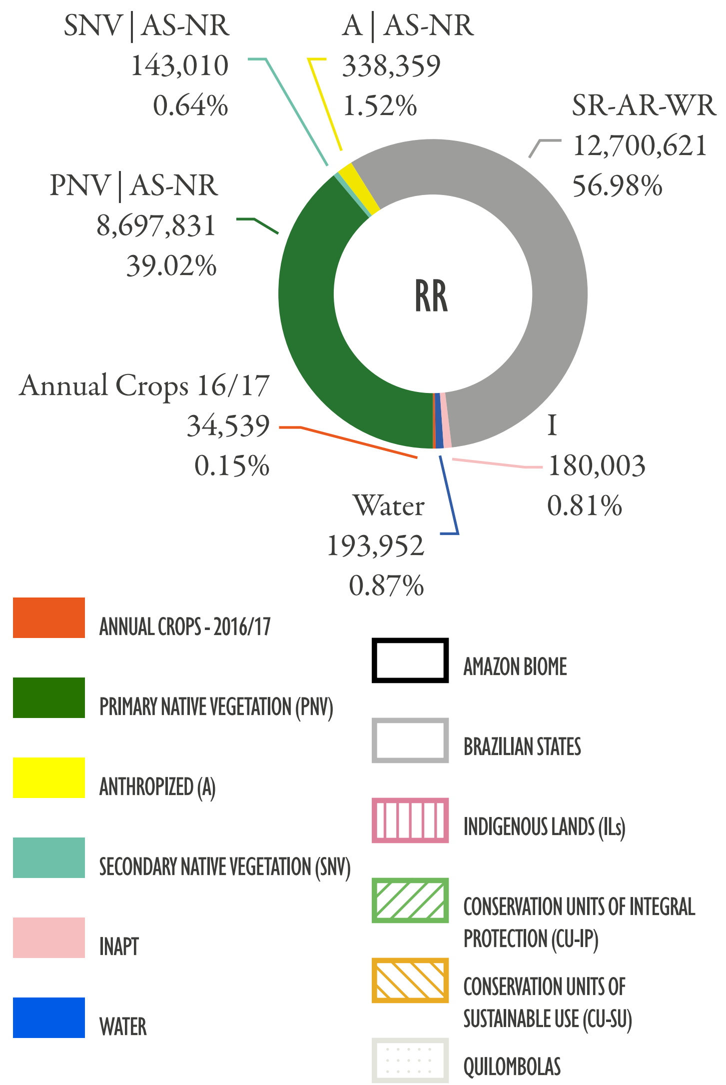


Figure A15 – Land use and land cover in the state of Roraima in 2015.





Observation:
PNV | AS-NR: Primary Native Vegetation (PNV) with Agricultural Suitability (AS) and No Restrictions to slope and altitude (NR);
A | AS-NR: Anthropized (A) with Agricultural Suitability (AS) and No Restrictions to slope and altitude (NR);
SNV | AS-NR: Secondary Native Vegetation (SNV) with Agricultural Suitability (AS) and No Restrictions to slope and altitude (NR);
SR-AR-WR: Without Agricultural Suitability due to Slope Restriction (SR), Altitude Restriction (AR), and slope and altitude restrictions (WR);
I: Inapt (e.g. urban areas, rocky outcrops etc.);
Water

Figure A16 – Agricultural suitability in the state of Roraima in 2015.

