Brazil Modal Share Analysis for Corn and Soybeans: 2010-19

Thiago Guilherme Péra, University of Sao Paulo, Luiz de Queiroz College of Agriculture, ESALQ-LOG Group, Brazil

José Vicente Caixeta-Filho, ESALQ-LOG, University of Sao Paulo, Luiz de Queiroz College of Agriculture, ESALQ-LOG Group, Brazil

Delmy L. Salin, USDA

Author Contact(s): Thiago Guilherme Péra, e-mail: thiago.pera@usp.br, phone number: +551934294580; José Vicente Caixeta-Filho, e-mail: jose.caixeta@usp.br, phone number: +551934294580

USDA Contact: Delmy L. Salin, e-mail: delmy.salin@usda.gov, phone number 202-720-0833

Recommended Citation: Péra, Thiago G., Jose V. Caixeta-Filho, and Delmy L. Salin, 2021. Brazil Modal Share Analysis for Corn and Soybeans: 2010-19. University of São Paulo, Escola Superior de Agricultura "Luiz de Queiroz," Brazil (ESALQ/USP). Web: https://esalqlog.esalq.usp.br/Brazil_modalshare_USDA-ESALQ2020.pdf

Acknowledgements: This research was supported by Cooperative Agreement Number 20-TMTSD-BZ-0001 with the U.S. Department of Agriculture, Agricultural Marketing Service.

EXECUTIVE SUMMARY

What Is the Issue?

Brazil is a country with continental dimensions and immense heterogeneity in transport infrastructure. The improved infrastructure has significantly contributed to higher production of corn and soybeans in recent years, totaling over 200 million tons in 2017. This boom in production has exerted significant pressure on the demand for logistics infrastructure, especially in major agricultural producing regions.

Historically, Brazil grain shipments abroad have relied heavily on roads to bridge the long distances between major production regions and the Brazilian ports. In the last decade, Brazil's transport infrastructure has received major overhauls with the expansion and consolidation of new transport corridors, as well as the country's use of new railways and waterways for exporting corn and soybeans.

The purpose of this study is to analyze the modal share change for the movement of soybeans and corn in Brazil (2010-19).

What Did the Study Find?

Brazil's revamped transportation system is a more balanced one, leveraging all major modes (truck, barge, rail, and ocean vessel) and resembling the U.S. system. However, a number of challenges persist, including the long distances between major production regions and barge and rail terminals, as well as *limited* rail and inland waterway infrastructure capacity.[1] Still grappling with these challenges, Brazil continues to depend heavily on truck transportation to ship grain to major destinations.

In the last decade, the use of barge transportation increased for shipping corn and soybean exports to major ports. Mostly, all the corn and soybeans for domestic consumption are shipped by truck, with an average distance of 574 miles (357 km) from farms to any destination other than the rail and barge terminals. Railways haul corn an average distance of 782 miles and

[1] In this study, short-haul trucks are not considered as part of the modal share to avoid double counting. In Brazil, these shipments refer to the average distance of 440 miles (707 kilometers (km)) from the farm to rail and barge terminals.

soybeans, 651 miles. On average, barge corn shipments travel 581 nautical miles (nm) and soybeans, 535 nm.

The main results for Brazilian *corn* for the analyzed period, 2010-19, show the following:

- Trucks shipped most corn from the farm to major destinations, accounting for nearly 69 percent of total movements in 2019, followed by rail (21 percent) and barge (10 percent).
- Truck market shares declined by nearly 15 percentage points, from 84 to 69 percent; rail increased 6 percentage points, from 15 to 21 percent; and barge increased significantly from 1 percent to nearly 10 percent.
- Rail shipped most corn to major export facilities, representing nearly 50 percent of the total corn exported in 2019, followed by truck (31 percent) and barge (19 percent).
- Barge gained a significant market share from about 3 percent to 20 percent, at the expense of rail, which fell from nearly 78 percent in 2010 to 50 percent in 2019. Truck also gained 11 percentage points of market share from 20 to 31 percent.

The main results found for Brazilian *soybeans* for the analyzed period, 2010-19, show the following:

- Trucks shipped most soybeans from the farm to major destinations, accounting for 67 percent of total movements in 2019, followed by rail (24 percent) and barge (9 percent).
- Truck market shares declined by about 8 percentage points, from 75 to 67 percent; rail increased about 4 percentage points, from 20 to 24 percent; and barge increased about the same from 5 to almost 9 percent.
- Trucks shipped most soybeans to major export facilities, representing 49 percent of the total soybeans exported in 2019, followed by rail (38 percent) and barge (13 percent).
- Barge and truck gained market share at the expense of rail, which fell nearly 9 percentage points—from 47 percent in 2010 to 38 percent in 2019. Barge shipments increased nearly 5 percentage points, from 8 percent to nearly 13 percent. Truck shipments increased 4 percentage points, from 45 percent to 49 percent.

How Was the Study Conducted?

The modal share analysis consisted of accounting for rail and barge movements, production, and export information from the consolidated database to generate three types of indicators related to corn and soybean transport movements in Brazil: truck, rail, and barge. We analyzed the modal shares both for the total tonnage and for the export and domestic market destinations.

We built and analyzed a database to illustrate what we called the "Logistical flows of corn and soybean in Brazil," by presenting rail and barge transport characteristics in the country. This study is based on secondary 2010-19 data from the National Land Transport (ANTT), National Water Transport Agency (ANTAQ), National Supply Company (CONAB), and COMEX-VIS, Ministry of Economy (Brazil).

