

SOYBEAN'S FOOTPRINT IN AMAZONIA: PAST AND CURRENT TRENDS

TRAJETÓRIAS DA SOJA NA AMAZÔNIA: TENDÊNCIAS ANTERIORES E ATUAIS

LA HUELLA DE SOJA EN AMAZONIA: TENDENCIAS PASADAS Y ACTUALES

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ABSTRACT

Soybeans have become Brazil's second most important export commodity accounting for roughly 10 percent of the country's exports in 2014. This is surprising given that only 30 years ago Brazilian production was three times smaller than that of the United States, which dominated almost entirely the global market. Brazilian rise as major exporter peaked in 2015 when the country became the world's largest exporter and producer of soybeans. A long road of policy reforms, seized market opportunities and increase of global demand, especially from China determined the country's success. However, while exports soared, researchers grew concerned about environmental impacts, given soybeans' encroachment into the tropical environments of Amazonia. This advance into the world's largest tropical moist forest is also surprising, given soybeans were originally grown as a temperate crop. In this paper I analyze the history of the development of soybeans agriculture in Brazil, how it crept northwards, the social and environmental impacts in the central Amazon region.

Keywords: Soybeans; Amazonia; Brazil.

RESUMO

A soja é a segunda mais importante commodity de exportação do Brasil, correspondendo a cerca de 10 por cento das exportações em 2014. Este crescimento é notável dado que há 30 anos atrás a produção brasileira era três vezes menor que a dos Estados Unidos, que até então dominava quase todo o mercado global. A ascensão do Brasil culminou em 2015, ocasião em que o país se tornou o maior exportador e produtor de soja do mundo. O sucesso do Brasil é resultado de uma longa jornada que envolveu reformas na política de exportação, oportunidades de mercado e crescimento da demanda global, especialmente da China. No entanto, paralelo ao crescimento das exportações, aumentou também a preocupação com relação aos seus impactos ambientais associados à proliferação da atividade dentro bioma amazônico. Este

avanço sobre a maior Floresta tropical do mundo é também surpreendente porque a cultivo de soja até pouco tempo era limitado às regiões de clima temperado. Neste artigo eu analiso a trajetória do desenvolvimento da agricultura de soja no Brasil, como ela se deslocou para o norte e os impactos sociais e ambientais observados na região central da Amazônia.

Palavras-chave: Soja, Amazônia, Brasil

RESUMEN

La soja es la segunda más importante commodity de exportación de Brasil, correspondiendo a cerca del 10 por ciento de las exportaciones en 2014. Este crecimiento es notable dado que hace 30 años la producción brasileña era tres veces menor que la de Estados Unidos, que hasta entonces dominaba casi todo el mercado global. El ascenso de Brasil culminó en 2015, ocasión en que el país se convirtió en el mayor exportador y productor de soja del mundo. El éxito de Brasil es el resultado de una larga jornada que involucró reformas en la política de exportación, oportunidades de mercado y crecimiento de la demanda global, especialmente de China. Sin embargo, paralelo al crecimiento de las exportaciones, aumentó también la preocupación con respecto a sus impactos ambientales asociados a la proliferación de la actividad dentro del bioma amazónico. Este avance sobre la mayor Selva tropical del mundo es también sorprendente porque el cultivo de soja hasta poco tiempo se limita a las regiones de clima templado. En este artículo analizo la trayectoria del desarrollo de la agricultura de soja en Brasil, como ella se desplazó hacia el norte y los impactos sociales y ambientales observados en la región central de la Amazonia.

Palabras clave: Soja, Amazonia, Brasil.

INTRODUCTION

Soybeans are the world's third most important crop by volume, 85% of which is crushed for animal food or vegetable oil (USDA 2016; FAO Stats 2016). Since the 1990's, the increase in production and consumption of animal protein in the developing world has led to a rise in demand for soybeans, this is especially true in the case of China, where domestic increase in animal-based protein triggered the upsurge of a strong animal feed industry, making it the world's largest importer of soybeans (USDA 2016). Without the upsurge of China, global production of soybeans would likely be 60% lower than actual figures. Currently Argentina, Brazil and United States account for nearly 90% of global production, of which 60% is exported to China. The USDA projection to 2025 indicates that Chinese demand and prices will continue to rise.

In this paper I argue that the articulation between external markets and a favorable domestic scenario was fundamental for Brazil's projection in the international soybean market. While the country became leader in agricultural commodity exports, significant volume of Amazon forest was converted into crop land. I sought to answer how the development of soybean agriculture in Brazil occurred and crept northwards and what was the social and environmental impacts for the central Amazon region.

I provide an account of the evolution of soybean agriculture in Brazil, and its emergence of that country's most important export crop. I take into consideration macro-economic factors, technological advances and government incentives, as well as the role of international markets, especially that of China, as the prime force behinds soybean expansion into the Amazon biome. I also provide a conceptualization of land change impacts associated with soybean agriculture, using the location rent model deriving from von Thunen. I conclude the article with a discussion of the environmental and social consequences of soybean farming's penetration of the Central Amazon Basin. My focus is on deforestation resulting from land use displacement as new crop fields encroach on pastures and low-intensity agriculture, a process called Indirect Land Use Change (ILUC).

BRAZIL AS A SOYBEAN GIANT

Until recently, the United States reigned as the world's largest producer of soybeans (FAO 2016, WTO 2016). Although most production satisfied domestic consumption, it nevertheless dominated global markets as the number one exporter (FAO 2016). This has begun to change, as ground has been given to Brazil. In 2001, the US share of the market was 52% while Brazil's was 26%; by 2014 the US share had dropped to 41% with Brazil's increasing to 40%. The fact that the US has lost ground in the international market does not necessarily mean a production drop; on the contrary, production in the US has never been higher (USDA 2016). What has happened is that domestic gains in demand for soybean meal and crushed soybeans is increasingly taking a bigger bite of the overall volume of production,

which affects the amount available for exports. The shortages of American exports paved the way for an increase in Brazilian exports to China, which in 2015 topped the US at \$2 billion (Figure 2-1). The USDA projections to 2025 indicate that Brazil will remain the world's largest exporter.