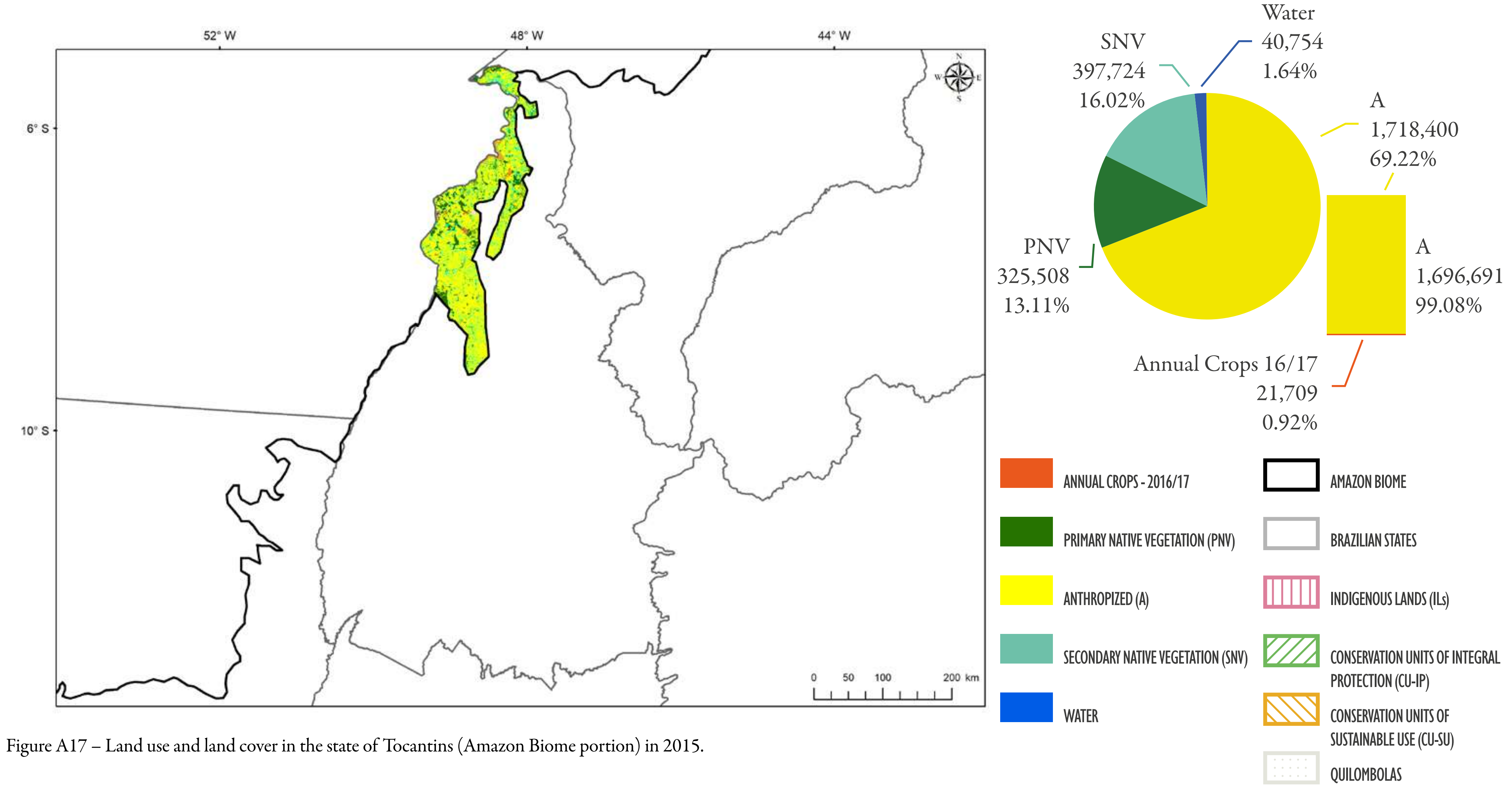
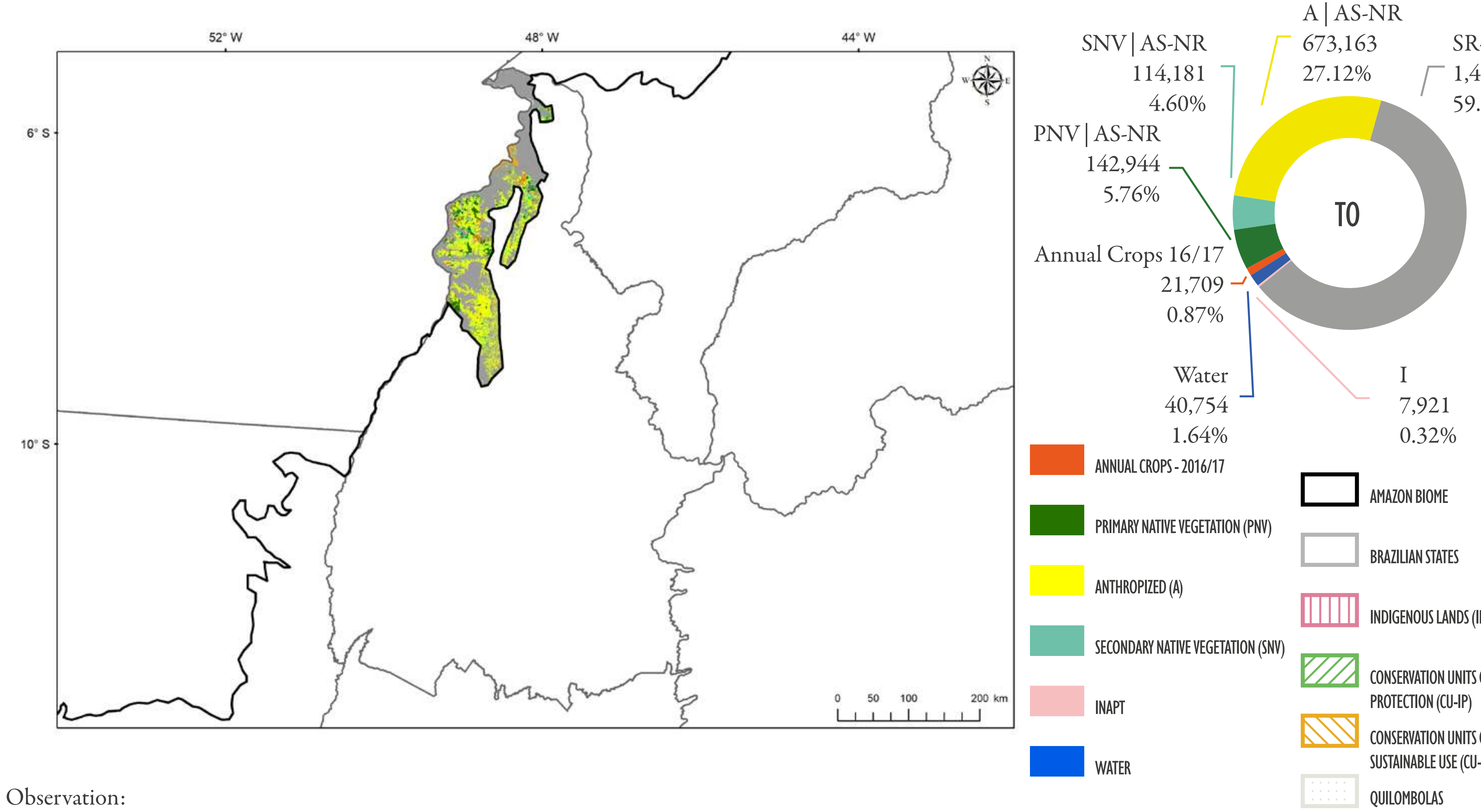


Figure A17 – Land use and land cover in the state of Tocantins (Amazon Biome portion) in 2015.



Observation:
PNV | AS-NR: Primary Native Vegetation (PNV) with Agricultural Suitability (AS) and No Restrictions to slope and altitude (NR);
A | AS-NR: Anthropized (A) with Agricultural Suitability (AS) and No Restrictions to slope and altitude (NR);
SNV | AS-NR: Secondary Native Vegetation (SNV) with Agricultural Suitability (AS) and No Restrictions to slope and altitude (NR);
SR-AR-WR: Without Agricultural Suitability due to Slope Restriction (SR), Altitude Restriction (AR), and slope and altitude restrictions (WR);
I: Inapt (e.g. urban areas, rocky outcrops etc.);
Water

Figure A18 – Agricultural suitability in the state of Tocantins (Amazon Biome portion) in 2015.

Table A1 presents the five land use and land cover LULC classes considered in the present study: 1) Annual Crops (AC-16/17), 2) Primary Native Vegetation (PNV), 3) Secondary Native Vegetation (SNV), 4) Anthropized other than AC and SNV (A), and 5) Water (W); these LULC classes were divided into the following sub-classes: 1) private properties & undesignated land (PP&UL), and special areas divided as: 2) Conservation Units for Integral Protection (CU-IP), 3) Conservation Units for Sustainable Use (CU-SU), 4) Settlements (SETT), 5) Indigenous Lands (IL), 6) Quilombolas (QUI) and OVERLAPS. This last sub-class is the result of the overall area of two or more sub-classes. The results presented in Table A1 also include, for each LULC class, the different agricultural suitability (AS) classes: i) AS-NR (AS with No Restrictions to slope and altitude); ii) AS-SR (AS with Slope Restriction; iii) AS-AR (AS with Altitude Restriction; iv) AS-WR (AS with restrictions to slope and altitude); v) I (Inadequate, irrespective of slope or altitude). For the Annual Crops (AC-16/17) class it is considered that those areas are all cultivated on land with AS-NR.

Table A1 – Area in hectares for the Land Use and Land Cover classes: Annual Crops (AC-16/17), Primary Native Vegetation (PNV), Secondary Native Vegetation (SNV), Anthropized other than AC and SNV (A), and Water with the corresponding classes of agricultural suitability (AS-NR, AS-SR, AS-AR, AS-WR) located in private properties & undesignated land (PP&UL) and in special areas of Conservation Units for Integral Protection (CU-IP), Conservation Units for Sustainable Use (CU-SU), Settlements (SETT), Indigenous Lands (IL), Quilombolas (QUI) and OVERLAPS, for each State of the Amazon Biome.

