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Soy Story: Deforestation in Brazil

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EXECUTIVE SUMMARY

Background: Soy production has led to deforestation in multiple regions of Brazil, including the states of Mato Grosso and Pará. A combination of laws, such as the Forest Code (1965), and voluntary agreements, such as the Soy Moratorium (2006), have been implemented to slow the rate of deforestation due to soy production in the Amazon. Although the overall deforestation rate has declined in Brazil from 2004 to 2013, it has increased along the BR-163 highway, also known as the “Soy Corridor.”¹ Our research examines each stage in the agro-industrialization of soy from harvest to transportation and, finally, to processing and export to determine which factors within this process have the greatest impact on deforestation and change in local community structure.

Purpose: This project seeks to quantify the effects of soy production, including cultivation, transportation, and processing, on deforestation and ecosystem services in Mato Grosso and Pará, a key region for the cultivation and transport of soy. We also investigated the public health and social development in communities that are involved in processing soy. Variables investigated include the annual deforestation rate and soy production in Mato Grosso, public health and social development measures in the Santarém municipality, and ecosystem services provided by tropical rainforest, among others.

Methodology: We analyzed annual soy production and deforestation in Mato Grosso and Pará between 2001 and 2015 to develop a fixed effects model to find the contribution of soy production to deforestation. The primary explanatory variable is soy production with three dependent variables: deforestation per year, aggregated deforestation, and area cultivated for soy. Data was also collected to assess for changes in public health, social development, and municipal development related to the introduction of a soy processing plant in Santarém, Pará from 1993 to 2013.

¹ Branford, Sue, and Mauricio Torres. “Getting There: The Rush to Turn the Amazon into a Soy Transport Corridor.” *Conservation News*, MongaBay, 5 Apr. 2017, news.mongabay.com/2017/02/getting-there-the-rush-to-turn-the-amazon-into-a-soy-transport-corridor/.

Results: Cumulative deforestation trends reveal that 18 million hectares of tree covered land is cleared in Brazil every year. Our research findings suggest that deforestation is occurring in place of reusing previously cleared land for agriculture. The fixed regression analysis shows that a one metric ton increase in soy production is associated with 1.15 hectares of additional deforestation, even though only 0.23 hectares of additional farmland is required to produce that amount of soy; the discrepancy is hypothesized to be due to the impact of developing transportation corridors to ports and processing hubs.

Limitations, and Implications, and Future Research: A lack of available data on public health, social development, and municipal development in Santarém limited analysis on the social and health issues; more research is necessary for conclusions to be reached in those areas. The discrepancy between amount of land needed for a unit of soy production and the actual amount deforested, as predicted by the model, suggests a need for developing more sustainable alternatives to the current method of soy production. The information gathered and analyzed in this report can also be used to lay groundwork for other research groups or organizations to understand deforestation from a quantitative lens and integrate this into the story of the impacts of soy production to local communities and ecosystems.

INTRODUCTION

Soy Demand

Originally from East Asia, soybean, otherwise known as soy or soya, is an edible bean. Most cultivated soy (85 percent) is processed for oil and soybean meal, while only a small percent (6 percent) is used for human consumption. Soy is grown around the world due to its high profitability. Demand for soy is driven by growing and emerging economies to meet demands for animal consumption. Global soybean cultivation has expanded from 27 to 269 million metric tons in the last 50 years; the United Nations predicts that soy production will more than double by 2050.²

² The Growth of Soy: Impacts and Solutions. 2014. WWF International, Gland, Switzerland.

Soy has undergone the greatest expansion of any global crop, threatening forests, and natural ecosystems.³ Many parts of the production process degrade ecosystems. Industrial harvesting requires land clearing. Soy processing contributes to deforestation and results in the displacement of local communities.

Brazil

This project seeks to quantify the effects of soy production on deforestation in two key states in Brazil. We analyzed the key drivers and impact of deforestation in the states of Mato Grosso and Pará. Mato Grosso, literally translating to ‘Thick Bush’, is a large state in the central portion of the country with three different ecosystems. Mato Grosso is the largest soy producing state in Brazil and has seen dramatic increases in its output of soy production in recent years. Northeast of Mato Grosso is the state of Pará. To meet global demand, a soy processing plant was strategically built in the city of Santarém, Pará. Santarém encompasses many tributaries to the Amazon River, which flows to the Atlantic Ocean, where a port was built in Belem, Pará to export soy. Together, the route between Mato Grosso to Santarém is called the “Soy Corridor.”

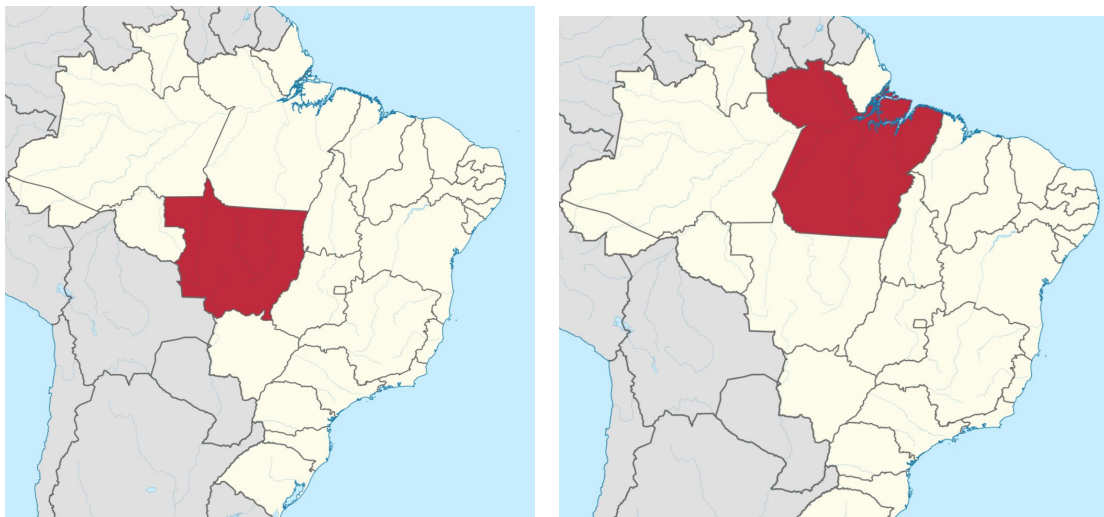


Figure 1. The states of Mato Grosso (left) and Pará (right) are facing significant amounts of deforestation due to the production of soy. Image source: Wikipedia, creative commons.

³ ibid

In 1997, Brazil's economy had recently been restructured by the International Monetary Fund (IMF) to pay back its mounting debt. The IMF mandated that Brazil increase its export income and foreign investments. The Brazilian Agricultural Research Corporation (EMBRAPA) investigated the feasibility of growing soy in the area around Santarém, Pará. EMBRAPA's research revealed that there was great potential for soy in the Santarém region due to a favorable climate and the proximity of the Amazon River shipping route.⁴ Given the findings of this report, the local government concluded that soy was a more profitable use of land than the status quo of small-scale family farming. The focus on soy as a development strategy in Santarém led to many infrastructural and institutional changes that brought a soy processing facility and export port, as well as a wave of soy farmers moving into the region.⁵ The state decided to focus its efforts on agro-industrial development, specifically soy production, to achieve the goals of exports and foreign investments.⁶

Deforestation and Soy

Soy production has led to deforestation in multiple regions of Brazil, especially in the *Cerrado*, the tropical savanna ecoregion in Mato Grosso. In the last two decades, more than 60 percent of the *Cerrado*'s 200-million hectares has been cleared for agriculture.⁷ The cultivation of soy requires clearing forests for farmland and the transportation of soy requires the construction of additional transportation infrastructure, including highways and railways. In 2004 to 2005, Brazil had the highest rates of deforestation in the world. Today, the total area of deforested land continues to increase despite reductions in the rate of deforestation in the last decade. As the world's second-largest producer, soy is a significant export commodity for Brazil. As the price of

⁴ Schoneker, Jake. "'Sustainable Soy' in Santarém: Power Struggles for the Future of Development" (2007). Independent Study Project (ISP) Collection. 249.
http://digitalcollections.sit.edu/isp_collection/249

⁵ Theis, Sophie, and Briana Swette. "Between Discourses of Extreme Pressure and Modernization: Small Farmers' Diverse Perceptions of Vulnerability to Soy in Santarém, Pará." *Consilience: The Journal of Sustainable Development*, vol. 8, no. 1, 2012, pp. 200–218.

⁶ Steward, Corrina. "From colonization to 'environmental soy': A case study of environmental and socio-Economic valuation in the Amazon soy frontier." *Agriculture and Human Values*, vol. 24, no. 1, 2007, pp. 107–122., doi:10.1007/s10460-006-9030-4.