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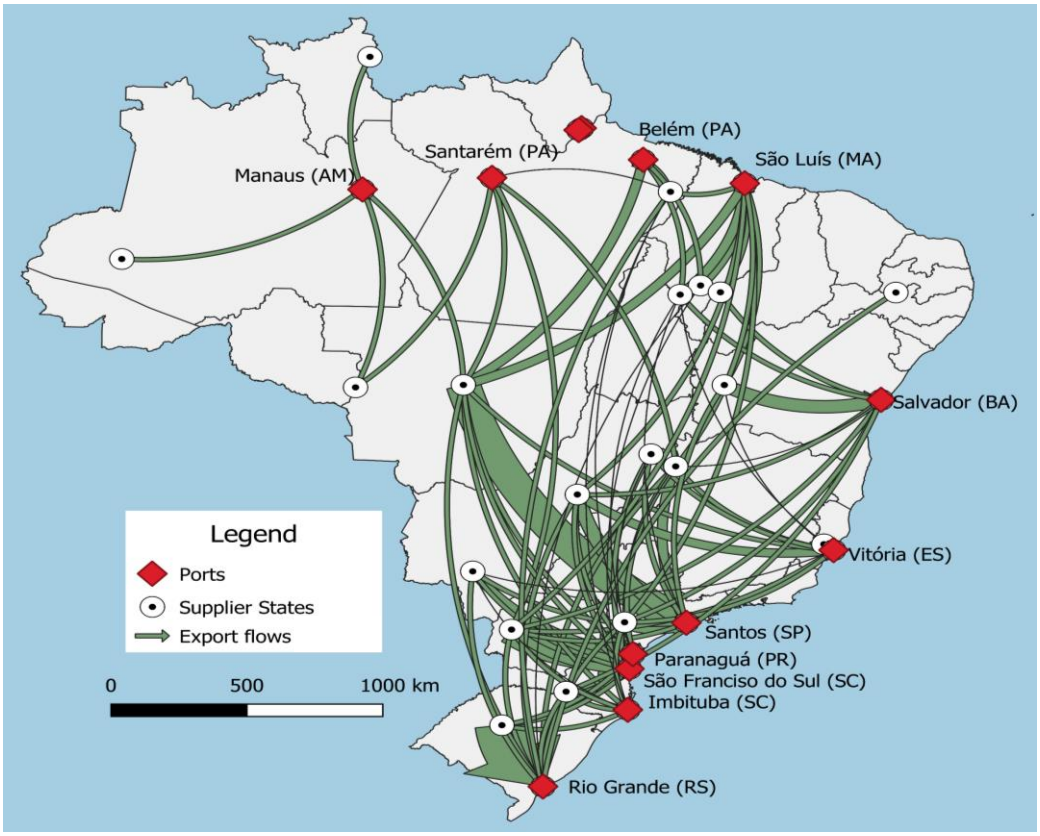
Introduction

Agricultural production, especially of corn and soybeans in Brazil, increased more than 70 percent from 2010 to 2019. The boom in production emerged from the adoption of new technologies, adaptation of second harvest for corn, and the expansion of new production areas, mainly in the north and northeast parts of the country.

The country reached the historic milestone with the production of more than 200 million tons of soybeans and corn in 2017. Moved mainly by trucks, these volumes have long distances to traverse from production regions to ports and Brazil's domestic market. In a conservative scenario, the Ministry of Agriculture, Livestock, and Supply (MAPA, 2020) projects growth to a total 280 million tons of grain by 2030 and, in an optimistic scenario, to 336 million tons by 2030. These growth estimates range from 17 to 41 percent.

Figure 1 maps the transport flows of corn and soybeans exports in Brazil, demonstrating the importance of the logistical corridors.[2]

Figure 1: Logistics flows of corn and soybean exports in Brazil



Note: Export flows are based on COMEX-VIS (2020).
Source: University of São Paulo, Escola Superior de Agricultura "Luiz de Queiroz," Brazil (ESALQ/USP).

[2] Grains refer to corn and soybeans in this study.

Historically, Brazil has always depended greatly on long-distance road freight transport for cargo handling, especially for grains. A reduction in the sector's efficiency affects the country's competitiveness in supplying grains in the domestic and export markets.

Numerous pressures have created a high demand for railways and inland waterways services, including the high volume of production, vastness of the geography, and the low supply of transport infrastructure.

According to National Transport Confederation (CNT, 2019), the Brazilian transportation infrastructure includes:

- About 1 million miles (1.6 million kilometers (km)) of highways (13 percent are paved);
- 18,641 miles (30,000 km) of railways—one third in commercial operation; and
- Just over half of the 22,462 nautical miles (nm) (41,600 km) of inland navigable waterways that are commercially operating.

As this profile of transport infrastructure implies, Brazil depends heavily on highways—around 61.1 percent of cargo is handled by highways, 20.7 percent by railways, 13.6 percent by barge, 4.2 percent by pipelines, and 0.4 percent by airways (CNT, 2019).

However, the transportation infrastructure for grains in recent years has changed as a result of a series of factors, including the following:

(i) **The need for new export corridors, with the goal of reducing transport costs.** The share of freight prices represents around 15-40 percent of the product price delivered at the port.

(ii) **Expansion of the Brazilian agricultural frontier.** This especially involves the states of Maranhão, Tocantins, Piauí, Bahia, and the northern region of Mato Grosso.

(iii) **The need to alleviate congestion on the traditional export corridors.** The additional traffic is the result of facing significant growth in production and export levels.

(iv) **Inland waterways in the northern region of the country.** Construction of these waterways was triggered by substantial investments from the private sector after the establishment of the Ports Regulatory Framework. These investments enabled the creation of private terminals outside the organized public ports (traditional public port facilities) to provide services.

(v) Expansion of railway capacity and new railroads for handling grain in the country.

No one mode or type of infrastructure handles all grain movements in Brazil. Instead, movements involve integration between highways, waterways, and railways to connect origins, departure terminals, and destinations (ports, processing centers, or industries).

The grain handling system in the country is multimodal. With the expansion of railways and inland waterways, the dependence on long-distance (direct) highway transport will decline and the demand for short-distance transport to supply the terminals directly will increase.

This research's general objective is to analyze the modal share change for the movement of soybeans and corn in Brazil (2010-19), by building a database from different Brazilian government information sources and the generation of indicators.

Methodology

Our method of determining modal shares follows the definition presented by Chang et al. (2019). Chang et al. define the shares of total tonnage handled for each commodity and for each mode of transport (barge, rail, and truck), expressed as percentages, for the reference period.

