GEOSCIENCES

Impacts of agrarian reform on land use in the biomes of the Midwest region of Brazil between 2004 and 2014

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Abstract: Brazil's Midwest is composed of four biomes: the Cerrado, predominant in the region; the Pantanal, the largest wetland in the world; the Amazon, which occupies part of Mato Grosso; and the Atlantic Forest. The objective of this study was to identify the evolution of occupation and use of land in the rural settlements of the Brazilian Midwest depending on the biome of location. A total of 54 settlements distributed in the four biomes of the region were analyzed using direct observation and Landsat images from the years 2004 and 2014. Using the software QGIS 2.8 Wien, the vegetation indices NDVI and NDWI were used to classify agricultural, pasture and forest areas by biome. Native vegetation is declining in most of the analyzed settlements and pastures, for milk production, occupied the largest area. Between 2004 and 2014, pasture areas expanded to the detriment of forests. Although they have the highest percentage of environmental preservation areas, the settlements we analyzed in the Amazon biome do not comply with legislation. Part of the forest in these settlements was transformed into areas of bushy cerrado. However, there was an increase in forests in the settlements of the Atlantic Forest biome.

Key words: Biomes, Deforestation, Environmental preservation, Family agriculture, Geotechnologies.
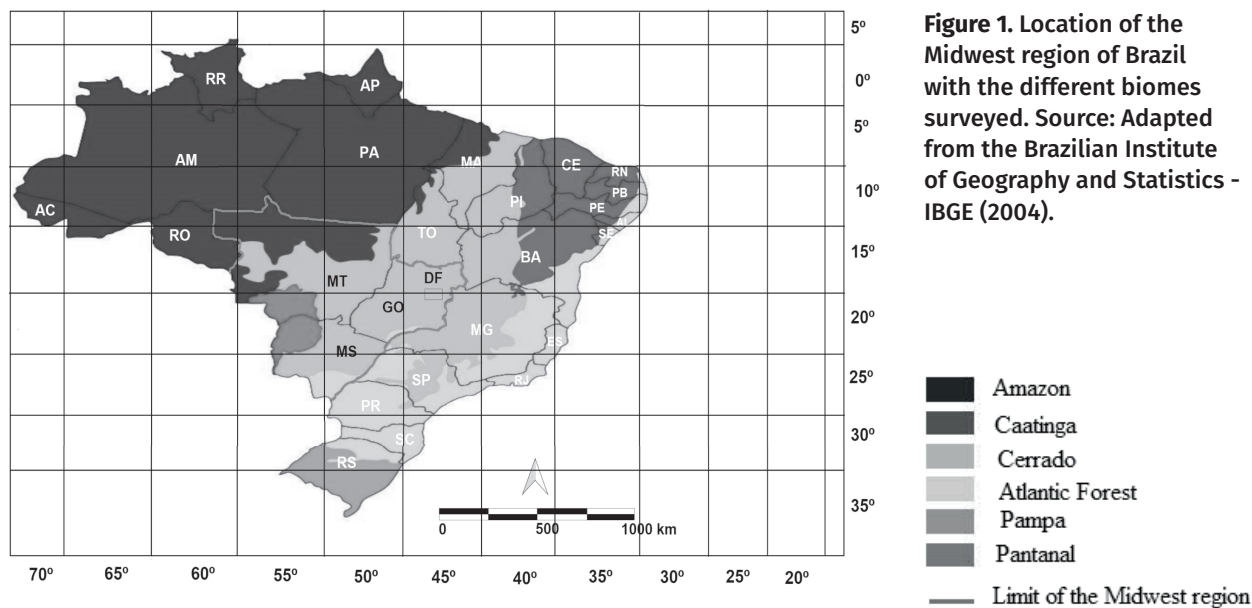
INTRODUCTION

The Brazilian Midwest is characterized by great diversity in vegetation and integrates four of the six national biomes: the Cerrado, or Brazilian savannah, which is predominant in the region; the Pantanal, a flooded savannah; the Amazon, which occupies part of Mato Grosso; and the Atlantic Forest, the most threatened biome in Brazil. These biomes give the Midwest great environmental importance in the global context (Figure 1).

The Cerrado occupies approximately 24% of Brazilian territory and extends through the central region of the country. It is the largest savannah region in South America, with an area of more than two million km^2. The Cerrado is home to many species of Brazilian fauna and flora (IBAMA 2011a, Ferreira 2010) but had 46% of its area suppressed in 2013 (MMA 2016). In the Midwest region, the Cerrado covers the whole of the Federal District, where is located Brasília, the Federal capital, 97% of the state of Goiás, 61% of Mato Grosso do Sul and around 40% of Mato Grosso (IBGE 2004).

Although it represents 49% of Brazilian territory, the Amazon biome is present in the Midwest region only in the state of Mato Grosso, occupying 54% of that state (IBGE 2004). With the highest concentration of natural forests in the world, the Amazon biome accounts for almost one-fifth of the world's freshwater reserves. In

Figure 1. Location of the Midwest region of Brazil with the different biomes surveyed. Source: Adapted from the Brazilian Institute of Geography and Statistics - IBGE (2004).

the last decades, this biome has witnessed the advance of different economic activities linked to agriculture (MIN 2007).

With approximately 2% of the national territory (IBGE 2004, IBAMA 2011b), the Pantanal biome is recognized as the Earth's largest wetland. Savannah vegetation predominates in this biome, which was declared a Biosphere Reserve and Natural World Heritage Site by UNESCO. The Pantanal biome is only present in the states of Mato Grosso, where it occupies less than 7% of the surface of the state, and Mato Grosso do Sul, where it occupies 25% of the state surface. The main economic activity in the Pantanal is raising beef cattle in extensive pastures, which is responsible for most deforestation in this biome (Abdon et al. 2007, IBAMA 2011b).

The last biome of the Midwest, the Atlantic Forest, contains one of the richest sets of ecosystems (Alliance for the Conservation of Atlantic Forest 2015). It is the second largest tropical rainforest on the American continent, which originally extended continuously along the

Brazilian coast (Tabarelli et al. 2005). The removal of native vegetation for use in agriculture, the extraction of wood and human occupation caused the destruction of most of this biome; only 7 to 8% of its original area remains (Alliance for the Conservation of Atlantic Forest 2015). In the Midwest, the Atlantic forest biome is present in the states of Mato Grosso do Sul, with 14% of the state surface, and Goiás, with only 3%.

Despite the importance of these biomes, it is necessary to consider the economic importance of agricultural and livestock production. The Midwest region is known for having large areas of agricultural production and livestock and is considered the largest producer of commodities in the country. In 2018 the region accounted for 21.3% of the national production of sugarcane, 51% of corn, 45.3% of soybean and 70.5 of cotton (SEAPA 2018). The region also accounted for 36.1% of slaughtered oxen in Brazil in 2016 (MAPA 2018). As a result, the region had more than 76 million livestock heads in 2016, or close to 8% of the world livestock, produced 47 million tons of soybeans (more than 14% of world production)

and 40 million tons of corn (approximately 4% of world production) (Castro 2014, CONAB 2016, FAO 2017).