⁷ Pearce, Fred. "The Cerrado: Brazil's Other Biodiverse Region Loses Ground" (2011). *YaleEnvironment360*.
http://e360.yale.edu/features/the_cerrado_brazils_other_biodiversity_hotspot_loses_ground

soy rises and demand surges, soy production will continue to drive deforestation, increased land usage, and the loss of ecosystems.

METHODOLOGY

Primary Research

We analyzed annual soy production and deforestation by developing a fixed effects model to find the contribution of soy production to deforestation. We used time and state as variables to control for observable and unobservable fixed effects. The primary explanatory variable is soy production, with three dependent variables: deforestation per year, aggregated deforestation, and area cultivated for soy.

We built a quantitative model including data from all 27 states in Brazil between 2001 to 2015 to find the association of soy and deforestation.⁸ The variable deforestation is defined variable as the net area of hectares of trees cut (hectares of trees cut minus hectares of trees grown, if any) in each state within a year.

Regression Analysis

We conducted a regression analysis on the number of units of soy produced as it relates to deforestation. The main explanatory variable was soy production and the three dependent variables we used were: deforestation per year, aggregated deforestation, and area planted. We used a bivariate regression model and then a fixed effects regression model. We used time and state to control for observable and unobservable fixed effects.

Bivariate Regression: $Y = \alpha + \beta X$

Equation: $Deforestation_{perYear} = \alpha + \beta Production$

This is the base equation to find association of production and deforestation. The concerned value in the equation is β , which is the coefficient of the variable production. The value of β

⁸ Data available on-line from: <http://earthenginepartners.appspot.com/science-2013-global-forest>.

describes the direction and the magnitude of association of soy production on deforestation. Similarly, we can calculate association for other dependent variables.

$$\text{Fixed Effect Model: } Y = \alpha + \beta_1 X_{it} + \beta_2 Z_i + B_3 S_t$$

$$\text{Equation: } \text{Deforestation}_{perYear} = \alpha + \beta_1 \text{Production}_{it} + \beta_2 \text{State}_i + B_3 \text{Year}_t$$

The above equation is a general form of time and states fixed effects model. The concerned value in this equation is of β_1 which is the coefficient of the variable production controlling for time and states fixed effects. This model reduces the omitted variable bias to give more accurate estimates.

Secondary Research

Secondary research was conducted to understand the current body of literature concerning the intersection of soy and deforestation, how to value of natural resources, the impacts of soy production on our geographical region of study, and the current regulatory environment in Brazil. To analyze the impacts of soy production in Santarém, data was collected from the Brazilian Institute of Geography and Statistics (IBGE), which compiled census information from 2000 and 2010, as well as from Santarém's Municipal Center for Environmental Studies (CIAM), which released reports in 2008 and 2013 containing information covering many social development and public health indices over a period of several years.^{9,10,11}

To analyze the quantitative measures on Santarém, an initial attempt was made to sample data on municipal developments, social developments, and public health in Santarém.

⁹ Brazil. Municipal Center of Environmental Information - CIAM. *Santarém Statistics*. Comp. Tania Mara Moraes Amazonas. 2008. Print.

¹⁰ *ibid*

¹¹ Cidades@IBGE (Instituto Brasileiro de Geografia e Estatística). (2013). Retrieved 2017, from https://ww2.ibge.gov.br/cidadesat/xtras/perfil.php?lang=_EN&codmun=150680&search=Pará%25257CSantarém

KEY FINDINGS OF QUALITATIVE ANALYSIS

Impact on Ecosystems

A significant impact of the soy trade is the loss of ecosystems due to the conversion of land from forests to soybean agriculture, which is reflected in the large decrease in land value for soybean areas relative to forests.

Transporting crops requires new railways and highways which open access to new areas of forest vulnerable to exploitation and deforestation. Ultimately, the continued growth in demand for soy will continue to drive land usage, contribute to deforestation, loss of ecosystems, and global warming.

Valuing Ecosystem Services for Different Land Uses

Quantitatively measuring the value of an ecosystem can be done by assigning a value to the benefits humankind derives from an ecosystem in its natural state, also known as ecosystem services. Ecosystem services include provisioning services such as water and timber; regulating services such as flood mitigation and water quality, cultural services such as tourism and cultural value, and supporting services such as nutrient cycling.¹² Although provisioning services can be specifically calculated, economists have a more challenging time to derive a value for hydrological and cultural services. The values of different ecosystem types can range greatly; tropical forests offer a range of ecosystem services and have a high value, while cultivated land, such as soybean, offer few ecosystem services.

Due to the challenges of assigning values to ecosystem services, values from one study to another can vary dramatically. Therefore, the most reliable method is to compare land use values calculated from the same study with consistent methodology.

A significant impact of the soybean trade is the loss of ecosystem services due to the conversion of land from tropical forests to soybean agriculture, which is reflected in the large

¹² MEA (2005) Millennium ecosystem assessment synthesis report. In: Reid W (ed) Island Press, Washington.

decrease in land value for soybean areas relative to tropical forests. Boerema, et al. found that tropical forests have a large range of economic values with a mean value of approximately \$17,500 per hectare per year, while the value of soybean areas is significantly less; approximately \$3,500 per hectare per year (both values in in 2008 US dollars).¹³

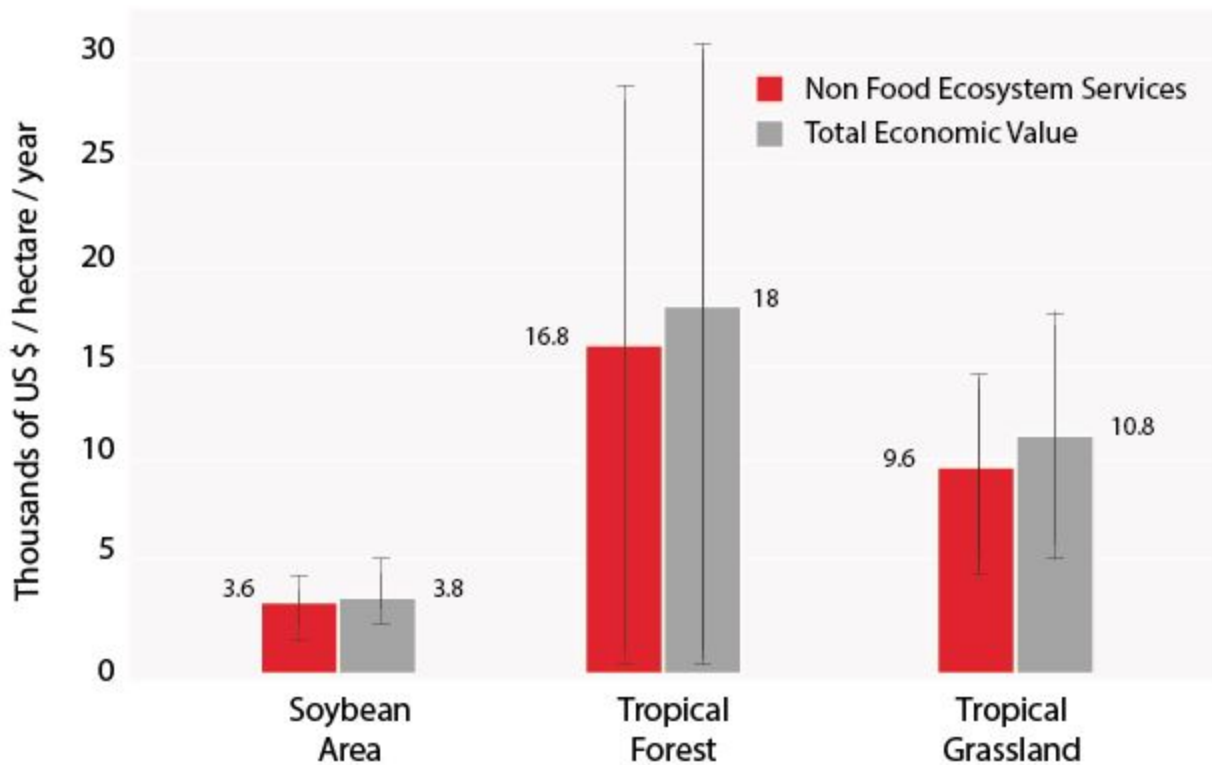


Figure 2. Ecosystem Services and Total Economic Value for different land-uses.¹⁴

The loss of ecosystem services can lead to economic losses, such as the loss of timber and tourism, that do not directly impact the multinational corporations, but can have a significant impact on local communities and the environment. However, the most significant losses are the environmental benefits, such as the regulating services that forests provide. Forests help stabilize soil to limit the loss of topsoil and the flow of sediment, as well as reducing the velocity of floodwaters and providing more area for water to soak into the soil. The loss of flood mitigation and erosion control services significantly affects nearby farming and settlements. A

¹³ Boerema, Annelies, et al. "Soybean Trade: Balancing Environmental and Socio-Economic Impacts of an Intercontinental Market." *PloS one* 11.5 (2016): e0155222.