This research's methodology involved the consolidation of information from public and official sources on transporting soybeans and corn in Brazil from 2010 to 2019. The source data are described below[3]:

- Rail movement data by origin, destination, period, and product: National Land Transport Agency (ANTT), period 2010-19.
- Barge movement data by origin, destination, period, and product: National Water Transport Agency (ANTAQ), involving inland transportation, period 2010-19.
- Soybean and corn production data: National Supply Company (CONAB), period 2010-19.
- Export Data: COMEX-VIS, Ministry of Economy (Brazil), period 2010-19.

The drivers for estimating transport types were:

- **Production:** corresponds to the quantity of product produced in the reference year obtained from the National Supply Company (CONAB) 2020.
- **Export movements:** corresponds to the export quantities of the analyzed product for the reference year, obtained through COMEX-VIS from the Ministry of Economy (COMEX-VIS 2020).
- **Domestic movements:** corresponds to the difference between production and export for the product and the reference period.

The types of transport and the calculation method employed are:

- **Total rail movement**: corresponds to the total rail movement of the analyzed product for the reference period, obtained from the National Land Transport Agency (ANTT) 2020.
- **Total barge movement**: corresponds to the total barge movement of the analyzed product for the reference period, obtained from the National Waterway Transport Agency (ANTAQ) 2020.

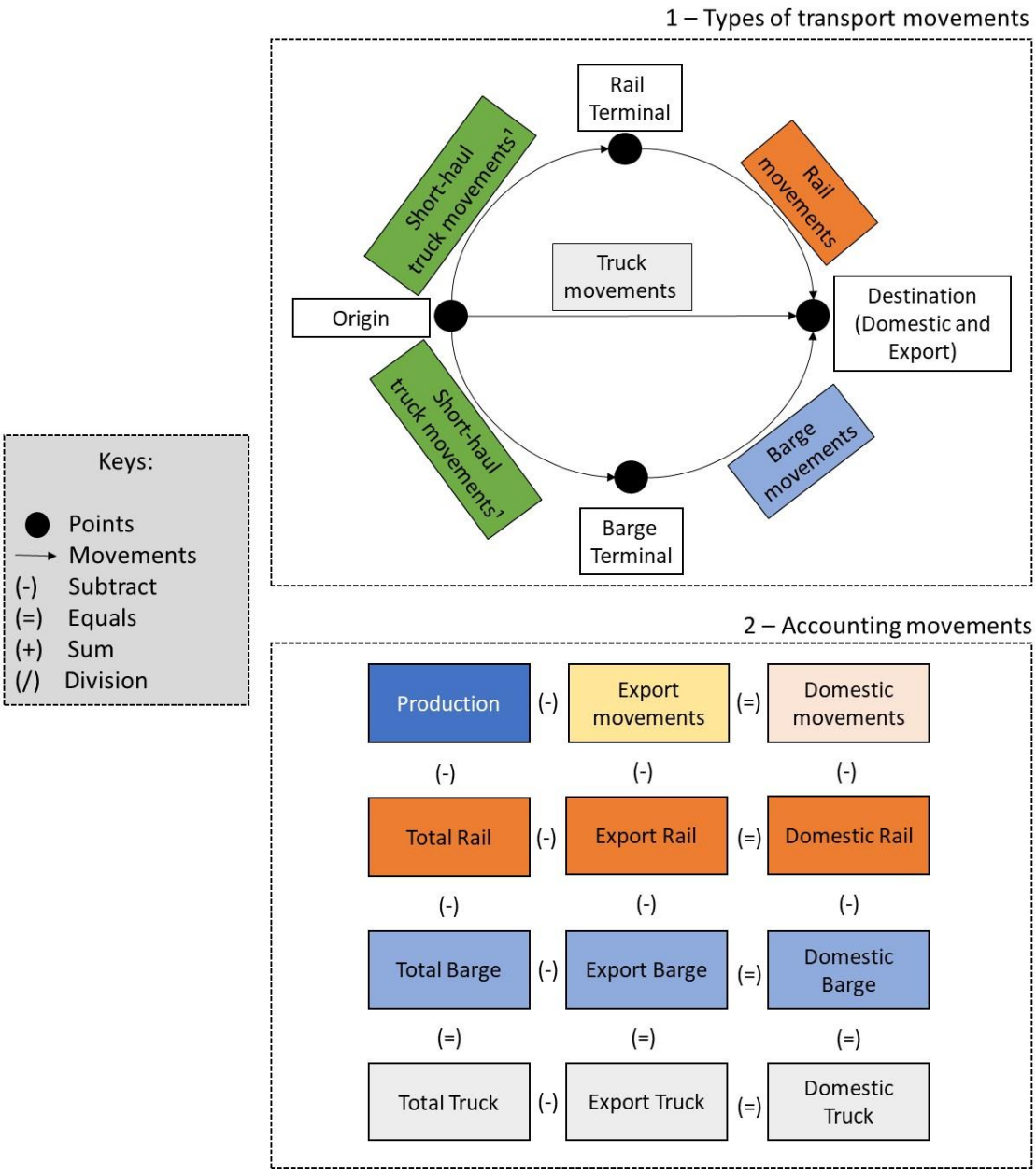
[3] See the reference section for specific information.

- **Total truck:** corresponds to trucks' movement from origin to destination (domestic and export). We estimate this movement as the difference between the quantity produced in the reference year and the sum of the amount handled by rail and barge. The average distance of this type of transport has been 574 miles (923 kilometers), according to SIFRECA (2020).
- **Export rail movement:** corresponds to the rail movement destined for the analyzed product ports for the reference period, obtained from the ANTT (2020).
- **Export barge movement:** corresponds to the barge movement destined for the analyzed product ports for the reference period, obtained from the ANTAQ (2020).
- **Export truck movement:** refers to a residual because there are no data available for the total truck export movement. We estimate this movement as the difference between total exports and the sum of the total tons handled by rail and barge movements for ports.
- **Domestic rail movement:** corresponds to the rail movement destined for the analyzed product's domestic market for the reference period, obtained from the difference between total rail movement and export rail movement.
- **Domestic barge movement:** corresponds to the barge movement destined for the analyzed product's domestic market for the reference period, obtained from the difference between total barge movement and export barge movement.
- **Domestic truck:** corresponds to the long-distance movement of trucks from the source to the domestic market destination. We estimate this movement as the difference between the domestic movement and the sum of the quantity handled by rail and barge for the domestic market in the reference year.