Brazil's outstanding performance in the international market was built on a series of domestic policy shifts that preceded the liberalization of the economy in the early 1990's. These shifts showed the country's willingness to fully embody the new economic order, established in 1991 under the Mercosur bloc, which includes four of the world's largest soybean producers, Argentina, Brazil, Paraguay and Uruguay. These measures started by dismantling the high taxes on import and export goods inherited from the military regime. Taxation on exports dropped from 44.4 to 16.6% for manufactured items, and from 31.6 to 9.1% for primary goods. After the transitional period to democracy in the mid-1980s, export tariffs have stabilized below 15% for manufactured goods and around 8-10% for resource and agricultural commodities (Richards 2012; World Bank 2012; Helfand and Rezende 2004). As a consequence of the success of these reforms, Brazil significantly increased its share of the international market of commodities and also became one of the world's leading exporters of iron ore, sugar, beef, coffee, tobacco, and orange juice (FAO Stats 2016). This growth was largely associated with China's rise as the world's largest consumer of primary products from Latin American countries (Gallagher and Porzecanski 2010). In 2014, for example, 71% of soybeans and 46% of iron ore exports went to China generating a revenue of \$50.5 billion (WTO 2016; OEC 2016).

THE DEVELOPMENT OF SOYBEAN AGRICULTURE

Although the neoliberal policy reforms just described are relatively recent, the emergence of soybean agriculture has a long history of technological innovation, seized market opportunities and government incentives. Brazil's first internationally documented soybean harvest dates from 1949 in Rio Grande do Sul state, where 25,000 tons were

harvested (Brown et al. 2005; Embrapa Soy 2015). Later, during the 1960's production increased dramatically, although Brazil's agricultural sector remained focused on wheat, with soybeans rotated in the offseason. By the end of that decade, production had jumped from 206,000 tons to 1,056,000 tons and was concentrated in the southern states of Rio Grande do Sul, Paraná and Santa Catarina (Embrapa Soja 2015).

The 1970s marked a period in which the geographic distribution of soybean farming began to change. In the face of growing domestic demand for crops and the need to create ways to ensure that the productive sector continue meeting demand, the federal government launched, in 1975, a package of measures for rural development called POLOCENTRO (Program of Development of the Central West), with a special focus on the states of Goiás, Minas Gerais, Mato Grosso and the Federal District. Rural development was promoted by financing production with a special credit line, by building roads, silos and warehouses and by providing technical support through research – during which the charter *cerrados*¹ of the Brazilian Agricultural Research Corporation (EMBRABA) was created (Embrapa Cerrados 2012 website). As a consequence, in five years production and planted areas soared from 1.5 million tons planted on 1.3 million ha, to over 15 million tons planted on 8.8 million ha (Warnken 1999; Embrapa Soy 2016).

The development of innovative techniques like the combination of soybean bacteria with pseudo-symbiotic relationships allowed soybeans to be planted with no application of nitrogen fertilizer (Fearnside 2001). Later, researchers developed a highly adapted variety that corrected genetic constraints related to low soil phosphorus and high aluminum (Alves et al. 2003; Spehar 1995). Perhaps the most import advance was the adoption, in the early 1970s, of no-tillage² agriculture to large scale farming in southern Brazil. Since the method significantly reduces soil disturbance, the technique ultimately enabled soybean cultivation on

¹ The central-west region of Brazil is vastly occupied by a savannah-like biome called cerrado. Because the biome extends throughout these states, the region as a whole is also known as cerrados.

² In the no-tillage technique no plowing or tilling is needed; seeds are planted in a narrow row with just sufficient depth to obtain proper seed cover. In large-scale cropping operations using the method in Brazil, harvesting and seeding are done at the same time. As harvesters lead the way, they separate grains from pulled stands that are chopped on the fly into straw and left on the field. No-till seeders run behind and immediately after the harvesting, plant seeds on straw covered soils.

erosional soils of the Amazon (Aprosoja website 2017; Kemper and Derpsh 1981; Santana 2006). In addition, the technique was useful for less capitalized farmers because it reduced input and labor costs. Currently, approximately 70% of 35 million hectares of croplands applies no-tillage, and production improved from one ton per hectare in the 1970s to 3.3 tons per hectare in 2012 (Aprosoja website 2017). Therefore, no-till farming allowed farmers to shift production to new lands, paving the way to encroaching on the cheaper lands available in the Amazon.

In late 1970s, the first soybean harvests occurred in the central region of Brazil. Although the stage was set for agricultural expansion, its growth was highly dependent on the ability of the internal market to absorb production. This is because the military dictatorship in power from 1964 to 1985 reinforced production of commodities for domestic consumption and industrialization based on import substitution (Hecht 2005; Walker and Defries 2009, Richards 2012). The import substitution policy charged high tariffs for both imports of agricultural inputs and commodities exports. Thus, high production costs together with export duties raised the prices of all agricultural commodities, undercutting any competitiveness in global markets. While the liberalization of the economy in the early 1990s dismantled the economic policy inherited from the military era, infrastructure investment accelerated with the program *Avança Brasil* (Forward Brazil) in 1995. Similar to POLOCENTRO, this new set of measures prioritized construction projects and improved internal transportation networks, thereby linking producers in Mato Grosso state's soy belt to Amazonian ports (Fernside 2001; Walker and DeFries 2009). In particular, the BR 163 highway, an import/export corridor linking the country's largest soy producer, Mato Grosso state, to the Amazon River, offered a shortcut to hauling production to international markets and relief from congested southern ports of Paranaguá and Santos.

In 2001 the European Union (EU) imposed a ban on the feeding of animal protein-based rations to all livestock in an attempt to reduce the risk of mad cow disease outbreaks. In doing so, the EU considerably stimulated demand for soybeans, thereby raising imports from Brazil to fatten their herds. Since then, soybeans have become the Amazon's most profitable

crop (Walker and Defries 2009; Richards 2014; CONAB 2015). In 2014, 36.5% of Brazilian soybeans were produced in the Legal Amazon³, occupying an area of roughly 10.4 million ha and yielding 28.4 billion Brazilian Reais in revenues (IBGE-Sidra 2016).

In sum, prior to 1970, soybeans were being planted in higher latitudes due to phenological limitations, especially those associated with warm climate and soils. These limitations were soon overcome; technological advances in farming techniques and more recently through genetically modified soybeans, allowed cultivation in lower latitudes (Walker and DeFries 2009; Embrapa Soy 2016). Improved practices and genetically modified soybeans made possible the movement of soybean agriculture from traditional production zones in the South to the warmer regions of the Amazon Basin, especially in Mato Grosso State.