¹⁴ Chart adopted from figure in Boerema, Annelies, et al. "Soybean Trade: Balancing Environmental and Socio-Economic Impacts of an Intercontinental Market." *PloS one* 11.5 (2016): e0155222.

study performed in the state of Pará explored the effects of deforestation on evapotranspiration and water flow rates and found that the length of the dry-season increased due to deforestation and the peak amplitude of water flows increased.¹⁵

The economic and ecosystem services valuation of forests also depends on the scarcity and location of forests. The ecosystem services of a patch of forest surrounded by small towns are more valuable than the ecosystem services offered by a more remote patch of forest. There is a currently undefined hyperbolic relationship, as shown below, between economic value of forests and remaining forest area. Similarly, as soybean increases in value and accessible land for cultivation decreases, there will be further motivation to clear land, despite the increasing value of the ecosystem services of a diminished forest.

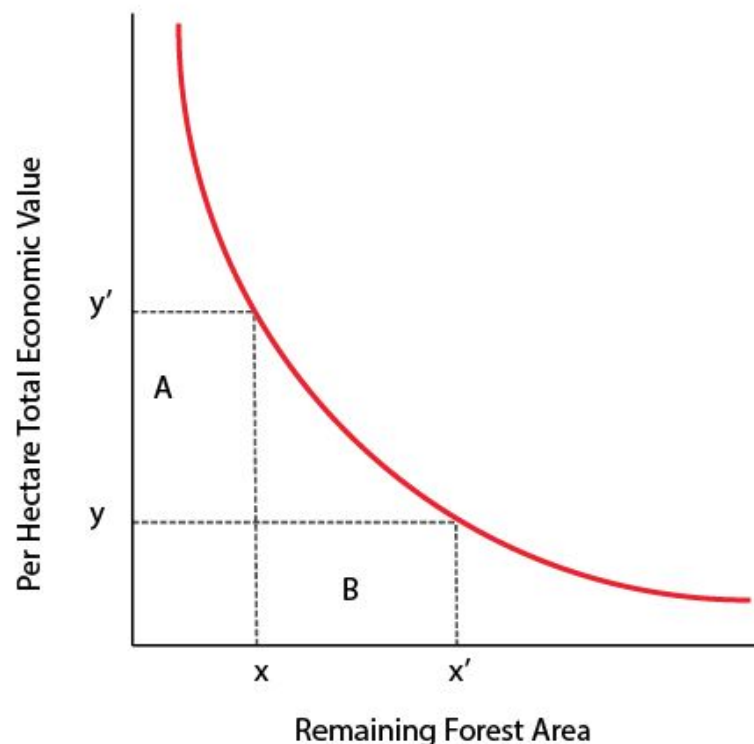


Figure 3. Theoretical curve showing relationship between the Total Economic Value of forests relative to the quantity of forest area remaining.¹⁶

¹⁵ Davidson, Eric A., et al. "Effects of soil water content on soil respiration in forests and cattle pastures of eastern Amazonia." *Biogeochemistry* 48.1 (2000): 53-69.

¹⁶ Torras, Mariano. "The total economic value of Amazonian deforestation, 1978–1993." *Ecological economics* 33.2 (2000): 283-297.

Tragedy of the Commons

Despite the clear value of ecosystem services, this value does not correlate to land-use values because profit cannot be directly derived from “public good” services such as flood mitigation.

These services cannot be easily traded on the open market, which means they have little to no value to many corporations, resulting in poor utilization under valuation of the ecosystems.¹⁷

Mann, M.L., et al. recommend utilizing a land conversion tax in Brazil due to feasibility in implementation and maximizing social benefits. They recommend assigning conversion taxes based on an assigned economic value derived from the point at which the economic benefits are equal to the damages created by the land use. While this strategy maximizes value and land use efficiency on a larger scale, it does ignore the consideration that often ecosystem services are of great value to local communities, while foreign corporations may realize significant benefits from the destruction of ecosystems.

Soy Production and Compounding Deforestation

The land use impact of soybean agriculture is not limited to the deforestation caused by clearing land for growing and processing soybean. To access fertile soy production land, roads are built through previously untouched forests. This expanding transportation network and clear cutting further promotes deforestation. Bonnie, et al. found that “road building has been the underlying cause of increased deforestation in the Brazilian Amazon since the 1970s.” The authors explored the links between development, transportation infrastructure, and deforestation and found that in one study, 90 percent of new clearing was within 25 kilometers of previously cleared areas and 74 percent occurred within 50 kilometers of major roads.¹⁸

This evidence explains the compounding effect of the soybean area. As more land is cleared for soybeans and infrastructure is constructed for transporting that soybean, surrounding forests are vulnerable due to increased accessibility. This also increases the profitability of other activities supported by deforestation, such as unsustainable logging.

¹⁷ Mann, M. L., Kaufmann, R. K., Bauer, D. M., Gopal, S., Baldwin, J. G., & Del Carmen Vera-Diaz, M. (2012). Ecosystem service value and agricultural conversion in the Amazon: implications for policy intervention. *Environmental and resource economics*, 1-17.

¹⁸ Bonnie, Robert, et al. "Counting the cost of deforestation." *Science* 288.5472 (2000): 1763-1764.

Expansion of Transportation Infrastructure to Support Soy Industry

Federal Highway BR-163

Destruction of the Amazon is directly pointed to the supply chain and production capacity in Belem, Pará's port-terminal. BR-163 is a federal highway, connecting the center of soy production in Mato Grosso to Santarém, Pará, that was built in 1972 as an initiative by the Brazilian government to integrate Amazonia with the rest of Brazil. This highway is integral to the regional and national economy as it decreases the distance soy must travel from Mato Grosso to northern ports by nearly 1,000 kilometers, greatly reducing the cost and time to transport to the international market. Brazil's transportation department, known as DNIT, communicated delays in paving of BR-163 due to contract dilemmas. A 97-kilometer stretch of the BR-163 remains unpaved in 2017, mostly in Pará, making transport of soy to Santarém and the Amazon waterway virtually infeasible during rainy seasons. The launch of the Pluriannual Plan of 2000 to 2003 by the Brazilian government came with the promise that the remainder of BR-163 would be paved to facilitate soy transport to the port-terminal in Santarém. The road was scheduled to be paved by 2012, and then by 2015, but is now anticipated to be completed by December of 2018.¹⁹ This causes a significant bottleneck in processing and production and increases costs of transportation; as high as three times the amount to transport soy in the United States.²⁰ This brings major challenges and rising costs for farmers, drivers, and producers.

¹⁹ Freitas, Tatiana, 2017.

²⁰ Alencar, Ane A.C. "Roads, conservation and governance: lessons from the BR-163 regional planning process." *IPAM Amazonia*, IPAM, 2008, ipam.org.br/bibliotecas/roads-conservation-and-governance-lessons-from-the-br-163-regional-planning-process/. Accessed 2017.

According to the Brazilian Meteorological Institute, the average monthly rainfall increases from 18 to 30 centimeters in the Itaituba municipality, which is on route to the port city of Santarém.²¹ This makes roadway conditions extremely treacherous on unpaved road.

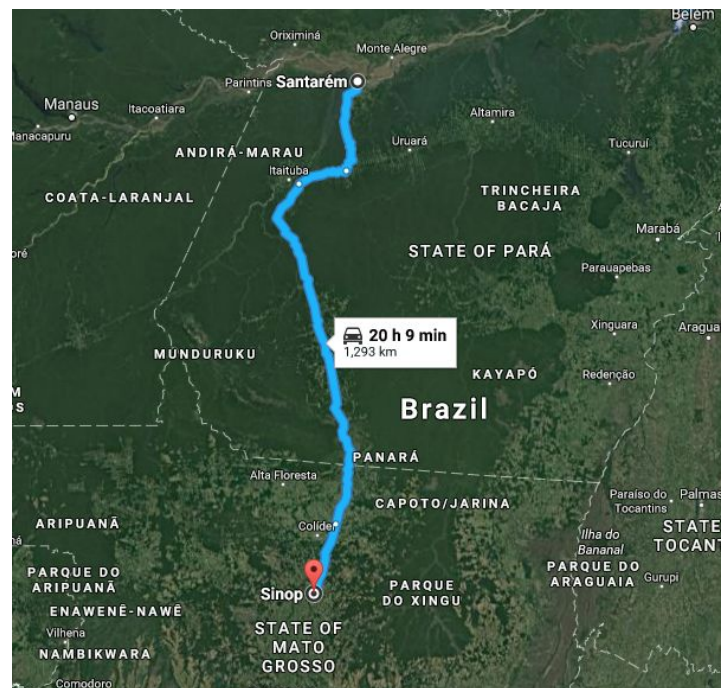


Figure 4. A map of BR-163 (known as the “Soy Corridor”) from Sinop, Mato Grosso, thru Itaituba, to Santarém, Pará. Source: Google Maps, November 15, 2017.