In the modal share analysis, we consider only the accounting for the tonnage of the long-haul truck, which is the long-distance movement involving the production regions and destinations (ports or domestic market). More specifically, in Brazil, due to the country's vastness, low density of the rail and waterway networks, and low number of terminals, transportation from production regions to terminals occurs exclusively by trucks, called short-haul trucks. In this study, short-haul truck shipments are not considered part of the modal share analysis to avoid double counting and to the fact that such movement represents the shortest segment of a long route to reach the port or domestic market. We refer to the average distance of 440 miles (707 kilometers (km)) from the farm to rail and barge terminals.

Figure 2 presents a summary table illustrating the method used. For more details, see Appendix A of this document.

Figure 2: Framework approach for estimating modal tonnages and shares



[1]Short-haul truck: corresponds to the movement between the producing regions and the terminals and is not counted in the modal share analysis.

Table 1 presents the tonnages of corn and soybean transported by type of market (export and domestic) and the production for 2010-19.

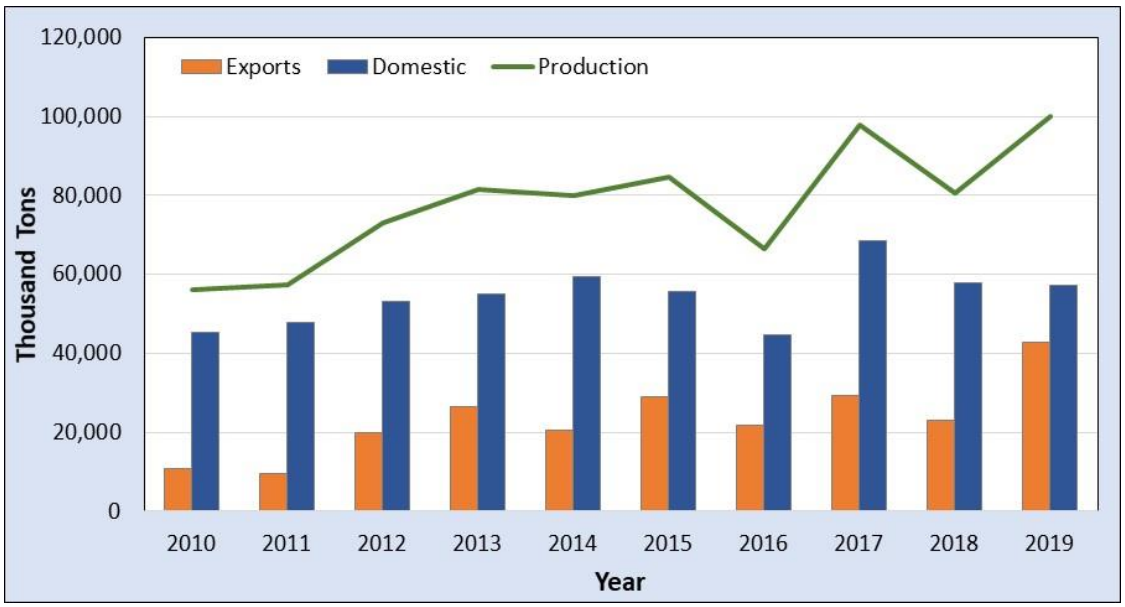
Table 1: Tonnages of corn and soybean transported by type of market, 2010-19

Year	Corn			Soybean		
	Production	Export	Domestic	Production	Export	Domestic
	1,000 tons					
2010	56,018	10,819	45,199	68,688	29,073	39,615
2011	57,407	9,482	47,925	75,324	32,976	42,349
2012	72,980	19,801	53,178	66,383	32,906	33,477
2013	81,506	26,624	54,882	81,499	42,796	38,703
2014	80,052	20,655	59,397	86,173	45,692	40,481
2015	84,672	28,924	55,749	97,094	54,324	42,770
2016	66,531	21,873	44,657	95,698	51,582	44,116
2017	97,843	29,266	68,577	115,027	68,155	46,872
2018	80,710	22,964	57,745	123,259	83,258	40,001
2019	100,043	42,752	57,291	119,718	74,073	45,645

Source: University of São Paulo, Escola Superior de Agricultura "Luiz de Queiroz," Brazil (ESALQ/USP).

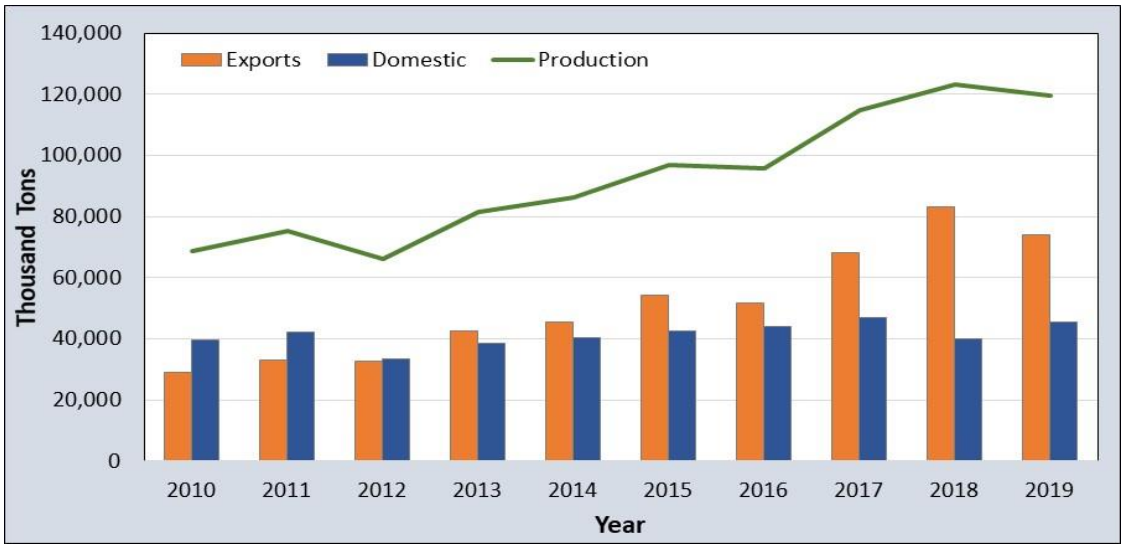
Figure 3 and Figure 4 present the corn and soybean movements for domestic and export markets in 2010-19, respectively.