ENCROACHMENT ON THE TROPICAL FOREST

From the mid-1990s to mid-2000s, soybean performance on external markets functioned as a thermometer of deforestation in the Amazon. High export prices signified high deforestation rates (Fearnside 2005; Morton et al. 2006). This was especially true considering that Brazil enjoyed an upswing in commodity prices, during what economists now refer to as the “commodities super-cycle.” This cycle was highly reliant on growth in markets of populous developing countries like China and India (Erten and Ocampo 2013; Canuto 2014). China’s participation on the global market as a commodity importer increased from 5% in the early 1990s to nearly 45% in 2015 (UN-Comtrade 2017).

During the cycle’s upsurge, there was a sharp expansion of soybean production in Brazil, particularly in the Legal Amazon; agricultural lands increased from 2.1 million ha in 1994 to 10.4 million ha in 2014 (IBGE 2016). In Mato Grosso state, Brazil’s largest producer,

³ Legal Amazon or Amazônia Legal is a geopolitical region assigned in 1966 by the Constitutional Law N° 5.173. Through this law, the delineation of the Legal Amazon is based on the Amazon River basin and includes the Amazon biome, the states of the country’s north (Acre, Amapá, Amazonas, Pará, Rondônia, Roraima and Tocantins) as well as Mato Grosso state in the central-west region and most of Maranhão state in the northeast region (IBGE, 2011).

crop fields grew from 2 million ha in 1994 to 8.6 million ha in 2014 (IBGE 2016). Evidence from studies using remote sensing and Geographic Information Systems (GIS) have shown that much of this expansion occurred at the expense of rainforests (Fearnside 2001, 2005; Brown et al. 2005; Morton et al. 2006; Galford et al. 2008). The direct advance of soybean fields onto primary forest was also observed elsewhere in the Amazon basin, and to get out ahead of political reactions by environmentalists, Brazilian soybean farmers declared a moratorium on deforestation, committing themselves to only plant on pre-existing crop fields or pastures (Nepstad et al. 2006, Butler and Laurance 2008, Arima et al. 2011). Thus, while offering opportunities for economically stagnant regions, large-scale agriculture in Amazonia may come with irreversible environmental costs.

Despite the economic crisis Brazil is now experiencing, net profit from soybean exports for 2016/17 manifests an upward trajectory and is expected to be 7.47% higher than the 2014/15 season (CEPEA-ESALQ 2016). Even so, deforestation has fallen more than 70% from 2005 to 2014, perhaps attributable to improved law enforcement and market-oriented mechanisms such as supply chain greening (Nepstad et al. 2009, 2014; Hecht 2012; Gibbs et al. 2015;). Although direct conversion of forest into croplands is presently very low, research has demonstrated that environmental impacts leak away from direct observation as by-products of land use policies (Lapola 2010; Lambin and Meyfroidt 2011; Arima 2011; Richards 2015). These researches have shown strong evidence of indirect land use change (ILUC), whereby changing location rents spark the displacement of pastures to forest frontiers as soybean comes in behind and pushes pasture to new areas, further investigated by (Walker, Browder, et al. 2009; Arima et al. 2011; Walker and Richards 2014). Arima et al. (2011) found strong statistical indications of ILUC in the Amazon basin between 2003 and 2008; their regression model shows that a ten percent reduction in the region's soybean fields would have reduced deforestation by up to 26,039 km² (40% of the period's deforestation). Similarly, Lapola et al. (2010) predict that ILUC stemming from expanding sugarcane and soybean production throughout Brazil will be responsible for ~60% of Amazonian forest loss out to 2020.

To date, ILUC research has tended to formalize its model statements using the location rent model of von Thunen, but adapted to large regions (Peet 1969; Katzman 1974; Walker, Browder 2009). I acknowledge the role of location rents in land change (Walker and Solecki 2004), but in this paper I focus on the ground-level mechanisms whereby one form of land use gives way to another through a transfer of property in land between two land managers. I explore the environmental and social repercussions of smallholder displacement by soybean farmers using the ILUC framework, which I directly apply to an important agricultural frontier in Brazil's Central Amazon. Here, ILUC appears to be at play in stimulating deforestation through smallholder displacement. Soybean farming largely expanded as infilling following land purchase by smallholders, who reestablished farmsteads in forest frontiers. Displacement of smallholdings is understood as the move from an original location to a new location; smallholder displacement occurred through land transactions between smallholders and soybean farmers.

ILUC AND LOCATION RENT

To better provide insight into the displacement process, I reconfigure the location rent model to describe graphically ILUC-driven deforestation. Specifically, land use and cover change dynamics take place in a two-crop scenario, soybeans and beef, where soybeans provide the more profitable crop. I acknowledge the location model has been criticized for (1) an equilibrium assumption, which is viewed as static in face of an essentially dynamic process that is land change, an issue addressed by Walker and Solecki 2004; (2) for a reductionist spatial geometry with concentric rings around a single core market and (3) for its detachment from land cover agency, addressed by Walker and Richards 2013. Nevertheless, I find the location rent theory useful in comprehending land use decisions within a spatial landscape where economic opportunities dictate land use allocation.

I first note that agricultural expansion can be conceptualized as being driven by an increase of rents (Walker 2004; Walker et al. 2009). A transportation network together with rising prices boosted soybean production and expansion, resulting in the increase of rents.

Although soybean is highly profitable, it is not the only agricultural venture being undertaken in Amazonia. In a particular area we may find different agricultural systems such as small-scale and large-scale agriculture and cattle ranching. Although they share infrastructure such as roads, land is always the subject of some kind of dispute among these agents, generating for example land bids, in which the more profitable activity wins over the less profitable. Thus, ILUC takes place in stages as just mentioned. In practical terms, this logic triggers ILUC, partly because of land clearing costs.

