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Agricultural Intensification Can Preserve the Brazilian Cerrado: Applying Lessons From Mato Grosso and Goiás to Brazil's Last Agricultural Frontier

Stephanie Spera

Abstract

Food security and climate change are two pressing issues shaping the future of tropical land use. Brazil, home to abundant land that is rich in carbon, water, and biodiversity and often cleared for agropastoral and renewable energy purposes, is the ideal location for studying socioeconomic and environmental trade-offs of land use dynamics. Here, I use recent (2000–2016) land-use land-cover change dynamics in the established agricultural states of Mato Grosso and Goiás to demonstrate how incentivizing intensive agricultural practices and improving degraded pastures may be a means by which Brazil can increase agricultural production while conserving the remainder of the Cerrado. I then discuss these outcomes with regard to agricultural expansion in the agricultural frontier region of Matopiba and briefly highlight contextual elements that need to be considered by other developing tropical countries looking toward Brazil as a model for agricultural and economic development.

Keywords

agriculture, intensification, preservation, Cerrado, Brazil

Introduction

Agricultural production and development in the Brazilian Cerrado has increased Brazil's role in the global marketplace. The country currently hails as the top exporter of beef, soy, chicken, orange juice, and coffee (Foreign Agricultural Service, 2016). Even though Brazil's GDP shrunk by 3.8% in 2015 due to both a recession and political unrest, the agricultural sector's GDP increased by 1.8% and was the only sector to report any job growth (Lewis, 2016; Ministério da Agricultura, Pecuária e Abastecimento, 2016). And, with over half of Brazil's agricultural land falling within the Cerrado biome boundary (Figure 1), land clearing in this region has been central to the development and strength of the country's agricultural sector.

The 2 million km^2 Cerrado (Figure 1) comprises a diverse array of flora with a wide range of physiognomies, spanning closed-canopy forests to grasslands (Eiten, 1972). Despite being classified as a biodiversity hotspot (Klink & Machado, 2005), there is no mention of the biome in the environmental section of Brazil's Constitution (1988), and consequently, it has remained relatively unprotected (Hecht, 2005; Oliveira & Hecht, 2016). Under the Brazilian Forest Code, landowners in the Cerrado are required to maintain just 20% to 35% of their properties as legal reserve, and only 3% of the land throughout the biome is legally designated as a "protected area" (Françoso et al., 2015). By the late 1990s, half of the Cerrado's native vegetation had been cleared for agropastoral purposes (Klink & Machado, 2005; Sano, Rosa, Brito, & Ferreira, 2010). Between 2000 and 2016 alone, more than 5.5 million ha of land were

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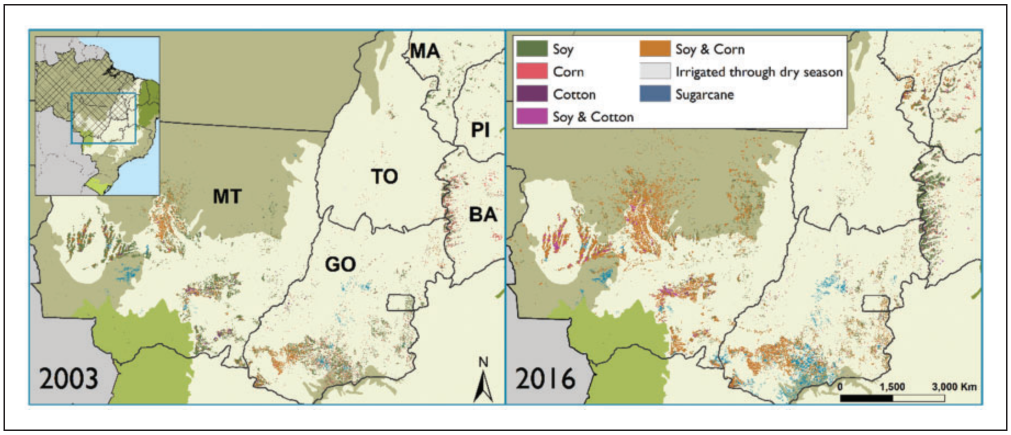

