THE SOYBEAN PRODUCTION AND SUPPLY CHAIN IN BRAZIL

Vitória Bento Botelho[1]; Joseph Youssif Saab Junior [2]

[1] Scholarship Student of the GCSP – IMT (EEM/CEUN-IMT)
[2] Mentor of the GCSP-IMT (EEM/CEUN-IMT)

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Abstract. *Brazil is often the largest soybean harvester in the World even though the nutritious food grains are most often than not used for feeding livestock. In order to understand the details of the CO_2-e emissions from the soybean farming, processing and distribution activities as a function of the process variables, this bibliographic research performed mostly during the Covid-19 pandemic quarantine restrictions, intends to shed light on the soybean production supply chain in Brazil and to identify its important descriptors and influence parameters. This research is part of a broader GCSP-IMT project that intends to set up a methodology for assessing the GHG emissions from soybean and other relevant grain farming, as a function of the land use, the methods and practices employed during growing and processing, and the supply chain emissions based on the geolocations and transportations modals between supply and demand centers. Since 7.1 gigatonnes of equivalent CO_2, or 14.5% of all GHG annual emissions comes from livestock, the broader GSCP-IMT project also seeks to investigate the impact of direct versus indirect human consumption of soybean, in terms of GHG emissions and energy efficiency.*

Keywords. *Soybean farming practices, farming CO_2-e emissions, sustainability, Grand Challenges Scholars Program, GCSP.*

Introduction

If the goals proposed by the Paris Protocol - and recently endorsed by the Glasgow Protocol - are to be met by mid-century, it is necessary to understand and adjust the food supply systems to simultaneously meet the needs of consumers, farmers and that of a sustainable planet.

This study is in line with the National Academy of Engineering (NAE) vision for the Grand Challenges Scholars Program which intends the engineers to deliver a sustainable and joyful World for its future inhabitants by the end of the XXI Century. Also, this study is in line with the research topic # 40 of the GCSP-IMT project theme *Environmental Impact of GHG (Green-House Gas) Emissions*, encompassing the *sustainability* and *health* grand areas.

When prioritizing the food supply chain for analysis, the soybean farming industry stands out due to the plantation area and economic and nutritional importance as illustrated by its high protein contents. In accordance with Embrapa figures (Embrapa, 2021) sourced from USDA and CONAB, Brazil is currently the number one soybean grower in the World in key performance indicators as production, planted area and productivity as shown in Table 1.

Table 1 – Soybean culture statistics (world x Brazil) (Embrapa, 2021).

Soybean Statistics	World	Brazil	%
	Production (millions of tonnes)		
	363	135	37,2
	Planted Area (millions of acres)		
	128	39	30,5
	Productivity (tonne/acre)		
	N/A	3.52	US Productivity is 3.38 tonne/acre

The soybean growing industry has thus been selected as a suitable backdrop over which to analyse and understand the impact of the many practices on the GHG emissions. In terms of land use, both the soybean industry and the livestock that feed from it may pose threats to wetlands and tropical rainforest areas of the Brazilian Centre and Northern Regions States, a situation that could benefit from a more systemic analysis.

This research, mostly based on bibliographic review, revealed the most relevant processes associated with soybean farming in Brazil, along with the variables that seem to influence each step and could lead to different CO2-e emissions. Also, relevant geoeconomics data was gathered for a future systemic analysis of this supply chain.

Objectives

This report is concerned with (i) understanding the processes involved in soybean growth and subsequent steps of this important supply-chain in Brazil, and (ii) to identify the main variables associated with the food-grain cultivation, processing, distribution and consumption system.

The outcome of this research will support the future steps of a broader GCSP-IMT project including the selection of acceptable criteria to quantify the GHG emissions from each step of the cultivation and supply chain processes; the sensitivity analysis on the emissions as a function of the identified variables; the development of a dynamic system model of the soybean production and distribution network, including land use, capable of supporting scenario analysis and decision-making by private and public institutions.