CLASSES	STATE (HECTARES)										
	AC	AM	AP	MA	MT	PA	RO	RR	TO	AMAZON BIOME	
										ha	%
AC-16/17	**0**	**0**	**19,046**	**98,413**	**3,706,345**	**450,282**	**256,834**	**34,539**	**21,709**	**4,587,168**	**1.10**
PP-UL	0	0	17,830	88,497	3,516,291	427,453	191,928	34,395	21,706	4,298,100	-
CU-IP	0	0	0	0	398	0	0	0	0	398	-
CU-SU	0	0	414	0	0	351	0	0	0	765	-
SETT	0	0	434	9,916	174,208	22,319	64,707	143	3	271,729	-
IL	0	0	0	0	15,449	0	172	2	0	15,622	-
QUI	0	0	49	0	0	142	0	0	0	191	-
OVERLAPS	0	0	319	0	0	17	27	0	0	363	
PNV | AS-NR	**9,299,402**	**102,668,875**	**4,918,632**	**1,036,939**	**16,298,073**	**42,723,384**	**8,399,035**	**8,697,831**	**142,944**	**194,185,115**	**46.43**
PP-UL	4,294,528	39,762,834	772,120	306,053	10,600,329	10,937,378	2,666,065	2,327,503	130,559	71,797,367	-
CU-IP	1,027,967	7,491,559	1,746,253	81,168	519,257	4,250,488	1,100,530	459,064	0	16,676,285	-
CU-SU	1,950,420	17,171,455	1,568,380	239,030	58,049	9,150,095	1,253,100	1,748,882	85	33,139,497	-
SETT	740,651	4,791,182	437,454	83,671	250,049	2,383,072	426,838	353,675	11,271	9,477,863	-
IL	1,200,801	30,132,652	327,104	294,244	4,381,244	14,373,759	2,268,842	3,763,678	1,030	56,743,353	-
QUI	0	358	6,675	2,104	0	103,328	347	0	0	112,811	-
OVERLAPS	85,036	3,318,835	60,646	30,670	489,145	1,525,264	683,313	45,029	0	6,237,938	

CLASSES	AC	AM	AP	MA	MT	PA	RO	RR	TO	AMAZON BIOME	
										ha	%
PNV | AS-SR	**3,551,374**	**11,425,645**	**4,670,282**	**280,241**	**2,787,744**	**23,946,014**	**1,169,024**	**5,488,972**	**22,101**	**53,341,397**	**12.75**
PP-UL	1,339,054	2,912,145	216,827	72,036	1,526,681	3,382,073	409,662	895,473	19,862	10,773,813	-
CU-IP	429,670	1,548,214	1,660,762	65,473	199,203	4,638,099	107,122	60,315	0	8,708,859	-
CU-SU	706,237	2,255,343	1,776,747	3,939	7,547	6,475,892	36,511	90,293	110	11,352,618	-
SETT	88,142	606,910	419,305	19,761	91,944	1,243,638	79,351	89,192	2,118	2,640,361	-
IL	932,756	3,029,942	571,091	117,718	815,728	6,910,256	383,761	4,296,127	11	17,057,390	-
QUI	0	0	375	15	0	31,565	0	0	0	101,385	-
OVERLAPS	55,513	1,073,092	25,175	1,299	146,641	1,264,492	152,617	57,571	0	2,776,400	
PNV | AS-AR	**1,176,957**	**29,287,489**	**3,151,350**	**1,256,821**	**9,300,760**	**20,692,747**	**4,023,915**	**6,162,343**	**144,945**	**75,197,328**	**17.98**
PP-UL	667,129	12,822,219	1,279,424	360,247	5,686,426	5,636,283	1,613,272	2,198,966	114,446	30,318,412	-
CU-IP	49,500	2,274,267	984,126	34,369	197,653	2,210,368	716,156	493,701	0	6,960,140	-
CU-SU	228,063	5,418,460	460,274	284,633	55,467	4,696,705	431,854	1,555,621	1,216	13,132,294	-
SETT	131,230	1,507,347	175,721	58,044	223,126	1,806,414	93,988	339,558	26,412	4,361,840	-
IL	95,116	6,251,965	215,340	489,924	2,815,361	5,406,522	737,256	1,568,687	1,611	17,581,781	-
QUI	0	104	12,232	2,826	0	78,287	6,683	0	1,253	101385	-
OVERLAPS	5,918	1,013,127	24,233	26,779	322,726	858,168	424,706	5,811	7	2,681,476	
PNV | AS-WR	**152,777**	**2,978,814**	**613,427**	**366,498**	**515,141**	**5,248,331**	**228,011**	**354,113**	**9,250**	**10,466,362**	**2.50**
PP-UL	77,262	1,201,083	77,668	126,666	307,669	1,043,816	126,552	110,978	7,872	3,079,566	-
CU-IP	10,157	378,006	185,090	9,186	11,634	911,256	8,881	10,079	0	1,524,289	-
CU-SU	31,335	544,899	264,261	1,056	5,508	1,359,295	16,342	33,762	642	2,257,101	-
SETT	10,447	244,135	51,263	30,393	16,733	530,663	11,273	25,420	705	921,032	-
IL	22,240	565,621	30,876	198,782	144,413	1,087,573	55,024	173,795	24	2,278,348	-
QUI	0	0	444	4	0	9,870	62	0	5	10,385	-
OVERLAPS	1,335	45,071	3,826	410	29,184	305,858	9,877	79	2	395,642	
SNV | AS-NR	**179,011**	**583,548**	**56,380**	**834,885**	**1,227,725**	**2,269,985**	**790,164**	**143,010**	**114,181**	**6,198,887**	**1.48**
PP-UL	100,728	360,648	39,026	267,480	1,047,831	1,609,433	579,164	89,073	103,900	4,197,284	-
CU-IP	6,021	5,260	1,481	5,662	6,873	29,645	8,409	431	0	63,782	-
CU-SU	17,590	56,922	3,443	371,659	804	155,901	30,215	639	3	637,175	-

CLASSES	AC	AM	AP	MA	MT	PA	RO	RR	TO	TOTAL	
										419,305	%
SETT	47,618	76,440	10,443	102,093	99,647	331,604	155,691	36,837	10,237	870,611	-
IL	6,601	78,573	1,486	6,743	71,297	65,693	13,161	15,978	10	259,542	-
QUI	0	0	141	6,286	0	15,587	22	0	29	22,065	-
OVERLAPS	452	5,705	360	74,961	1,273	62,122	3,502	52	2	148,429	
SNV | AS-SR	**47,962**	**113,320**	**24,297**	**140,118**	**239,303**	**875,167**	**272,079**	**37,861**	**43,695**	**1,793,801**	**0.43**
PP-UL	26,997	65,752	10,945	67,345	188,564	557,750	209,961	20,420	41,541	1,189,275	-
CU-IP	487	690	2,442	5,510	4,401	39,337	660	67	0	53,595	-
CU-SU	5,438	15,855	3,127	34,743	49	73,811	3,703	109	96	136,932	-
SETT	12,315	18,731	5,835	18,605	34,347	177,357	52,373	9,763	2,044	331,369	-
IL	2,602	11,439	1,794	2,584	11,230	20,611	3,938	7,446	0	61,642	-
QUI	0	0	9	18	0	908	0	0	2	937	-
OVERLAPS	123	853	145	11,314	711	5,392	1,443	56	13	20,050	
SNV | AS-AR	**121,550**	**682,065**	**35,223**	**580,001**	**962,240**	**2,610,792**	**406,077**	**160,706**	**224,374**	**5,786,027**	**1.38**
PP-UL	80,608	449,919	25,061	336,221	819,568	1,792,225	329,741	81,923	182,735	4,098,003	-
CU-IP	1,647	3,695	870	6,334	4,121	19,618	2,628	1,853	0	40,766	-
CU-SU	7,945	67,304	2,891	83,085	1,900	182,948	13,964	2,230	1,814	364,081	-
SETT	27,013	71,267	5,166	97,757	81,470	484,964	46,913	64,277	39,345	918,170	-
IL	3,909	84,447	865	32,431	54,312	60,674	10,626	10,382	158	257,804	-
QUI	0	0	166	3,065	0	31,438	121	0	142	34,933	-
OVERLAPS	427	5,434	205	24,107	869	38,925	2,084	40	180	72,271	
SNV | AS-WR	**15,730**	**139,437**	**10,759**	**382,165**	**74,109**	**539,581**	**62,672**	**24,093**	**15,232**	**1,263,778**	**0.30**
PP-UL	10,413	87,169	5,597	283,918	60,991	371,940	49,757	10,930	13,383	894,098	-
CU-IP	159	715	210	3,495	309	4,660	298	545	0	10,392	-
CU-SU	1,008	17,900	1,385	2,268	208	37,764	906	143	638	62,221	-
SETT	3,469	19,776	3,007	81,983	8,937	111,975	10,031	11,237	1,108	251,523	-
IL	615	13,028	442	9,331	3,569	6,939	1,494	1,237	2	36,656	-
QUI	0	0	5	1	0	2,262	5	0	0	2,274	-
OVERLAPS	65	847	113	1,170	95	4,040	182	1	101	6,615	