While infrastructure challenges such as transportation during the rainy season remain, Brazil still rivals the U.S. as an agricultural superpower. Major corporations that sell commodities see Brazil as an underutilized market with vast undeveloped land.

²¹ Freitas, Tatiana. “Mired in Mud, Brazil’s Unpaved Roads Delay Farming Promise.” Bloomberg, January 3, 2017
<https://www.bloomberg.com/news/articles/2017-01-04/mired-in-mud-brazil-s-unpaved-roads-delay-agricultural-promise>



Figure 5. A paved section of BR-163 runs North-South through Sinop in Mato Grosso. This region was previously tropical rainforest and has now been significance of BR-163 leading to Santarém, Pará. Source: Google Maps, November 15, 2017.

Corporate Initiated Railway

As a result of infrastructure delays, more companies are decreasing their reliance on the Brazilian government for soy production. Trading companies are planning to build and operate a railway that would run from Sinop, a soybean-growing region in Mato Grosso, to Itaituba, a key economic hub in Pará. The grains will then be dumped into barge fleets and hauled to different ports in the north. The 1,125-kilometer railway is estimated to cost \$4.5 billion and will take 12 years to complete.²²

²²Freitas, Tatiana “Mired in Mud, Brazil’s Unpaved Roads Delay Farming Promise.” Bloomberg, January 3, 2017
<https://www.bloomberg.com/news/articles/2017-01-04/mired-in-mud-brazil-s-unpaved-roads-delay-agricultural-promise>

Community Impacts of Industrialized Soy Production

Santarém

Santarém, located at the confluence of the Tapajós and Amazon rivers, has played an important role in the exploration and development of the Lower Amazon meso-region. The city includes 25 municipalities and is home to 295,000 inhabitants; 73 percent of which are classified as urban.²³ The GDP of Santarém primarily comes from commercial activities, industrial production, and commercial agro-pastoral activities. Family farming and low-intensity cattle ranching have historically played a considerable role in the local economy, providing fresh food for local markets. There has been a recent decline in family farming due to the expansion of soybean farming in the early 2000s.²⁴ The area surrounding Santarém is the only region in the state of Pará with soy production and the first concentration of commercial agricultural production in the middle of the Amazon basin.²⁵

Although the official process of incorporating soy production into local development occurred in the mid-1990s, the socioeconomic and environmental conditions that allowed the region to support soy production are due to the Brazilian government's colonization projects that began in the 1960s.²⁶ Agrarian reform projects of the 1960s led to the creation of a large network of roads into the Amazon, resulting in thousands of families moving into Amazonia in the hopes of economic opportunities that the urban centers closer to the coast could not provide. During this period, Santarém's population nearly doubled as waves of '*colonos*' arrived to settle the surrounding rural areas.²⁷

In 1970, the Brazilian government created the Institute of Colonization and Agrarian Reform (INCRA) to further facilitate the migration to and development of the Amazon Basin to boost the country's economic performance. INCRA was designed to help families secure land ownership

²³Cidades@IBGE (Instituto Brasileiro de Geografia e Estatística). (2013). Retrieved 2017, from [https://ww2.ibge.gov.br/cidadesat/xtras/perfil.php?lang=_EN&codmun=150680&search=para%25257CSa ntarem](https://ww2.ibge.gov.br/cidadesat/xtras/perfil.php?lang=_EN&codmun=150680&search=para%25257CSa%20ntarem)

²⁴ De Castro, Fabio, et al. "Santarem, Brazil (Re)Introducing the commons: Implementation of Agro-Extractive Settlements in the Lower Amazon Floodplain." 2010, UCLG Inclusive Cities Observatory.

²⁵ Theis, Sophie, and Briana Swette.

²⁶ Steward, Corrina.

²⁷ Schoneker, Jake.

in their new homes, but due to lack of resources and oversight, private migration outside of the purview of INCRA led to a rise in illegal ownership. Controversy over land ownership in the Santarém municipality has only gotten worse over the years and is currently influencing the current conflict between *colonos* and potential soy plantation owners.²⁸

Lack of government support from INCRA, as well as difficulties growing crops in the nutrient-poor Amazon soil, led many families to either move into local cities, making them more densely populated, or move deeper into the forest, clear-cutting massive amounts of forest to grow rice, beans, and corn. The construction of the BR-163 highway connecting Santarém to Mato Grosso in 1995 only served to bring about more relocation and development to the area, setting the scene for soy to enter and radically alter the Santarém economy.²⁹

The Development of BR-163 Highway

The announcement of intended paving of BR-163 lead to massive migration to Santarém and the surrounding cities and villages in anticipation of work opportunities in the region. The increase in population has led to intensified conflicts over land and resources, creating a polarization between local traditional communities opposing the paving of BR-163 and the private sector, which welcomed the development. Social organization began to develop in response to these rapid changes, and in 2003, grassroots citizens groups met with the local representatives over the course of four regional meetings with the objective of creating a development platform based on a list of governance priorities for the BR-163 region near the highway to be paved. The outcome of these meetings was a proposal for the sustainable development of BR-163 and the surrounding communities called the “Letter of Santarém”, which was given to the Ministers of the Environment and National Integration for implementation; the outcome of this action could not be determined. As of May 2016, there have been a multitude of first-hand reports of deforestation, community displacement and conflicts in the areas surrounding this controversial highway.³⁰

With Santarém’s location at the crossroads of the Amazon and BR-163, it was chosen as the site for a large soy processing plant and port facility, which was completed in 2003.

²⁸ Schoneker, Jake.

²⁹ *ibid*

³⁰ Alencar, Ane A.C.

Industrialized Soy Production

In the late 1990s, the Santarém local government decided to expand its port due to the increase of soy production in the region and the anticipation of soy traffic via the Amazon. A major soy exporter won the contract and began construction a grain terminal and soy processing port on the Tapajós River.³¹ Completion of the BR-163 highway would save producers up to 27 USD per metric ton of soy in processing costs compared to the current alternative of transporting soy solely over land to coast cities such as Paránagua and Santos in southern Brazil.^{32,33}

However, in 1999, the Santarém Federal Court ordered the exporter to halt construction of the terminal until an Environmental Impact Assessment (EIA) addressing the direct and indirect impacts of the opening of the port has been completed. The exporter was able to appeal the decision and continued construction, completing the project in 2003.³⁴ Beginning in June 2003, the exporter began exporting soy to the European Union, Japan, China, and the United States for livestock feed and human consumption. By the end of 2003 approximately 200 agro-industrial farms were producing soy in the Santarém region.³⁵ Soy producers from Mato Grosso were also actively being recruited by Santarém officials to the area with the promise of cheap land and a guaranteed buyer.³⁶

After 2003, the Federal Tribunal and Supreme Court ordered the exporter to halt processing multiple times due to operating illegally without an approved EIA; each time, they appealed the decision and were allowed to continue production in the interim.³⁷ Finally, in February 2007, the Federal Public Ministry ordered the immediate closure of the terminal port until the EIA was submitted. However, the port and processing facility reopened in 2012 and has been functioning ever since, despite the opposition of multiple environmental organizations, local government

³¹ Theis, Sophie, and Briana Swette.

³² "The impact of the Cargill soybean terminal in the Amazon town of Santarém." *DSC Publications*, Dutch Soy Coalition, 2008, 141.105.120.208/dsc/wp-content/uploads/2014/04/Case-study-2.-The-impact-of-the-Cargill-soybean-terminal-in-the-Amazon-town-of-Santar%C3%A9m.pdf. Accessed 2017.

³³ Copyright Soybean and Corn Advisor, Inc. 2009-2017. (n.d.). Retrieved October 14, 2017, from <http://soybeansandcorn.com/Brazilian-Infrastructure>

³⁴ "The impact of the Cargill soybean terminal in the Amazon town of Santarém."

³⁵ Steward, Corrina.

³⁶ Theis, Sophie, and Briana Swette.

³⁷ "The impact of the Cargill soybean terminal in the Amazon town of Santarém."

agencies, and local NGOs due to its negative effects on the Santarém region, including the displacement of communities and illegal seizure of land for large-scale soy farming.³⁸

Regulatory Environment

The Brazilian Forest Code is a piece of legislation passed in 1965. There has been significant controversy over the code, mostly surrounding the requirement for landowners to maintain at least 80 percent of forests as legal reserves, which still allows landowners to cut down 20 percent of their land. Additionally, the government has no enforcement mechanisms which has led to destruction of the Brazilian Amazon and necessitated the Soy Moratorium as a public-private cooperative agreement to address deforestation in Mato Grosso.