Large-scale production has caused serious environmental problems arising from the replacement of natural vegetation by areas of agriculture and extensive livestock. According to Alves et al. (2012), the Midwest, together with the Northeastern region, is the region of Brazil with the highest Gini index for land concentration, at 0.91. For Van De Steeg et al. (2006), Wittman (2009, 2010) and Ludewigs et al. (2009), agrarian reform is frequently considered as a solution to the problem of land inequality and an inducing agent for the organization and occupation of the territorial space. There are more than 130,000 families located in 1,214 settlements distributed in an area of over 8 million hectares in the Midwest (National Institute of Colonization and Agrarian Reform - INCRA 2016).

According to Chapell et al. (2013), small producers are associated with crops and various animal species, which favors the maintenance of ecosystem services. Alfatin (2007) attributed the function of environmental preservation to small farmers, although this is considered a controversial issue. According to the author, the relationship between small farmers and natural resources is positive because of the ability of the farmers to coexist in harmony with natural ecosystems. On the other hand, when in a situation of risk, the need for survival causes farmers to consume the available resources, which damages the environment (Alfatin 2007, Soares 2001).

Doubts about the role of the settler in maintaining the environment are becoming increasingly important in the context of land redistribution and environmental resource management. The development of research that can solve these doubts has thus become essential. Leite et al. (2004), Brandão Jr &

Souza Jr (2006) and Le Tourneau & Bursztyn (2010) identified a negative impact of agrarian reform on environmental preservation. However, research is restricted to the Amazon region, with large forest areas and agricultural pressures much smaller than in the Midwest.

Because there is little data available to evaluate the impact of agrarian reform on the occupation and use of land in the Midwest region, the need to generate information in this region is warranted. After the preceding initial presentation, the following questions arise: Do the rural settlers of the agrarian reform in the Brazilian Midwest preserve the native land cover? Do the occupation of land by settlers vary with the biome in which they are located?

To complement this research, another question focuses on the type of production: have rural settlers of the agrarian reform in the Midwest changed their production practices over time to adapt to the local situation?

Based on these questions, this paper aims to verify the evolution of occupation and use of land in the rural settlements of the Brazilian Midwest depending on the biome of location.

In Land use Brazilian settlements we present the land uses in the Brazilian settlements, followed by the methodological procedures that precede the results and discussions. Finally, the last section is intended for conclusion.

Land use in Brazilian settlements

According to Shikida (2013), the economy of the Brazilian Midwest was initially based on mining (exploitation of precious metals) but then transitioned to livestock and, from the end of the twentieth century, grain production. The production model was based on space occupation and favored large-scale production.

In Brazil, the percentages of areas intended for forest and native vegetation protection vary based on the biome where rural property

is located. Since its implementation until 1996, the Forest Code of 1965 (Brasil 1965) emphasized that forests and other forms of native vegetation should constitute a Legal Reserve with a proportion of at least 50% of rural property when located in the Amazon. In 1996, through Provisional Measure No. 1511/1996 (Brasil 1996), the federal government proposed to increase the 50% of the Legal Reserve area of the rural properties located in the Amazon region to 80%. In 2001, Provisional Measure No. 2,166-67 (Brasil 2001) consolidated the percentages of Legal Reserve for the Amazon region and established the percentage of 35% of rural property located in the Cerrado when belonging to the Legal Amazon region (includes only the state of Mato Grosso in the Midwest), and 20% of rural properties located in the other regions of the country.

The New Forest Code, Law No. 12.651 and 12.727, of 2012 (Brasil 2012a, b) did not change these percentages.

IBGE data for 2006 and 2013 shows substantial growth of areas planted with sugarcane, corn, soybeans and cotton to the detriment of traditional crops reserved for small producers, such as rice and cassava. In 2013, production of soybeans accounts for 56.5% of the total harvested area in the region, followed by corn (27.3%) and sugar cane (7.8%) (IBGE 2013).

Wittman (2009) has stated that the simplification and standardization of production practices used in large-scale agriculture leads to a reduction in the number of seed varieties used for major crops, which reduces the diversity of agricultural landscapes. Simplification of the landscape because of monoculture allowed the widespread application of agricultural inputs, especially chemical inputs such as fertilizers and pesticides. The evolution of agriculture was essentially aimed at increasing the worldwide availability of food. However, the implementation of intensive farming practices, which require high levels of external chemical inputs, has caused environmental degradation, desertification and water pollution.

Due to the problems associated with large-scale agriculture, Chapell et al. (2013) argued that there is a growing body of evidence indicating that landscapes dominated by small, diversified production may be the most effective way to conserve biodiversity and preserve rural landscapes. Being more diversified, small-scale farmers not only conserve the resources of their crops but also many wild varieties associated with traditional systems, local values, autonomy and biodiversity.

In this scenario, the agrarian reform process is highlighted as a way to ensure the redistribution of land and the maintenance of small farmers. According to Bergamasco & Norder (1996), rural settlements can be defined as the creation of new agricultural production units through government policies aimed at the reordering of land use to the benefit of landless or small rural workers.

According to INCRA (2016), the state with the highest number of settlements in the Midwest is Mato Grosso, with 551 settlements, followed by Goiás (439), Mato Grosso do Sul (204) and the Federal District (22).

Despite recognizing the problems associated with large-scale agriculture, Shiki (2010) associates the same problems with agriculture from agrarian reform, because its forms of occupation reproduce the same pattern of land use: extraction of timber, deforestation (slash and burn), temporary cultivation and cattle ranching. Pacheco (2009) mentions that when smallholders develop complex land-use mosaics forest cover is retained but when they turn to cattle ranching, they convert most of the landscape into pasture. For the author, agrarian reform should favor the development of more

diversified production systems combining annuals, perennial, and cattle ranching.

METHODOLOGY

This section presents the methodology used in the field research and to process satellite images.

Field research

The research in the settlements of the Midwest region of Brazil covered the four biomes present in the region: the Cerrado, predominant in the region; the Pantanal, present in the states of Mato Grosso and Mato Grosso do Sul and which advances to the borders of Bolivia and Paraguay; the Amazon, which occupies part of Mato Grosso as an extension of the Amazon rainforest; and the Atlantic Forest, which covers the south of Mato Grosso do Sul and a small part of Goiás (IBGE 2004).

We selected 54 settlements located in the Cerrado, Amazon, Atlantic Forest and Pantanal biomes (Table I). We selected settlements at least five years of age, an age used by Vilpoux (2014) and considered sufficient for the settlements to stabilize. The visits were conducted from May to November 2014.

Of all the settlements, 32 in the Cerrado, 06 in the Amazon and 06 in the Atlantic Forest have been created by the INCRA. The other settlements have been created by the state agrarian reform agencies. Two settlements from INCRA in the Amazon biomes were PDS-type settlements; the others were all traditional settlements. The PDS settlements were the youngest of all the visited settlements and were five years old when we made the research.

