AGRICULTURAL PRODUCTION GAINS IN BRAZILIAN COMMODITY HOTSPOT: CASE STUDY STATE OF MATO GROSSO

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ABSTRACT

The state of Mato Grosso leads the soybeans production in Brazil. In the last years is one of the world's states fast moving agricultural frontiers. The goal of this work is to evaluate the expansion and intensification of agriculture and the consequences in forest and savanna areas in the state of Mato Grosso from 2001 to 2017, using satellite images time series. We observe the mainly agricultural areas in this state expanded 5.7 Mha, between 2001 and 2017. At the same period the natural vegetation had a drastic decrease, principality the savanna areas (7.4 Mha). When we divided the period studied between pre and post soy moratorium, we observe the soybean planted area, between 2001 and 2008, increased 2.6 Mha and forest decreased 6.9 Mha. In the post moratorium period, between 2009 and 2017, the soybean expanded 2.4 Mha, and the forest declined 0.21 Mha. With the data observed in this study it was verified the public policies such as the soybean moratorium have been effective in combating deforestation caused by agriculture.

Key words — Satellite image time series, soybean, soy moratorium, agricultural expansion, agricultural intensification.

1. INTRODUCTION

Given the continued increase in world population and the need for resource supply, including the expansion of new arable land, it is necessary to explore sustainable alternatives to land-use change with reduced impacts [1]. The Food and Agriculture Organization of the United Nations [2] expect the global demand for food to grow 70% by 2050. Brazil is already the world's largest producer of sugarcane, coffee, orange juice, and the world's second largest producer of soybeans, beef and poultry meet, but becomes the world's largest food producer by 2050 [3]. This makes Brazilian agriculture and livestock farming face a major challenge, of producing food for a growing population and having an obligation to reduce their deforestation rates and greenhouse gas emissions [4]. One solution would be to intensify land use through crop intensification, which would increase the production of raw material for food and biofuels without an increasing demand for land [5]. An important concern about the agricultural expansion in Brazil has been the environmental impacts of the expansion of crop production and cattle-raising in its Amazonia and Cerrado biomes [6].

Previous studies on the Brazilian agricultural dynamics, using satellite remote sensing, have focused in the state of Mato Grosso, one of the world's fast moving agricultural frontiers [7]. Spera et al. [6] analyze cropland expansion in Mato Grosso from 2001 to 2011. They use the MODIS EVI time series, coupled with a decision-tree algorithm. The authors note the farmers increased double cropping systems to make up for the scarcity of high quality remaining agricultural land. Arvor et al. [8] use MODIS EVI time series to classify the state of Mato Grosso in 2000 to 2007. The authors studied the intensification in two periods, 2000–2001 and 2006–2007. In 2000–2001, the system (soybean followed by either maize or cotton) was only adopted in a small area in a central region of Mato Grosso. In 2006–2007 double cropping systems appeared to be applied in the three main agricultural regions in the central and western regions, over 50% of the total cropped area was intensively cultivated; in the southeastern region, intensive agricultural practices were also adopted, but to a lesser extent (less than 50% of the total cropped area). Finally, double cropping systems are nearly nonexistent in the eastern region. Kastens et al. [7] describe the spatial dynamics of crop production in Mato Grosso from 2001 to 2014, use MODIS NDVI time series. The authors observe between 2001 and 2014, soybean (planted in the single crop system) increased from 3.3 to 7.8 Mha. And, soybean planted in double crop system, the increase from 3.7 in 2001 to 12.8 Mha in 2014.

There are studies that show agriculture intensification in the state of Mato Grosso [6, 7 and 8], however none of them correlate this data with natural vegetation (forest and savanna). Therefore, the goal of this work is to evaluate the expansion and intensification of agriculture and the consequences in forest and savanna areas in the state of Mato Grosso from 2001 to 2017, using a satellite image time series.

2. MATERIAL AND METHODS

2.1. Study area

Mato Grosso (MT) has 903,357 km of extension, being the third largest state of Brazil. It includes three of Brazil's biomes: Amazonia, Cerrado and Pantanal (Fig. 1). The state of Mato Grosso leads the soybeans production in Brazil [8], in 2016, produced 26.3 million tons of soybean. The state also produced 2.2 million tons of cotton and 30.3 million of cattle head, in 2016. According to the Mato Grosso Institute of Agricultural Economics (IMEA - Instituto Mato-grossense de Economia Agropecuária, *in Portuguese*), in 2015, agribusiness represents 50.5% of the state's Gross Domestic Product (GDP) [9].