Although soybean farming is mechanized and not labor intensive, it requires extensive use of technology to clear and correct terrain. Usually soybean farmers prefer not to engage in that route because of the costs and time associated with it. A cheaper option is to buy and convert previously cleared holdings into fields. However, this does not spell the end of the displaced activity. Sooner or later, the prior activities on the purchased properties will begin to exert a demand for land. Ultimately, displaced ranchers and peasants migrate to other areas to start over. These areas are often in forest frontiers, far from markets but still connected to them. Finally, displaced activities engage in deforestation as forests have no immediate economic value to the new arrivals. Figure 2-2 presents ILUC in graphical terms. As has been stated, there are two possible outcomes: displacement and forest conversion. As for displacement, consider two economic activities: soybean farming and cattle ranching being undertaken in the same time in a particular area. The rent function for soy farming is given as: $p_s q_s - d_s q_s t$; the rent function for cattle ranching is given as $p_c q_c - d_c q_c t$. ILUC happens when:

$$p_s q_s - d_s q_s t > p_c q_c - d_c q_c t \quad (2-1)$$

Assuming that revenues from $p_s q_s$ are greater than $p_c q_c$ soybean farming is a preferred activity closer to the market. In a first moment R_s , soybean farming is practiced up to the intensive margin, a ; from here, cattle ranching is more profitable, given soybean's higher transportation costs. The intensive margin marks the boundary between soy farming

and ranching in two different moments characterized by different transportation costs t ; transportation rate at R_s' is smaller than at R_s . Thus, every time there is a reduction in cost of t , rents will increase.

Since cattle ranching is less profitable than soybean farming, it is technically passive to soybean rents. As infrastructure drives the transport rates down, rents grow, and soybeans are now commercially viable at longer hauls from the market. This expansion, however, only occurs with the displacement of ranching. The second rent curve for soybean farming (dashed red line) shifts to the right, given higher rent R_s . Therefore, displacement of cattle ranching happens any time that rents are positive for soybean farming. In fact, ranching activities are passive to changes in soybean parameters, such as the transportation rate. However, ranching also benefits from decreases in the transportation rate, driven by improvements in infrastructure in both moments. Thus, ranching is economically feasible in at distance d and d' . Land conversion is an outcome of this leapfrogging dynamic. Forested areas, also known as marginal lands, are converted into pastures at any time, with increasing soybean rents.

SOYBEAN CULTIVATION IN THE CENTRAL AMAZON BASIN

Santarem County, located in Pará state, encompasses the town of Mojuí dos Campos and Belterra, shown in Figure 2-3. The county sits on a plateau at approximately 100 to 150 m above sea level called the planalto do Tapajós/Xingu. Most of the urban part of the county is located on the Amazon River basin relief or Bacia do Amazonas (Prefeitura Municipal de Santarém 2011). The vegetation is composed of secondary forest or capoeira generated by peasant agriculture and cattle ranching. Primary tropical forest is found approximately 70 km south of Santarem and extends continuously southward. Soils are oxisols, typical of tropical rain forests, with low fertility for agricultural purposes, but responsive to fertilizing treatment. The County is connected to major producers in the central part of the Brazil via the BR-163 highway.

Mechanized monoculture agriculture in Santarem became viable after the Avança Brasil program in 1995, especially because it mandated the paving of the BR-163 highway.

Between 1997 and 1998, Embrapa, together with the local government, initiated campaigns in states such as Mato Grosso and Paraná to attract farmers to Santarem by offering tax cuts and other benefits. In the same period, the state government hired agribusiness consultants to study the region's potential for agribusiness, they identified three regional hubs with greater chances of success of soybean farming: the northeast hub, southern hub and west pole, where Santarem is located (Figure 2-3). Beginning in 2001, a set of Embrapa's technical reports assessed the productive rates of soybean varieties capable of adapting to the moist, rainy central Amazon basin. Most of them concluded that the majority of the available lands were highly suitable for large-scale agriculture (Embrapa 2001; Steward, 2007).

In the early 2000s, the incentives had taken effect and private investments on export ports in central Amazonia, such as the Itacoatiara port by the Amaggi Group and the Cargill port in Santarem, signaled a permanent presence of the agribusiness sector in the region. From 1998 to 2000 the first crop farmers arrived, and in doing so, bought parcels from smallholders. In the beginning, one hectare of land cost around R\$1,000.00 (about U\$500.00). In 2003 when Cargill inaugurated its terminal, there were about 200 large-scale crop farms established and the price of land doubled in value. Mechanized agriculture's advance on the region occurred in two stages, the first beginning in 1997 with local incentives, and the second from 2003 with the opening of the Cargill storage terminal (Steward 2007). Currently, Santarém county is ranked the state's second largest soybean producer (IBGE 2016).

More recently in mid-2014, the northern soybean corridor was enhanced with cargo transshipment stations located in the Miritituba district, south of Santarem. Long haul transport of soybeans and corn is now enabled by the Tapajós River waterway. By rerouting from Santarem to Miritituba, major grain traders and their logistics companies shortened the distance from producers in the mid-and northern part of Mato Grosso to the Santarem export port by 350 kilometers. The transshipment stations shift nearly half of transport from truck to barges, reducing the dependency on trucks and significantly reducing costs. The Tapajós River near Miritituba is not deep enough to allow cargo ship traffic, and as a result grains are loaded in barges and then shipped to the export terminals of Santarem, Vila do Conde and

Santana (Figure 2-3). At these ports, the grains are reloaded onto cargo ships that head out to sea, initiating a long journey to European and Asian ports. These ships and barges make the return to the Amazonian port, bringing electronic products and agricultural inputs. It is estimated a \$4 save for every ton exported from Miritituba, and together these companies seek to export up 37% of Mato Grosso's production, currently at 31 million tons. Projections to 2024 anticipate that \$13 billion will have been exported from Miritituba, generating a transportation economy of \$130 million. Because traders are in charge of transportation from the farm, the reduction in transportation cost is not passed on to farmers.

The promotion of the initiatives outlined above has focused on connecting the national soybean agenda with the local development agenda. A bottleneck in this strategy of economic development is the lack of use of local labor. During the process of installation of the operational infrastructure such as silage and grain transshipment machinery, outsourced companies hire local labor on a temporary basis. In addition, due to the lack of local expertise in working with grains, agribusinesses engaged in soybean agriculture often bring labor from headquarters outside the region. Given the limitations with labor, it is unlikely that soybean cropping would have arisen in central Amazonia by the initiative of local entrepreneurs for many reasons, but inadequate local labor supply and quality is a prime factor (Brondizio et al. 2002). Hence, whether or not the current agribusiness fashion is capable of fostering Amazonian development and deepening its human capital remains uncertain.