Figure 1. Map of cropland agriculture between 2003 and 2016 across the Cerrado states of Mato Grosso (MT), Goiás (GO), Maranhão (MA), Tocantins (TO), Piauí (PI), and Bahia (BA), the latter four of which comprise the Matopiba region. The map is derived from MODIS 250 m Enhanced Vegetation Index (EVI) data using a method described in Spera et al. (2016). It highlights the expansion and intensification of row-crop agriculture throughout the Cerrado. Between 2003 and 2016, Goias predominantly experienced an intensification of row-crop agriculture, Mato Gross experienced an expansion and intensification of row-crop agriculture, and Matopiba experienced an expansion of row-crop agriculture. Inset: The Cerrado biome is featured in ecru, and our region of interest is bounded by the blue box. The Amazon forest is the olive green region in the northwestern portion of the country, and the Atlantic Forest is the green region along the eastern portion of the country. The Legal Amazon boundary is cross-hatched.

converted to large-scale, market-oriented agriculture (Figure 1; Spera, Galford, Coe, Macedo, & Mustard, 2016). In 2010, the Brazilian government passed the Action Plan for Prevention and Control of Deforestation and Fires in the Cerrado as part of Brazil's National Climate Change Policy (Ministry of the Environment, 2016), which introduced many Cerrado-based conservation goals. But there has been little effort and support to put this plan into action (Garrett & Rausch, 2016), and Cerrado deforestation rates skyrocketed in 2011 (7,415 km^2) and 2012 (7,652 km^2), exceeding even Amazon deforestation rates (6,418 km^2 and 4,541 km^2, respectively; Figure 2; Câmara, De Morisson, Valeriano, & Soares, 2006; Laboratóorio de Processamento de Imagens e Geoprocessamento [LAPIG], 2015).

While voluntary supply-chain-oriented conservation policies have been touted as models of deforestation governance in export- and market-oriented agricultural regions like the Cerrado and Amazon (Gibbs et al., 2015; Nepstad et al., 2014), the much-lauded Soy Moratorium does not apply to the Cerrado. And as of 2013, only 30 farms (amounting to less than 1% of Brazil's total soy production) had been certified through the Roundtable for Responsible Soy (Garrett & Rausch, 2016), another international effort to encourage environmentally responsible cultivation and production of soy products through certification schemes.

In the following sections, I describe land-use land-cover change dynamics across the established agricultural states of Mato Grosso and Goiás. I then discuss agricultural development in the frontier region of Matopiba and argue that Brazil can increase agricultural production while protecting the remainder of this biome through conscious agricultural intensification.

The Heartland: Goiás and Mato Grosso

Both Goiás and Mato Grosso are established Brazilian agricultural states. Most farms here are large, capital-intensive operations; economies-of-scale have left little room for smallholders. In 2006, in Goiás, over 80% of the total agricultural area in the state belonged to farms larger than 100 ha; and in Mato Grosso, over 74% of the total farm area belonged to farms larger than 1000 ha (Brazilian Institute of Geography and Statistics [IBGE], 2006).

The export-oriented Brazilian farmers in these states have demonstrated that they are able to increase their agricultural production by intensifying their existing agricultural lands rather than clearing new land: supporting the notion that under specific conditions, intensification of agriculture can result in land sparing (Ceddia, Bardsley, Gomez-y-Paloma, & Sedlacek, 2014; Green, Cornell, Scharlemann, & Balmford, 2005; Phalan, Onial, Balmford, & Green, 2011; Rudel et al., 2009; Tilman, Balzer, Hill, & Befort, 2011). In Goiás, planted sugarcane area increased from less than 142,000 ha to over 1,080,000 ha; soy-corn double-cropping areas increased from 373,000 ha to 1,400,000 ha; and cattle stocking rates increased from 1.17 to 1.24 heads/ha between 2003 and 2016 (IBGE, 2016; Spera, VanWey, & Mustard, 2017). However, of the total Cerrado clearing between 2000 and 2015, less than 10% occurred within Goiás (Figure 2; LAPIG, 2016). Farmers across the state

