



EARTH SCIENCES

Field and remote observations to determine the environmental impact of agrarian reform in the Brazilian Midwest

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Abstract: Brazil's Midwest is composed of four biomes, the Cerrado (Brazilian savannah), predominant in the region; the Pantanal, the largest irrigated plain on the planet; the Amazon biome; and the Atlantic Forest. The Midwest is the largest producer of grains and livestock in Brazil, activities that have a negative impact on environmental preservation. Agrarian reform redistributes land and reinforces small family farming, which many authors consider as favorable to environmental protection. The objective of this study is to characterize the impact of agrarian reform on environmental preservation and agriculture on each biome of the Brazilian Midwest. Fifty-four settlements were surveyed using direct observation and Landsat images available for the year 2014. QGIS software 2.8 Wien was applied to calculate NDVI and NDWI vegetation indices to classify areas of agriculture, pasture, and environmental preservation. Pasture and savannah land occupy the largest areas in all biomes, with the main human activity based on livestock. Most settlements in the Midwest lead to small-scale activities such as dairy farming and polyculture, practices that differ from large-scale farming based on monoculture, and are more favorable to environmental protection.

Key words: Amazon, Atlantic Forest, Cerrado, family agriculture, geotechnologies, Pantanal.

INTRODUCTION

The Midwest region of Brazil covers an area of 1.6 million km², where about 14 million inhabitants live in 467 municipalities (IBGE 2010). The region has great diversity in its plant formations and integrates the Cerrado (Brazilian savannah), Pantanal, Amazon, and Atlantic Forest biomes, which gives it great environmental significance in the global ecosystem.

The Midwest is a Brazilian region that is currently the scene of increased production of *commodities*, characterized by farms geared to large-scale production and extensive livestock farming. Castro (2014) states that the expansion of agricultural activities in the region did not occur without generating adverse effects, such

as damage to the environment (notably in the Cerrado biome), which does not guarantee future sustainability of these activities.

Environmental degradation linked to agricultural activities is essentially related to the production of soybeans, sugarcane, cotton, and extensive livestock ranching, practiced on large farms. It is important to remember that the distribution of land in Brazil is one of the great problems originating in the colonial period, with public policies that, for many years, greatly favored large-scale producers.

According to Souza & Silva (2012), the 2006 Census of Agriculture shows the aggravation of land concentration in the country, with a Gini Index of 0.872, higher than the 1985 indexes (0.857) and 1995 (0.856). The Northeast and

Midwest regions had a higher than national average index, with a Gini index of 0.91 (Alves et al. 2012).

In response to this scenario of inequality in land distribution, agrarian reform appeared a possible solution. The importance of agrarian reform as an inductive agent for the organization and occupation of territorial areas was highlighted. Agrarian reform is based on the principle of the reordering of rural space, previously occupied and managed by a single individual or company, in which the use and occupation of the land occurred according to the economic interest of these owners.

According to Chapell et al. (2013) there is a strong debate on the relationship between biodiversity and productivity. To this end, smallholder agriculture favors crops and a much greater variety of animal species (including wild animals) and enables the ecological services of the existing ecosystems to be maintained.

According to Alfatin (2007), the role of environmental preservation has been attributed to small family farming, although this is still a controversial issue. For the author, the relationship between small family agriculture and natural resources is considered positive in relation to its potential to promote ecological sustainability, especially its ability to coexist in harmony with natural ecosystems, which are perceived as family assets. On the other hand, when at risk, the need for survival can cause farmers to consume all the available resources, which damages the environment (Alfatin 2007, Soares 2001).

Vilpoux & Cereda (2014) argue that many doubts remain about the role of settlers from agrarian reform in environmental sustainability, for example, whether family producers actively participate in the preservation of natural resources or are indifferent to this issue, as highlighted in GTZ (1998). Vilpoux & Cereda (2014)

state that in the settlements of Mato Grosso do Sul, legal reserves continue to be exploited for illegal rearing of animals and logging, causing the integrity of these reserves to decrease over time.

Doubts about the role of the settler in maintaining the environment have become increasingly important from a perspective of land redistribution and the management of socio-economic and environmental resources. To resolve these doubts, the development of appropriate research has become essential.

In this sense, the need to generate information on occupation and use of land in agrarian reform in the Midwest region of Brazil is highlighted, because there is little data available from which to evaluate the environmental impact of this reform in the region. This region was chosen because it is the largest producer of commodities in Brazil, with the greatest increase in production in recent years and the greatest environmental changes.

After the initial presentation, the question arises: Do the settlers of agrarian reform in the Midwest of Brazil preserve the environment?

In order to complement the research, the second research question focuses on the type of production: Do these settlers practice a different type of production from large scale farming, which dominates the region and is based on production of grains, cotton, sugarcane and beef cattle?

Based on these questions, the research reported in this article aimed to characterize the impact of agrarian reform on environmental preservation and agriculture in the Midwest of Brazil. The analysis is for the year of 2014 and is presented for the different biomes of the region.

Next, we present the themes related to the use and occupation of land in the Midwest region of Brazil and the geotechnologies used in the research. The following section presents

the methodological procedures, which are succeeded by the results and discussion. Final considerations are presented in the last section.

BIOMES OF THE MIDWEST REGION OF BRAZIL

The Midwest of Brazil comprises four of the seven ecosystems present in Brazil (Figure 1): the Cerrado biome (Brazilian savannah) is predominant in the region. The Pantanal, the largest irrigated plain on the planet, is present in the states of Mato Grosso and Mato Grosso do Sul. The region consisting of the Amazon biome, which occupies part of Mato Grosso, is an extension of the Amazon rainforest. The Atlantic Forest biome covers the states of Mato Grosso do Sul and Goias (IBGE 2004).

With the highest concentration of natural forests in the world, the Amazon biome has the largest freshwater source, accounting for almost one-fifth of the world's reserves, arousing worldwide interest in its wealth and preservation (Margulis 2003).

Although it accounts for 49% of Brazilian territory and an area of 4,196,943 km², the biome of the Amazon forest is present in the Midwest region only in the state of Mato Grosso, occupying 54% of the state and including 85 municipalities (IBGE 2004).