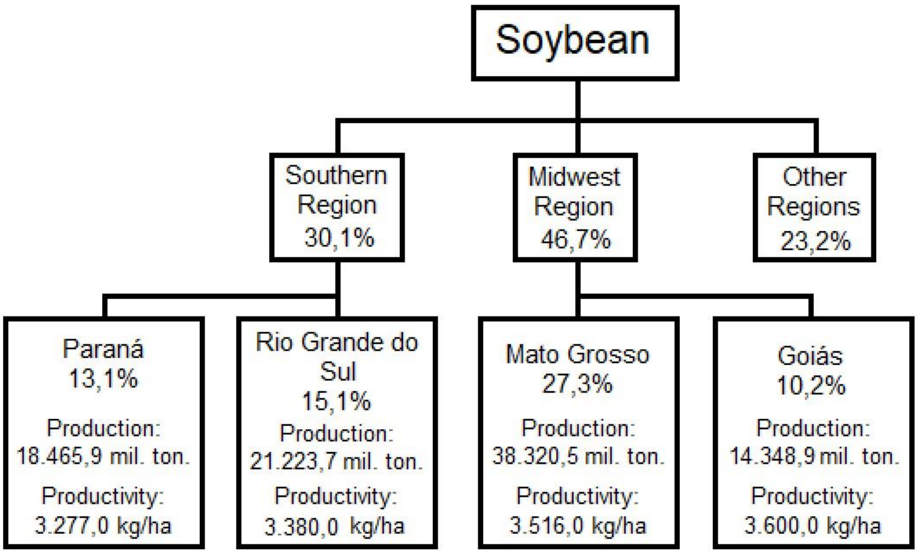
Development

The first mentions of soy appear in the period between 2883 and 2838 BC, when it was considered a sacred grain, alongside rice, wheat, barley and millet. Soybean has its origin in Asia, mainly near Chinese rivers, and was a low-growing plant, unlike the way it is today. Scientists in ancient China performed natural crosses between two wild soybean species, which led to the “improved” soybeans we use today. Despite being known and consumed by eastern civilization for thousands of years, it was only introduced in Europe at the end of the 15th century, as a curiosity. In the second decade of the 20th century, the oil and protein content of the grain began to arouse the interest of world industries. The powers, Russia, England and Germany, tried to implement the cultivation of soybeans, however, they failed, probably due to unfavourable weather conditions (EMBRAPA,2021).

Soybean appeared originally in southern Brazil in the 1960s due to the need to feed swine and poultry, which had begun to be produced on a large scale. In addition, soybeans, which are adapted to a hot climate, appeared as a succession to wheat that could not be produced in the summer. By the end of the decade, Brazil was already producing a significant amount of the grain. In the mid-1970s, there was a rise in the price of soybeans on the world market. Brazil begins to benefit and to have a competitive advantage in relation to other producing countries. The harvest in Brazil occurs during the American off-season, that is, when prices reach the highest values. Thus, the Brazilian Agricultural Research Corporation (EMBRAPA) led the country in investing in technology to optimize cultivation.

The three main producers in Brazil are Mato Grosso (MT) in first place followed by Rio Grande do Sul and Paraná. The second and third place have a small difference of not even 1 million tons compared to the 15 million tons that Mato Grosso produces more than the second place. However, MT also has twice as much planted land. Producers of this important grain face production challenges and whoever manages to find the best solutions will achieve the lowest production losses. Mato Grosso, despite being the leader in the total amount produced, loses to several states in terms of productivity. Who wins in this regard is Goiás with 3,714 kg per hectare (Makiya et al.,2010)

Table 2 – Soybean production in Brazil, by Brazilian states. (Embrapa, 2021).



The main objective in this field is to find ways to reduce production losses. Harvest loss is very common, ranging between 5% and 10% in Brazil, due to the positioning of the plants and, mainly, adjustments in the harvester. There are also losses due to crop formation and management, representing at least 20% of total losses.

Soybean is the world's main source of protein for animal feed and is also used in human food, in industry and in the manufacture of biofuels. Domestic consumption estimated in 2020 was 46.845 million tons of soybeans. (estimate on 05/14/2021 - EMBRAPA). As previously mentioned, the initial cultivation took place in the southern region of country, then expanded to the Midwest, Southeast and North.