Forest Code

The Forest Code covers the Brazilian Amazon, which for more intuitive understanding, comprises of a landmass six times that of Texas. One significant challenge is that only 14 percent of Amazonian land has a legal owner.³⁹ This makes ownership, land rights, and conservation difficult. Although Brazilian government policy is strict and requires landowners to preserve 80 percent of the forest on their land, 20 percent is allowed to be cleared, and compliance rates to this provision are approximately 2 percent. The law also requires that landowners register their property to be monitored. Even with monitoring, the government only catches 15 to 50 percent of illegal large-scale deforestation.⁴⁰

Despite strict rules, low accountability leads to low compliance. According to Soares-Filho et al. (2014), approximately 8.8 million hectares are still legally eligible for deforestation—that is equivalent to the land area of France and the United Kingdom combined. Between 2009 and

³⁸ Bolaños, Omaira. "Redefining identities, redefining landscapes: indigenous identity and land rights struggles in the Brazilian Amazon." *Journal of Cultural Geography*, vol. 28, no. 1, 2011, pp. 45–72., doi:10.1080/08873631.2011.548480.

³⁹ Tyrrell, Kelly A. "Study shows Brazil's Soy Moratorium still needed to preserve Amazon." University of Wisconsin-Madison, January 22, 2015

<http://news.wisc.edu/study-shows-brazils-soy-moratorium-still-needed-to-preserve-amazon/>

⁴⁰ Jackson, Rachel. "A Credible Commitment: Reducing Deforestation in the Brazilian Amazon, 2003–2012." *Princeton University: Innovations for Successful Societies*. <http://www.princeton.edu/successfulsocieties> accessed 15 (2016).

2012, the annual deforestation rate in one region of Mato Grosso increased dramatically by 156 percent, from 298,900 hectares to 765,200 hectares.⁴¹

Soy Moratorium

The Soy Moratorium is a public-private-partnership created as a reaction to the rapid expansion of soy in the Brazilian Amazon causing the second highest annual deforestation rate on record. As a result of consumer groups and environmental agency publicity and pressure, the Brazilian Vegetable Oil Industry Association and the National Association of Cereal Exporters signed the Soy Moratorium on July 24, 2006. These two entities controlled 92 percent of the soybean production in Brazil.⁴² The Soy Working Group was formed, and other organizations signed onto the Soy Moratorium. The Soy Moratorium protects land deforested after 2006 through a voluntary agreement that traders made to not buy soy from producers that did not comply with the commitment to not deforest. In 2008, the Brazilian government started to sign the Soy Moratorium annually.⁴³

In May of 2016, the agreement was renewed to last indefinitely. The agreement has made significant strides to the Mato Grosso region, which is protected by the Soy Moratorium. The University of Wisconsin conducted a study examining satellite images of deforestation from 2000 to 2014. Only 115 people violated the Soy Moratorium, a public-private partnership, while over 600 violated the Forest Code, a Brazilian governmental law. The results revealed that farmers are more likely to violate government policy than private sector agreements.⁴⁴

⁴¹ Soares-Filho, Britaldo, et al. "Cracking Brazil's forest code." *Science* 344.6182 (2014): 363-364.

⁴²Adario, Paulo. "The Soy Moratorium, 10 Years on: How One Commitment Is Stopping Amazon Destruction." *Greenpeace International*, 27 July 2016, www.greenpeace.org/international/en/news/Blogs/makingwaves/the-soy-moratorium-10-year-anniversary-stopping-amazon-destruction/blog/57127/.

⁴³ibid

⁴⁴ibid

FINDINGS OF QUANTITATIVE ANALYSIS

Regression Analysis Overview

The following four regression analysis include results from 2001 to 2015 and all 27 states of Brazil. The explanatory variable, production of soy, remains the same. All the results are significant at 99 percent confidence.

Bivariate Regression Analysis Findings

1. Each metric ton increase in soy production is associated with 1.02 hectares of additional deforested land.
2. Each metric ton increase in soy production is associated with 0.34 hectares of deforestation for the direct cultivation of soy.

The first and second regression results suggest that even though the land required for one metric ton of soy production is 0.34 hectares, approximately 1.02 hectares of land are deforested. This bivariate regression did not control for other variables which could cause omitted variable bias. To reduce the bias, we considered results from the fixed effects regression.

Table 1. Bivariate Regression

Dependent Variables	(1) Aggregated Deforestation	(2) Planted Area
Production	1.016*** (0.227)	0.339*** (0.00491)
Constant	4.754e+06*** (912,364)	90,782*** (18,865)
Observations	280	280
R-squared	0.157	0.959

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Fixed Effects Regression Analysis Findings

The regression results changed when we controlled for the observable and unobservable fixed variables. All the coefficients are significant at 99 percent confidence.

1. Each metric ton increase in soy production is associated with 1.15 hectares of additional deforested land.
2. Each metric ton increase in soy production requires 0.23 hectares of additional farmland for soy cultivation.

Table 2. Fixed Effects Regression

Dependent Variable	(1) Aggregated Deforestation	(2) Planted Area
Production	1.153*** (0.435)	0.226*** (0.0285)
Years (suppressed)		
States (suppressed)		
Constant	-3.570e+06 (2.577e+06)	-226,311*** (86,214)
Observations	280	280
R-squared	0.862	0.988

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

The first regression result shows that every increase in production of soy by one metric ton is associated with 1.15 hectares additional deforested land. This means that even though the rate of deforestation is decreasing, increase in soy production still causes 1.15 hectares of deforestation.

The second regression result shows that one metric ton increase in production of soy is associated with 0.23 hectares additional land cleared to cultivate soy. This number decreased when we controlled for fixed effects. This suggests the bivariate regression was not controlling for other fixed variables other than soy production that caused deforestation. Factors would be fixed to some extent in each state due to the quality of technology or availability of certain resources in each state.

We analyzed the two regression models together and found that the land required to produce soy is less than the area deforested for the same level of production. This may suggest that not all the land deforested due to soy production is directly used to grow soy. Indirect uses include infrastructure such as roads, houses, and storage facilities. Additional land is not utilized because it becomes degraded due to soil conditions and overuse. If soy producers account for the complete cost of deforestation, they might invest more in the existing land to increase the land's productivity.

KEY DRIVERS OF DEFORESTATION

Soy Cultivation

A constantly increasing global demand of soy drives increased demand. The increased demand requires additional land for cultivation, driving conversion of forests to croplands.

We found soy production in Brazil increased from 40 million metric tons in 2001 to 98 million metric tons in 2015. On average there is a 3.5 million metric ton annual increase in soy production in Brazil.

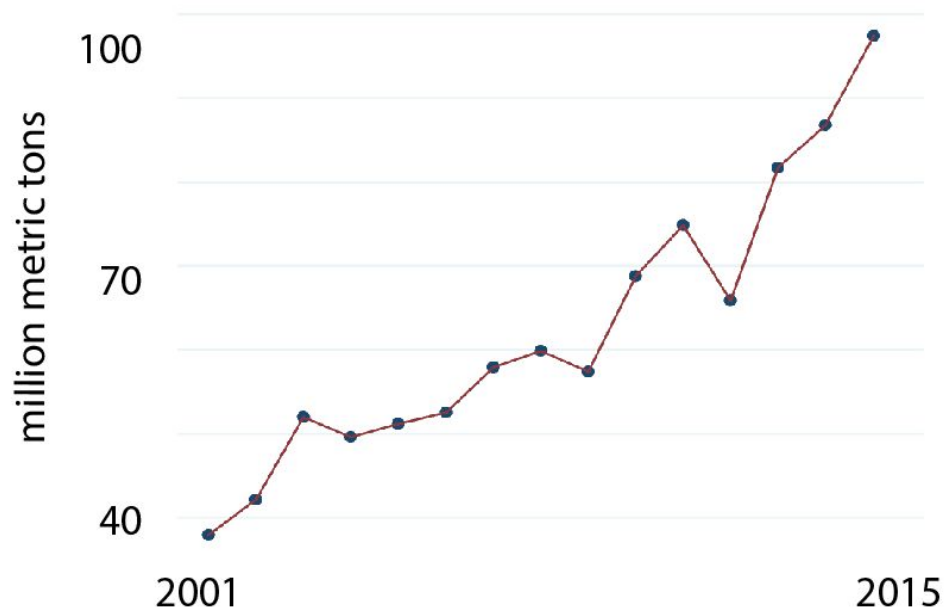


Figure 6. Annual soy production between 2001 through 2015.

Deforestation in Brazil from 2001 to 2015

Deforestation rates have slowed since the early 2000s when the issue gained international attention and began to decrease due to increased environmental laws and voluntary agreements. The graph below shows the trend of annual deforestation from 2001 to 2015.