Unlike the Amazon biome, the Legal Amazon covers about 60% of the country's territory (nine Brazilian states), corresponding to an area of 5 million km² (Margulis 2003, Fearnside 2005). The Legal Amazon is present in the Midwest region only in the state of Mato Grosso.

The Amazonian biome is the part of the Midwest that has the least human presence, but has recorded, in the last decades, the advance of different economic activities, including logging and agricultural penetration, along with

the formation of urban centers (MIN 2007). The extent of the Amazonian biome that has been most affected by the expansion of soybeans and livestock has been the transition forest, which occurs in the states of Mato Grosso and Pará. More specifically, transition forest occupies a zone between the dense forest and the Cerrado (Domingues & Bermann 2012). Regarding environmental preservation, Brazilian law points out that the legal reserve should cover at least 80% of the rural property located in forest areas (Brasil 1965, 2012).

Second among Brazilian biomes in extent, the Cerrado occupies about 24% of area of Brazil and extends through the central region of the country. It is the largest tropical savannah region in South America, occupying an area of over two million square kilometers (IBGE 2004).

The process of mechanization and technical evolution of agriculture, especially the technologies related to fertilization, irrigation, and use of crop varieties better adapted to the region, have provided conditions favorable for the development of agriculture in the Cerrado (MMA 2011a).

The extensive anthropogenic transformation of the Cerrado has the potential to cause large losses of biodiversity. In the period 2002–2008, the annual rate of deforestation was 0.7%, the highest rate among the six Brazilian biomes (MMA 2011a).

According to Brazilian law (Brasil 1965, 2012), the area of environmental conservation on farms (Legal Reserve) should comprise at least 20% of the property area if the property is located in the Cerrado. If the property is located within the Legal Amazon in the Cerrado (i.e., the Cerrado areas located in the state of Mato Grosso), at least 35% of the property area should be reserved to environmental conservation.

However, complementary Law n°. 38/1995 (Mato Grosso 1995), which provides for the

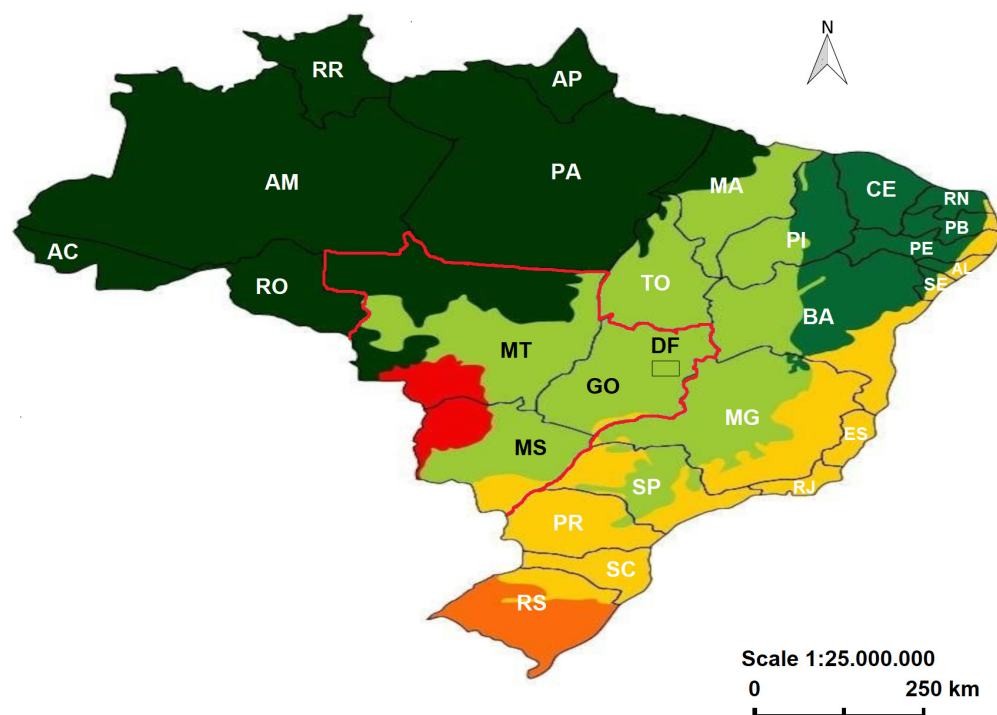


Figure 1. Location of the biomes of Brazil, with delimitation of the Midwest region. Source: Adapted from IBGE (2004).

Environmental Code of the state of Mato Grosso, considers that the Cerrado areas in the state of Mato Grosso should allocate a minimum of 20% as the legal reserve, a lower percentage than the 35% mandated by Federal Law. The two Laws are in mutual conflict, but as the Federal Law supersedes the State Law, the 35% limit should be enforced. However, most of the farms located in the Cerrado area of Mato Grosso consider the State Law, with a limit of 20%. Thus, it is this limit that was considered in the research.

With an area of 150,000 km² the Pantanal is recognized as the largest continuous flood plain of the planet. It was declared a Biosphere Reserve and Natural World Heritage by UNESCO and is present in the states of Mato Grosso (40.3%) and Mato Grosso do Sul (59.7%) occupying around 2% of the national territory (IBGE 2004, MMA 2011b).

The expansion of agricultural activities has contributed to the degradation of part of the natural environment present in this biome. The

main economic activity in the Pantanal biome is beef cattle grazing on extensive pasture, which is responsible for most of the deforestation that occurs there (MMA 2011b).

As in the Cerrado biome, the percentage of areas destined for Legal Reserve must respect the minimum of 20% of the rural property located in the Pantanal biome.

The last biome of the Midwest, the Atlantic Forest, constitutes one of the richest ecosystem sets, and extends from the southeastern coastal region to the plateaus and inland mountains (IBGE 2004). In the Midwest, the Atlantic Forest biome is present in the states of Mato Grosso do Sul and Goias.