Table I indicates that the oldest settlement in the Amazon Biome was implanted in 1995, one year before the publication of Provisional Measure No. 1511/1996, which changed the mandatory percentage of environmental reserve from 50 to 80% in the Amazon biome. The other settlements were all created after the change, with a legal reserve of 80% of the settlement area. As the oldest settlement was still in the implantation phase when the Provisional Measure was published, the limit of 80% was considered as the one to be respected in all the settlements surveyed in the Amazon biome.

The research used field data and image analysis. Due to the difficulties in accessing many settlements, mainly in the Amazon region of Mato Grosso, it was not possible to select the settlements according to the representativeness of each biome. Despite these difficulties, settlements were selected from various parts of the Midwest at different distances from the

Table I. Distribution of the settlements surveyed in the Midwest, by biome, and age of implantation in 2014.

Biomes	Number of Settlements	Age (years)		
		Maximum	Minimum	Average
Amazon	7	19	5	12.1
Cerrado	37	25	5	15.1
Atlantic Forest	8	17	12	13.8
Pantanal	2	13	8	10.5

urban centers and covering the geographic range of each state, as shown in Figure 2.

In order to meet the objectives of this paper, we also verified the conservation of agricultural area, presence of degraded pastures, existence and use of collective reserves and main productions encountered in the settlements.

To evaluate degraded pastures were considered pasture areas with the presence of invasive plants, exposed soils and small shrubs. The criterion used was the ratio of the pasture areas having these characteristics divided by the total pasture area observed in the visited plots. In all, 20 to 30 plots were visited in each settlement, totaling 1,162 plots.

The criteria used to evaluate conservation of the agricultural areas were the existence of crop rotation and the presence of level curves in the visited plots.

Image analysis

After being selected, the methods of image analysis were tested in three representative settlements of the biomes surveyed.

Methods used in the research

The images used to identify the land cover were from the Landsat Program (Land Remote Sensing Satellite). To carry out multitemporal analysis for a period of 10 years, we obtained TM sensor (Thematic Mapper) images from the Landsat 5 satellite for the year 2004 and OLI (Operational Land Imager) images from the Landsat 8 satellite for the year 2014.

The coordinates of field control points were collected in the field by the application Mobile Topographer V. 7.2.0 (STGRDEV Android Developer 2014), using a Global Navigation Satellite System receiver (GNSS) by cell phone.

It was possible to identify the orbit/point of the image to be used based on the geodetic coordinates of each settlement. In many cases, the downloaded image included more than one settlement, which reduced the number of images to be acquired. The Landsat 8 (OLI) satellite images (27 in total) were obtained from the USGS (United States Geological Survey 2015) website, and 27 images from the Landsat 5 (TM) satellite were obtained from the INPE (National Institute of Space Research 2015) website.

Images were downloaded for the period between June and October because of the low influence of clouds during this period (dry season); this is the period of greatest contrast between phytophysiological features in the biomes of the region.

The images were then composed using the free and open source software QGIS 2.8 Wien (QGIS Development Team 2015).

Landsat 8 satellite images are available for georeferenced download. However, it was necessary to perform an atmospheric corrections using the Geosud TOA Reflectance plug-in available in QGIS 2.8 Wien software. For the Landsat 5 satellite images, the atmospheric correction was performed using the Atmospheric Correction plugin of the Geomatics Focus software (PCI 2003). The images were sequentially georeferenced using the OrthoEngine module of the Geomatics Focus software (PCI 2003).

The areas of each of the selected settlements were then identified and delimited using the layers available in the I3Geo, a tool created by INCRA. For the states settlements we used the maps available in the local rural technical assistance agencies (EMPAER, AGRAER, EMATER). For a better accuracy, we updated the boundaries of each settlement with GPS coordinates obtained in situ and maps from Google Earth software (Google 2015). This method is similar with the one used by Michalski et al. (2010).

After the stage of identification and delimitation of settlements, the vegetation
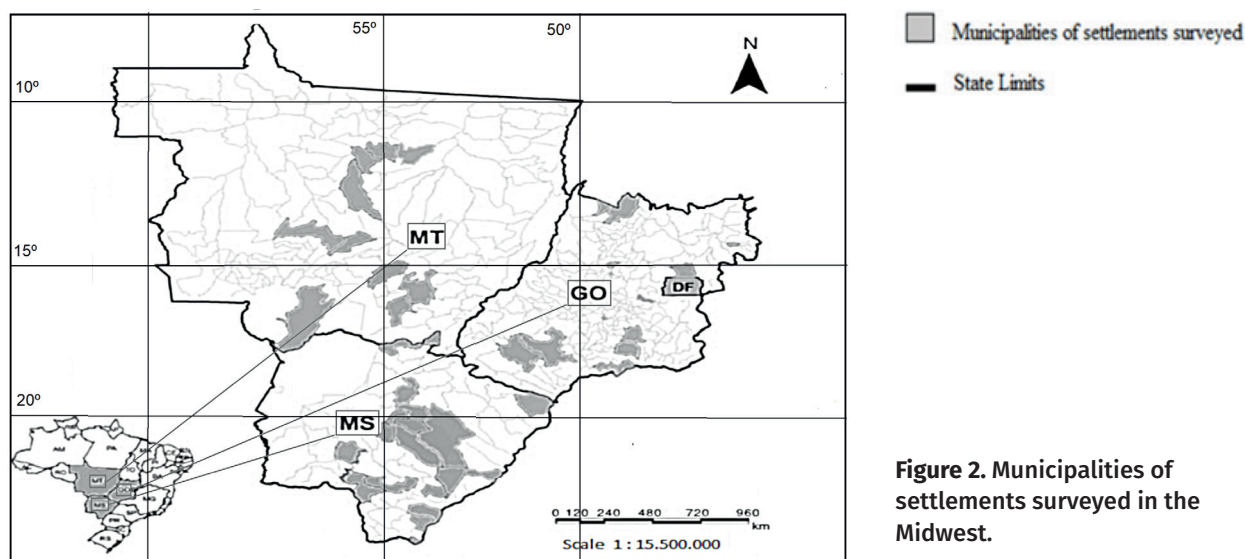
Figure 2. Municipalities of settlements surveyed in the Midwest.

indices NDVI (Normalized Difference Vegetation Index) developed by Rouse et al. (1974) and NDWI (Normalized Difference Water Index) proposed by Hardisky et al. (1983) and Gao (1996) to measure areas for agriculture, livestock and environmental preservation were determined.

Vegetation indices are used to monitor the vegetation cover of a given region. They present several possible applications, such as the identification and classification of agricultural and forest areas, soil moisture, and the measurement of water content within vegetation, among other applications. Since the 1980s NDVI has been widely used for monitoring the ecosystem and evaluating the process of land cover change.