LAND COVER CHANGE IMPACTS

As discussed, mechanized agriculture causes both direct and indirect deforestation. Several studies based on remote sensing analysis have demonstrated direct encroachment of agriculture in forested areas; here I highlight research conducted in three important Amazonian agricultural frontiers (northern Mato Grosso state; central Amazonia and Rondônia). Morton et al. 2006 found 12 to 14% direct conversion of forest to cropland in the Mato Grosso state between 2001 and 2004; they also revealed a strong correlation between deforestation and soybean prices, which were relatively high during the period (Table 2-1). In

the case of the Central Amazonia (municipios of Santarém and Belterra) 10% of the deforestation observed from 1999 to 2005 is attributed to mechanized agriculture (Venturieri et al. 2007).

Similarly, in western Amazonia in the Vilhena município, roughly 22% of dense forest and 20% of less dense forest were directly converted to cropland from 1996 to 2001 (Brown et al. 2005). Thus, from 1996 to 2005, the total area of tropical forest converted into crop land in these three regions was 5,155⁴ km². The majority of the deforestation reported in the above-mentioned studies occurred from 1999 to 2005. Coincidentally, Richards et al. (2014) findings for indirect deforestation fall within that period, especially from 2001 to 2004 with increase of soybean exports. The authors estimate that one third of total deforestation since 2002 was indirectly driven by increases in soybean exports.

Specifically, for Santarém county, Venturieri et al. 2007 provides detailed assessment of how the county's land change dynamics occurred between 1999 to 2005. Since there was an insignificant number of mechanized enterprises in the region prior to 1999, forest and land use conversions to mechanized agriculture are described after 1999. As shown in Table 2-2, from 1999 to 2005 10.7%, or about 59 km² of forested areas, were converted to cropland. Most conversions to mechanized agriculture from 1999-2005 occurred in areas previously deforested by other activities such as peasant agriculture and cattle ranching. By 2005, 66.7% of the fields under mechanized agriculture came from these two types of land use.

Such changes consequently determined two different but correlated effects. A direct effect was the clearing of remnant forest (secondary forest or capoeira, Table 2-2) present on smallholder properties. Highly capitalized new land owners had the logistics and resources necessary to clear vast extents of areas impractical by smallholders, therefore, aside from agricultural land, 36.5% of contiguous secondary forests were also engulfed from 1999-2005. An indirect effect was the displacement of smallholders, who migrated to the city or to new frontiers on the edge of the region. Those who migrated to the forest occupied unclaimed lands or created new agrarian reform settlement, with consequent deforestation (Figure 2-3).

⁴ I averaged the range obtained by Morton et al. 2006.

SOCIAL IMPACTS AND DYNAMICS

The arrival of mechanized farming in the Santarem region sparked land speculation and contention between soybean interest and smallholders, triggering an exodus of hundreds of families to the urban areas of Santarem and other fronts. According to the Pastoral Land Commission (Comissão Pastoral da Terra-CPT), smallholders dispossessed from their land migrated to other surrounding areas and inevitably entered another race for land, competing with both soybean farmers and other smallholders (Figure 2-3). It has been suggested that about 500 families left behind their old holdings after land sale or coercion on part of land speculators and farming interests (CPT 2005). Local social movements and NGO's, such as the Santarem Smallholders Union or Sindicato de Trabalhadores Rurais de Santarém (STTR), Saúde e Alegria and Greenpeace, have also reported eutrophication of lakes, streams and rivers, a silent ongoing issue resulting from intense use of fertilizers that directly affect wildlife and community livelihoods. Perhaps the worst effect was driven by the massive migration to conflict zones, which became a stage for land clashes among displaced populations (CPT 2005).

CONCLUSIONS

In this paper I discuss the evolution of the agriculture of soybeans in Brazil and its expansion to Amazonia within a broad historical, political and economic context. While technological innovation was key to the shift north, it could have not been done without market incentives and the macroeconomic reforms that followed the liberalization of the Brazilian economy. The expansion of agribusiness into Central Amazonia materialized in the early 2000s with the opening of export ports and transport corridors. I argue that the expansion generated both direct and indirect conversion of forests. I further illustrate indirect forest loss using the Thunian framework. Furthermore, I speculate that broader aspects of the process of soybean agricultural expansion have greatly been overlooked, for example the spatial rearrangement that resulted when less profitable economic activities competed for land with corporate agriculture. Following consolidation of mechanized farming in a region,

displaced activities are reconstituted in hinter lands, generating new deforestation. This was the case of smallholder agriculture in Santarem, in which many households moved to government settlements and resumed deforestation on new land (Figure 2-3).

In Santarem County, agricultural expansion occurred by infilling degraded pasture and parcels traditionally used by smallholders. The local debate about intensive agriculture and its social and environmental impacts opens the way for discussions about appropriate development models for the Amazon with respect to social benefits and environmental sustainability. Despite local debates, the external demand for commodities will probably increase, as will global concerns about the loss of environmental services provided by forests, and the livelihoods of local populations. History often repeats itself. Smallholder displacement is not new in Brazil, and James (1940) introduced the concept of hollow frontiers to describe smallholding consolidation through capitalized coffee farmers in the southern and central parts of the country.

Once displaced, smallholders migrated to other areas, leaving behind a demographically hollow frontier controlled by relatively few wealthy largeholders. This brings into reflection whether or not the current processes of land cover change in the vicinity of Santarem fits into conventional paradigms for explaining environmental change. Under actual circumstances, for example, such changes cannot be interpreted as an externality effect of population growth since population in the Amazon's rural areas has been declining and shifting to urban centers as result of the hollow frontiers phenomena.

Table 2-1. Deforested area converted to mechanized agriculture and area converted to mechanized agriculture from forest reported in literature for three areas.

Study location	Period	Deforested area ^a (km ²)	Area converted to mechanized agriculture ^b	Deforested area converted to mechanized agriculture area (km ²)	Deforested area converted to mechanized agriculture (% of total)	Area converted to mechanized agriculture from forest (% of total)	Source
		(a)	(b)	(c)	(c)/(a)	(c)/(b)	
Mato Grosso State	2001-2004	38,097	16,370	4,670-5,463	12.25-14.34	28.53-33.37	<i>Morton et al.</i> [2006]
Santarém and Belterra, Pará municípios	1975-1986 1986-1997 1997-1999 1999-2004 2004-2005	821 739 419 527 140	0.0 0.0 0.0 544 560	0.00 0.00 0.00 44 15	0.00 0.00 0.00 8.35 10.7	0.00 0.00 0.00 8.09 2.68	<i>Venturieri et al.</i> [2007]
Vilhena Rondônia município	1996-2001	not reported	70.36	15.71 (dense) 14.21 (less dense)	not reported	22 (dense) 20 (less dense)	<i>Brown et al.</i> [2005]

^a Includes parcels deforested for all uses including mechanized agriculture, pastures, and not in production.