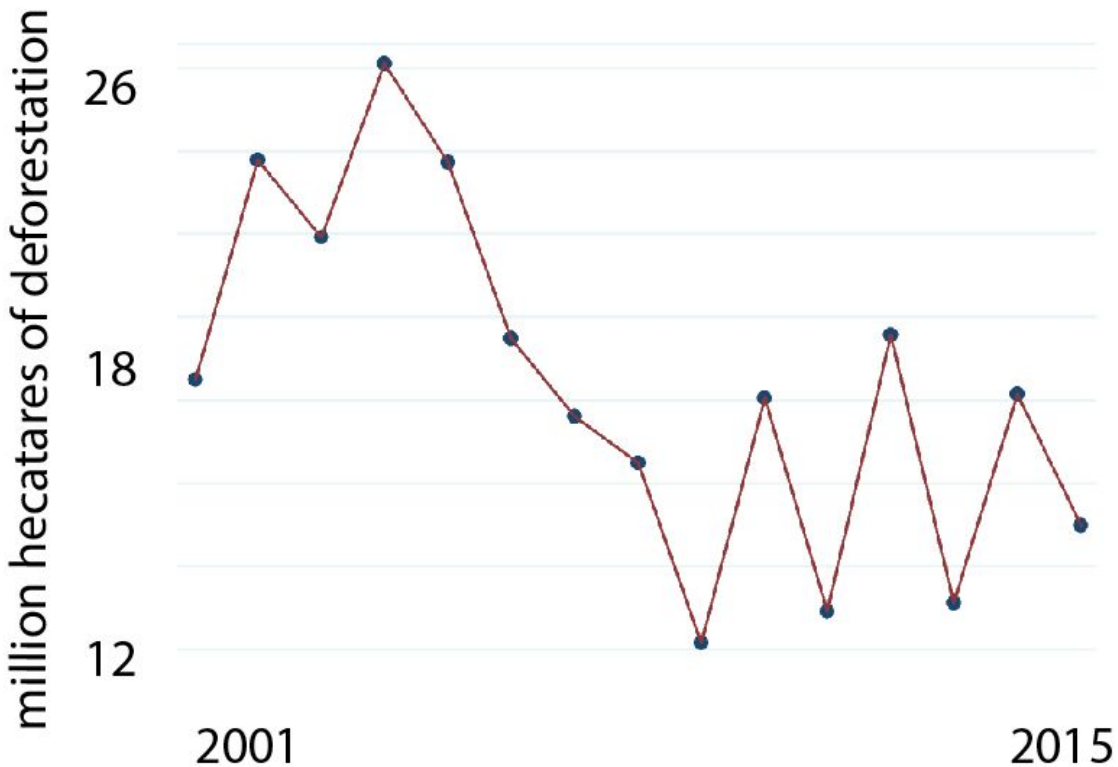


Figure 7. Total annual deforestation in Brazil from 2001 to 2015. The rate of deforestation peaked in 2004. However, the rate continues at an unsustainable rate.

The maximum amount of deforestation was performed in 2004 when approximately 26 million hectares of land was deforested. Since then there has been a slight downward trend in per year deforestation. This downward trend indicates that deforestation is slowing, but continuing. Taken alone, this chart demonstrates a positive story of a reduction in the rate of deforestation. Companies are using this information to frame the soy production and deforestation in a positive light. However, this is not the full story, and must be considered with the graphs below.

It is also important to realize that the area deforested remains deforested due to the lack of reforestation projects and can still be used for a variety of uses, however, the fertility of the land quickly decreases after clearing. Rearranging the data by adding the deforested land over the years gives us a different picture.

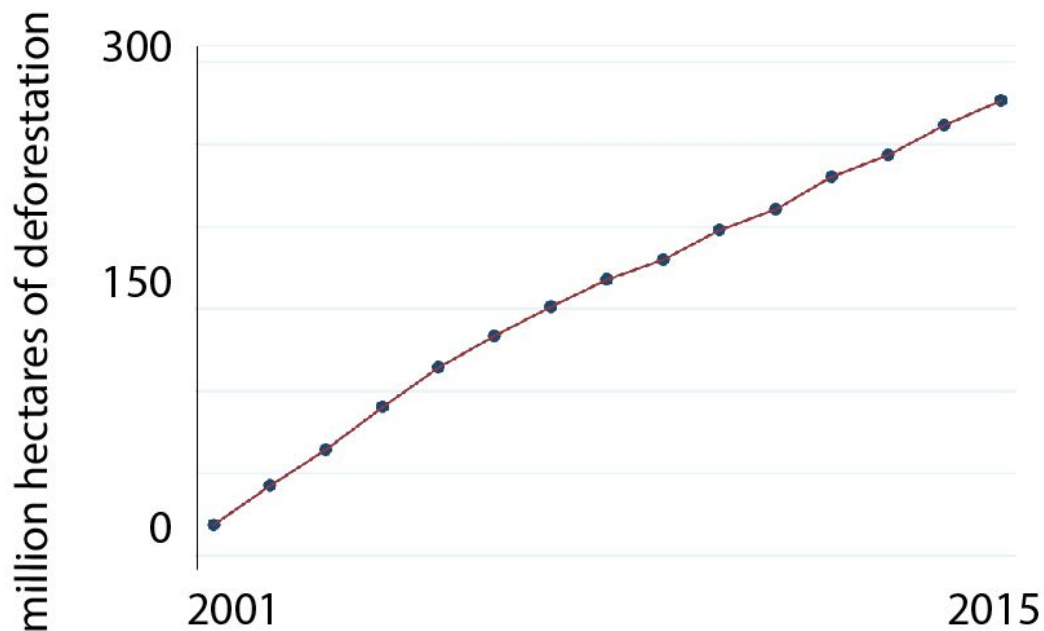


Figure 8. Cumulative deforestation in Brazil from 2001 to 2015.

The above graph shows a linear trend of deforested land over the years. Around 18 million of hectares of land is cleared every year. Land cleared may also be used to develop infrastructure, replace the degraded farm land, or go unutilized due to poor soil conditions.

Soil Depletion

Due to their soil properties, tropical rainforests are not generally fertile lands and make for inefficient farmlands because of a thin layer of topsoil and inability with efficiently store nutrients. After a relatively short time, the nutrients are depleted by soy, leaving the soil in a degraded state. This drives farmers and corporations to increase cultivated land in other locations to satisfy demand.

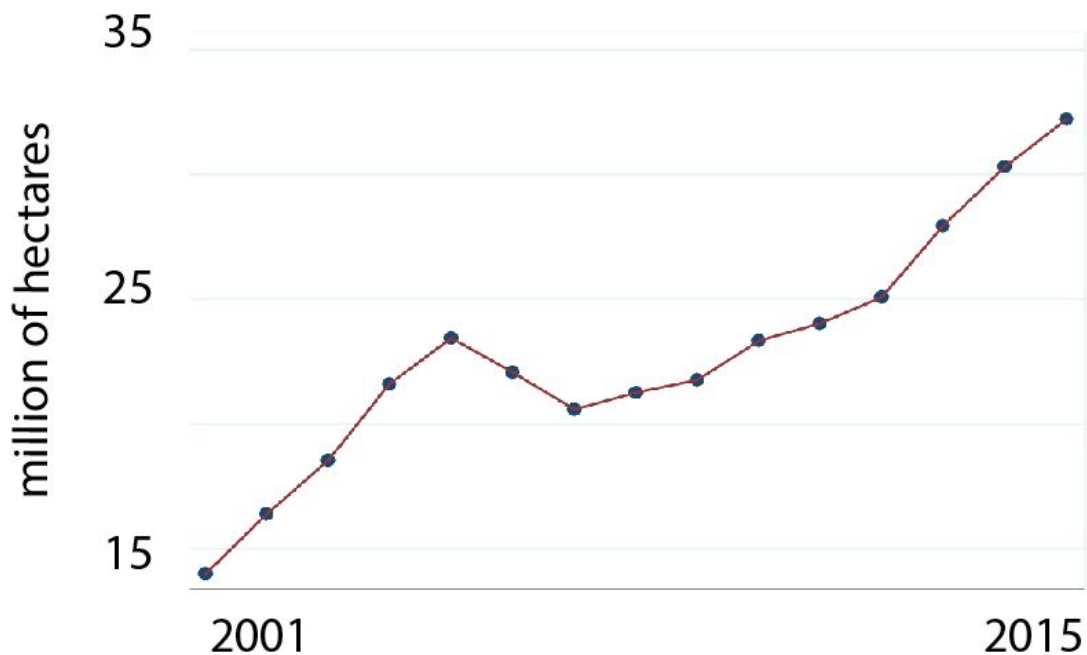


Figure 9. Amount of farmland in Brazil used for the cultivation of soy from 2001 to 2015.

The area used to plant soy increased from 14 million hectares in 2001 to 32 million hectares in 2015. On average, an additional one million hectares of land are used to harvest soy every year.

Transportation Infrastructure

To improve capacity of the Soy Corridor, a 1,125-kilometer railroad is planned for 2018 to be built parallel to BR-163 to meet demand for soy. The *Ferrogrão*, or “grain train,” will connect Sinop, Mato Grosso and Miritituba, Pará, bypassing the unpaved, and frequently inaccessible, BR-163 highway currently being utilized. The project is estimated to take 12 years with an estimated cost is 4.5 billion USD to achieve a capacity of up to 50 million metric tons per year. One unintentional byproduct of the *Ferrogrão* is that new transportation corridors facilitate the economical deforestation of previously inaccessible forests.