CLASSES	AC	AM	AP	MA	MT	PA	RO	RR	TO	TOTAL	
										419,305	%
A | AS-NR	**956,044**	**1,014,523**	**144,572**	**1,805,140**	**6,959,802**	**8,315,369**	**4,271,868**	**338,359**	**673,163**	**24,478,840**	**5.85**
PP-UL	552,944	691,517	112,151	882,286	5,937,565	6,099,532	3,337,036	255,803	604,391	18,473,226	-
CU-IP	8,023	7,565	1,244	10,175	24,049	48,428	12,872	407	0	112,763	-
CU-SU	51,405	57,450	12,978	451,815	1,561	344,593	61,573	636	242	982,254	-
SETT	335,493	197,653	15,600	371,846	870,072	1,688,047	831,295	65,758	68,236	4,444,02	-
IL	6,664	52,942	1,403	6,165	124,712	84,422	18,508	15,712	11	310,540	-
QUI	0	0	381	2,932	0	11,835	16	0	279	15,443	-
OVERLAPS	1,514	7,396	814	79,921	1,843	38,511	10,567	43	4	140,613	
A | AS-SR	**218,776**	**178,170**	**35,871**	**182,402**	**782,450**	**2,376,790**	**931,751**	**58,577**	**144,177**	**4,908,964**	**1.17**
PP-UL	120,019	101,037	15,588	104,170	609,080	1,545,477	696,853	35,055	137,696	3,364,975	-
CU-IP	705	1,051	1,907	13,256	6,613	18,558	963	59	0	43,112	-
CU-SU	14,982	17,865	6,547	13,504	229	140,815	6,095	164	66	200,268	-
SETT	80,101	49,263	10,008	43,496	149,940	635,441	219,373	15,893	6,406	1,209,921	-
IL	2,458	8,038	1,622	4,090	15,160	25,899	5,722	7,359	0	70,348	-
QUI	0	0	11	6	0	939	0	0	0	957	-
OVERLAPS	510	916	188	3,879	1,428	9,661	2,744	47	9	19,383	
A | AS-AR	**633,253**	**939,155**	**98,433**	**2,632,374**	**4,888,360**	**8,328,875**	**2,039,357**	**375,703**	**838,491**	**20,774,002**	**4.97**
PP-UL	378,506	671,768	76,724	1,914,825	4,178,390	6,069,843	1,745,379	217,132	687,549	15,940,117	-
CU-IP	2,842	3,745	1,402	24,254	13,395	32,306	4,761	1,539	0	84,245	-
CU-SU	23,404	74,761	7,053	214,788	3,060	365,163	25,462	1,800	6,404	721,895	-
SETT	221,310	115,061	10,908	369,945	608,456	1,683,075	248,438	136,297	142,439	3,535,929	-
IL	5,829	70,284	1,256	55,659	83,441	101,773	13,239	18,913	464	350,858	-
QUI	0	0	272	3,516	0	24,658	434	0	1,139	30,19	-
OVERLAPS	1,361	3,537	818	49,388	1,617	52,056	1,643	22	497	110,939	
A | AS-WR	**69,856**	**180,004**	**17,876**	**868,006**	**237,692**	**1,299,022**	**196,712**	**38,252**	**39,449**	**2,946,869**	**0.70**
PP-UL	39,635	110,137	9,458	652,359	182,145	882,321	157,354	17,651	34,871	2,085,931	-
CU-IP	283	572	221	12,848	417	4,687	518	275	0	19,821	-
CU-SU	3,435	21,493	2,788	1,976	330	79,189	1,449	179	1,693	112,533	-

CLASSES	AC	AM	AP	MA	MT	PA	RO	RR	TO	TOTAL	
										419,305	%
SETT	25,230	34,680	4,730	176,194	50,307	313,706	35,314	19,282	2,636	662,079	-
IL	933	12,414	557	23,557	4,276	10,751	1,775	863	1	55,127	-
QUI	0	0	4	1	0	1,768	5	0	0	1,779	-
OVERLAPS	341	707	117	1,071	218	6,600	296	1	247	9,599	
PNV | I	**2,829**	**661,995**	**89,871**	**356,031**	**86,298**	**576,050**	**519,266**	**179,088**	**6,267**	**2,477,696**	**0.59**
PP-UL	2,370	414,732	40,884	53,237	52,412	317,455	70,604	23,993	4,927	980,614	-
CU-IP	76	46,164	46,910	228	1,862	32,476	116,546	640	0	244,904	-
CU-SU	12	122,789	1,107	287,735	48	62,827	22,009	12,938	1,102	510,567	-
SETT	283	37,113	509	716	867	81,523	910	145	186	122,252	-
IL	83	36,880	92	269	30,943	58,230	169,718	141,368	1	437,584	-
QUI	0	0	0	52	0	3,255	9	0	51	3,367	-
OVERLAPS	4	4,316	369	13,794	166	20,283	139,471	4	0	178,406	
SNV | I	**714**	**26,131**	**105**	**36,113**	**3,163**	**13,872**	**5,465**	**337**	**242**	**86,142**	**0.02**
PP-UL	591	18,422	95	3,507	2,854	8,228	4,565	159	176	38,597	-
CU-IP	8	35	6	125	0	687	62	2	0	925	-
CU-SU	1	3,391	3	23,266	1	1,660	623	54	59	29,060	-
SETT	112	2,981	1	49	164	2,413	63	1	5	5,788	-
IL	1	1,099	0	33	143	330	132	121	1	1,860	-
QUI	0	0	0	4	0	8	0	0	0	12	-
OVERLAPS	2	203	0	9,127	0	546	20	0	1	9,899	
A | I	**1,642**	**57,852**	**159**	**63,333**	**5,646**	**40,426**	**15,843**	**578**	**1,412**	**187,891**	**0.04**
PP-UL	1,425	45,764	129	8,799	5,196	27,057	14,468	285	859	103,983	-
CU-IP	14	61	15	183	0	1,874	82	2	0	2,232	-
CU-SU	5	3,598	13	45,041	8	4,473	1,039	11	473	54,662	-
SETT	189	7,119	1	138	212	5,266	156	2	69	13152	-
IL	6	1,200	0	99	229	1,224	78	279	9	3,123	-
QUI	0	0	0	11	0	114	0	0	0	125	-
OVERLAPS	3	109	1	10,061	2	419	19	0	1	10,614	