The Atlantic Forest is the second largest tropical rainforest on the South American continent, which originally extended continuously along the Brazilian coast, penetrating eastern Paraguay and northeastern Argentina in its southern portion (Tabarelli et

al. 2005). However, this biome is in a state of intense fragmentation and destruction (Peres 2010), reflecting its occupation and the disorderly exploitation of its natural resources. The removal of the vegetation cover, aimed at opening up the area for agriculture, the extraction of wood, and human occupation; has caused the destruction of most of this biome, leaving only 7–8% of its original area intact (Alliance for the Conservation of Atlantic Forest 2015).

As in the Cerrado and Pantanal biomes, the percentage of areas destined for Legal Reserve in the Atlantic Forest biome should respect the minimum of 20% of rural property (Brasil 1965, 2012).

AGRICULTURE IN THE MIDWEST AND THE ROLE OF AGRARIAN REFORM

According to Shikida (2013) the economy of the Midwest region was initially based on mining (exploitation of precious metal mines), but soon expanded to include livestock and, from the late twentieth century, grain production. The expansion of these activities had several implications on the format of the agrarian space of the region. With regard to the potential of the national and international markets, the production model was based on space occupation, favoring large-scale production, without attention to environmental factors.

By analyzing the land structure in the region, it is possible to observe that 65% of the area of rural properties corresponds to large-scale properties (i.e., those larger than 15 fiscal modules¹) (MDA / DIEESE 2011). Among the

predominant farming activities in the Midwest, according to the information contained in the Municipal Agricultural Production Survey (IBGE 2013), soybean production stands out, with 56.5% of the total area harvested in the region; followed by corn and sugarcane production, with 27.3 and 7.8% of the total area harvested in the Midwest.

By contrasting data for 2006 and 2013, it is possible to observe the substantial growth of sugarcane, corn, soybean, and cotton production areas, to the detriment of traditional crops, such as rice and cassava. In this scenario, the agrarian reform process has been highlighted as a way to ensure the redistribution of land in the region and the maintenance of these crops (IBGE 2009, 2013).

According to Bergamasco & Norder (1996), rural settlements can be defined as the creation of new agricultural production units, through governmental policies aimed at reordering the land use, to the benefit of landless rural workers.

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

When looking at areas for agrarian reform in the region, the state of Mato Grosso leads, with about 6.1 million hectares and 82,952 families settled. Next comes the state of Goiás, with 1,124,709 hectares of land incorporated into the agrarian reform program in 439 settlements, totaling 22,755 settled families. The state of Mato Grosso do Sul has about 716 thousand hectares for agrarian reform, with 27,868 families settled. Finally, the Federal District presents 9,658 hectares for agrarian reform and 957 settled families (INCRA 2016).

¹The fiscal module is defined in Article 50 of Law 4.504 / 64 as a unit of measure of area, expressed in hectares, and that varies according to the peculiarities existing in each municipality of the country. The fiscal module is considered the minimum area required for a farm to be economically viable. In the state of Mato Grosso, the average fiscal module is 83 hectares, in Mato Grosso do Sul it is 47, in Goiás 56 and 5 hectares in the Federal District.

Family farming and environmental preservation

In Law No. 11.326 of July 24, 2006, the family farmer, also called rural family entrepreneur, is defined as a producer who does not have an area greater than 04 fiscal modules, with essentially family labor (maximum of two permanent employees), with income originating essentially from his property, and who lives in his land or nearby (Brasil 2006). According to Van Der Ploeg (2013), family farming plays an important role in the national economy of many countries, especially (but not only) in less developed countries.

From the environmental and ecological point of view, Wittman (2009) states that the simplification and standardization of production practices used in large-scale production leads to reduction in the number of seed varieties used for the main crops, reducing the diversity of agricultural landscapes. This simplification of the landscape due to monoculture has allowed the widespread application of packages of agricultural inputs, especially chemical inputs such as fertilizers and pesticides. The evolution of agriculture has essentially been aimed at increasing the availability of food worldwide. However, the implementation of intensive agricultural practices, requiring high levels of external chemical inputs, has caused environmental degradation, desertification, and water pollution (Wittman 2009).

According to Guzman & Molina (2005), the use of natural resources by family farmers is the only efficient solution to the current socio-environmental problem. For the authors, the “peasant model” is based on sustainable agriculture, which respects the ecological management of natural resources.

Chapell et al. (2013) argue that there is a growing body of evidence indicating that landscapes dominated by small, diversified production may be the most effective way

of conserving biodiversity and preserving the rural landscape. This evidence, combined with evidence of the failure of the agro-export model as a solution to reduce rural poverty and biodiversity conservation in Latin America, suggests that a new integrated approach is needed to simultaneously conserve biodiversity and eliminate poverty (Chapell et al. 2013).

By preserving their traditional farming practices, small-scale farmers not only retain the resources of their crops, but also sustain the use of many wild varieties associated with traditional systems, local values, autonomy, and biodiversity (Chapell et al. 2013).

This section sought to characterize family agriculture and its importance for environmental preservation. The next section deals with geotechnologies available for mapping land use and occupation.

USE OF GEOTECHNOLOGIES IN LAND USE MAPPING

The use of Geographic Information Systems (GIS) has become increasingly important because it facilitates the understanding and spatialization of quantitative and qualitative data. For decades the integration of social and territorial information through GIS was exclusively quantitative, and the qualitative data were neglected, reducing the possibilities of applications in the most diverse areas (Verd & Porcel 2012).

The GIS presents an integrated collection of software and data used to visualize and manage information related to specific locations (Esri 2011).

It covers all forms of spatial data collection, especially satellite images, widely used to monitor and map areas of interest. The data obtained by remote sensors have been used

in several areas of study, such as evaluation of vegetation cover, studies in urban areas and monitoring of agricultural and forest areas (Fonji & Taff 2014).

Lillesand & Kiefer (1994) define remote sensing as the science and art of obtaining information about an object, area, or phenomenon by analyzing the data acquired by a device that is not in direct contact with the object, the area, or phenomenon that is under investigation.