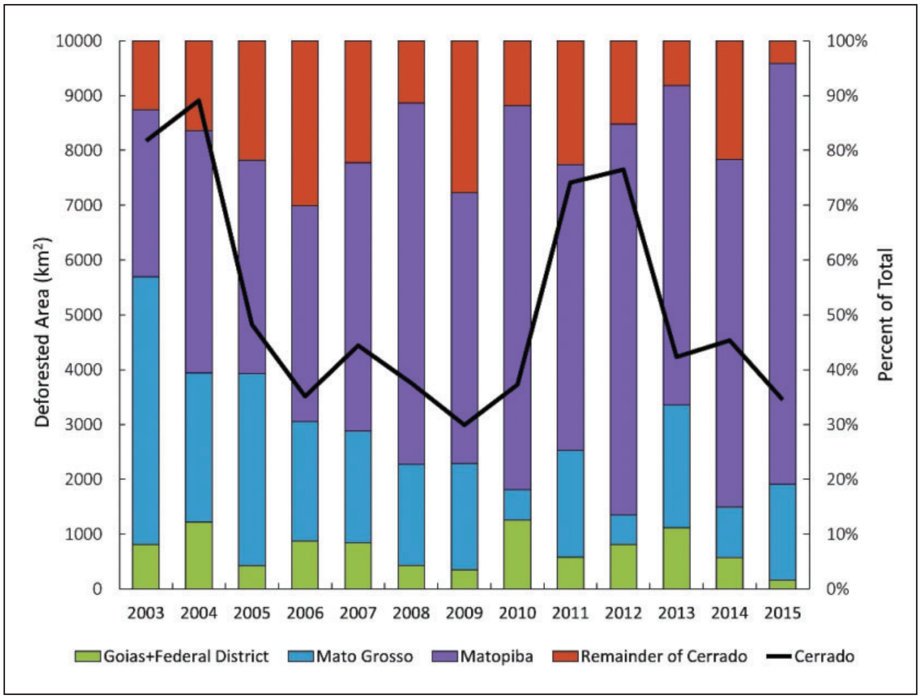

Figure 2. The black line (left y-axis) represents the total area deforested each year within the Cerrado (SIAD data: LAPIG, 2015). The bar graphs represent the percentage of total deforestation in each region: green is Goiás and the Federal District, blue is Mato Grosso, purple is Matopiba, and orange is the remainder of the Cerrado.

have instead been converting degraded pasture to row-crop agriculture, intensifying existing row-crop agriculture, and increasing cattle stocking rates as means of increasing production (Spera et al., 2017). Likewise, in Mato Grosso, intensive soy-corn double-cropping rotations expanded from 460,000 ha to over 4,300,000 ha between 2001 and 2016 (Spera et al., 2016); and both Amazon and Cerrado clearing rates declined in the state between 2006 and 2015 (Câmara et al., 2006; LAPIG, 2016).

Policy Drives Intensification in Northern Mato Grosso

Analyses of the drivers of agricultural dynamics in Goiás and Mato Grosso highlight the complex interactions between local, regional, and global influences on land-use and land-cover change within the Cerrado (Garrett, Lambin, & Naylor, 2013; Richards, Pellegrina, VanWey, & Spera, 2015; Spera et al., 2014, 2017; Vera-Diaz, Kaufmann, Nepstad, & Schlesinger, 2008). In the northern, Amazon portion of Mato Grosso, declining deforestation rates have been primarily attributed to effective governance. During mid-1990s, the Brazilian government both began monitoring deforestation using satellite data and expanded the number of permanently protected areas within the Amazon biome (Soares-Filho et al., 2010). The post-2006 decoupling of soy production from deforestation rates has also been attributed to the Soy Moratorium (Gibbs et al., 2015; Macedo et al., 2012). And as highlighted earlier, this decrease in deforestation has occurred in conjunction with an increase in intensive agriculture. Amazon-based environmental regulations created a type of land scarcity. As a result, for farmers in northern Mato Grosso to increase production while still complying with the Soy Moratorium, they needed to intensify their existing agricultural lands, rather than to expand onto new lands (DeFries, Herold, Verchot, Macedo, & Shimabukuro, 2013).