CLASSES	AC	AM	AP	MA	MT	PA	RO	RR	TO	TOTAL	
										419,305	%
WATER | I	**23,855**	**4,453,701**	**218,877**	**209,625**	**241,009**	**3,968,325**	**223,781**	**193,952**	**40,754**	**9,573,879**	**2.29**
PP-UL	19,596	3,156,092	171,494	28,444	152,418	2,953,332	190,291	82,810	36,954	6,791,432	-
CU-IP	627	267,004	32,564	119	11,815	39,183	5,063	10,674	6	367,055	-
CU-SU	463	510,862	7,901	167,187	3,431	586,479	10,730	74,073	3,363	1,364,490	-
SETT	1,225	190,307	5,182	491	2,160	228,531	6,406	520	324	435,145	-
IL	1,896	305,455	1,139	343	68,684	93,819	9,425	25,853	5	506,619	-
QUI	0	0	0	102	0	12,817	53	0	101	13,073	-
OVERLAPS	49	23,981	597	12,939	2,500	54,166	1,813	22	0	96,066	
TOTAL	**16,451,730**	**155,390,723**	**14,105,159**	**11,133,103**	**48,315,860**	**124,275,014**	**23,811,856**	**22,288,315**	**2,482,387**	**418,254,147**	**100.00**

Table A2 – Municipalities identified and mapped with first-crop of soy, corn and cotton in the Amazon Biome.

MUNICIPALITY	UF	CROP YEAR 2016/17			CROP YEAR 2014/15			CROP YEAR 2009/10			CROP YEAR 2006/07			CROP YEAR 2000/01		
		SOY	CORN	COTTON	SOY	CORN	COTTON	SOY	CORN	COTTON	SOY	CORN	COTTON	SOY	CORN	COTTON
Floresta	MT	15,982	134	0	8,701	270	0	204	0	0	0	0	0	92	0	0
Alto Boa Vista	MT	21,555	0	0	20,773	0	0	1,101	0	0	0	0	0	0	0	0
Araputanga	MT	590	1,156	0	174	748	0	0	487	0	0	170	0	0	0	0
Arenápolis	MT	3,848	987	0	3,267	132	0	559	0	0	0	0	0	0	0	0
Aripuanã	MT	335	470	0	505	0	0	0	0	0	0	0	0	0	0	0
Barra Do Bugres	MT	1,220	0	0	785	0	0	1,133	0	0	2,005	137	0	0	0	0
Bom Jesus Do Araguaia	MT	95,815	389	0	91,752	0	0	38,367	0	0	18,269	0	739	656	0	0
Brasnorte	MT	70,968	518	0	55,736	432	0	19,638	0	0	14,684	0	0	1,115	350	0
Cáceres	MT	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Campo Novo Do Parecis	MT	3,985	0	0	3,990	0	0	3,962	0	0	3,960	0	0	1,338	459	1,339
Canabrava Do Norte	MT	15,120	600	0	13,226	34	0	2,895	0	0	2,058	937	0	402	0	0
Canarana	MT	137,443	245	0	132,938	0	0	64,896	215	0	37,655	39	0	19,274	100	0
Carlinda	MT	5,886	0	0	4,835	0	0	0	0	0	0	0	0	0	0	0
Castanheira	MT	0	162	0	0	193	0	0	0	0	0	0	0	0	0	0
Cláudia	MT	88,314	0	0	82,080	0	0	45,578	0	0	24,417	604	0	1,729	0	0
Colíder	MT	11,183	167	0	6,976	0	0	175	0	0	0	0	0	0	0	0
Comodoro	MT	50,350	0	0	59,794	0	0	42,894	0	0	38,726	355	0	6,853	47	0
Confresa	MT	34,752	0	0	30,646	115	0	953	0	0	0	0	0	0	0	0
Conquista D'Oeste	MT	1,698	0	0	972	0	0	0	0	0	0	0	0	0	0	0
Curvelândia	MT	72	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Denise	MT	6,248	0	0	5,899	0	0	776	0	0	0	0	0	0	0	0
Diamantino	MT	86,450	662	199	86,850	174	2,642	76,998	0	3,391	64,296	340	1,489	49,123	819	10,857
Feliz Natal	MT	101,793	76	0	88,062	0	0	58,601	0	0	29,231	0	0	786	0	0

MUNICIPALITY	UF	CROP YEAR 2016/17			CROP YEAR 2014/15			CROP YEAR 2009/10			CROP YEAR 2006/07			CROP YEAR 2000/01		
		SOY	CORN	COTTON	SOY	CORN	COTTON	SOY	CORN	COTTON	SOY	CORN	COTTON	SOY	CORN	COTTON
Figueirópolis D'Oeste	MT	0	466	0	0	0	0	0	0	0	0	0	0	0	0	0
Gaúcha Do Norte	MT	148,669	572	0	138,110	0	0	67,499	0	0	34,095	0	0	2,610	0	0
Glória D'Oeste	MT	66	0	0	0	0	0	0	0	0	0	0	0	0	84	0
Guarantã Do Norte	MT	10,670	383	0	8,416	211	0	1,465	0	0	24	0	0	69	0	0
Indiavaí	MT	0	569	0	0	502	0	0	427	0	0	0	0	0	0	0
Ipiranga Do Norte	MT	105,467	0	0	103,821	0	0	86,019	0	103	65,083	0	0	10,047	432	226
Itanhangá	MT	85,733	89	0	80,980	0	0	35,255	0	0	20,391	0	0	890	0	0
Itaúba	MT	44,285	0	0	41,062	0	0	17,123	0	0	9,906	0	0	2,445	0	0
Jauru	MT	0	0	0	0	74	0	0	0	0	0	0	0	0	0	0
Juara	MT	28,864	700	0	19,850	0	0	884	0	0	0	0	0	0	0	0
Juína	MT	4,027	657	0	1,719	715	0	0	0	0	0	0	0	0	0	0
Juruena	MT	139	759	0	0	0	0	0	0	0	0	0	0	0	0	0
Lambari D'Oeste	MT	1,347	0	0	0	0	0	0	0	0	919	0	0	228	0	0
Lucas Do Rio Verde	MT	9,050	0	0	8,559	0	0	6,830	0	0	4,604	0	0	695	0	0
Marcelândia	MT	47,511	0	0	37,663	0	0	1,116	0	0	785	0	0	147	0	0
Matupá	MT	31,350	4	0	23,830	0	0	4,001	0	0	1,181	0	0	1,005	0	0
Mirassol D'Oeste	MT	3,953	0	0	1,895	0	0	689	0	0	963	0	0	0	0	0
Nortelândia	MT	19,501	0	0	17,854	0	0	15,374	0	0	11,416	155	0	3,905	0	0
Nova Canaã Do Norte	MT MT	34,710	0	0	28,956	0	0	9,885	0	0	4,923	0	0	321	0	0
Nova Guarita	MT	9,408	100	0	8,832	0	0	1,844	0	0	0	0	0	0	0	0
Nova Lacerda	MT	17,809	768	0	15,660	0	0	4,799	0	0	2,040	0	0	0	0	0
Nova Marilândia	MT	12,431	0	0	13,303	0	0	10,686	0	0	9,202	216	421	8,532	67	0
Nova Maringá	MT	139,650	89	0	127,143	119	0	61,706	33	0	34,480	81	0	291	0	0
Nova Monte Verde	MT	613	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nova Mutum	MT	13,945	0	0	13,618	0	0	8,321	0	0	4,617	82	0	350	0	0