Figure 3: Corn movements to domestic and export markets, 2010 -19



Source: COMEX-VIS (2020), CONAB (2020) and authors.

Figure 4: Soybean movements to domestic and export markets, 2010-19

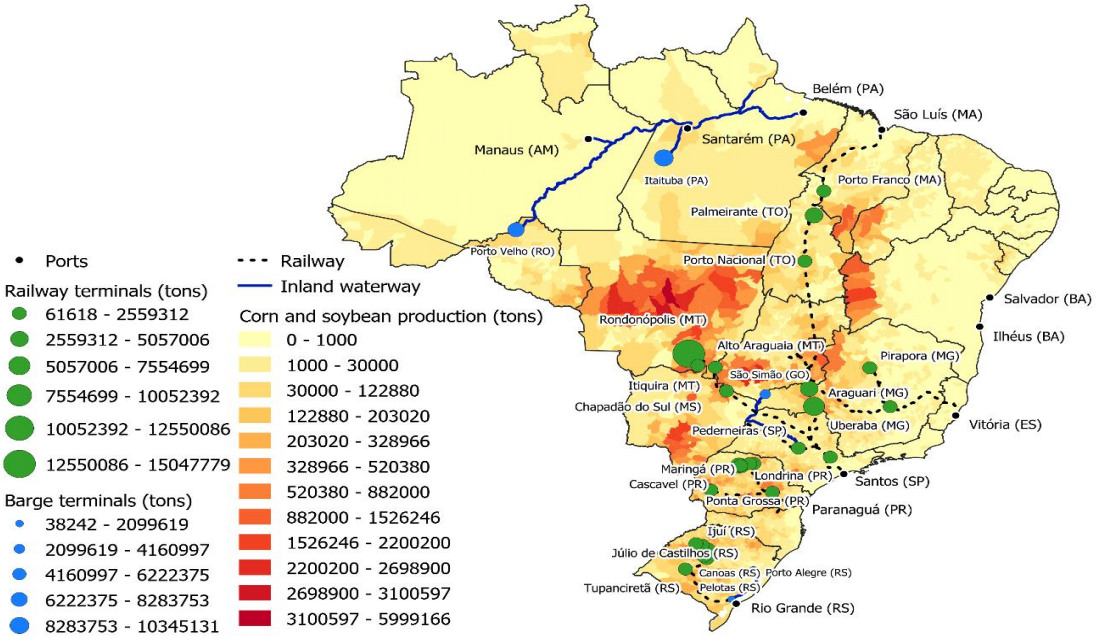


Source: COMEX-VIS (2020), CONAB (2020) and authors.

Corn and soybean logistics infrastructure and transportation indicators

Figure 5 illustrates the corn and soybean logistics infrastructure in 2019, involving the main multimodal terminals and ports.

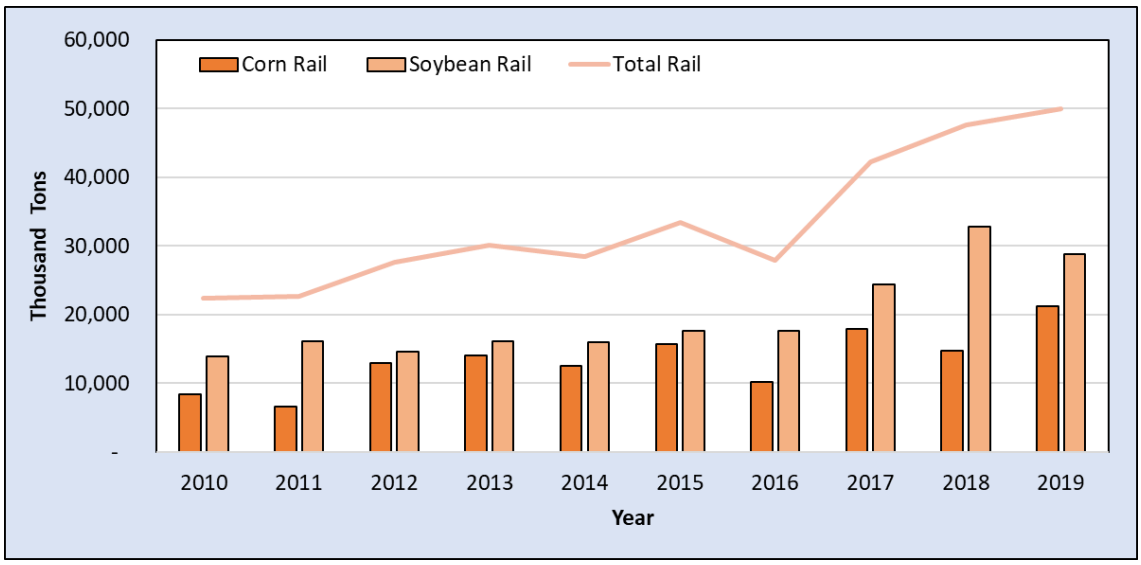
Figure 5: Corn and soybean logistics infrastructure, 2019



Source: University of São Paulo, Escola Superior de Agricultura “Luiz de Queiroz,” Brazil (ESALQ/USP)