Remote sensing has become widely used because it allows rapid monitoring and evaluation of important environmental variables, and several other factors related to human activities. In addition, it is possible to have a wide view of a region, allowing analysis of the landscape dynamics at much larger spatial and temporal scale (Shimabukuro et al. 2009, Albuquerque et al. 2014).

According to Paranhos Filho et al. (2003) the Geographic Information Systems (GIS) environment is ideal for integrating data, information, and charts of different content and scale. In this sense, remote sensing and GIS play an important role in the understanding of natural resources. Remote sensing allows provision of a greater range of data about the Earth's surface, by detecting and recording images and/or data of objects without direct contact with them.

The GIS allows the verification of changes in the study area using multi-temporal analysis, that is, allows monitoring the dynamics of land cover over time by superimposing maps of different times for the same region of study of times many different. Landscape patterns analysis using spatial information inherent to images may suggest guidelines for the use and occupation of these areas (Gillanders et al. 2008, Kindu et al. 2013).

In most countries, the function of estimating the agricultural harvest is carried out by official

agencies, which are responsible for carrying out the technical survey of harvest forecasts, often subject to errors and manipulations, given the subjective nature of the techniques adopted. Based on this scenario, Rizzi & Rudorff (2005) developed a methodology using image classification to estimate soybean area in municipalities in southern Brazil. For the development of the methodology, the authors used the digital classification method for visual interpretation of the Landsat images, through images obtained by the TM and ETM + sensors on the Landsat 5 and 7 satellites. The results obtained were compared with the estimates of the Brazilian Institute of Geography and Statistics (IBGE).

Gusso et al. (2012) developed a methodology using the time profile of "enhanced vegetation index" (Evi) calculated from "Moderate Resolution Imaging Spectroradiometer" (MODIS) images to estimate soybean area in municipalities in southern Brazil. The Evi data, product of MOD13Q1-V005, were chosen due to their potential capacity to reduce atmospheric and soil background effects, and classification was done using the Modes crop detection algorithm (MCDA) algorithm. The results of the MCDA obtained were compared to the official soybean area estimates of the Brazilian Institute of Geography and Statistics. The determination coefficients ranged from 0.91 to 0.95, which indicates a good fit between the estimates, the MCDA being able to estimate the planted area and generate thematic maps in the analyzed municipalities (Gusso et al. 2012).

Most of the studies carried out for the mapping of agricultural crops favor large arable areas, given the limitations in usual rankings, with low or medium spatial resolution images such as Landsat images (TM sensor). Vasconcelos et al. (2013) performed research in the state of Paraná (southern Brazil), aiming to evaluate

the application of geotechnologies for the identification and estimation of planted area of industrial cassava using Landsat 5 images (TM sensor). The results of the research proved the potential for using images provided by this technology, to estimate the areas of cassava planted, and to offer information with accuracy >95%. The limitations of the methodology adopted were due to the minimum area size, because the identification was only possible in areas > 2 ha (Vasconcelos et al. 2013).

In this section we sought to present the definition of geotechnologies and some of the research carried out for the identification and mapping of land use and cover. The following section presents the methodology adopted in this research.

MATERIALS AND METHODS

This section was subdivided between the research methodology used in the field, and description of the geotechnologies used to obtain and process satellite images.

Field research

The research used *on-site* observation of the legal reserves, the presence of erosion, the percentage of closed lots, the quality of the pasture, the general profile of the settlements and the distance from the county seat.

As a result of the difficulties in obtaining a more representative sample, the selection of the settlements was done through a convenience sample, which seeks to obtain a convenient sample of elements, leaving the selection of the sample units to be carried out by the researcher (Malhotra 2001).

The choice of this technique was due to the distances and isolation of the settlements, as well as to difficulties of access caused by

blocks by indigenous groups and roads in bad condition.

Despite these difficulties, settlements were selected in various parts of the Midwest, with different distances from the urban centers, covering the geographic range of each state to the maximum, as shown in Figure 2.

In the end, 20 settlements were visited in the state of Mato Grosso do Sul, 15 in the state of Goiás, 17 in the state of Mato Grosso, and 02 in the Federal District. We selected settlements of at least five years old (a time frame already used by Vilpoux (2014) and considered sufficient for them to stabilize). The visits were carried out from May to November 2014.

In addition to analysis of the land occupation area, a correlation analysis was performed to verify the variables that might explain the importance of the forest reserves present in the settlements. Some of the variables selected were generated through remote sensing techniques, such as the number of hectares destined for agricultural production and pasture. Other variables were obtained from direct observation in the settlements, such as the existence of collective or individual reserves, degraded pastures, main crops, average size of the lots, and distance between the settlement and the nearest city.

Degraded pastures were defined as pasture areas containing invasive plants, exposed soils, and small shrubs. The criterion used to establish the percentage in the analysis used the proportion of the pasture area with these characteristics divided by the total pasture area observed in the lots visited.

Conservation of the agricultural area has also been the subject of research. The criterion used was the existence of crop rotation and the presence of level curves in the lots visited.