MUNICIPALITY	UF	CROP YEAR 2016/17			CROP YEAR 2014/15			CROP YEAR 2009/10			CROP YEAR 2006/07			CROP YEAR 2000/01		
		SOY	CORN	COTTON	SOY	CORN	COTTON	SOY	CORN	COTTON	SOY	CORN	COTTON	SOY	CORN	COTTON
Nova Olímpia	MT	7,193	0	0	7,070	0	0	4,017	0	0	1,911	0	0	365	0	0
Nova Santa Helena	MT	20,211	0	0	15,261	0	0	3,783	0	0	1,962	0	0	1,029	0	0
Nova Ubiratã	MT	118,752	1,684	0	122,790	0	0	94,677	0	0	60,372	586	2	3,934	0	0
Novo Horizonte Do Norte	MT	4,316	0	0	2,731	0	0	0	0	0	0	0	0	0	0	0
Novo Mundo	MT	24,882	45	0	17,660	0	0	2,436	0	0	1,000	0	0	1,049	0	0
Paranaíta	MT	2,653	0	0	1,230	0	0	257	0	0	0	0	0	0	0	0
Paranatinga	MT	56,018	2,560	0	56,393	0	5,502	28,245	0	0	20,832	0	0	0	0	0
Peixoto De Azevedo	MT	19,392	305	0	17,182	0	0	1,178	190	0	0	0	0	77	0	0
Pontes E Lacerda	MT	17,599	754	0	13,223	558	0	6,522	81	0	3,529	81	0	0	0	0
Porto Alegre Do Norte	MT	27,726	0	0	19,622	293	0	4,066	0	0	0	0	0	0	0	0
Porto Dos Gaúchos	MT	168,150	0	0	150,967	0	0	88,170	0	0	59,123	0	0	7,313	175	792
Porto Esperidião	MT	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0
Porto Estrela	MT	0	0	0	0	0	0	92	158	0	878	0	0	0	0	0
Querência	MT	351,340	1,886	0	341,260	380	0	224,432	76	0	149,264	659	0	22,412	182	0
Ribeirão Cascalheira	MT	64,652	1,674	0	54,527	0	0	20,740	0	0	12,343	0	0	53	0	0
Rondolândia	MT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Salto Do Céu	MT	1,447	0	0	1,455	0	0	0	0	0	365	0	0	0	0	0
Santa Carmem	MT	114,105	0	0	109,981	0	0	71,391	0	0	45,025	0	0	9,665	49	0
Santa Cruz Do Xingu	MT	21,525	0	0	18,627	0	0	554	0	0	2,835	0	0	0	0	0
Santa Terezinha	MT	2,133	0	0	1,248	0	0	909	0	0	207	0	0	0	0	0
Santo Afonso	MT	8,668	0	0	7,998	0	0	218	0	0	14	0	0	0	0	0
São Félix Do Araguaia	MT	202,191	343	0	174,418	847	0	43,189	26	0	20,872	0	0	52	0	0

MUNICIPALITY	UF	CROP YEAR 2016/17			CROP YEAR 2014/15			CROP YEAR 2009/10			CROP YEAR 2006/07			CROP YEAR 2000/01		
		SOY	CORN	COTTON	SOY	CORN	COTTON	SOY	CORN	COTTON	SOY	CORN	COTTON	SOY	CORN	COTTON
São José Do Rio Claro	MT	12,618	0	0	11,018	0	0	236	0	0	237	0	0	0	0	0
São José Do Xingu	MT	51,465	0	0	33,839	0	0	1,422	0	0	0	0	0	0	0	0
São José Dos Quatro Marcos	MT	3,425	0	0	2,397	0	0	806	0	0	1,104	27	0	0	0	0
Sinop	MT	163,277	3	0	160,050	0	329	130,749	0	0	100,864	987	0	32,580	309	3,220
Sorriso	MT	132,296	0	0	129,915	0	292	127,776	0	0	115,445	228	0	75,539	364	179
Tabaporã	MT	157,155	2,089	0	150,215	0	0	103,977	0	0	68,025	0	0	6,587	140	0
Tangará Da Serra	MT	38,281	238	0	35,862	0	0	17,153	221	0	7,156	749	0	2,921	0	1
Tapurah	MT	104,156	66	0	98,858	0	0	66,878	0	0	53,517	303	0	19,796	276	0
Terra Nova Do Norte	MT	18,165	0	0	14,203	0	0	2,050	0	0	1,464	0	0	245	0	0
União Do Sul	MT	52,444	0	0	40,578	0	0	12,813	0	0	5,400	0	0	0	0	0
Vale De São Domingos	MT	0	0	0	0	0	0	0	0	0	111	0	0	0	0	0
Vera	MT	145,982	0	0	142,668	0	0	128,358	0	459	105,595	2	1,944	21,728	121	1,291
Vila Bela Da Santa Trindade	MT	18,622	4,696	0	14,149	1,025	0	5,582	172	0	4,765	349	0	40	0	0
Vila Rica	MT	25,138	289	0	14,404	78	0	3,156	0	0	1,312	240	0	0	0	0
Abel Figueiredo	PA	163	61	0	33	7	0	0	0	0	0	0	0	0	0	0
Afuá	PA	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Água Azul Do Norte	PA	326	254	0	0	500	0	0	42	0	0	629	0	0	0	0
Altamira	PA	7,471	100	0	1,951	313	0	0	0	0	0	0	0	0	0	0
Bannach	PA	0	71	0	0	63	0	0	0	0	0	0	0	0	0	0
Belterra	PA	16,300	408	0	15,121	338	0	8,258	704	0	3,464	2,005	0	0	63	0
Brasil Novo	PA	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Capitão Poço	PA	236	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Conceição Do Araguaia	PA	1,435	34	0	762	0	0	0	39	0	95	0	0	174	0	0