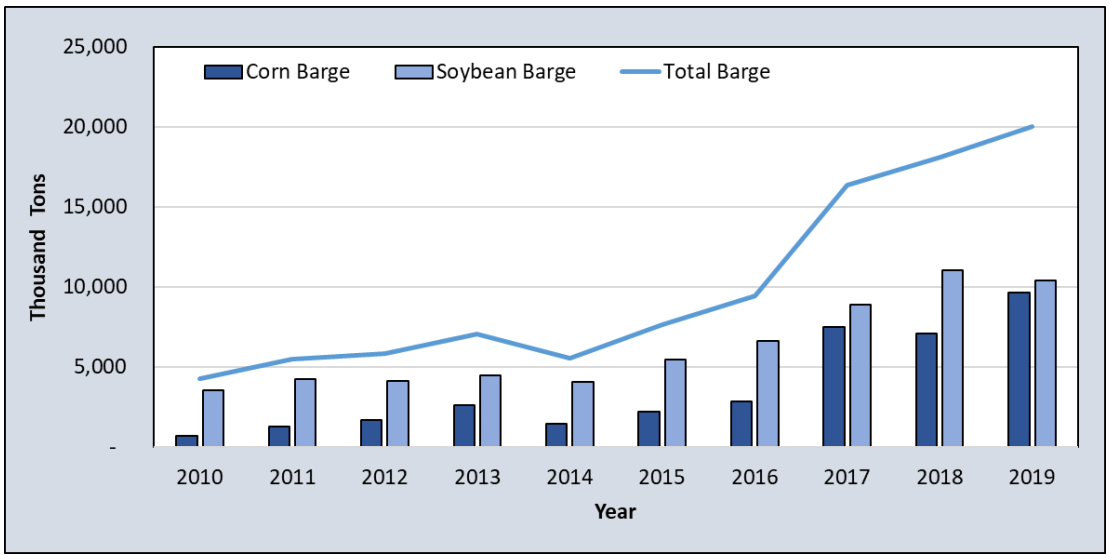
Figure 6 and Figure 7 present the rail and barge movements for corn and soybean, respectively, in 2010-19.

Figure 6: Corn and soybean movements by rail, 2010-19



Source: ANTT (2020).

Figure 7: Corn and soybean movements by barge, 2010-19



Source: ANTAQ (2020).

Table 2 presents the rail and barge average distance for corn and soybean total movements in 2010-19. Railways haul corn an average distance of 782 miles and soybeans 651 miles. Barge corn shipments, on average, travel 668 miles and soybeans 615 miles.

Table 2: Corn and soybean average distance—rail and barge, 2010-19

Year	Corn		Soybean	
	Railway average distance	Barge average distance*	Railway average distance	Barge average distance
	(miles)			
2010	745.0	519.3 (451.2 nm)	609.90	510.3 (443.4 nm)
2011	734.1	626.7 (544.5 nm)	628.40	571.8 (496.8 nm)
2012	734.5	627.9 (545.6 nm)	632.60	649.7 (564.5 nm)
2013	771.3	683.2 (593.6 nm)	631.20	599.4 (520.8 nm)
2014	796.5	769.3 (668.5 nm)	688.20	605.3 (525.9 nm)
2015	801.1	792.0 (688.2 nm)	681.30	649.7 (564.5 nm)
2016	841.1	730.8 (635 nm)	679.70	656.8 (570.7 nm)
2017	781.0	666.5 (579.1 nm)	665.80	654.7 (568.9 nm)
2018	861.0	639.9 (556 nm)	633.00	618.1 (537.1 nm)
2019	757.9	627.8 (545.5 nm)	659.60	637.3 (553.7 nm)
Average	**782.3**	**668.3 (580.7 nm)**	**651.0**	**615.3 (534.6 nm)**

*Nautical miles (nm)
Source: elaborated by the authors based on ANTAQ (2020) and ANTT (2020).

Corn Modal Shares

In this section, we present the modal share indicators for corn. Specifically, Table 3 shows the tonnage and the modal shares. The share of corn shipments by rail increased from 15 percent in 2010 to 21 percent in 2019. Barge share increased significantly from 1 percent in 2010 to nearly 10 percent in 2019

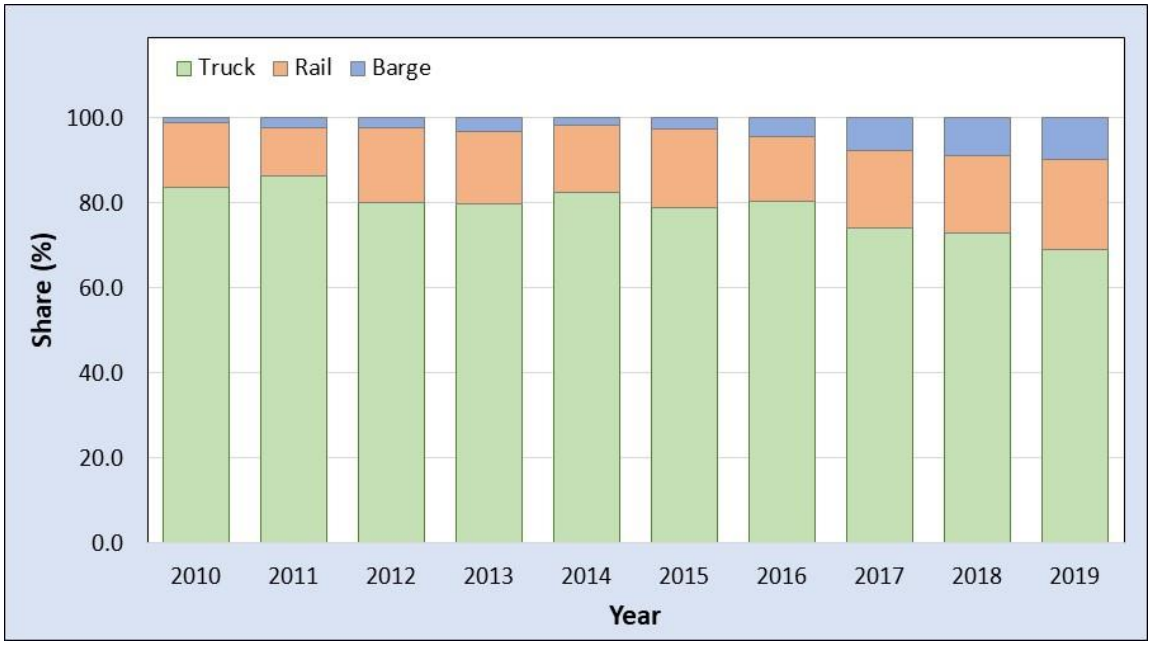
Table 3: Tonnages and modal shares for corn, 2010-19