The NDVI is the ratio of the difference between the near-infrared band and the visible red band to the sum of the near-infrared and visible red bands, according to Equation (1).

$$NDVI = \frac{\rho NIB - \rho V}{\rho NIB + \rho V} \qquad (1)$$

ρNIB = Near Infrared Band
ρV = Visible Red Band

In the literature, the use of NDVI has been used in estimating yields in individual crops (Becker-Reshef et al. 2010, Esquerdo et al. 2011, Huang et al. 2013), in multiple plantations (Biradar & Xiao 2011, Bolton & Friedl 2013, Kastens et al. 2017), or to monitor the changes in landscapes of ecosystems, being an effective tool to provide information and fundamental questions about the ecological condition, degradation of forest areas, evaluation of long dry periods in agricultural areas (Constantini et al. 2012, Gandhi et al. 2015, Zhang & Wang 2015, Zhao et al. 2017).

Given the heterogeneity of the vegetation cover in the settlements of the Midwest region it was not possible to detect the differences between landscapes with the exclusive use of the NDVI, being necessary to use it together with the NDWI. Previous studies (Jackson et al. 2004, Chen et al. 2005, Sahu 2014) have shown that it is very important to correlate the results obtained by the two indices (NDVI and NDWI) in agricultural areas and regions of dense or tenuous forest.

The NDWI is the ratio of the difference between the near infrared band and the medium

infrared band, and the near infrared sum to the medium infrared bands, according to Equation (2).

$$NDWI = \frac{\rho NIB - \rho MIB}{\rho NIB + \rho MIB} \qquad (2)$$

ρNIB = Near Infrared Band

ρMIB = Medium Infrared Band

The NDWI is used to monitor changes in water content of leaves and as for NDVI is used to evaluate the vegetation cover, which explains the correlation between the two indices. The presence of irrigation could interfere with the analysis, but in the researched settlements irrigation was only used by a few producers and always in very small areas, which do not interfere in the analysis.

Thus, it was possible to correlate the two indexes generated to improve the identification of the different types of vegetation cover present in the biomes surveyed.

The entire procedure for calculating NDVI and NDWI was performed with the free software QGIS 2.8 Wien. For the NDVI, the classes of interest were selected based on literature data for each kind of land cover and on the values obtained in the vegetation cover samples in each study area, with adjustments using the results of NDWI. The classification method is explained in more detail in classification indices.

Five classes were established: urban, agricultural areas, pasture, bushy cerrado and forest. The urban class has not been used in the analysis.

In the agricultural class were considered the classes of latosols, representing exposed soils, plowed lands and agricultural zones. In the pasture class were considered the areas of prairies with green response (false-color composition RGB 453), formed by areas of dry fields and pasture. Areas of prairies with small and sparse shrub vegetation were also

considered. These areas are considered poorly managed pastures, with low presence of small trees. In the field research the use of these areas for grazing animals was verified.

Garcia & Ballester (2016) describe the cerrado in the South of the Midwest region as composed of areas of forests and of bushy cerrado, less shaded areas with shrub layers and herbaceous components. The woody cerrado was made of two kinds of forests, one with a continuous canopy with trees up to 12 m high and one with a canopy cover ranging from 50% to 90%. For the INPE (2008) due to the spatial resolution of satellite images, it is difficult to make the difference between a forest of 50% and 100% of vegetation cover. Thus, in our analysis all the woody cerrado was classified in the forest class, together with the Amazon and the Atlantic forests.

On the other side, Garcia & Ballester (2016) identified two kinds of bushy cerrado, one dominated by shrub species and trees, with clumps of herbaceous plants interspersed with spaces of exposed soil. This type of cerrado is the result of forest degradation by cattle grazing and/or vegetation recovery after deforestation or abandonment of pastures. The other kind of bushy cerrado has been identified as "campo sujo" (dirty field). This vegetation is a native physiognomies in the Cerrado biome, which occurs in intensely drained sites, with a deep water table and a strong seasonal water deficit at the topsoil level. As it has not been possible to separate the vegetation from "campos sujos" from the one of the degradation or recovery of forests, all of these areas were classified in the bushy cerrado class.

Classification indices

In order to establish the classification indices for the classes of land use, 03 settlements were

selected, one in each state of the Midwest region: Itamarati settlement in Mato Grosso do Sul, Keno settlement in Mato Grosso and Canudos settlement in Goiás.

The Itamarati settlement is located in the southern region of the state of Mato Grosso do Sul, geographical coordinates 22°10'15" south and 55°31'44" west. Its main activity is the production of grains (soybean and corn) and is located in the transition area between the Cerrado and Atlantic Forest biomes.

The Keno settlement is located in the state of Mato Grosso, at the geographical coordinates 11°24'22" south and 54°98'84" west. The settlement is located in the Amazon biome and develops agroforestry activities, in addition to small-scale agricultural production.

Finally, the Canudos settlement is located in the state of Goiás, in the Cerrado biome, at 16°80'33" south and longitude 49°72'45" west. It stands out in the production of milk and vegetables.

The settlements were chosen due to the heterogeneity of their activities and to be located in different biomes.

At first, a field research was realized in these settlements, where the predominant activities and the different land cover were observed, as well as information on infrastructure, soil conservation, existence and conservation of legal reserves and pasture quality.

After the field visits, thematic maps were elaborated from the results obtained with NDVI calculations. We used the metadata generated by the QGIS that offer the values of maximum, average, minimum and standard deviation by class of interest. These classes were previously established according to data available in the literature. For exemple, Jackson & Huete (1991) worked with bare soil class, Carvalho Júnior et al. (2008) with woody and bushy cerrado, Ke et al. (2015) with forest, crops and water.

However, the classes used in the literature do not correspond to the classes of interest found in the researched settlements, since they do not include all types of landscapes found or a same kind of land cover can be different according to the region. As an example, the characteristics of the forests surveyed by Ke et al. (2015) in China and Korea may be different from the forests in the Midwest. Thus, based on the field observations in each of the three settlements a classification adapted to the researched landscapes was performed. The classification occurred according to the biomass and phytophysiognomy of each type of vegetation cover.

Figure 3 illustrates the results obtained through the NDVI calculations by the QGIS software, after classification in the classes of interest.

Figure 3 clearly shows the different classes evaluated. In order to complement the analysis, and with the purpose of considering the specificities of each region evaluated, the NDWI indices were calculated, as presented in Figure 4. The calculation of the NDWI was similar to the NDVI. The metadata originating from the QGIS were adopted and the classes were previously established according to Ceccato et al. (2001), Jackson et al. (2004), Chen et al. (2005), Peter & Ruhoff (2013), among others.