In order to consider whether the municipality where the settlement was located

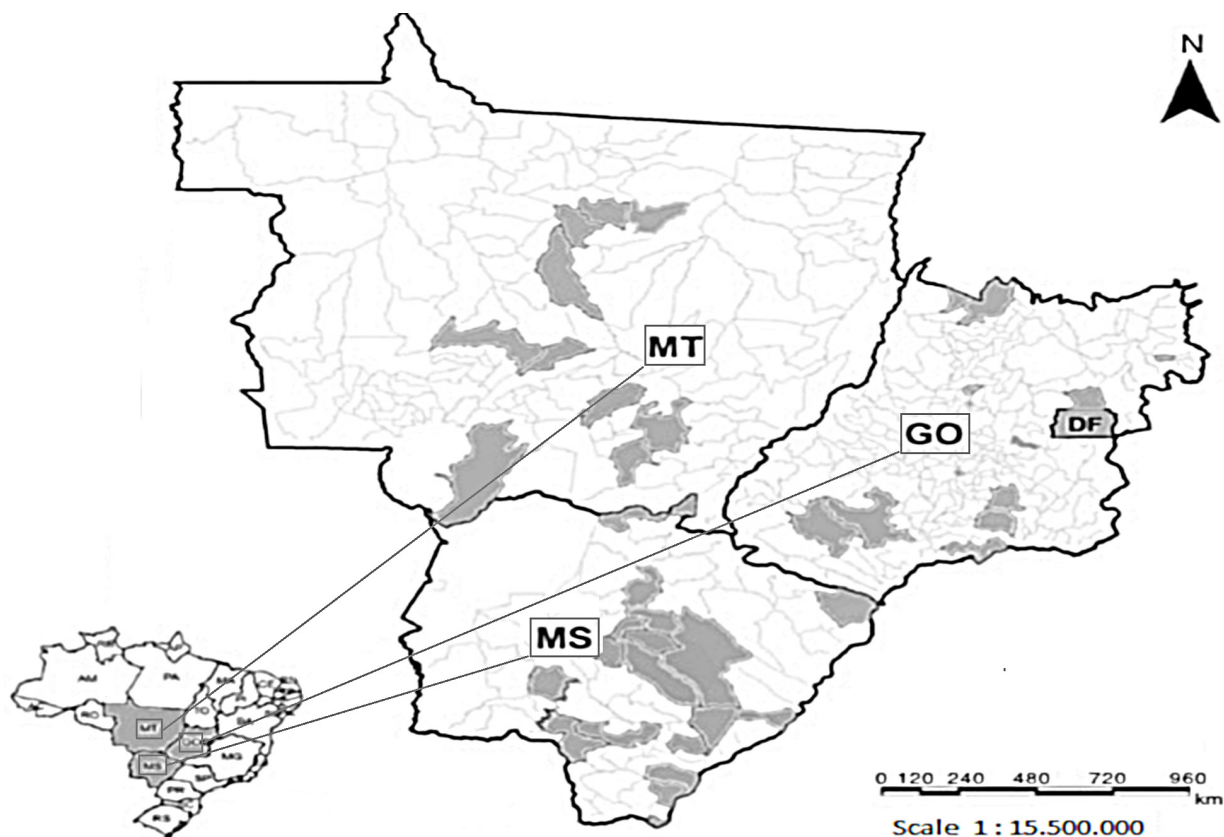


Figure 2. Municipalities of the settlements surveyed in the Midwest.

belonged to an area producing corn, soybean, cotton, or sugarcane, the total produced in tons per municipality was used in the four types of production, based on IBGE (2014). The result was transformed into a *dummy* variable with the value 1 for production area and 0 for non-producing area. The biome and state variables were also transformed into *dummy* variables to make the analysis.

Data processing was performed for statistical analysis using the XLSTAT program (Addinsoft 2014).

To verify if there were differences between the results obtained by state and by biome, a single factor analysis of variance (ANOVA) and the Tukey averages comparison test were performed. It was considered that a difference was significant if the probability value (p) was less than or equal to 0.05.

Geotechnologies used

The images used in the survey to identify the land cover were the Landsat Program (Land Remote Sensing Satellite) satellite Landsat 8, OLI sensor (Operational Land Imager), 2014.

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

Based on the geodetic coordinates of each settlement, it was possible to identify the orbit/point of the image to be used. In many cases, the images downloaded included more than a settlement, reducing the number of required images. Twenty-seven Landsat 8 satellite images (OLI) were obtained from the USGS site (United States Geological Survey 2015).

After this step, atmospheric correction of the bands used for the composition of the images of the satellite Landsat 8 was conducted using the plugin Geosud Toa Reflectance of QGIS 2.8 Wien software (QGIS Development Team 2015).

Then, after combining the bands 1 to 7, image composition proceeded with QGIS 2.8 Wien software. Each image was saved in a single file (GEOTIFF format), and can be viewed with the color characteristics of each spectral band.

The period from June to October 2014 was established as the interval for which to download the Landsat 8 images, given the low influence of clouds in this period (dry season). This is the period of highest contrast between existing vegetation types in the biomes of the region.

Sequentially, the areas of each of the selected settlements were identified and delimited. This step was carried out with the help of Google Earth software (Google 2015) and with the maps available in the official rural technical assistance agencies and other entities related to agrarian reform of the Midwest region.

After identification and delimitation of the settlements, the vegetation indexes NDVI - Normalized Difference Vegetation Index (developed by Rouse et al. 1974) and NDWI - Normalized Difference Water Index (proposed by Hardisky et al. 1983, Gao 1996) were applied to measure agricultural, livestock, and environmental preservation areas.

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

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

ρNIB = Near Infrared Band

ρV = Visible Red Band

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).

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

ρNIB = Near Infrared Band

ρMIB = Medium Infrared Band

The entire procedure for NDVI and NDWI calculations was performed with the free and open source software QGIS 2.8 Wien.

For the NDVI, the classes of interest were reclassified, according to the values obtained from the vegetation cover samples in each study area.

Based on previous studies (Jackson et al. 2004, Chen et al. 2005, Sahu 2014), it is known to be of great importance to correlate the results obtained by the two indices (NDVI and NDWI) in agricultural areas and in dense or scattered forest regions, where it is possible to quantify the chlorophyll and the moisture present in the vegetation cover.

In order to do this, the NDVI and NDWI indexes were correlated using the Pearson correlation coefficient (Hoffmann 1998, Johnson & Bhattacharyya 2000) in the areas corresponding to each settlement, aiming to estimate the areas of agriculture and environmental preservation.

Figure 3 presents results obtained by calculations of NDWI and NDVI, respectively, for the area of a settlement in Mato Grosso do Sul.

Based on the reclassification of the NDVI it was possible to measure the percentage coverage corresponding to each interest class. It is important to emphasize that the results obtained with the NDWI calculation were used to evaluate the environmental quality in order to complement the results obtained with the NDVI.