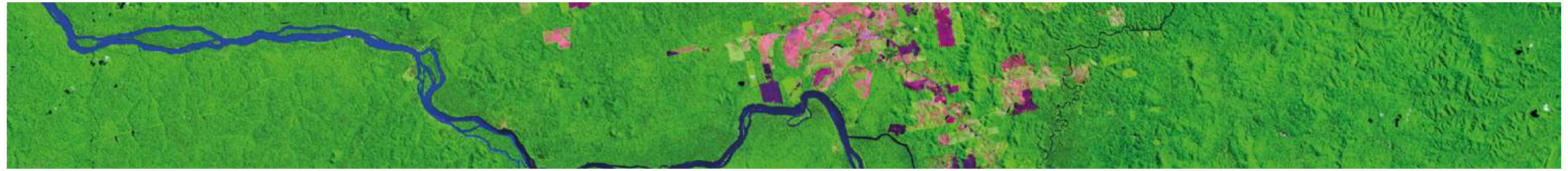
MUNICIPALITY	UF	CROP YEAR 2016/17			CROP YEAR 2014/15			CROP YEAR 2009/10			CROP YEAR 2006/07			CROP YEAR 2000/01		
		SOY	CORN	COTTON	SOY	CORN	COTTON	SOY	CORN	COTTON	SOY	CORN	COTTON	SOY	CORN	COTTON
Cumaru Do Norte	PA	12,135	208	0	12,273	212	0	0	55	0	0	0	0	0	0	0
Curionópolis	PA	1	1,324	0	228	794	0	0	0	0	0	0	0	0	0	0
Dom Eliseu	PA	53,408	6,473	0	46,732	4,025	0	12,468	4,094	0	4,122	6,460	0	0	961	0
Eldorado Do Carajás	PA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Floresta Do Araguaia	PA	3,231	0	0	1,803	0	0	566	0	0	481	0	0	178	0	0
Goianésia Do Pará	PA	110	272	0	77	220	0	0	0	0	0	0	0	0	0	0
Ipixuna Do Pará	PA	4,527	1,224	0	4,699	229	0	635	132	0	0	0	0	0	0	0
Itupiranga	PA	0	21	0	0	0	0	0	0	0	0	0	0	0	0	0
Jacareacanga	PA	243	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jacundá	PA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Marabá	PA	254	473	0	0	0	0	0	0	0	0	0	0	0	0	0
Moju	PA	1,712	2,245	0	641	1,147	0	0	331	0	0	0	0	0	0	0
Mojuí Dos Campos	PA	29,279	335	0	25,985	572	0	14,250	201	0	7,299	428	0	0	235	0
Nova Esperança Do Piriá	PA	8,579	1,746	0	7,900	619	0	508	0	0	0	258	0	0	0	0
Novo Progresso	PA	7,191	0	0	3,957	213	0	0	0	0	449	0	0	0	0	0
Paragominas	PA	101,521	12,982	0	89,925	11,936	0	30,045	13,744	0	8,149	16,187	0	312	3,763	0
Pau D'Arco	PA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Piçarra	PA	0	0	0	136	0	0	0	0	0	0	176	0	0	0	0
Placas	PA	665	0	0	436	156	0	115	0	0	129	0	0	0	0	0
Redenção	PA	5,533	289	0	2,896	902	0	420	0	0	915	0	0	188	0	0
Rio Maria	PA	480	52	0	480	67	0	0	0	0	0	0	0	0	0	0
Rondon Do Pará	PA	23,074	3,216	0	17,369	2,587	0	1,016	0	0	0	0	0	0	0	0
Rurópolis	PA	382	23	0	399	0	0	72	0	0	0	204	0	0	0	0
Santa Maria Das Barreiras	PA	24,648	484	0	10,148	227	0	2,985	0	0	1,493	0	0	0	0	0

MUNICIPALITY	UF	CROP YEAR 2016/17			CROP YEAR 2014/15			CROP YEAR 2009/10			CROP YEAR 2006/07			CROP YEAR 2000/01		
		SOY	CORN	COTTON	SOY	CORN	COTTON	SOY	CORN	COTTON	SOY	CORN	COTTON	SOY	CORN	COTTON
Santana Do Araguaia	PA	57,799	452	0	39,597	880	0	5,382	396	0	5,413	0	0	0	0	0
Santarém	PA	14,737	253	0	13,880	255	0	8,550	28	0	5,646	701	0	24	97	0
São Félix Do Xingu	PA	2,506	148	0	1,099	0	0	0	0	0	0	0	0	0	0	0
São João Do Araguaia	PA	326	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sapucaia	PA	0	504	0	1	453	0	0	116	0	0	0	0	0	0	0
Tailândia	PA	377	2,871	0	717	1,361	0	129	510	0	0	200	0	0	0	0
Tucumã	PA	0	150	0	1	708	0	0	43	0	0	0	0	0	0	0
Ulianópolis	PA	28,150	5,780	0	27,352	2,103	0	8,144	6,557	0	2,165	7,976	0	0	1,196	0
Uruará	PA	243	199	0	733	630	0	1,324	271	0	311	194	0	0	0	0
Xinguara	PA	0	588	0	58	1,006	0	0	0	0	0	232	0	0	0	0
Alta Floresta D'Oeste	RO	609	119	0	404	85	0	0	0	0	0	0	0	0	0	0
Alto Alegre Dos Parecis	RO	1,212	183	0	1,108	49	0	108	0	0	0	0	0	0	0	0
Alto Paraíso	RO	6,617	0	0	2,700	202	0	0	0	0	140	0	0	0	0	0
Alvorada D'Oeste	RO	411	0	0	554	142	0	0	0	0	0	0	0	0	0	0
Ariquemes	RO	3,934	0	0	2,202	232	0	946	99	0	0	0	0	0	0	0
Cabixi	RO	21,826	1,130	0	19,904	0	0	11,346	0	0	5,325	300	0	277	0	0
Cacoal	RO	1,008	0	0	265	0	0	0	0	0	0	0	0	0	0	0
Candeias Do Jamari	RO	3,317	391	0	862	0	0	0	0	0	0	0	0	0	0	0
Castanheiras	RO	2,157	0	0	1,504	0	0	0	0	0	0	0	0	0	0	0
Cerejeiras	RO	34,534	0	0	33,510	0	0	23,115	0	0	14,262	310	0	3,047	150	0
Chupinguaia	RO	23,045	1,122	0	21,108	79	0	11,231	135	0	7,684	0	0	0	0	0
Colorado Do Oeste	RO	2,662	0	0	3,137	20	0	2,159	0	0	1,728	0	0	537	0	0