Land Scarcity Drives Intensification in Goiás and Southern Mato Grosso

In Goiás and the southern, Cerrado-portion of Mato Grosso, the trend toward intensification rather than expansion can be attributed to biophysical land scarcity. In both regions, local variables such as biophysical suitability, local institutions, and access to infrastructure are related to where native vegetation and pasture are converted to extensive and intensive agricultural lands (Jasinski, Morton, DeFreise, Shimabukuro, & Anderson, 2005; Spera et al., 2014, 2017; Vera-Diaz et al., 2008). In Goiás, only 30% of the Cerrado remains undisturbed (Sano et al., 2010). And, due to high rates of land clearing in Mato Grosso's Cerrado during the early 2000s, areas of highly suitable agricultural land for both single- and double-cropping decreased by 40% and

50%, respectively, between 2001 and 2011 (Spera et al., 2014). In these regions, then, scarcity of suitable agricultural land has contributed to decreasing deforestation rates and provided an impetus for increasing production of intensive double-cropping (Spera et al., 2014, 2017).

Brazil's "Last Agricultural Frontier"

In May of 2015, 337 municipalities in the northeastern Cerrado states of Maranhão, Tocantins, Piauí, and Bahia were officially designated "Matopiba" by the Brazilian government, and a bill was ratified committing the government to investing in infrastructure, agricultural technology, and the expansion of the rural middle class. Matopiba is the newest and potentially last agricultural frontier region within the Cerrado (Figure 1).

Unlike Goiás and Mato Grosso, this northeastern portion of the Cerrado still contains a large portion of intact natural vegetation and most clearing of natural Cerrado vegetation during the past decade has occurred within Matopiba (Figure 2). Also unlike Goiás and Mato Grosso, there still exist abundant smallholder farmers in the region. Embrapa reports that 94% of the farmers in Matopiba are classified as "very poor" or "poor," while just 5% belong to the middle class (Embrapa, 2015). The 0.42% of farmers that comprise the upper class generate almost 60% of the farm income in the region (Embrapa, 2015).

Currently, the Brazilian government expects cultivated agricultural areas in Matopiba to expand by another 2.7 million ha by 2025 (Ministério da Agricultura, Pecuária e Abastecimento, 2015). However, developers of the Matopiba region can learn from the land-use change dynamics of Mato Grosso and Goiás. Agricultural production dynamics in Goiás and Mato Grosso demonstrate that it is possible to increase agricultural production without clearing what is left of natural vegetation. Focusing agricultural development on mechanisms to support intensive agriculture with land sparing in mind is essential. In 2015, 15% of the large-scale agriculture in Matopiba was double-cropped (Spera et al., 2016). Intensifying agriculture from single-cropping regimes to double-cropping regimes on the remaining 85% of already cultivated land could provide large gains in agricultural production. Moreover, this is technologically feasible because Embrapa has already developed a Matopiba-adapted soybean cultivar that matures in only 110 days, which enables the cultivation of two crops per growing season. Furthermore, ascertaining which lands are most agronomically suitable for intensive agriculture and selectively cultivating and intensifying these lands could prevent extensive Cerrado clearing by farmers trying to determine suitability through trial-and-error. Predetermining the biophysical suitability of lands in Matopiba is especially crucial as the sandier soils are less physically suitable than those in Mato Grosso and Goiás and the region receives less rainfall.

Furthermore, across the Cerrado, between 50% and 60% of the pastures are degraded (Assunção & Chiavari, 2015; Strassburg et al., 2014). Improving these pasture lands could also be incentivized. Increasing pasture productivity by just 20% would allow Brazil to meet food and energy demands until 2040 (Strassburg et al., 2014). Incentives for increasing cattle stocking rates on productive pasture, in addition to increasing agricultural production on previously cleared land and degraded pastures, may prove to be an effective policy that also disincentives new Cerrado land clearing.

It is important to recognize that the expansion of intensive agriculture in Matopiba may not be readily embraced by smallholders in the region, especially given the fate of smallholders in Mato Grosso and Goiás. Instances of violent conflict and vocal smallholders resisting agribusiness' entry to the region have already been reported (Arsenault, 2016; Guest, 2015; Hill, 2015). However, providing smallholders who comply with existing environmental regulation access to credit, capital, and agricultural technology may help increase agricultural productivity on land that has already been cleared and help the government achieve their goal of expanding the middle class. A fifth of the variation in agricultural productivity in Brazil has been correlated with credit access (Assunção & Chiavari, 2015). Moreover, nearly 40% of all smallholder farmers in Brazil do not have land titles (Lapola et al., 2014). Agricultural cooperatives, which proved so integral to the colonization of Mato Grosso and Goiás (see Hecht, 2005; Jepson, Brannstrom, & Filippi, 2010), may be crucial to helping smallholders navigate the legal system and acquire property rights. In regions like Matopiba, giving smallholders property rights to their already cleared land, access to subsidized credit, and technology that supports intensive agriculture may help them increase production gains and access the agricultural market while still sparing land. Moreover, intensive agriculture has been linked to positive socioeconomic (better schools, new jobs, and higher GDPs per capita) and environmental (evapotranspiration rates akin to native Cerrado vegetation) outcomes elsewhere in the Cerrado (Richards et al., 2015; Spera et al., 2016; VanWey, Spera, de Sa, Mahr, & Mustard, 2013). Incentivizing intensive agriculture could promote socioeconomic development and provide a means for increasing agricultural production while sparing what is left of the Cerrado.