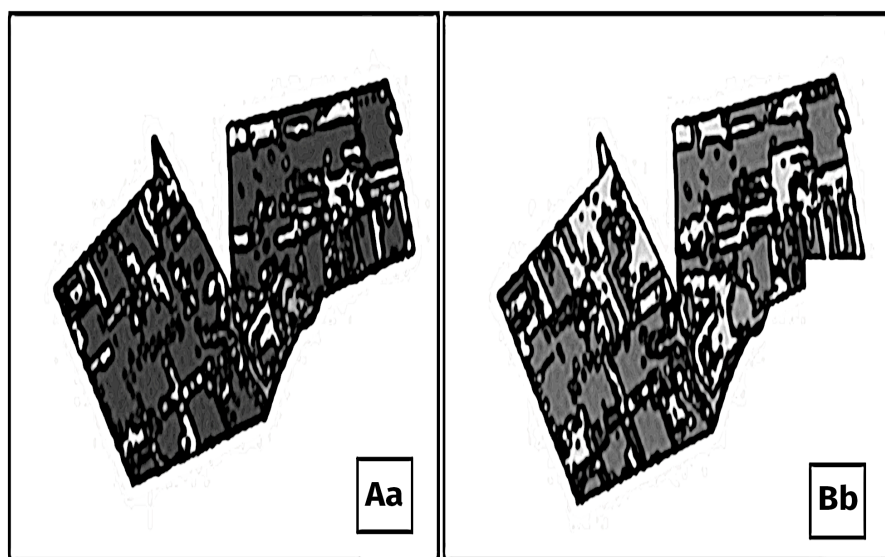


Figure 3. NDWI (Aa) / NDVI (Bb) spatial distribution in a Midwest settlement in the year 2014.

Four classes of interest were established: agricultural, pasture, savannah (bushy vegetation typical of the Cerrado biome) and forest (with higher vegetation). The forest and the savannah correspond to the areas of environmental preservation. The savannah could also represent areas of poorly tended pasture with many small trees. Urban areas covered with water were also identified.

Then, the results obtained through the vegetation indexes were compared with the information obtained from the field survey variables.

USE AND OCCUPATION OF LAND IN SETTLEMENTS OF THE MIDWEST

Among the sampled areas, the Cerrado biome predominated with 37 visited settlements, the Atlantic Forest biome was represented by eight settlements, the Amazon biome by seven, and the Pantanal biome by two.

Table I presents the results of biome-based soil use, obtained for 2014. The table presents the mean percentage and standard error of each class according to ANOVA, and indicates the

results of the Tukey averages comparison test. In the analysis presented in Table I, the savannah regions were distinguished from those of forest, where the trees are higher and occur in greater density. From this analysis, the environmental reserves are constituted of forest and savannah areas.

In the comparison between the biomes, significant differences were found between pasture and forest areas. In the pasture class there was a statistical difference between the Cerrado and Amazonian biomes, while the Atlantic Forest, and Pantanal areas have intermediate values. In the Forest class the significant difference is between the Amazon biomes on one side and the Cerrado and Pantanal on the other.

The Amazon biome is the one with the highest percentage of forest areas, with fewer savannah and pasture areas (Table I). It is important to note that even after adding the savannah and forest percentages in the settlements of the Amazon biome, the minimum of 80% for environmental reserve required by law is not reached.

Table I. Mean values (%) of the interest classes for the settlements of the Midwest region in 2014, with the standard error of each class.

BIOME	URBAN	AGRICULTURAL	PASTURE	SAVANNAH	FOREST
Amazonian	0.078 ^a ± 0.11	9.95 ^a ± 7.12	24.35 ^b ± 8.49	27.15 ^a ± 6.87	44.18 ^a ± 13.75
Cerrado	0.22 ^a ± 0.12	12.24 ^a ± 4.28	42.02 ^a ± 4.30	30.59 ^a ± 4.29	15.88 ^b ± 3.52
Atlantic Forest	0.42 ^a ± 0.59	15.12 ^a ± 9.11	32.68 ^{ab} ± 7.61	26.67 ^a ± 13.56	26.72 ^{ab} ± 15.15
Pantanal	0.20 ^a	4.32 ^a ± 7.56	31.70 ^{ab} ± 18.43	54.25 ^a ± 31.37	9.29 ^b ± 6.03

Lowercase subscript letters in the same column do not differ statistically according to the Tukey averages comparison test, at the 5% level of significance.

In the Cerrado and Pantanal biomes, there is a predominance of savannah areas representative of these biomes, with a low proportion of forest. In these biomes, pastures are predominant and represent the main activity of the settlements. In the Pantanal many pastures are native grasslands that may have been confused with the savannah, explaining the high percentages of this class.

Pastures are also the main land cover area in settlements in the Atlantic Forest biome. However, this biome is essentially characterized by large trees, such as in the Amazon rainforest, which explains the large presence of forest areas. This biome was also characterized by large areas of savannah and smaller vegetation not typical of the Atlantic Forest that may indicate the presence of degraded pastures.

Due to the possibility of classification error in the savannah class, verification of the environmental preservation in the settlements was carried out based on two analyses: considering only the forest areas, and combining the forest and savannah areas. The first analysis underestimates the total area of environmental preservation of the settlements, while the second one overestimates this data.

Table II classifies the settlements according to the ratio of the preservation area calculated by the minimum obligatory area, which depends on the biome where the settlement is located.

The settlements that respect the legislation are those classified above 100% (area of preservation in the settlements above the minimum obligatory area).

Most of the settlements do not meet the minimum conditions required in the legislation when considering only the forest areas. Considering this, the Cerrado and Atlantic Forest biomes include the highest percentage of settlements that comply with environmental legislation.

When the savannah areas are disregarded, all the settlements in the Pantanal and Amazonian biomes are well below the criteria established by law. In the case of the Pantanal biome, consisting essentially of savannah, this result is easily explained. In the case of the Amazon biome, essentially consisting of forest, the result may indicate environmental problems.

When considering the forest and savannah areas, Pantanal, Atlantic Forest, and Cerrado biomes have all the settlements with areas destined for environmental preservation within the limits of the law, except for one settlement in the Cerrado biome. In all the settlements of the Atlantic Forest and Pantanal biomes, and in most of those located in the Cerrado, the preservation areas are at least 20% greater than required by the legal limits. This allows for the assumption that these settlements continue to respect the limits set for legal reserves even if

Table II. Percentage of settlements in each biome, according to the ratio of the area of environmental preservation to the area required by the legislation, in 2014.