Figure 10. The Ferrogrão is a proposed railway for the Soy Corridor, from Sinop, Mato Grosso reaching Miritituba, Pará. Multinational corporations are bidding for a construction date starting in 2018. Image source: FerPress, 2017.

Production Facilities

In 2003, a soy processing plant and port facility were completed in Santarém, leading to an increase in soy cultivation, population growth and unsustainable development of cities in the Amazon. Displaced families moved further into forests to practice subsistence farming.

Deforestation and Soy Production by State 2001 to 2015

States within Brazil are not all the same due to different resources and activities. It is important to consider desegregated deforestation and soy production trends. Most of the states have flat curves for both deforestation and production of soy. This indicates that in these states deforestation is under control and there is no growth in production. In some states there is deforestation but there is no growth in soy production indicating that the land cleared might be

used for other things. Mato Grosso and Pará have both deforestation and production of soy trending upwards.

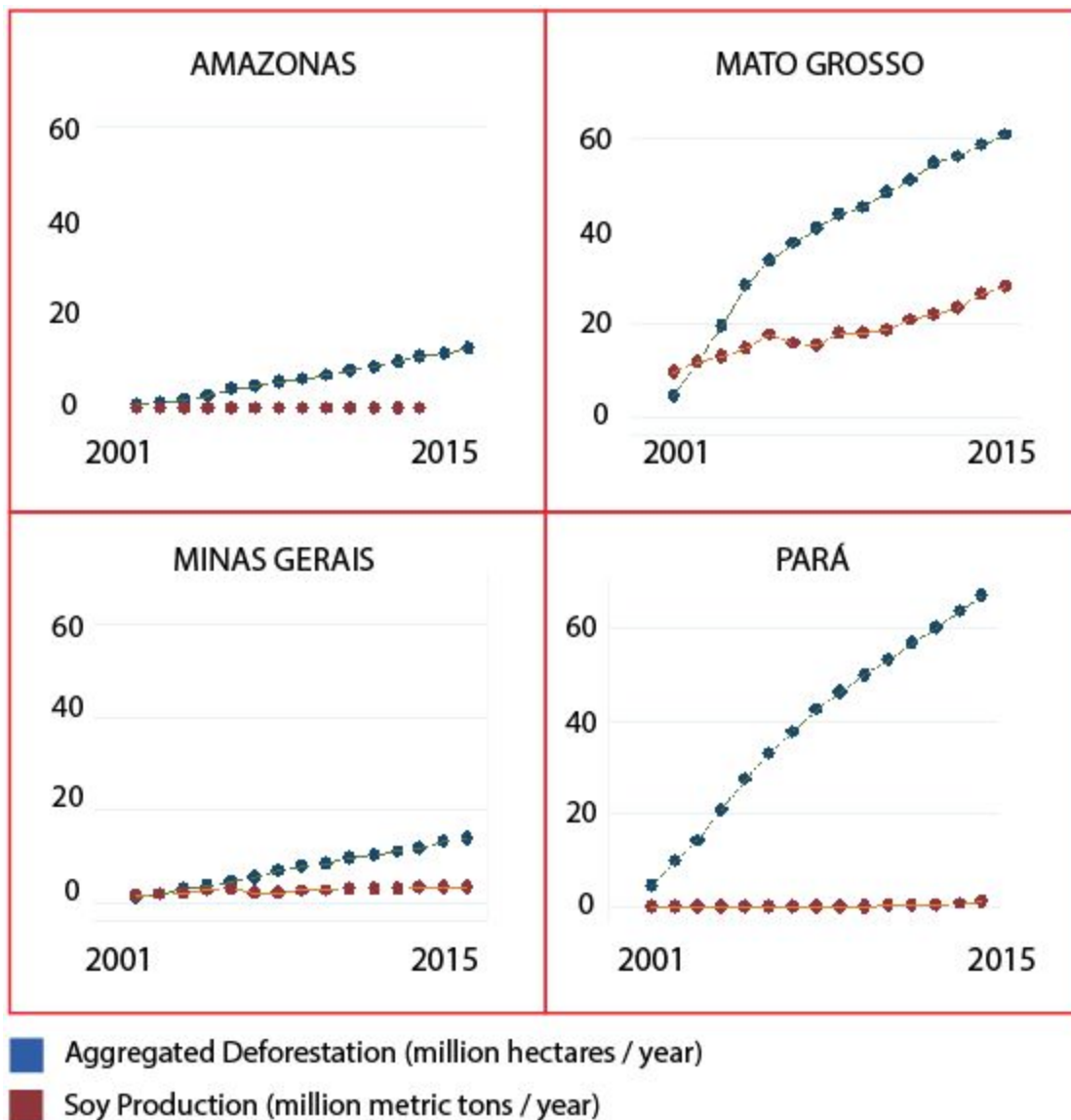


Figure 11. From 2001 - 2015, deforestation rates have varied greatly among Brazilian states. Mato Grosso and Pará have experienced greater amounts of deforestation when compared to other states of Brazil.

ANALYSIS OF SECONDARY FINDINGS

Impact of Santarém Development on Surrounding Communities

Most of the information on the impact of the soy processing terminal construction on the communities surrounding Santarém has been qualitative in nature and based mainly on reports from primary sources. However, multiple sources have reported the displacement of rural farmers by incoming soy producers, sometimes through illegal, coercive, or violent means. After selling or losing their land, these farming families either move into the more impoverished areas of urban Santarém, putting pressures on job markets and public services, or they migrate farther into the Amazon, illegally claiming land and further contributing to deforestation.⁴⁵ Estimates suggest that, between 2000 and 2003, 600 rural families sold their land to incoming soy plantation owners, which led to a 70 percent reduction in population in rural communities.⁴⁶ Projeto Saúde e Alegria, a local NGO, also estimated that 26 communities completely disappeared between 1998 and 2007.⁴⁷

This massive shift in population over a few years led to the rapid deterioration of social structure that previously allowed these communities to thrive. The role of community organization in rural Santarém was integral to the livelihoods of every resident. Individual community associations served to govern the community, organize resource distribution, and manage the processing and sale of local goods and crops.⁴⁸ Community associations were also responsible for maintaining local infrastructure such as schools, churches, community centers, and businesses, as well as access to electricity, water, and public transit into urban Santarém for access to markets and health systems. Thus, when farmers were forced to relocate from

⁴⁵ Schoneker, Jake.

⁴⁶ "The impact of the Cargill soybean terminal in the Amazon town of Santarém." *DSC Publications*, Dutch Soy Coalition, 2008, 141.105.120.208/dsc/wp-content/uploads/2014/04/Case-study-2.-The-impact-of-the-Cargill-soybean-terminal-in-the-Amazon-town-of-Santar%C3%A9m.pdf. Accessed 2017.

⁴⁷ Theis, Sophie, and Briana Swette.

⁴⁸ *ibid*

their communities, they lost access to school systems, work opportunities, and often water and electricity.⁴⁹

Those that did stay in their communities after selling their land were faced with very few employment opportunities for rural, unskilled labor. Although the new soy plantations did provide some jobs, the farms often did not require as large a workforce needed to employ all the farmers that had been earning a living on the land previously.⁵⁰

The farmers that did not sell were also faced with difficulties. Multiple shareholders reported that the use of pesticides on neighboring soy farms drove pests to their plots, forcing them to switch from growing beans and rice to growing manioc, which is more resistant to pests. Other agro-toxins used in soy production were reported to cause a reduction in the volume of crops that smallholders were able to grow, as well as local water source pollution and subsequent negative health effects.⁵¹ Significant erosion and the destruction of local waterways resulting in impaired small-scale farming has also been reported.

Despite these reports, the rural communities do not have a uniformly negative experience as the result of soy production in Santarém. Some are still hopeful that soy expansion into the region will bring higher median income to farming communities, as it has in neighboring regions like Mato Grosso.⁵² More research must be done to further elucidate quantifiable measures of how communities are impacted by local soy production.

Lessons from Community Organizing

Similar to the Soy Moratorium, consumer action groups and NGOs need to bring light to these issues and pressure companies that want to lower their cost of commodities production to take extra precautionary measure to reduce their impacts. This can take the shape of greater collaboration to limit the number of allowed routes through the Amazon and carefully monitor for deforestation near the railway. There are significant externalities; costs not reflected in the price

⁴⁹ Steward, Corrina.

⁵⁰ Adams, Ryan Thomas. "Neoliberal Environmentality among Elites: Becoming "Responsible Producers" in Santarém, Brazil." *Culture, Agriculture, Food and Environment*, vol. 37, no. 2, 2015, pp. 84–95., doi:10.1111/cuag.12055.

⁵¹ Theis, Sophie, and Briana Swette.