Then, for each settlement the results of the NDVI and NDWI indices were correlated using the Pearson correlation coefficient (r). When the correlation between the two indices results in a r value ≥ 0.9 (p = 0.05) the analysis was considered valid for the identification of the classes of vegetation and the created algorithm used without modification. Correlation values lower than 0.9 could mean the use of a poor quality image with the presence of clouds. The maintenance of a correlation less than 0.9 after the image change meant the need to adjust the
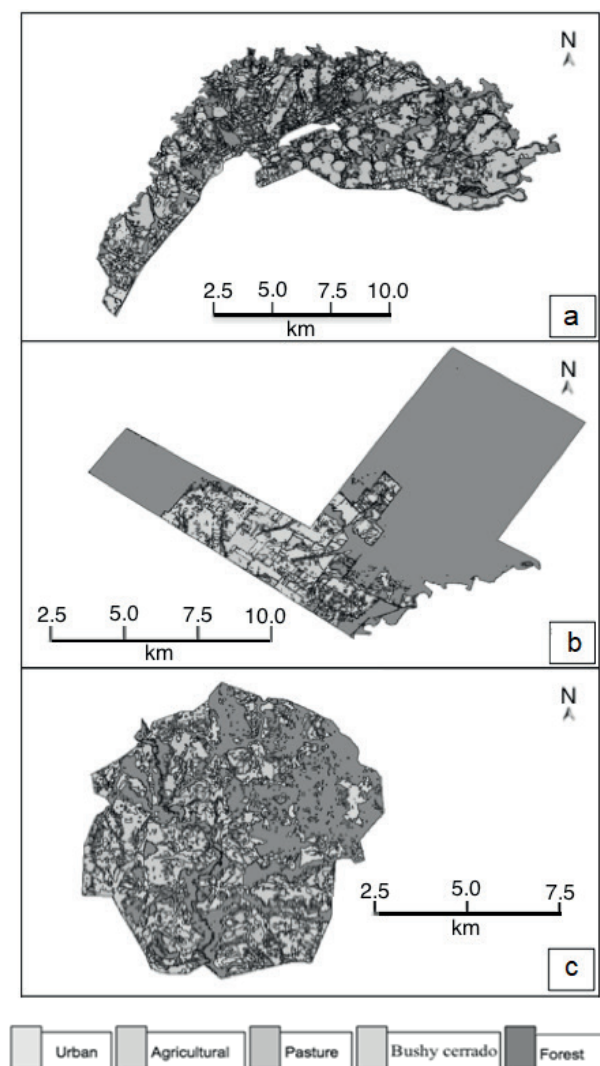
Figure 3. NDVI spatial distribution in the Itamarati (a), Keno (b) and Canudos (c) settlements, in 2014.

classification. The adjustment of the algorithm was performed considering reference points (new samples), with a known soil cover (points identified during the visits).

Figure 4 presents the moisture information according to the coverage and productive activities predominant in each settlement.

It is possible to observe for the settlement Itamarati (a) the predominance of areas of minimum and medium humidity, classified as agricultural and pasture areas. In this settlement, it is possible to perceive typical irrigated crop

circles (Figures 3a and 4a). However, irrigation systems have all been shut down for several years, not interfering with the results. Even so, the producers continue to cultivate in the areas that were previously irrigated, which explains the results obtained. In the Keno settlement (b) the areas of maximum humidity are predominant, characteristic of areas of dense and thin forests. For the Canudos settlement it is possible to observe areas of maximum humidity, corresponding to areas of forest, along with areas of minimum and medium humidity, representing the areas of agriculture and livestock.

With the TM sensor images of the year 2004 the same analysis was done, with the same criteria.

RESULTS AND DISCUSSION

This section presents the evolution of the occupation and use of land in the visited settlements.

To facilitate the analysis, the results were divided between the evolution of native vegetation cover and use in agriculture and livestock.

Evolution of native vegetation cover by biome

The analysis allows a good separation of the forest areas, always considered as native vegetation areas, since the occurrence of planted forests, mainly Eucalyptus, was still very limited in the researched settlements. In the case of the settlements located in the Amazonian and Mata Atlantica biomes, the native areas are essentially constituted of forest, bushy cerrado areas indicating areas of forest degradation by cattle grazing or vegetation recovery after deforestation or abandonment of pastures.
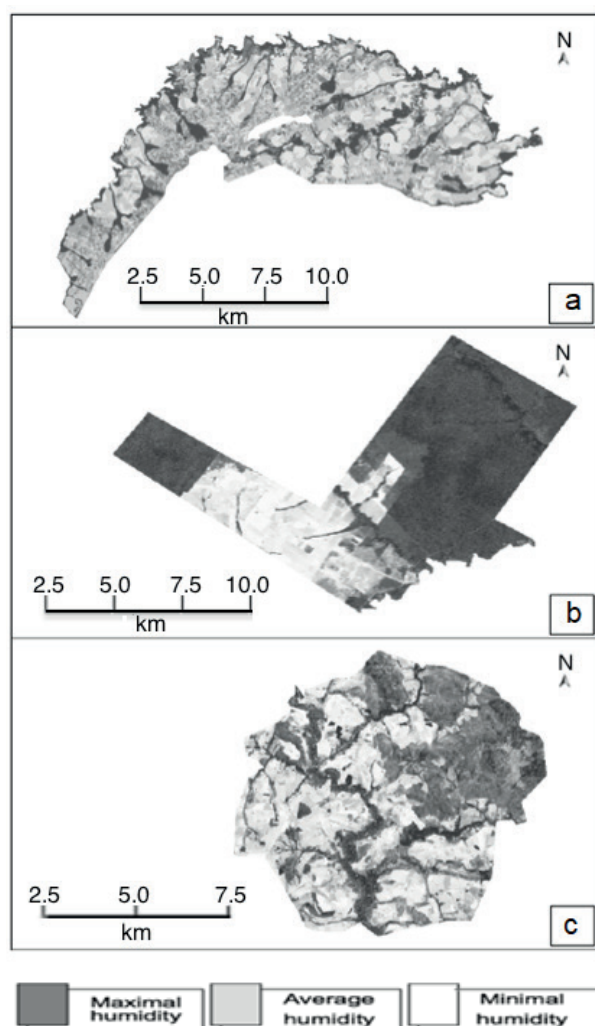
Figure 4. NDWI spatial distribution in Itamarati (a), Keno (b) and Canudos (c) settlements, in 2014.

In the Pantanal, the native vegetation is constituted of the areas of forest and of buschi cerrado, a typical vegetation of the region. Many pastures in the Pantanal biome are also native, without the possibility in the analysis to differentiate native pastures from the one planted with exotic varieties.

The cerrado is the biome where there is the greatest difficulty to identify the area of native vegetation. If in this biome the forest constitutes the majority of native vegetation, there are also areas of "campos sujos", that are made of native

vegetation, as indicated by Garcia & Ballester (2016), and that were classified in the bushy cerrado class, together with areas of forest degradation or vegetation recovery.

Table II presents the results of the forest and bushy cerrado areas obtained for the years 2004 and 2014 in the 54 surveyed settlements, in percentages of the total area of the settlements. The table presents the average percentage and the standard error of the bushy cerrado and forest classes based on the ANOVA tests and indicates the results of the Tukey average comparison test.

The analysis identified that the settlements of the Amazon biome have the highest average percentage of forest areas. However, the total value does not reach the 80% of environmental reserve required by law and deforestation was of more than 55% in 2014, more than the average of the Amazon biome settlements of 40% (Alencar et al. 2016, Yanai et al. 2015). Despite the decrease in deforestation in the Amazon region (Wandelli & Fearnside 2015, De Souza et al. 2013), between 2004 and 2014 there was a 30% reduction in the forest cover of the researched settlements, which can be explained by the fact that these are located along the arch of deforestation, at the border of Cerrado biome. Despite the negative situation in this biome, it was possible to perceive a more favorable situation in the two PDS-type settlements, with a 10-year reduction in forest coverage of only 8 and 11%.