Due to this spatial change in production, there was an increase in the distance to be traveled between the production and processing zones and/or export ports. In soybean marketing, the simplified route is from production area to the warehouse or cooperative and, from these, to the factory or port, or directly from the production area to the factory or port (Soares et al., 1997). Transport is an important step in this process, it has the responsibility to supply the consumer needs in terms of price, quality and delivery time. Therefore, it involves choosing the best alternatives of transportation modals. The Brazilian Transport Planning Company – GEIPOT - (1995) introduced the transportation corridors in Rio Grande, Paraná/Santa Catarina, Santos, Central-East, Rio de Janeiro, Northeast and North for the flow of grains. They all involve road, rail and waterway modes. However, road transportation by trucks is the transportation mode most resorted to due to the lack of infrastructure in the other cheaper alternatives (Antunes et al.,2015). The channels for the flow of soybean production from the centre and southern regions runs through the ports of Santos and Paranaguá (Center-South-Southeast channel); through the ports of Madeira and Itacoatiara (Center-North-Northeast channel); through the ports of São Francisco do Sul and Rio Grande (Southern Region channel) and; to through the ports of Vitória and Ponta da Madeira (Southeast-Northeast channel).

The estimate for domestic soy consumption in Brazil in 2021 is 50,44 million tons. In addition to considering the environmental impact associated with the production and consumption of food of animal origin, an estimate from the Food and Agriculture Organization of the United Nations (FAO) (2015) points out that the world today produces enough tons of this grain to feed the world's population, which leads to questioning whether soy is being directed in the best possible way for the environment.

Competency development opportunities

Multidisciplinary. This project required extensive research on the production, processing and transport of food (due to research on food chains), involving issues of engineering, chemistry, biology and agronomy; business management (due to the need to understand the logistics involved in grain processing). This created an affinity for innovation, as the activity creatively and effectively combined existing practical scientific knowledge from different areas to tackle the problem.

Multicultural. This competence is being developed so far through the study of different approaches for soybeans production in different regions of Brazil and abroad. The Food is an integral part of the culture of each people/region and the successful use of the analysis tool and the proposed solutions, whether locally or globally, must consider the local production of food that is relevant to the culture of each region. Sometimes the higher CO2 emission associated with cultural reasons in one region may be offset by the reduction in CO2 emission related to transport, when consumption is local. This type of compensation can be revealed and respected when considering local uses and customs.

Social Consciousness. Since August, plant-based meals have been delivered every Friday to people in socially vulnerable situations (homeless) near Liberdade. On average, 50 meals are made with its own investment and also with third-party donations. In addition, workshops are being planned to educate the women assisted by the association

AFATEC to educate them on how it is possible to use products with lower GHG emissions and how to have a healthier diet with less investment. The association's directors have already agreed with the educational work that will start in 2022.

Results and Discussion

Table displays the areas with significant soybean plantations in Brazil and ranks them in terms of planted area. Also, whenever the data is available the approximate date when this culture was adopted in that area and which original culture or soil type it displaced are mentioned.

Table 3 – Main Soybean production centers in Brazil.

State	Production (x thousand tonnes)	Planted Area (x thousand ha)	Productivity	Introduced on (date)	Type of Land (original)	Typical local cultures	References
Mato Grosso	38.320,5	10.898,9	3.516 kg/ha	Oct 2021	Latosols Neosols Plintosols	Conventional	EMBRAPA (2021); UNIVERSIDADE DO ESTADO DE MATO GROSSO s.d.; CANAL RURAL (2020)
Paraná	18.465,9	5.635,0	3.277 kg/ha	Sept/Oct 2021	Nitosols Argisols Latosols	Conventional	
Rio Grande do Sul	21.223,7	6.279,2	3.380 kg/ha	Oct 2021	Latosols	Conventional	
Goiás	14.348,9	3.985,8	3.600 kg/ha	Oct 2021	Latosols Cambisols	Conventional	

Table 4 upper part reveal the average distance among the growing centers (producers) and the main ports for shipping soy; while the lower part shows distances among main shipping and receiving ports. These data will be useful for future estimating of carbon emission from transportation.

Table 4 – Distance between production centers and ports

Producer→ Port↓	Mato Grosso	Paraná	Rio Grande do Sul	Goiás	References
Santos Port	1.291 km	999 km	1.964 km	1.255 km	SEA ROUTE AND DISTANCE (2010), STATISTA (2020/21)
Port of Paranaguá	1.490 km	600 km	1.128 km	1.621 km	
Rio Grande Port	2.365 km	1.020 km	612 km	2.515 km	
Port of Belém	2.317 km	3.232 km	4.125 km	1.891 km	

Producer→ Port↓	Santos Port	Port of Paranaguá	Rio Grande Port	Port of Belém	References
China (Shanghai)	13.256 nm	13.230 nm	12.927 nm	14.773 nm	SEA ROUTE AND DISTANCE (2022), STATISTA (2020/21)
North America (LA)	8.718 nm	8.920 nm	8.993 nm	6.235 nm	
Europe (Rotterdam)	6.749 nm	6.951 nm	7.380 nm	5.716 nm	
Mexico (Michoacán)	7.076 nm	7.278 nm	7.354 nm	4.596 nm	

Table 5 lists all processes associated with each identified step of the soybean growing activity, from soil preparation to selling models and culture rotation practices, along with the identified existing variations in the processes.