^b Includes parcels converted to mechanized agriculture from all land cover including forests, pastures and successional vegetation.

Adapted from Walker, Robert et al. 2009. "The Expansion of Intensive Agriculture and Ranching in Brazilian Amazonia." *Amazonia and Global Change*, 61–81.

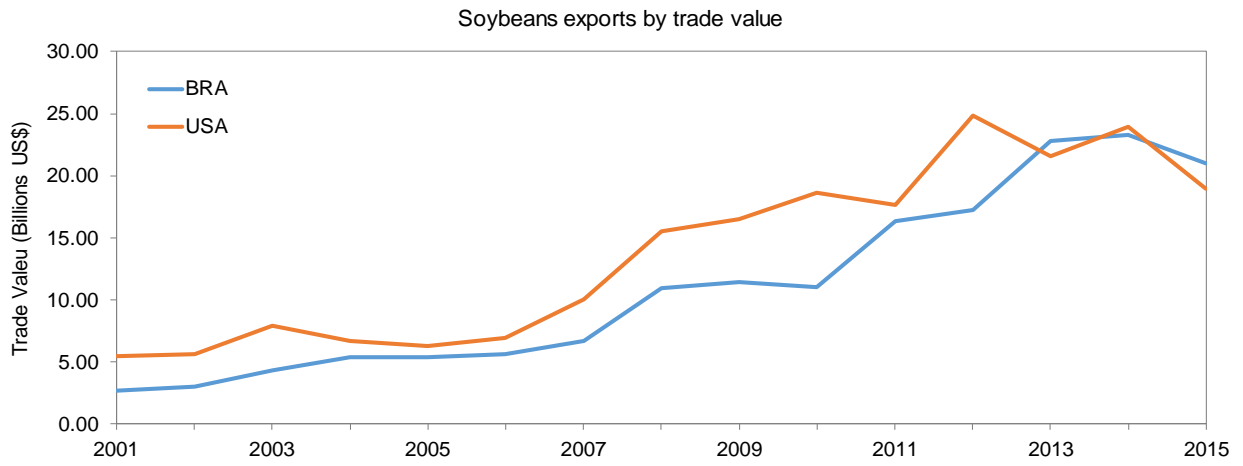


Figure 2-1. Global soybeans exports from Brazil and USA by trade value.

Table 2-2. Land use and land cover change dynamics in Santarém County.

1999-2004		Mechanized agriculture	Pasture	Secondary growth	Cattle ranching
Converted to:					
	Forest	8.00	12.01	13.72	15.43
	Mechanized Agriculture	0.00	0.00	0.00	0.00
	Pasture	15.89	39.06	3.10	7.61
	Secondary growth	24.98	12.20	54.37	23.04
	Cattle ranching	51.14	36.72	28.81	53.93
<hr/>					
2004-2005					
Converted to:					
	Forest	2.71	7.82	2.10	4.88
	Mechanized Agriculture	69.39	6.38	1.06	6.09
	Pasture	0.76	34.80	1.1	5.20
	Secondary growth	11.54	14.09	63.53	18.89
	Cattle ranching	15.60	36.91	32.22	64.94

Adapted from Venturieri, Adriano et al. 2007. "Análise Da Expansão Da Agricultura de Grãos Na Região de Santarém E Belterra, Oeste Do Estado Do Pará." *Simpósio Brasileiro de Sensoriamento Remoto* 13 (2007): 7003–7010.

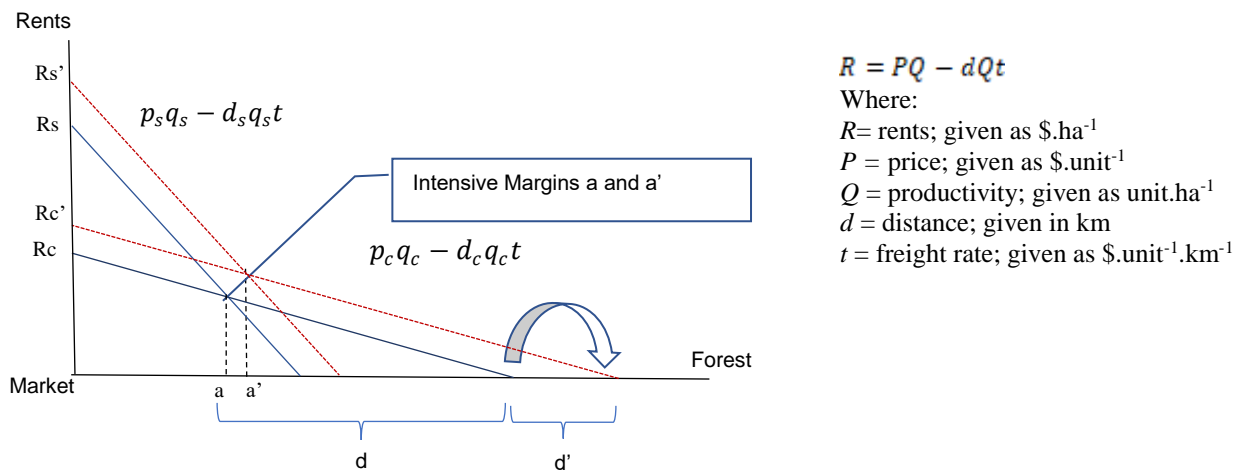


Figure 2-2. ILUC explained with the Von Thunen model.