Another highlight is the behavior of the areas of bushy cerrado in the studied settlements of the Amazon biome. Between 2004 and 2014, the proportion of areas with bushy cerrado doubled in these settlements. In the Amazon biome, the vegetation is essentially made of forest, with high density of large trees, and a reduction of forest class indicates that part of the forest presents in this biome has undergone deforestation, with

Table II. Mean values in percentage of bushy cerrado and forest areas for the settlements of the Midwest region in 2004 and 2014 per biome, with the standard error of each class.

BIOMES	2004		2014	
	Bushy cerrado	**Forest**	**Bushy cerrado**	**Forest**
Amazon	$13.60^b \pm 5.57$	$63.49^a \pm 15.89$	$27.15^a \pm 6.87$	$44.18^a \pm 13.75$
Cerrado	$28.18^{ab} \pm 4.29$	$29.44^b \pm 6.79$	$30.59^a \pm 4.29$	$15.88^b \pm 3.52$
Atlantic Forest	$30.12^{ab} \pm 8.02$	$21.71^b \pm 10.52$	$26.67^a \pm 13.56$	$26.72^{ab} \pm 15.15$
Pantanal	$45.05^a \pm 49.40$	$12.64^b \pm 12.60$	$54.25^a \pm 31.37$	$9.29^b \pm 6.03$

Equal lowercase letters in the same column do not differ statistically according to the Tukey test at the 5% level of significance.

few remaining trees and shrub, identified as areas with bushy cerrado by remote sensing.

Because the decrease of the forest area in this biome was greater than the increase of areas with bushy cerrado, part of the deforested areas must also have been transformed into agricultural and pasture areas.

Comparing the values obtained between the periods, settlements located in the Cerrado biome had the greatest reduction of the proportion of forest areas at 46%. The opening of new production areas, the extraction of wood and the raising of grazing animals were some of the practices observed in the field that explain this evolution. As the area occupied by bushy cerrado remained stable, the deforested areas in the settlements of the Cerrado were used for production, mainly in cattle ranching.

When analyzing the areas of native vegetation in the Cerrado biome, it is possible to perceive a strong degradation of the forest area, which went from values above the limits established by the legislation for legal reserves, to a lower percentage. As part of the bushy cerrado areas should be counted as native areas, it is possible to estimate that, on average, native vegetation areas in the settlements of

the Cerrado biome still meet the limits of the legislation for legal reserves, but with strong degradation between 2004 and 2014.

Because of similarities in its formation with the Cerrado biome, the greater part of the Pantanal biome is occupied by vegetation typical of cerrado (woody and native bushy cerrado). The Pantanal is the most preserved biome in Brazil, which can be verified by the great stability of the areas of bushy cerrado and of forest between the two periods studied. The percentages of these two classes of areas are well above 20%, the legal limit for legal reserve in this biome, not counting the native pastures included in another class.

In the Atlantic Forest biome, forest areas characterized by large trees similar to those found in the Amazon rainforest increased by 23% in the period, whereas the areas with bushy cerrado decreased by 11%. Field research made it possible to observe the large number of previously degraded areas that appeared as areas with bushy cerrado in 2004 that were being recovered in attempts to approach the original formation, which confirmed the increase in forest.
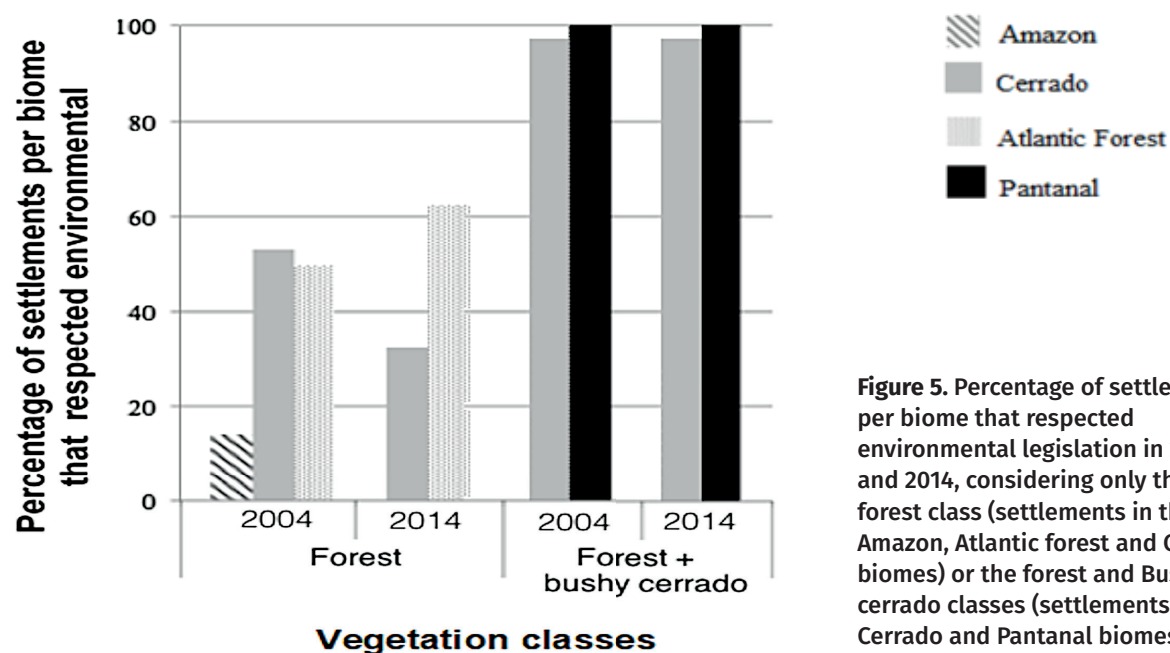
Figure 5. Percentage of settlements per biome that respected environmental legislation in 2004 and 2014, considering only the forest class (settlements in the Amazon, Atlantic forest and Cerrado biomes) or the forest and Bushy cerrado classes (settlements in the Cerrado and Pantanal biomes).

Figure 5 shows the percentages of settlements per biome that meet the minimum environmental reserves required by the legislation, considering only the forest areas for the settlements in the Amazon, Atlantic forest and Cerrado biomes or the forest and areas with bushy cerrado, for settlements in the Cerrado and Pantanal biomes [1]. The settlements in the Cerrado have been included in both analyses, as native vegetation in this region includes parte of the class defined as bushy cerrado.

According to Figure 5, most of the settlements of the Amazon, Atlantic forest and Cerrado biome did not meet the minimum environmental preservation area required by the legislation in 2004 and 2014, a situation that worsened over time, except for the Atlantic Forest biome. The decrease in forest cover indicates that, although the Federal Government started to worry about the environment in 1995 (Wittman 2010), the environmental issue continued to deteriorate.