⁵² Adams, Ryan Thomas.

of soy despite the consequences of environmental degradation and deforestation which impact both residents of Brazil and the global community.

RECOMMENDATIONS

Our findings resulted in three concrete recommendations:

- (1) Increase efficiency of land use by focusing on improving yields rather than expanding cultivated area.
- (2) Incorporate sustainable soy practices, such as soil conservation and reforestation on degraded lands.
- (3) Incorporate policies to Integrate the value of ecosystem services and land use conversion into the cost of soy. This includes the true cost of deforestation into the price of soy will increase costs to corporations and consumers, but will incentive more efficient use of land and serve as a stronger disincentive to committing deforestation.

Utilization of Findings

The story presented on deforestation is qualitative and lacks quantitative analysis. This information can be used by environmental organizations, such as Climate Advisors, to build a story and case around requiring companies to perform impact studies and implement risk mitigation tactics to lessen impacts by improving land reuse practices through more sustainable soy practices, such as soil conservation and reforestation. This report and information will provide a data driven context to understanding the factors of deforestation outside of soy production.

LIMITATIONS

Due to the sparsity of literature containing quantitative measures of how the introduction of the soy industry, as well as the soy terminal, affected the Santarém community, a primary collection of data regarding municipal development, social development, and public health in Santarém was attempted. The purpose of this data collection and subsequent analysis was (1) to determine if any measures changed over time in such a way that might be correlated with the introduction of the soy industry into the community or the construction of the soy terminal and

(2) to determine which of these measures are important to consider when looking at the impact of introducing soy or any other large industry into a community. It was also noted that most of the literature that we could find on the impact of soy production in Santarém focused primarily on rural populations; this data collection was hoped to also include the urban/suburban population of Santarém as well.

Yearly data points for multiple indices (See Appendix A) were sought for the ten years leading up to the completion of the soy terminal, as this event represented a more concrete timeline than that of soy industry development as a whole, and ten years after (1993 to 2013). The intention was then to plot changes in these indices over time to determine if any of these changes seemed to mirror events related to the soy terminal construction and operation. If any relationships were present, further research would be done into the related variables to further elucidate the cause of the change.

Despite searching through many public databases and obtaining data directly from the Santarém municipality, there was not enough data collected to perform any analysis to determine any relationships between changes in these indices and the construction or operation of the soy terminal. The challenges faced were two-fold: either (1) a database would have a wealth of information on each of the indices chosen but only for one to two years, such as with the census data from IBGE; or (2) a database would have data spanning multiple years but for only a limited number of indices, such as the reports on Santarém compiled by CIAM. None of the indices had data points spanning the full 20-year study period. All the databases used were primarily written in Portuguese, requiring the use of translation applications. The data we were able to collect can be found in the Social/Health Data Appendix (CIAM only) and includes information on population trends, electricity usage, waste disposal, health services and infectious disease prevalence.

Future studies into the development of communities following the introduction of a new industry will need to address this gap in information before any definitive conclusions can be made. It is recommended that a strong working relationship with the municipality in question be sought to facilitate data collection; on-site data collection should also be considered as remote data mining proved inefficient and challenging due to multiple factors.

Many studies have shown that various drastic changes to a community, whether that be the introduction of a new transportation system or a new industry, can have far-ranging negative impacts on social development and public health if not adequately prepared for. Future research into this area will further clarify what specific indicators are most predictive of a community's ability to adapt to change and thus which areas local governments can focus on when preparing for such changes.

DISCUSSION

The cultivation of soy is highly profitable for multinational organizations in Mato Grosso, especially within the *Cerrado* region. Due to preferable climate and fertile land conditions, Brazil is a large exporter of soy. However, industrialized soy production threatens forests and natural ecosystems. Our research finds land used for soy production is significantly associated ($p < 0.001$) with deforestation. A total of 1.15 hectares of land is deforested for every ton of soy that is produced; only 0.23 hectares for every ton of soy is directly deforested for farmland. This is attributed to the drivers of deforestation examined in this paper: soy cultivation, transportation, soil depletion, and to build production site capacity.

Cumulative deforestation trends reveal that, every year, 18 million hectares of tree covered land are cleared in Brazil. Every year, an additional million hectares of land is used for soy harvesting. Since our findings conclude that 1.15 hectares of land is deforested when only 0.23 is required, it is clear that more land is deforested than required for soy production. The exact reasons are unknown. However, an insight may be that incremental deforestation is less costly than the associated cost of soil conservation practices to ensure the ongoing fertility of farmland used for soy.

The problem is exacerbated as the demand for soy is on the rise. In Brazil, soy production increases by 3.5 million metric tons every year. And as more developing countries' economies grow, demand for soy will continue to increase. As calculated utilizing assumptions from sources stated in the findings, if production demands rise and no remedial action is taken, 9.6 to 18.5 million hectares of land will be deforested.

To meet growing global demand, soy transportation infrastructure plans are underway. Large national and multinational corporations with interests in soy production are behind new transport infrastructure projects connecting large stretches of the Amazon. Research shows that additional infrastructure compounds deforestation in the Amazon.

As industrialized soy production continues to have an increasing impact on the environment and local communities, more impactful mitigation actions and environmental impact studies must be demanded to hold national and multinational corporations accountable.

Regulations and partnerships must be continuously reevaluated and improved. Consumer action groups and NGOs need to balance holding corporations accountable while working alongside them to reduce deforestation.

The implication for this research is to provide a quantitative understanding of deforestation as associated to soy cultivation, transportation, and production. The fixed regression analysis shows that a one metric ton increase in soy production is associated with 1.15 hectares of additional deforestation, even though only 0.23 hectares of additional farmland is required to produce that amount; the discrepancy is hypothesized to be due to the impact of developing transportation corridors to ports and processing hubs. A lack of available data on public health, social development, and municipal development in Santarém limited detailed analysis; more research is necessary for conclusions to be reached.

The discrepancy between the amount of land needed for a unit of soy production and the amount deforested, as predicted by the model, suggests a need for developing more sustainable alternatives to the current method of soy production. The information gathered and analyzed in this report can also be used to lay groundwork for other research groups or organizations to understand deforestation from a quantitative lens and integrate this into the story of impacts on soy production to local communities and ecosystems.

APPENDIX A - Data Indices

Table A-1: Data Indices for Santarém Case Study

Municipal Development Data

- GDP of metro Santarém area
- Rate of expansion of metro Santarém area
- Changes in land use/zoning in metro Santarém area
- Numbers/types of industries in metro Santarém area
- Rate of construction of infrastructure (e.g. roads, sewers, public transit, utilities, etc.)
- Types of infrastructure available
- Methods of waste disposal
- Housing units per square kilometer
- Housing units with adequate sanitation per square kilometer
- Rates of change in traffic (e.g. foot, vehicle, water, etc.)
- Schools per square kilometer/per capita
- Rates/types of water and air pollution

Social Development Data

- Population (by age, sex, and race)
- Average monthly income (by age, sex, and race)
- Illiteracy rates (by age, sex, and race)
- Unemployment rates (by age, sex, and race)
 - Rates of employment of migrant or temporary workers
- Changes in food prices
- Rates of non-violent and violent crime (e.g. prostitution, human trafficking, drug trafficking, robberies, assault, murder, etc.)

Public Health Data

- Health care professionals/facilities per square kilometer/per capita
 - Type of health care staff at each facility
 - Services offered at each facility (e.g. primary care, surgical procedures, etc.)
- Changes in health practices
 - Role of traditional medical providers, indigenous medicines, and unique cultural health practices
- Disease prevalence by age, sex, and race
 - Vector-borne: Malaria, leishmaniasis, dengue fever, tuberculosis, leprosy, schistosomiasis, Zika virus
 - Respiratory/Housing Issues: Acute respiratory infections (bacterial and viral), pneumonias
 - Veterinary Medicine and Zoonotic Issues: Brucellosis, rabies, bovine TB, avian flu
 - Sexually Transmitted Infections: HIV/AIDS, syphilis, gonorrhea, chlamydia, hepatitis B
 - Soil- and Water-Related Diseases: Giardiasis, worms, other diarrheal illnesses, etc.
 - Food and Nutrition-Related Issues: Stunting, wasting, anemia, micronutrient diseases (including deficiencies of folate, Vitamin A, iron, iodine); gastroenteritis (bacterial and viral)
 - Accidents and Injuries: Road-traffic related, spills and releases, construction (home- and project-related) and drowning
 - Exposure: Pesticides, fertilizers, road dust, air pollution (indoor and outdoor, related to vehicles, cooking, heating, or other forms of combustion or incineration), landfill refuse or incineration ash, and any other project-related solvents, paints, oils or cleaning agents, by-products, or release events
 - Social Determinants of Health: alcohol and tobacco use, recreational drug use
 - Non-communicable Diseases: Hypertension, diabetes, stroke, cardiovascular disorders, cancer, asthma, and mental health