MUNICIPALITY	UF	CROP YEAR 2016/17			CROP YEAR 2014/15			CROP YEAR 2009/10			CROP YEAR 2006/07			CROP YEAR 2000/01		
		SOY	CORN	COTTON	SOY	CORN	COTTON	SOY	CORN	COTTON	SOY	CORN	COTTON	SOY	CORN	COTTON
Corumbiara	RO	40,470	87	0	43,603	41	0	24,106	224	0	13,803	0	0	76	0	0
Cujubim	RO	6,341	0	0	2,321	948	0	0	0	0	0	0	0	0	0	0
Espigão D'Oeste	RO	1,162	6	0	891	0	0	0	0	0	0	0	0	0	0	0
Itapuã Do Oeste	RO	1,808	0	0	1,511	0	0	597	0	0	0	0	0	0	0	0
Machadinho D'Oeste	RO	4,226	0	0	2,188	1,120	0	92	0	0	0	0	0	0	0	0
Monte Negro	RO	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nova Brasilândia D'Oeste	RO	223	0	0	297	0	0	0	0	0	0	0	0	0	0	0
Novo Horizonte Do Oeste	RO	1,696	0	0	402	0	0	0	0	0	0	0	0	0	0	0
Parecis	RO	522	0	0	1,000	0	0	0	0	0	0	0	0	0	0	0
Pimenta Bueno	RO	528	0	0	275	0	0	122	0	0	0	93	0	0	0	0
Pimenteiras Do Oeste	RO	35,596	79	0	28,573	180	0	9,148	421	0	5,874	93	0	713	144	0
Porto Velho	RO	870	37	0	207	0	0	199	0	0	0	0	0	0	0	0
Primavera De Rondônia	RO	0	29	0	0	0	0	0	0	0	0	0	0	0	0	0
Rio Crespo	RO	7,601	0	0	4,020	434	0	134	0	0	0	0	0	0	0	0
Rolim De Moura	RO	3,408	0	0	2,539	0	0	0	0	0	0	0	0	0	0	0
Santa Luzia D'Oeste	RO	1,560	506	0	1,507	93	0	204	125	0	0	0	0	0	0	0
São Felipe D'Oeste	RO	131	46	0	367	0	0	0	0	0	0	0	0	0	0	0
São Francisco Do Guaporé	RO	180	109	0	0	0	0	0	0	0	0	0	0	0	0	0
São Miguel Do Guaporé	RO	8,430	260	0	3,903	336	0	0	0	0	0	0	0	0	0	0
Seringueiras	RO	4,078	55	0	3,240	162	0	0	0	0	0	0	0	0	0	0
Theobroma	RO	571	0	0	203	0	0	0	0	0	0	0	0	0	0	0

MUNICIPALITY	UF	CROP YEAR 2016/17			CROP YEAR 2014/15			CROP YEAR 2009/10			CROP YEAR 2006/07			CROP YEAR 2000/01		
		SOY	CORN	COTTON	SOY	CORN	COTTON	SOY	CORN	COTTON	SOY	CORN	COTTON	SOY	CORN	COTTON
Vale Do Anari	RO	0	0	0	59	0	0	0	0	0	0	0	0	0	0	0
Vilhena	RO	31,933	0	0	34,003	0	0	30,225	0	0	23,516	244	0	14,069	111	0
Açailândia	MA	29,309	9,613	0	18,904	3,939	0	1,046	559	0	140	1,663	0	0	0	0
Alto Alegre Do Pindaré	MA	1,114	71	0	654	164	0	272	146	0	38	412	0	0	0	0
Amarante Do Maranhão	MA	0	66	0	0	0	0	0	0	0	0	0	0	0	0	0
Arame	MA	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Bom Jardim	MA	3,765	1,642	0	493	139	0	0	0	0	0	0	0	0	0	0
Bom Jesus Das Selvas	MA	1,898	2,449	0	0	461	0	0	0	0	0	0	0	0	0	0
Buriticupu	MA	16,711	3,609	0	5,559	1,316	0	0	0	0	0	0	0	0	0	0
Cidelândia	MA	1,477	148	0	1,099	0	0	0	55	0	0	0	0	0	0	0
Grajaú	MA	67	0	0	67	0	0	0	0	0	0	0	0	0	0	0
Itinga Do Maranhão	MA	10,726	2,697	0	7,367	345	0	148	0	0	0	0	0	0	0	0
Santa Luzia	MA	3,302	6,564	0	326	1,335	0	0	0	0	0	0	0	0	0	0
São Francisco Do Brejão	MA	0	160	0	0	0	0	0	0	0	0	0	0	0	0	0
São Pedro Da Água Branca	MA	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Vila Nova Dos Martírios	MA	2,992	31	0	2,741	0	0	0	0	0	0	0	0	0	0	0
Alto Alegre	RR	11,292	22	0	8,665	0	0	331	0	0	2,833	0	0	390	75	0
Boa Vista	RR	9,249	283	0	9,780	0	0	1,347	10	0	2,197	0	0	142	514	0
Bonfim	RR	9,173	1,883	0	6,727	0	0	1,486	612	0	1,574	0	0	264	124	0
Cantá	RR	682	0	0	475	0	0	0	0	0	0	0	0	304	185	0
Iracema	RR	1,021	0	0	0	268	0	0	0	0	0	0	0	0	0	0
Mucajaí	RR	827	108	0	447	214	0	0	115	0	0	210	0	0	0	0

MUNICIPALITY	UF	CROP YEAR 2016/17			CROP YEAR 2014/15			CROP YEAR 2009/10			CROP YEAR 2006/07			CROP YEAR 2000/01		
		SOY	CORN	COTTON	SOY	CORN	COTTON	SOY	CORN	COTTON	SOY	CORN	COTTON	SOY	CORN	COTTON
Araguaína	TO	6,417	0	0	5,741	0	0	0	0	0	0	0	0	0	0	0
Arapoema	TO	809	0	0	1,407	0	0	530	0	0	904	0	0	0	0	0
Bandeirantes Do Tocantins	TO	343	0	0	329	0	0	0	0	0	0	0	0	0	0	0
Bernardo Sayão	TO	0	0	0	0	47	0	0	0	0	0	0	0	0	0	0
Carmolândia	TO	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Couto Magalhães	TO	35	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fortaleza Do Tabocão	TO	1,539	0	0	1,321	0	0	819	0	0	182	0	0	0	0	0
Guaraí	TO	204	0	0	88	0	0	112	0	0	104	0	0	0	0	0
Muricilândia	TO	0	0	0	156	8	0	0	0	0	0	0	0	0	0	0
Nova Olinda	TO	0	0	0	63	0	0	0	0	0	0	0	0	0	0	0
Pequizeiro	TO	131	91	0	66	1	0	0	0	0	0	0	0	0	0	0
Piraquê	TO	5,866	0	0	4,030	0	0	0	0	0	0	0	0	0	0	0
Santa Fé Do Araguaia	TO	5,274	232	0	1,367	779	0	0	0	0	0	0	0	0	0	0
Wanderlândia	TO	553	0	0	158	0	0	0	0	0	0	0	0	0	0	0
Xambioá	TO	193	0	0	193	0	0	0	0	0	0	0	0	0	0	0
Ferreira Gomes	AP	133	0	0	8	0	0	110	0	0	0	0	0	0	0	0
Itaubal	AP	2,799	0	0	1,800	0	0	151	0	0	0	0	0	0	0	0
Macapá	AP	11,117	111	0	8,206	0	0	1,538	0	0	387	0	0	0	0	0
Tartarugalzinho	AP	4,886	0	0	2,321	0	0	0	0	0	0	0	0	0	0	0
TOTAL		4,482,438	104,531	199	4,007,347	52,559	8,765	2,104,553	31,849	3,953	1,406,279	46,304	4,596	338,984	11,590	17,905



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