Concluding Remarks

Brazil's government and economy are currently troubled. As evidenced by the recent increase in deforestation, a weak *real* makes Brazilian exports more attractive, incentivizing deforestation (Richards & Hoelle, 2016; Richards, Myers, Swinton, & Walker, 2012). The conservation of the remaining Cerrado ecosystem should be considered a high priority. Replacing natural Cerrado with agropastoral lands has affected biodiversity (Françoso et al., 2015), carbon stocks (Bustamante, Corbeels, Scopel, & Roscoe, 2006), and the regional water balance via changes in evapotranspiration (Spera et al., 2016). This last point is critical because future agricultural production and ecosystem sustainability depend on a stable precipitation regime. Successful crop yields in the Cerrado are contingent on a long, stable wet season, as over 95% of the crops in this region are rain-fed (IBGE, 2016). Moreover, climate modeling experiments have shown that preserving remnant Cerrado may be integral to the health of both the Cerrado and Amazon biomes (Coe, Brando, et al., 2017; Coe, Marthews, et al., 2017; Costa & Pires, 2010; Malhado, Pires, & Costa, 2010; Oliveira, Costa, Soares-Filho, & Coe, 2013; Spracklen, Arnold, & Taylor, 2012). Thus, the environmental stability of the region is important in terms of ecosystem services and agricultural and economic development.

As highlighted earlier, policies supporting intensive double-cropping and reclamation of degraded pastures could be integral to this preservation. Mato Grosso and Goiás have demonstrated that farmers can increase agricultural production by intensifying their land when either policy or land scarcity have constrained expansion; in other words, there is incentive for them to do so. It seems, then, that the Cerrado does not need to continue to be cleared for increases in agricultural production. The Brazilian government should focus their efforts on managing and intensifying previously cleared lands. A pro-business government not focused on *sustainable* development coupled with increased global demand for Brazilian goods due to a weaker *real* leave both the Amazon and Cerrado biomes in a precarious state.

Other tropical developing countries may look to Brazil as a model for agricultural and economic development. The goal of these countries, then, should be to promote sustainable agricultural development, and make efforts to increase agricultural production without widespread clearing, as both Mato Grosso and Goiás have of late. But, two major considerations must be noted when thinking about the applicability of Brazil's model elsewhere. First, Brazil's government has been investing money and personnel in the development of the agricultural sector since the early 1970s. Since the creation of Embrapa in 1973, investment in agricultural research and development has led to innovations in agricultural technology such as adjustments to soy's photoperiod which enables the crop to grow in tropical regions; improving soil quality through the addition of lime to soils with high concentrations of aluminum and low pHs; and the creation of short-cycle soy crop to enable double-cropping rotations. Broadly, this commitment to the agricultural sector, along with agricultural cooperatives and international investments, has facilitated Brazil's ability to increase agricultural production on a massive spatial and rapid time scale. Thus, agricultural technologies suited for the region are integral to the development of these sectors in other countries. Second, as described earlier, there exist means to encourage sustainable export-oriented agriculture. But, when demand is inherently tied to a country's currency's strength in the global marketplace, both the government and farmers need to buy into any conservation initiatives; because when the demand for goods is high, so too is the allure to clear cut land for agriculture. A country could promote conservation efforts through strong national or local policy or voluntary supply chain governance. More likely, though, countries and their farmers may need to be offered something (subsidies, bank credits, or other incentives) in exchange for not deforesting, as more often than not, the temptation to sacrifice natural vegetation for increased returns will outweigh sustainable development and conservation efforts.

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