Figure 1. State of Mato Grosso location relative to Brazil and South America continent.

2.2. Data

We use the land use maps produced by Camara et al. (2017) [10], available at the PANGEA Earth Sciences Data Repository. These authors apply big Earth observation data analytic to get a consistent sequence of classified land use and land cover maps. We use the nine land cover classes: (1) forest; (2) savanna; (3) pasture; (4) soybean-fallow (single crop); (5) fallow-cotton (single crop); (6) soybean-cotton (double crop); (7) soybean-corn (double crop); (8) soybean-millet (double crop); (9) soybean-sunflower (double crop). According to Picoli et al. [11] the cross validation estimates an overall accuracy of 94% and the Kappa index was 0.92. Producer's and user's accuracies of all classes were close to or better than 90%.

The authors combine satellite image time series (SITS) with a statistical learning method: support vector machines. To classify the state of Mato Grosso, they used MODIS sensor, product MOD13Q1, and the indices and bands: Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), and the original bands red, blue, near infrared and middle infrared.

2.3. Production crop assessment

To analyse the crop production increase in terms of the expansion area, we calculated the crop areas year by year. We compared these agricultural areas with the forest and pasture classes, to verify if the crop area increase resulted in a natural vegetation or pasture areas decrease.

To verify if the crop production gains increase, we have analyzed the conversion of single to double crop. We made this analysis for two different periods: pre-soybean moratorium (2001-2008) and post soybean moratorium (2009-2017). The pre-soybean moratorium period (until 2008), the soybean could be planted over forest in the Amazon biome, compliance with the Brazilian forest code. After that period, deforestation could not plant soybean over forest in Amazon biome.

3. RESULTS AND DISCUSSION

The soybeans planted areas which are usually planted in the first harvest, and in the second harvest the same area is used to plant another crop, were divided into two groups: (1) soybean + non-commercial crop (single-crop), (2) soybean + commercial crop (double-crop). Non-commercial crops generally are: millet, brachiaria and crotalaria, even in this class was included fallow areas (areas where no crops in the winter). The most representative commercial crop in the state of Mato Grosso is maize.

The production gains were mainly due to the change in production system. In 2001 the most part of the state of Mato Grosso was planted with single-crop. But there has always been a tendency to increase planting in the double-crop system, in 2012 this system goes through the single-crop system (Fig. 2a). The soybean planted area in single-crop system was 3 Mha in 2001 decrease to 2.4 Mha in 2017; and in double-crop system was 0.3 Mha in 2001 increase to 6.1 Mha in 2017. In 2017, 87% of the double-crop areas was planted with maize in the second harvest. One hypothesis for the increase of planting in the second harvest is that according to According to the Brazilian National Supply Company [12], in the last five years, 30% of Brazilian maize production has been destined to the international market. This happened due to government support for the disposal of surplus production, competitiveness caused by the appreciation of the exchange rate and the conquest of new markets due to product quality. Spera et al. [6] and Kastens et al. [7] also observed the increase of the double crop system.

In total, the soybean crop expand 1.8 Mha between 2001 and 2017, from 3.3 to 8.5 Mha. The commercial crop maize increased from 0.3 to 5.3 Mha, and cotton areas increased from 280 to 796 thousand hectares, in the studied period. Meanwhile, the forest class had a decrease in this period, equivalent to 1.3 Mha, went from 38.5 to 37.2 Mha. Pasture areas, and agriculture, also increase. Pasture class increase from 21.3 to 24.7 Mha, between 2001 and 2017. The natural savanna areas, and the forest areas, also decreased, went from 25.8 to 18.3. This was the class that most declined in the studied period. Today it is estimated more than 50% of the natural vegetation in Cerrado biome have already been deforested [13].