Table 5 – Soybean production process

Major Step	Sub step	Additional info	References
1. Soil Analysis and Correction	None	- use of cover crops; - adequate physical conditions; - efficient control of erosion and water infiltration; - direct seeding system and; - balanced nutrient supply Mainly Limestone	SLC AGRÍCOLA (2018), CHBAGRO (2015), CAVALETT (2008), O BLOG AEGRO (2020)
2. Choice of seeds and preparation	a) Fungicide Treatment		
	b) Use of Inoculants	- use of inoculants is mandatory in areas of first soybean cultivation or areas that have not been cultivated for several years	
	c) Storage	- ideal refrigerated sheds	
	d) Transport of grains		
3. Planting	a) Model of plantation	- Conventional; - Direct; - Double row; - Grouping of Plants; - Reduction of Spacing; - Cross planting;	
	b) Machinery	Involves: - Choosing the right machinery; - Analyzing the Machinery speed: ideal 4km to 6km for mechanics and 7.5km maximum for tyres; - Overhaul and repair of machinery;	
	c) Fertilization		
4. Monitoring	a) Pest Control	- Chemicals; - Biological agents (predators, parasitoids and bacteria, fungi or viruses); - Plant extracts; - Pheromones; - Varieties of pest resistant plants;	

	b) Weeds		
	c) Diseases		
5. Harvest	None	- Acceptable loss levels less than or equal to 1 bag of 60 kg/ha; - Average loss is almost two bags per hectare (almost R$ 4.3 billion per country) - Approximately 80% of these losses related to the lack of adjustments in the mechanisms used in harvesting and the speed of movement of the machines; - recommended humidity for soy harvest vary between 13% to 15%.	SLC AGRÍCOLA (2018), CHBAGRO (2015), CAVALETT (2008), O BLOG AEGRO (2020)
6. Post Harvest	a) Pre-Cleaning		
	b) Drying		
	c) Storage	- Prevent moisture migration, cool the grain mass and remove bad odors	
7. Sales	a) Counter	- Delivery to the hopper (Wooden piece in which the grains are placed so that they can be crushed)	SLC AGRÍCOLA (2018), CHBAGRO (2015), CAVALETT (2008), O BLOG AEGRO (2020)
	b) Spot or soy available	- the producer assumes the responsibility of drying and cleaning the grains	
	c) Lots	- used to refer to sales that occur in large quantities	
	d) Future Market	- negotiations guarantee the price level at a time that the producer considers positive for him; used to guarantee production costs to capitalize on investing in crops	
	e) Hedge	- protect the sale value of a product on a certain date, ensuring protection against volatility or a scenario of price losses	
	f) Pre-Fixation	- negotiation between the producer and his buyer in which the soy grower “locks in” the prices on the date and commits to physically delivering the grain	
	g) Prepayment	- the buyer advances the payment in cash to the producer, who undertakes to physically deliver the product, charging interest	
	h) Barter	- exchange of soybean bags for inputs, through a pre-fixed negotiation in which the producer anticipates the soybean remuneration to obtain inputs for the harvest	
8. Crop	None	- Efficient crop rotation is needed	

Rotation		to ensure the long-term sustainability of the soil, natural resources and the productive system	

Conclusions

The extensive bibliography review accomplished has shed light on the processes involved into the soybean cultivation industry in Brazil and highlighted the variations in the processes demanded by geographical or cultural/customs variations in the different growing regions, allowing the objectives of the research to be fully met.

Also, a methodical approach allowed the extraction of useful data and preparation of tables with the variables that will be needed for estimating the typical GHG emissions for 1 ton of soybean grown in each region considered and to perform the sensitivity analysis that could lead to insights on how to grow/distribute/consume the soyean in ways to lessen the GHG emission over time.

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