Although the two PDS-type settlements had a reduced rate of deforestation, around 10% between 2004 and 2014, they do not have the legal minimum environmental reserve. Since these settlements were created after 2004, non-compliance with environmental legislation is explained by the environmental passive that existed prior to the creation of the settlement, a problem already raised by Van De Steeg et al. (2006).

The fact that environmental legislation establishes environmental reserves at 80% in the Amazon biome clearly harms the producers, who cannot respect this limit. Leite et al. (2004) explain that the establishment of settlements in environmentally sensitive areas compromises economic activities. Le Tourneau & Bursztyn (2010) arrived at the same conclusion when they indicate that it is illusory to have a productive agriculture with reserves of 80% or even, according to the authors, of 50%.

[1]Have been considered 80% in the Amazon biome and 20% in the other biomes, even in the Cerrado biome located in the legal Amazon region.

All settlements in the Pantanal biome met the limits set by the legislation when considering the forest and Bushy cerrado areas. Despite the strong deforestation observed in the Cerrado biome, 95% of the settlements of this biome continued to respect the limits of the legislation in 2014 when considering these two classes of vegetation. Nevertheless, as part of bushy cerrado is not native vegetation, the reality is between 30%, when considering only forest, and 95%.

From the field observations, collective reserves were identified in 86% of the settlements in the Amazon biome, 81% in the Cerrado biome, 50% in the Atlantic Forest biome and 100% in the Pantanal. Traces were found that indicated the presence of grazing animals inside the reserves in 43% of the settlements in the Amazon biome, 32% in the Cerrado and 25% in the Atlantic Forest biome. No traces of grazing animals were found in the collective reserves visited in the Pantanal.

Individual reserves were also present in 38% of the settlements of the Cerrado biome, 37% of the settlements of the Atlantic Forest, 100% in the Pantanal and 28% of the settlements in the Amazon biome.

The field observations indicated a greater use of collective reserves in the Amazon biome for the management of animals. The animals are left to graze freely in the environmental reserves and eat shrubs and small plants, threatening the forest's biodiversity and its renewal in the medium and long term.

Evolution of agricultural and pasture areas by biome

Table III presents the results of the evolution of pasture and agricultural areas from 2004 to 2014, in percentages of the total area of the settlements. The analysis includes the average percentage and the standard error of the classes, according to ANOVA and Tukey's average comparison test.

Comparing the average percentages of the agricultural and pasture areas between the biomes, there was a significant difference in pastures between the Cerrado and Amazon biomes for the year 2014. The other results did not indicate statistically significant differences. The lowest proportion of pastures in the settlements of the Amazon biome can be explained by the large proportion of areas occupied by forests.

Pastures are the main type of land use in all biomes. Comparing the 2004 and 2014 results, pasture areas expanded, with the settlements of the Cerrado and Amazon biomes having the highest gain. This expansion occurred to the detriment of the forest, as was highlighted in the previous section.

The Atlantic Forest and Pantanal biomes had a reduction in agricultural areas. The reduction of agricultural area in the Atlantic Forest can be explained by the increase of pasture and forest areas, as was observed in the field with the presence of forest recovery. Despite this reduction, the proportion of agricultural area in the settlements of the Atlantic Forest biome continued to be higher than in the settlements of the other biomes.

The agricultural area in Pantanal traditionally was of little importance because it is a region of pastures. In this case, the settlers followed the vocation of the region.

In addition to environmental preservation, this research aimed to identify the activities of producers. Table IV shows the total average size of the plots, the areas used for agricultural and livestock production in hectares and per biome for the years 2004 and 2014, as well as the percentage of evolution in the period. The total agricultural and pasture areas were evaluated by image analysis and divided by the number of families settled in each settlement,

Table III. Mean values in percentage of the agricultural and pasture areas for the settlements of the Midwest in 2004 and 2014 per biome, with standard errors.

Biome	2004		2014		Evolution (%)	
	Agriculture	Pasture	Agriculture	Pasture	Agriculture	Pasture
Amazon	8.38[a] ± 5.18	18.00[a] ± 14.64	9.95[a] ± 7.12	24.35[b] ± 8.49	18.7	35.3
Cerrado	10.43[a] ± 2.81	32.70[a] ± 6.21	12.24[a] ± 4.28	42.02[a] ± 4.30	17.3	28.5
Atlantic Forest	18.90[a] ± 7.19	30.48[a] ± 10.91	15.12[a] ± 9.11	32.68[ab] ± 7.61	-20.0	7.2
Pantanal	10.76[a] ± 20.20	30.53[a] ± 16.14	4.32[a] ± 7.56	31.70[ab] ± 18.43	-59.9	3.8

Equal lowercase letters in the same column do not differ statistically according to the Tukey test at the 5% level of significance.

according to INCRA (2016). To obtain the average size of the plots, we divided the total area of each settlement, based on INCRA (2016), by the number of families settled in each settlement. In this analysis, only the INCRA settlements were considered because of the difference in the size of the plots of settlements coming from states programs. Pantanal biome settlements were not considered because they were not implemented by INCRA.

The average areas used in the plots in the biomes increased, except for the Atlantic Forest biome. Although small, the reduction observed in this biome may have been influenced by the increase of forest areas identified in the previous analysis and the reduction of agricultural area.

The deforestation identified in the settlements of the Amazon biome allowed the area used to increase; it approached the average area used per plot in the Atlantic Forest but remained much lower than that observed in the Cerrado biome. Figure 6 shows the average areas in hectares effectively used for agriculture and livestock in 2004 and 2014.

Pasture areas in the evaluated settlements of Cerrado and Amazon biomes increased. As highlighted in Table III, the deforested areas in the settlements of the Cerrado biome were converted into pasture areas, whereas those in the settlements of the Amazon biome were essentially divided between areas of bushy cerrado and pasture.

The settlements of the Cerrado biome had a small increase of agricultural area compared with the increase observed in the pasture area. According to field observations, most pastures were reserved for dairy farming. As a consequence, the increase in pasture areas indicates a specialization in milk production. Vilpoux (2014), in a study in the settlements of Mato Grosso do Sul, already emphasized the importance of milk. The production was essentially extensive, necessitating large pasture areas.

The areas of agriculture and livestock stabilized in the settlements of the Atlantic Forest biome. In these settlements, the area of agricultural was more important than in other biomes and the difference between agricultural and livestock areas was much lower, which may indicate that producers depended more on agriculture and less on livestock.

Table IV. Average size of the plots and of the areas used for agricultural and livestock production in settlement of the Midwest region in 2004 and 2014 per biome.

Biome	Average Size of plots (ha)	Used area (Agriculture & Pastures) (ha)		Evolution of used area 2004/ 2014 (%)
		2004	**2014**	
Amazon	41,5	6.61	11.42	72.8
Cerrado	30,0	19.16	24.44	27.6
Atlantic Forest	23,2	13.85	13.57	-2.02

The agricultural area remained small in the settlements of the Amazon biome. The settlements of this biome are more specialized in cattle raising, as in the settlements of the Cerrado biome, but the pasture area in 2014 was twice as large in the Cerrado biome. Therefore, the continuation of livestock in the Amazon biome, an extensive activity, indicates the need to increase pasture areas, which means more deforestation in the coming years.