Biomes	Forest ¹				Forest and Savannah ²			
	<80%	80-99%	100-120%	> 120%	<80%	80-99%	100-120%	> 120%
Amazonian	100	0	0	0	28.57	42.85	28.57	0
Cerrado	62.16	5.40	8.10	24.32	0	2.70	5.40	91.89
Atlantic Forest	37.5	0	25	37.5	0	0	0	100
Pantanal	100	0	0	0	0	0	0	100

¹Relation between the percentage of environmental preservation in the settlements, considering only the forest areas, on the percentage of preservation required by the legislation. ²Relation between the percentage of environmental preservation in the settlements, considering forest and Cerrado areas, on the percentage of preservation required by the legislation.

some degraded pasture areas, which include shrubs, have been classified as savannah areas.

The settlements located in the Amazon biome present a very different reality, with more than 70% of settlements not complying with the legislation, and 28% with area < 80% of the legal limits. All those who comply with the legislation are in the range of 0 to 20% above the required limits, which means that the exclusion of degraded pastures, mixed with the savannah areas, should cause some of these settlements also to fall below the legal limits.

The results obtained in the Amazon biome indicate strong pressure on the areas of environmental preservation, with the forest reduction. This biome does not appear to be sustainable even for small producers, who deforest for the establishment of new production areas (initially for pastures), as Fearnside (2005) points out. Later, these areas are transformed into areas for grain production, according to Alencar et al. (2004).

Field research has shown that some of the settlements located in the Cerrado and Atlantic Forest biomes, especially in the Atlantic Forest biome, have areas used for environmental recovery, which are positively impacting the percentage of areas destined for preservation. These areas were former degraded areas intended for environmental preservation,

or were located near rivers and lakes that are being restored, to approximate their original condition.

Using the field observations, it was possible to verify the state and format of reserves in the settlements. Individual reservations were found, where the settler reserved a portion of his plot for environmental preservation; as were collective reservations, where there is a common area with restricted access, intended for environmental preservation. Some settlements had both types of reserves.

Collective reserves were found 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. There were records of management of grazing animals within the reserves in 43% of the settlements of 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.

The results for the Amazon biome indicate greater use of the collective reserves, either for the management of animals, for the extraction of native plants and fruits, or by selective cutting of existing wood in the reserves.

Individual reserves were 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 Amazon settlements have the highest percentage of animals present in the reserves, indicating that it is a common practice adopted by the settlers in this biome. It was also possible to observe the extraction of native plants and fruits, especially in the Amazonian biome, which characterizes another use of forest areas.

In addition to environmental preservation, the research aimed to identify the activities of producers. Table III presents the average area of cultivation and pasture in hectares per biome, according to the results of image analysis. In order to obtain the average size of the plots, the total of agricultural and pasture areas evaluated in the image analysis, divided by the number of families settled by settlement, was considered. Only the settlements of INCRA were considered, due to the differences in the size of the plots of the settlements originating from state or municipal land credit programs. Thus, Pantanal biome settlements were not considered because they were not implemented by INCRA.

The analysis presents the areas effectively used for agriculture and livestock, without the influence of the savannah and forest classes, which represent the environmental reserves. It should be noted that the savannah includes areas of environmental reserve and degraded pasture, with no possibility of differentiation, which could have influenced the pasture areas calculated in Table III. However, the areas of degraded pastures are only minimally exploited by the settlers and can be excluded in the analysis of the areas used for production. In this case, the areas presented in Table III can be considered reliable in assessing areas effectively used by farmers.

In the majority of the settlements visited, the presence of polyculture was observed, with

the production of cassava, corn, beans, fruits and vegetables for subsistence and the local market. Polyculture corresponds to the normal activity of family agriculture, as highlighted by Van Der Ploeg (2013) and Chapell et al. (2013). The agricultural activities raised differ from the activities of large producers, who specialized in only a few crops (e.g., soybean, corn, cotton, and sugarcane). In the case of pastures, dairy farming stands out as the main activity in most of the settlements. These data confirm the information of Vilpoux (2014), who identified dairy production as the main economic activity of the settlers of Mato Grosso do Sul.

The Cerrado biome presents the largest average area for pasture, with areas more than twice as large as the pasture areas of the Amazon and Atlantic Forest biomes. The Atlantic Forest biome settlements have the largest agricultural areas and the ones in the Amazonian biome the smallest.

The settlements in the Amazonian biome are those with the smallest production area, with less than half of the total area verified in the Cerrado settlements. These areas of reduced production, especially in the case of agricultural area, may explain the greater use of deforestation by settlers in the region. It is important to indicate that these numbers already include deforested areas and that if the legislation were respected, the areas available in the settlements of this biome would be even smaller.

Observations in the field allowed verification of the percentage of areas of degraded pastures and conservation practices in agricultural areas (crop rotation and contour lines). The settlements in the Cerrado and Atlantic Forest biomes presented the lowest percentage of degraded pastures, with 9% and 23%, respectively. The settlements of the Amazonian biome were the ones with the highest percentage observed

Table III. Average area of agriculture and pasture in settlements in 2014, per biome.

Biome	Average plots (ha)	Agriculture		Pastures	
		% Observed	Area (ha)	% Observed	Area (ha)
Amazonian	11.42	9.95	2.88	24.35	8.54
Cerrado	24.44	12.24	5.05	42.02	19.39
Atlantic Forest	13.57	15.12	5.58	32.68	7.99

(53%) of degraded pastures, which indicates the frequent use of pasture areas without adequate management in this biome. Degradation of pastures and deforestation are two factors that raise concerns about agrarian reform in the Amazon biome.

The agricultural areas were better conserved in the settlements of the Cerrado and Atlantic Forest biomes (70% and 35%, respectively). The settlements of the Amazonian biome showed conservation practices in only 18% of the total agricultural area. In the Pantanal biome, conservation practices were not found, which was understandable given the character of the region, which focuses on livestock.