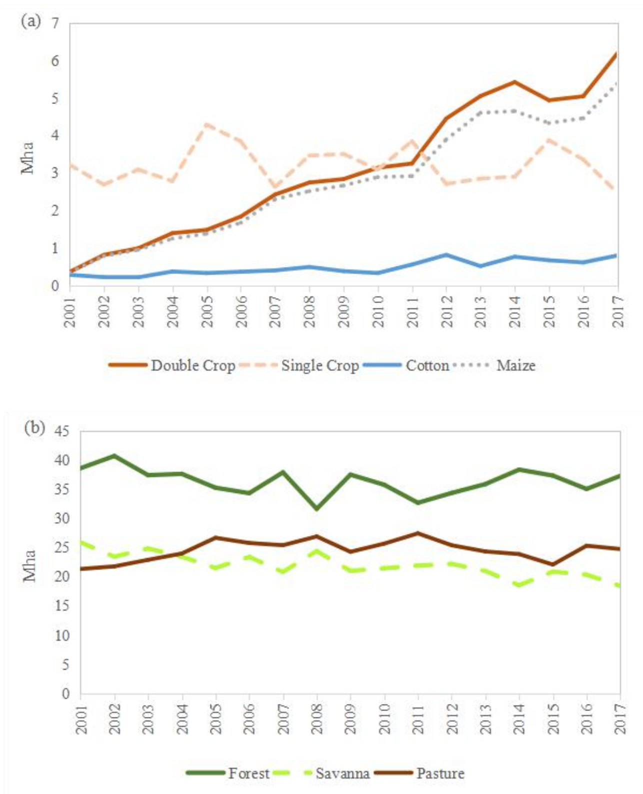

Figure 2. Planted area (Mha) with: (a) cotton, soybean + noncommercial crop, soybean + commercial crop, maize; (b) savanna, forest and pasture, in the state of Mato Grosso.

In 2006, was created an agreement to stop deforestation caused by soybeans (soy moratorium). In this agreement is guaranteed that traders did not buy soybeans grown in the Amazon on deforested lands after 2006. However, in 2013 the cut line was changed from 2006 to 2008, in alignment with the new Brazilian forest code. When we divided between pre and post soy moratorium period, we observe the soybean planted area, between 2001 and 2008, increased 2.6 Mha and forest decreased 6.9 Mha. In the post moratorium period, between 2009 and 2017, the soybean expanded 2.4 Mha, and the forest declined 0.21 Mha. During the pre-moratorium period the pasture expanded 5.5 Mha, and in the post moratorium expanded 0.47 Mha. As the moratorium prohibits the soybeans planting over forest, it is possible to affirm that the expanded areas of soy occurred directly on other uses (not forest).

As observed in Figure 3 the northwest region of the state of Mato Grosso there was an intense pasture expansion over forest. Between 2001 and 2008 the pasture expansion occurred over large forest areas in the municipality of Colniza (Figure 3). Between 2008 and 2017 pasture areas have also increased, but in smaller amounts.

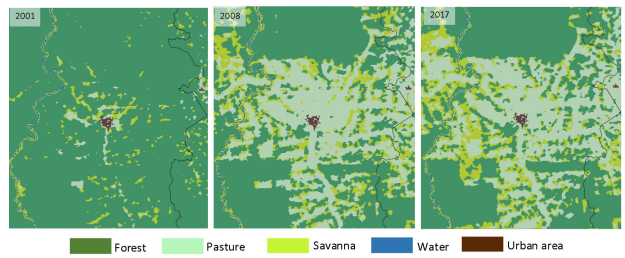

Figure 3. Pasture expansion over forest areas in the municipality of Colniza - MT, between 2001 and 2017.

4. CONCLUSIONS

Using satellite image time series (SITS) data is fundamental for the monitoring and understanding of agricultural dynamics. Using this data provides reliable agricultural statistics, and can assist the government in promoting and enforcing public policy. With the data observed in this study it was verified that public policies such as the soybean moratorium have been effective in combating deforestation caused by agriculture. However, new measures must be taken to reduce deforestation caused by other drivers, such as pasture expansion.

In Mato Grosso, between 2001 and 2017, besides the expansion of agricultural areas (mainly soybean, cotton and maize) (5.7 Mha), production gains due to the double-crop plantation system increased from 0.3 (in 2001) to 6.1 Mha (in 2017). Despite the large agricultural expansion in this state, the forest areas, after they implemented the soy moratorium, had a large reduction in the deforestation rate.

Using satellite image time series has been a tool that has been moving in parallel with the agricultural issues and food security, and its interaction with the environment.

5. ACKNOWLEDGEMENTS

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