The field research confirmed the results obtained by the analysis of the images; an agriculture based on the production of fruits and vegetables for local markets was observed in a large part of the settlements of the Atlantic Forest biome. The production of industrial cassava destined for starch factories in the region was also observed.

Field research also verified the percentage of areas of degraded pastures and the conservation of the agricultural areas of the settlements, evaluated by the presence of level contours and crop rotation. The Atlantic Forest and Cerrado biomes had the lowest percentages of degraded pastures at 9 and 23%, respectively. The settlements of the Amazon biome had the highest percentage observed at 53%, which indicates the use of pasture areas without adequate management in this biome. Degradation of pastures and deforestation are two factors that increase the concern about agrarian reform in the settlements of the Amazon biome located in Mato Grosso.

Agricultural areas were better conserved in the settlements of the Cerrado and Atlantic Forest biomes: 70% and 35%, respectively. The settlements of the Amazon biome had only 18% of the total agricultural area with conservation practices.

The results illustrate the environmental fragility of the settlements located in the Amazon biome, with strong anthropic pressure on the forest, pasture and crop areas. Specialization in livestock farming, an activity that requires large areas, has further damaged preservation in this biome. These results confirm the research done by Brandão Jr & Souza Jr (2006), Le Tourneau & Bursztyn (2010) and Shiki (2010), among others, on the negative effects of agrarian reform on fragile biomes, especially the Amazon region. Van De Steeg et al. (2006) calculated an Environment Quality Index (EQ), with the worst
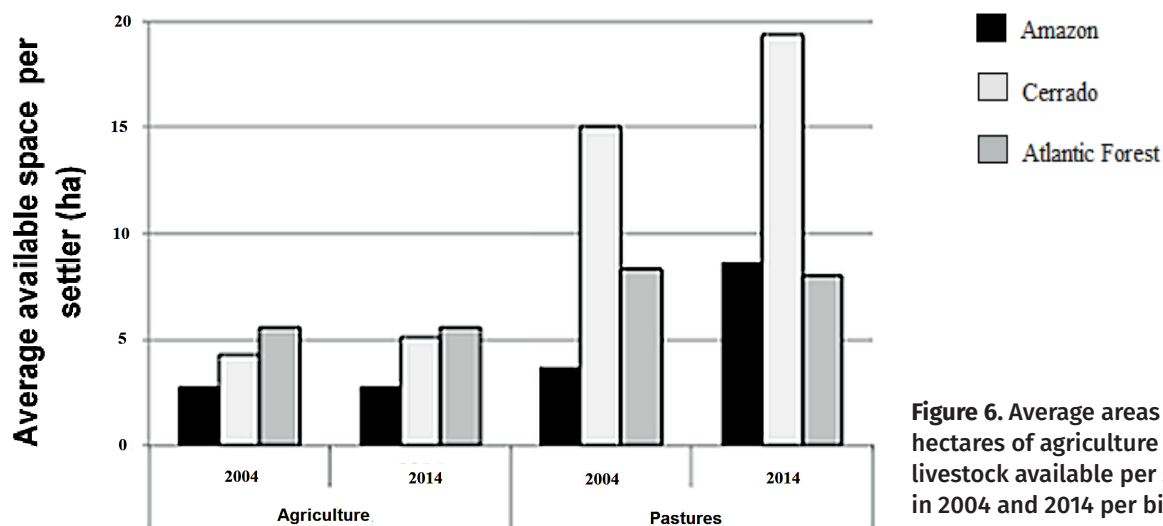
Figure 6. Average areas in hectares of agriculture and livestock available per settler in 2004 and 2014 per biome.

results attributed to the Northeast and North regions, where the Amazon biome is located.

The devastation of the evaluated settlements in the Amazon biome has been reinforced by the practice of agriculture without conservation practices, characterized by the low presence of level contours and low adherence to crop rotation, coupled with the use of pasture areas without adequate management. These results reinforce the work of De Souza et al. (2013) and Alencar et al. (2016), for whom low levels of technology facilitate deforestation.

CONCLUSION

The analysis by biome revealed that the settlements remained within the limits of the Law most of the time, except for the settlements located in the Amazon, where the limit of 80% of environmental reserve seems to have been difficult to maintain for the settlers. The researched settlements in this biome have the smallest areas to be used and the highest percentages of degraded pastures and agricultural areas without conservation, which indicates that increasing the size of the plots

is not an efficient solution. Change must pass through the most efficient use of areas already in production. Deforestation in the settlements of this biome indicates that forest areas have been transformed mainly into area of bushy cerrado, which may indicate that forests are exploited more for economic gain that for the opening of new production areas. In contrast, the settlements of the Atlantic Forest biome showed an increase in forest areas.

Most settlements continued to use the same production practices over time, conducting small-scale production activities, predominantly dairy farming and polyculture with the cultivation of cassava, corn and vegetables. It was also possible to observe the specialization of settlements in extensive pastures in the Cerrado and Amazon biomes, which require more land. This specialization, as already mentioned by Pacheco (2009), constitutes a threat to environmental preservation, as was verified in the settlements of the Amazon biome, where deforestation and the presence of degraded pastures was very high. It is also a change in the type of production expected for family farming, based on polyculture.

There was also a predominance of dairy farming in the settlements of the Atlantic Forest biome, but with a significant presence of agricultural production, which requires less land and which may facilitate the preservation of native cover. To this end, as already mentioned by Alencar et al. (2016), it is necessary to provide quality technical assistance with the objective of preventing environmental degradation, even in agricultural areas where small-scale and diversified crops dominate, as was identified in this research.

The evolution of native covers was negative in the settlements of all biomes, with the exception of those located in the Atlantic forest biome. In the settlements of the Amazon biome the percentage of 80% for Legal Reserve is not respected. In this region, the average percentage of forest areas was almost half of the percentage established in Law.

The lack of control to prevent the presence of animals in environmental reserves and the low efficiency of producers, characterized by the high percentage of degraded pastures and poorly conserved agricultural areas, are other problems that can harm the long-term environmental sustainability of these settlements. Providing technical assistance and an efficient monitoring system could prevent environmental degradation not only in forest areas but also in pasture and agriculture areas.

Acknowledgments

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Author contributions

Alencar Garcia Bacarji conducted the study collecting the observations in the field, performing the image processing, generating the multitemporal analysis for the results and discussion of the study. Olivier François Vilpoux responsible for the settlement research project, funded by CNPq and which gave rise to the research. Specialist in settlements in Brazil and participated in the analysis of data on the evolution of the occupation of plots and forest reserves. Antonio Conceição Paranhos Filho, act in geotechnologies applied to the environment, co-supervised the research, guiding the processing of images and the use of the adopted geotechnologies, in addition to contributing to the results and discussion of the study.