The results indicate the environmental fragility of the settlements located in the Amazon biome, featuring strong anthropic pressure on the forest, pasture, and crop areas. The practice of non-conservation agriculture (characterized by the low presence of contour lines and low adherence to crop rotation), coupled with the use of pasture areas without adequate management, reinforce the picture of environmental damage in this biome.

The analysis allowed observing that most settlements comply with environmental legislation, except for those located in the Amazon biome. The settlements in this biome are the ones that deforested the most land and, even so, are also those with the pastures and agricultural areas in the worst condition regarding conservation.

Variables that influence environmental preservation in the researched settlements

In order to evaluate what may influence environmental preservation in settlements of Brazilian Midwest, analyses of Correlation and Multiple Linear Regression were performed.

The results were obtained through two analyses: the first considering as a dependent variable the percentages obtained in the forest class, and the second considering the forest and savannah classes. The ratio between the preserved area and the minimum area required by law was used.

The independent variables selected included the state and biome in which a settlement was located, the percentage obtained in the agricultural class, the average size of the plots, the existence or not of collective reserves, the distance from the settlement in relation to the nearest city, and the location of the settlement within an area producing commodities.

The variable “percentage of pastures” was not considered in the analysis given the multicollinearity existing with the variable “percentage of agricultural area”.

The calculation of the independent variables was made from analysis of the images and from the direct observations recorded in the settlements. Table IV presents the results with regression analysis.

Considering only the forest class as an environmental preservation area, it was possible to observe the positive impact of collective reserve areas on environmental preservation.

Table IV. Multiple regression results for variables influencing environmental preservation.

Variable	Forest (β)	Forest and Savannah (β)
(%) Agricultural	-0.20	-0.41 *
Mato Grosso do Sul	-0.8	-0.11
Mato Grosso	0.31	-0.01
Goiás	0.56	0.11
Closed Biome	-0.05	0.76
Amazonian Biome	-0.21	-0.51 *
Pantanal Biome	-0.18	0.13
Atlantic Forest Biome	0.36	0.30
Lot size	0.68	0.63
Collective reserve	0.38 *	0.14
Distance from the city	0.11	0.11
Area commodities	0.13	0.14

*Significant β value $p < 0.1$.

Collective reserves are important to maintain environmental preservation; however, they are treated as a common resource, with unlimited access, and shared by a group of users. Often the settlers seek their own advantage, without worrying about the management and maintenance of these resources. This causes their reduction and exhaustion.

Considering forest and savannah as areas of environmental preservation, the analysis indicates a negative correlation with the percentage of agricultural areas. As agricultural areas increase, preservation areas tend to decline. The coefficient of determination (R^2) generated in this analysis was 0.64, compared to 0.32 with only the forest areas.

Another association identified as negative was the fact that a settlement belonged to the Amazonian biome. This result confirms that the activities carried out in the settlements located in this biome exert a strong (negative) influence on environmental preservation.

The size of the plots did not influence environmental preservation. Thus, increasing the size of plots in the Amazon settlements would not solve the problem of environmental preservation. This assertion can be confirmed

by the fact that despite smaller plots, the settlements in the Amazon biome were those with greatest degradation of pastures and least conserved agricultural areas. In this case, better technical assistance seems the most urgent solution.

The analysis allowed the observation that some variables did not influence environmental preservation as expected. The location within a commodity producing region did not interfere in the modes of production of the settlers, which were characterized by maintaining mixed farming and dairy farming, activities typical of family farming. The distance from a city was another variable that did not interfere with environmental preservation.

CONCLUSIONS

When observing the percentage of areas designated as environmental reserves, all biomes comply with the legislation, except for those located in the Amazon biome. The high percentage of degraded pastures, the lack of conservation of agricultural areas, the use of unsuitable cultural practices coupled with the existence of small production areas, and the need to preserve 80% of the area all reinforce the difficulties of environmental preservation in these settlements.

The negative results of environmental preservation in the settlements of the Amazon biome indicate the need for specific preservation policies in this biome. Increasing the size of the area to compensate for the need to preserve the forest is not an efficient solution, as evidenced in the analysis of previous Session. The first step would be to encourage more efficient use of the land already available for production, reducing degraded pastures, and improving the conservation of agricultural land. It is possible

to think of a more careful distribution of land, selecting producers with previous experience in agriculture, preferably in the region. Providing quality technical assistance could also prevent environmental degradation, not only of forests, but also of pasture and agriculture.

Regarding the preservation of environmental reserves, the analysis identified that settlements with collective reserves have larger areas of environmental protection than settlements where individual reserves predominate. However, although it is a restricted and non-integrated area of access to the individual areas of each plot, many producers use these reserves to manage animals, posing a threat to maintenance, and requiring more intensive enforcement actions. The occupation of these reserves by domestic animals impairs the renewal of the areas in the long term, but this is not apparent in the satellite images and is difficult to control.

Most of the settlers conduct their activities as small-scale production, with a predominant presence of dairy farming and polyculture, with cultivation of cassava, corn, and vegetables. These practices differ from the mode of production of the large-scale farming based on monoculture, and are more favorable to the protection of the environment.

Despite expectations, the survey did not identify any influence on the modes of production of settlers when located in municipalities near producers of commodities on a large scale, such as soybeans, corn, and cotton. This result indicates a limited transfer of practices and technologies between settlers (small-scale farmers) and large regional farmers (commodities producers).

The research allowed identification of the use and the occupation of the land in the settlements of the Midwest, and made it possible to observe the reality of the environmental

preservation between the biomes. However, the analysis indicates only the situation in 2014, without the possibility of knowing if the situation is worsening or if, after receiving their plots in highly degraded condition, the settlers are restoring their land. For this, it is necessary to verify the evolution of land use in these settlements in recent years.

Complementary studies should also be carried out in rural settlements in other regions, such as in the South, where traditional and mechanized family farming is very strong, or in the Northeast, where there is less-mechanized agriculture, under unfavorable climatic conditions.

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Alencar Garcia Bacarji conducted the study collecting the observations in the field, performing the image processing, 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.