Year	Truck		Short-haul truck*				Tonnage	
			Rail		Barge			
	1,000 tons	Percent	1,000 tons	Percent	1,000 tons	Percent	1,000 tons	
Total								
2010	46,882	83.8	8,441	15.0	694	1.2	56,017	Production Tonnage
2011	49,569	86.4	6,555	11.4	1,283	2.2	57,407	
2012	58,301	80.0	12,973	17.7	1,706	2.3	72,980	
2013	64,926	79.8	13,993	17.1	2,586	3.1	81,505	
2014	66,101	82.6	12,501	15.6	1,450	1.8	80,052	
2015	66,808	79.0	15,671	18.5	2,193	2.5	84,672	
2016	53,473	80.5	10,228	15.3	2,829	4.2	66,530	
2017	72,477	74.2	17,896	18.2	7,469	7.6	97,842	
2018	58,852	73.0	14,786	18.3	7,072	8.7	80,710	
2019	69,153	69.2	21,240	21.2	9,650	9.6	100,043	
Export								
2010	2,150	20.0	8,392	77.5	276	2.5	10,818	Export Tonnage
2011	2,176	23.1	6,504	68.5	802	8.4	9,482	
2012	6,003	30.4	12,895	65.1	903	4.5	19,801	
2013	11,068	41.6	13,927	52.3	1,629	6.1	26,624	
2014	6,785	32.9	12,420	60.1	1,450	7.0	20,655	
2015	11,206	38.9	15,525	53.6	2,193	7.5	28,924	
2016	9,635	44.1	9,566	43.7	2,672	12.2	21,873	
2017	4,824	16.6	17,852	60.9	6,590	22.5	29,266	
2018	1,981	8.7	14,606	63.6	6,378	27.7	22,965	
2019	13,220	31.0	21,193	49.5	8,339	19.5	42,752	
Domestic								
2010	44,732	99.0	49	0.1	418	0.9	45,199	Domestic Tonnage
2011	47,393	98.9	51	0.1	480	1.0	47,924	
2012	52,298	98.4	78	0.1	802	1.5	53,178	
2013	53,859	98.2	66	0.1	957	1.7	54,882	
2014	59,315	99.9	82	0.1	0	0	59,397	
2015	55,603	99.8	146	0.2	0	0	55,749	
2016	43,838	98.3	662	1.4	157	0.3	44,657	
2017	67,653	98.8	44	0	880	1.2	68,577	
2018	56,871	98.5	180	0.3	694	1.2	57,745	
2019	55,933	97.8	47	0	1,311	2.2	57,291	

Note: Data compiled from the National Land Transport Agency (ANTT); National Land Transport Agency (ANTAQ), Comex-Vis, Ministry of Economy, and National Supply Company (CONAB).
* Short-haul truck shipments refer to the average distance of 440 miles (707 kilometers (km)) from the farm to rail and barge terminals.
Source: Modal share analysis results—calculations by the University of São Paulo, Escola Superior de Agricultura "Luiz de Queiroz," Brazil (ESALQ/USP) and USDA, Agricultural Marketing Service.

Figure 8 presents the Brazil corn modal shares for 2010-19. The use of trucks went from nearly 84 percent in 2010 to about 69 percent in 2019, reducing the dependence on long-distance transportation. On the other hand, rail increased from almost 15 percent to 21 percent, while the barge market share increased significantly from 1 percent to nearly 10 percent.

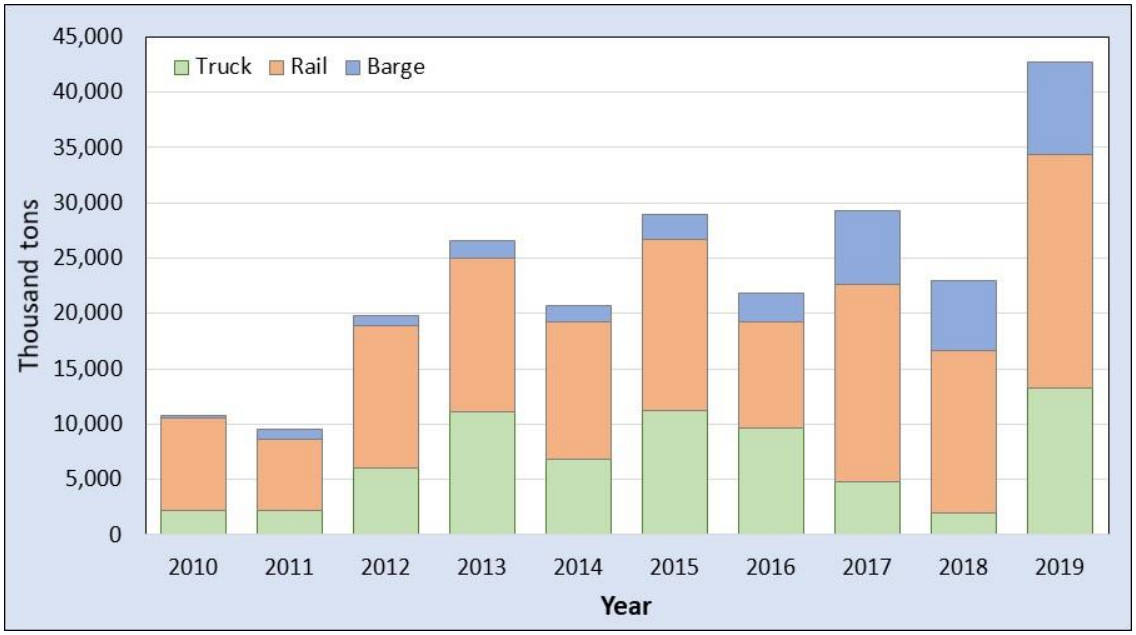
Figure 8: Corn modal shares, 2010-19



Source: elaborated by the authors based on ANTAQ (2020), ANTT (2020), COMEX-VIS (2020) and CONAB (2020).