SOYBEAN'S FOOTPRINT IN AMAZONIA: PAST AND CURRENT TRENDS

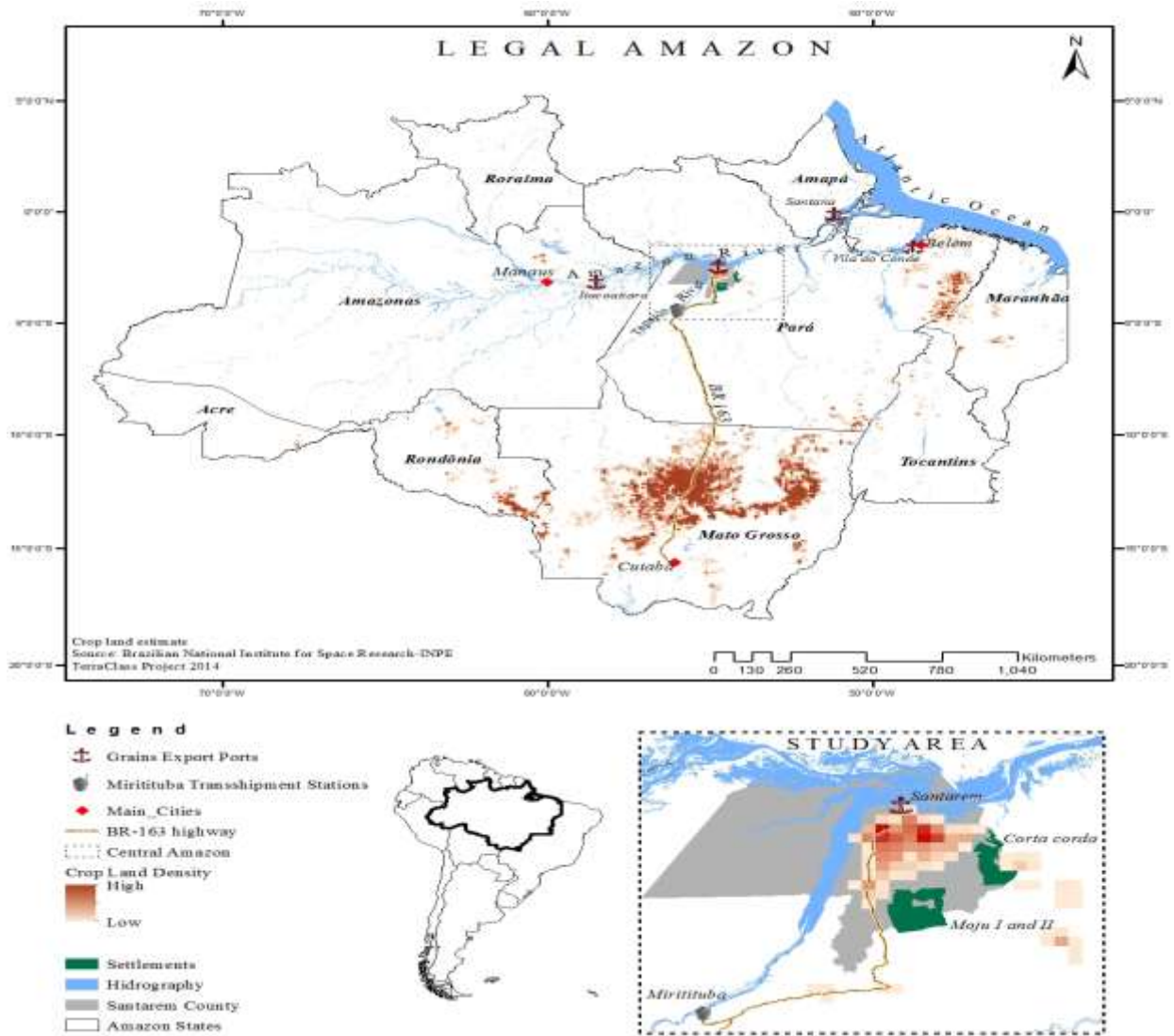


Figure 2-3. Legal Amazon. Featuring soybean crop lands, ports, government settlements and study area.

REFERENCES

- “A História Da Soja - APROSOJA/MT.” Accessed September 16, 2016. <http://www.aprosoja.com.br/soja-e-milho/a-historia-da-soja>.
- Alves, Bruno JR, Robert M. Boddey, and Segundo Urquiaga. “The Success of BNF in Soybean in Brazil.” *Plant and Soil* 252, no. 1 (2003): 1–9.
- “APROSOJA/MT.” Accessed January 22, 2017. <http://www.aprosoja.com.br/>.
- Bickel, Ulrike, and Jan Maarten Dros. “The Impacts of Soybean Cultivation on Brazilian Ecosystems.” Three Case Studies, 2003. http://commodityplatform.org/wp/wp-content/uploads/2007/09/05_impacts_of_soy_bean_cultivation_on_brazilian_ecosystems3.pdf.
- Brown, J. Christopher, Matthew Koeppe, Benjamin Coles, and Kevin P. Price. “Soybean Production and Conversion of Tropical Forest in the Brazilian Amazon: The Case of Vilhena, Rondonia.” *AMBIO: A Journal of the Human Environment* 34, no. 6 (2005): 462–469.
- Canuto, Otaviano, and others. “The Commodity Super Cycle: Is This Time Different?” *Economic Premise* 150 (2014). http://www.traderiskconsulting.com/s/CS_Commodity-Super-Cycle-0614.pdf.
- “Centro de Estudos Avançados Em Economia Aplicada - CEPEA/ESALQ/USP.” Accessed September 17, 2016. <http://cepea.esalq.usp.br/soja/>.
- “Doc275-P64.Pdf.” Accessed January 21, 2017. <http://ainfo.cnptia.embrapa.br/digital/bitstream/item/82270/1/Doc275-p64.pdf>.
- “Download Trade Data | UN Comtrade: International Trade Statistics.” Accessed September 17, 2016. <http://comtrade.un.org/data/>.
- “Drought Sensitivity of the Amazon Rainforest | Science.” Accessed September 23, 2016. <http://science.sciencemag.org/content/323/5919/1344.full#otherarticles>.
- “Embrapa Cerrados.” Accessed September 18, 2016. <http://www.cpac.embrapa.br/unidade/historia/>.
- Erten, Bilge, and José Antonio Ocampo. “Super Cycles of Commodity Prices since the Mid-Nineteenth Century.” *World Development* 44 (2013): 14–30.
- “Exchange Rates, Soybean Supply Response, and Deforestation in South America - 1-S2.0-S0959378012000167-Main.Pdf.” Accessed September 26, 2016. http://ac.els-cdn.com/S0959378012000167/1-s2.0-S0959378012000167-main.pdf?_tid=ed67029e-841b-11e6-9871-00000aab0f02&acdnat=1474916796_b9f3de734ce988f08bd289a336d12961.
- “Export Sales Query System.” Accessed September 17, 2016. <http://apps.fas.usda.gov/esrquery/esrq.aspx>.
- “FAOSTAT.” Accessed September 17, 2016. <http://fenix.fao.org/faostat/beta/en/#home>.

Fearnside, Philip M. "Deforestation in Brazilian Amazonia: History, Rates, and Consequences." *Conservation Biology* 19, no. 3 (2005): 680–688.

Gallagher, Kevin, and Roberto Porzecanski. *The Dragon in the Room: China and the Future of Latin American Industrialization*. Stanford university press, 2010. https://books.google.com/books?hl=en&lr=&id=WgBh_SvQKJkC&oi=fnd&pg=PR5&dq=Gallagher+and+Porzecanski+2010&ots=P5zzBs4ee5&sig=YUKIUK9_iGBwhjgVw6iHPfSfdm0.

Helfand, Steven M., and Edward S. Levine. "Farm Size and the Determinants of Productive Efficiency in the Brazilian Center-West." *Agricultural Economics* 31, no. 2–3 (2004): 241–249.

Kemper, B., and R. Derpsch. "Results of Studies Made in 1978 and 1979 to Control Erosion by Cover Crops and No-Tillage Techniques in Paraña, Brazil." *Soil and Tillage Research* 1 (January 1, 1980): 253–67. [https://doi.org/10.1016/0167-1987\(80\)90028-8](https://doi.org/10.1016/0167-1987(80)90028-8).

Morton, Douglas C., Ruth S. DeFries, Yosio E. Shimabukuro, Liana O. Anderson, Egidio Arai, Fernando del Bon Espirito-Santo, Ramon Freitas, and Jeff Morissette. "Cropland Expansion Changes Deforestation Dynamics in the Southern Brazilian Amazon." *Proceedings of the National Academy of Sciences* 103, no. 39 (2006): 14637–14641.

Nepstad, Daniel, David McGrath, Claudia Stickler, Ane Alencar, Andrea Azevedo, Briana Swette, Tathiana Bezerra, et al. "Slowing Amazon Deforestation through Public Policy and Interventions in Beef and Soy Supply Chains." *Science* 344, no. 6188 (2014): 1118–1123.

Nepstad, Daniel, Britaldo S. Soares-Filho, Frank Merry, André Lima, Paulo Moutinho, John Carter, Maria Bowman, et al. "The End of Deforestation in the Brazilian Amazon." *Science* 326, no. 5958 (2009): 1350–1351.

"OECD - Brazil (BRA) Exports, Imports, and Trade Partners." Accessed September 17, 2016. <http://atlas.media.mit.edu/en/profile/country/bra/>.

Peet, J. Richard. "The Spatial Expansion of Commercial Agriculture in the Nineteenth Century: A von Thunen Interpretation." *Economic Geography* 45, no. 4 (1969): 283–301.

Press, Stanford University. "The Dragon in the Room: China and the Future of Latin American Industrialization | Kevin P. Gallagher and Roberto Porzecanski." Accessed September 23, 2016. <http://www.sup.org/books/title/?id=20122>.

Richards, Peter D., Robert J. Myers, Scott M. Swinton, and Robert T. Walker. "Exchange Rates, Soybean Supply Response, and Deforestation in South America." *Global Environmental Change, Adding Insult to Injury: Climate Change, Social Stratification, and the Inequities of Intervention*, 22, no. 2 (May 2012): 454–62. <https://doi.org/10.1016/j.gloenvcha.2012.01.004>.

Richards, Peter D., Robert T. Walker, and Eugenio Y. Arima. "Spatially Complex Land Change: The Indirect Effect of Brazil's Agricultural Sector on Land Use in Amazonia." *Global Environmental Change* 29 (November 2014): 1–9. <https://doi.org/10.1016/j.gloenvcha.2014.06.011>.

“Rolf Derpsch: Historical Review.” Accessed September 17, 2016. <http://www.rolf-derpsch.com/en/no-till/historical-review/>.

Santana, José Carlos Cruz Ramon Costa Alvarenga Joao Herbert Moreira Viana Israel Alexandre Pereira Filho Manoel Ricardo de Albuquerque Filho Derli Prudente. “Plantio Direto.” Accessed January 22, 2017. http://www.agencia.cnptia.embrapa.br/gestor/milho/arvore/CONTAG01_72_59200523355.html.

“Sistema IBGE de Recuperação Automática - SIDRA.” Accessed September 17, 2016. <http://www.sidra.ibge.gov.br/bda/tabela/protabl.asp?c=1612&z=p&o=30&i=P>.

“Sistema IBGE de Recuperação Automática - SIDRA.” Accessed January 22, 2017. <https://sidra.ibge.gov.br/Tabela/1612>.

“Spatially Complex Land Change: The Indirect Effect of Brazil’s Agricultural Sector on Land Use in Amazonia - 1-S2.0-S0959378014001162-Main.Pdf.” Accessed September 26, 2016. http://ac.els-cdn.com/S0959378014001162/1-s2.0-S0959378014001162-main.pdf?_tid=f72bd228-841b-11e6-b13b-00000aacb35d&acdnat=1474916812_2d4a1480fe8178932a6635b66b0f97bf.

Spehar, Carlos R. “Impact of Strategic Genes in Soybean on Agricultural Development in the Brazilian Tropical Savannas.” *Field Crops Research* 41, no. 3 (1995): 141–146.

Tecnologia, Imagenet. “Consultas ao Banco de Dados do Site - Centro de Estudos Avançados em Economia Aplicada - CEPEA-ESALQ/USP.” *Desenvolvimento de Sites*. Accessed January 22, 2017. <http://www.cepea.esalq.usp.br/br/consultas-ao-banco-de-dados-do-site.aspx>.

The Observatory of Economic Complexity, OEC. “Countries That Export Soybeans (2014).” *The Observatory of Economic Complexity*. Accessed January 22, 2017. http://atlas.media.mit.edu/en/visualize/tree_map/hs92/export/show/all/1201/2014/.

“Trade Map - List of Importing Markets for the Product Exported by Brazil in 2015.” Accessed September 17, 2016. http://www.trademap.org/Country_SelProductCountry.aspx.

“What Drives Deforestation in the Brazilian Amazon? - MITJPSPGC_Rpt16.Pdf.” Accessed September 19, 2016. http://dspace.mit.edu/bitstream/handle/1721.1/3633/MITJPSPGC_Rpt16.pdf.