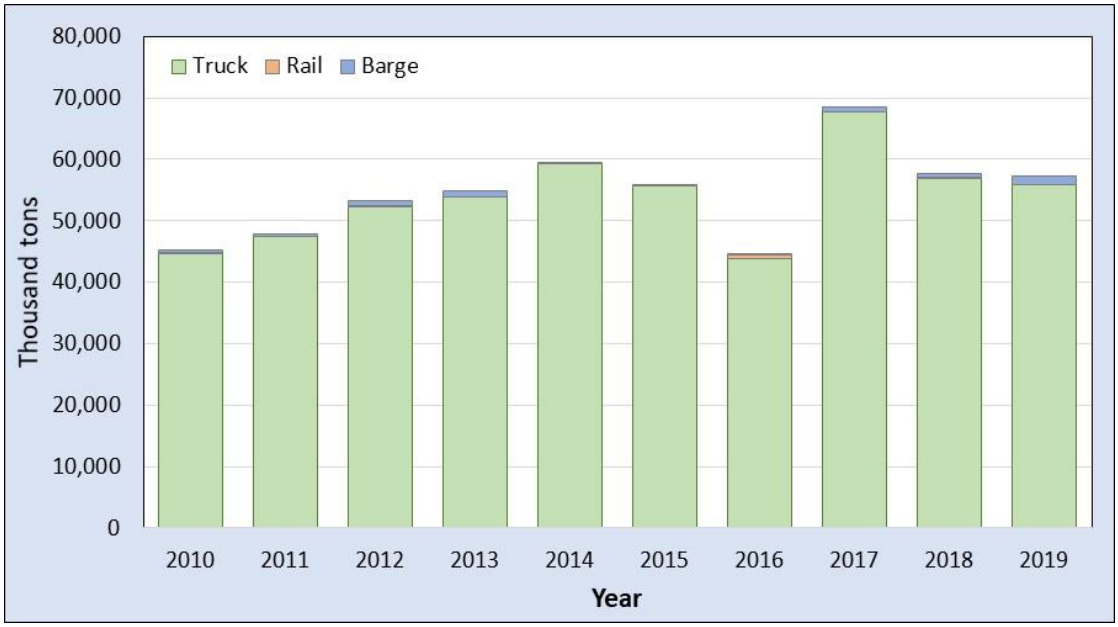
Figure 9 and Figure 10 shows the Brazil corn export and domestic shipments by mode in the period 2010-19, respectively.

Figure 9: Corn export shipments by mode, 2010-19



Source: elaborated by the authors based on ANTAQ (2020), ANTT (2020), COMEX-VIS (2020) and CONAB (2020).

Figure 10: Domestic corn shipments by mode, 2010-19



Source: elaborated by the authors based on ANTAQ (2020), ANTT (2020), COMEX-VIS (2020) and CONAB (2020).

Soybean Modal Shares

In this section, we present the modal share indicators for soybean. Table 3 shows the relationship between soybean production and modal shipments from 2010-19. The share of soybean production by rail increased from 20 percent in 2010 to 24 percent in 2019. Barge share increased significantly from 5 percent in 2010 to nearly 9 percent in 2019.

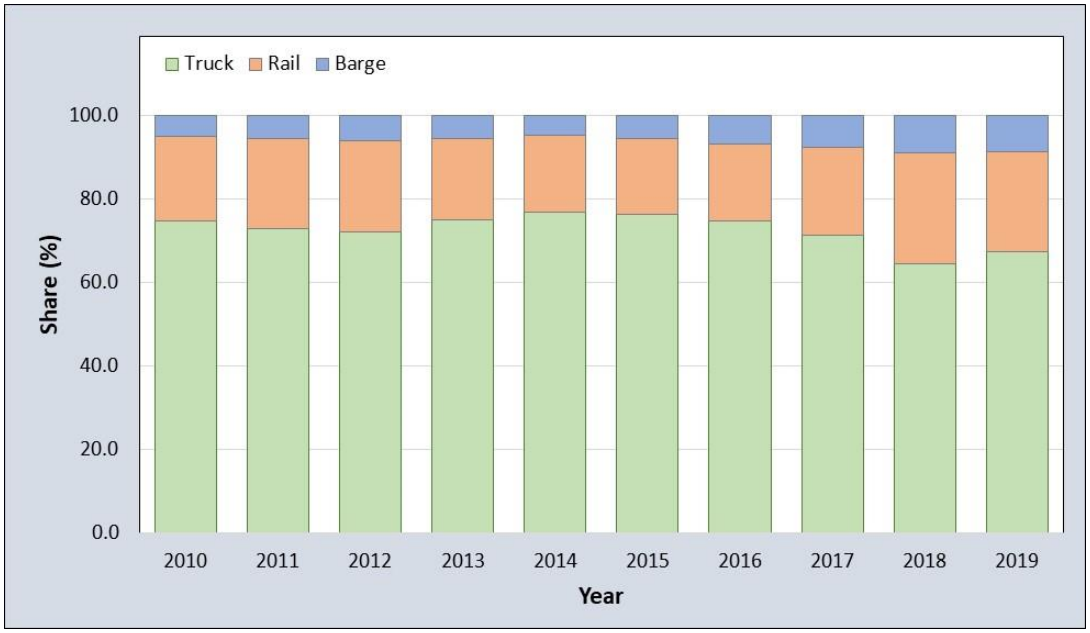
Table 4: Tonnages and modal shares for soybeans, 2010-19

Year	Truck		Short-haul truck				Tonnage	
			Rail		Barge			
	1,000 tons	Percent	1,000 tons	Percent	1,000 tons	Percent	1,000 tons	
Total								
2010	51,218	74.7	13,908	20.2	3,562	5.1	68,688	Production Tonnage
2011	54,936	73.0	16,169	21.4	4,219	5.6	75,324	
2012	47,679	72.0	14,596	21.9	4,108	6.1	66,383	
2013	60,908	74.9	16,120	19.7	4,472	5.4	81,500	
2014	66,119	76.8	15,985	18.5	4,069	4.7	86,173	
2015	73,941	76.2	17,691	18.2	5,462	5.6	97,094	
2016	71,408	74.7	17,666	18.4	6,624	6.9	95,698	
2017	81,817	71.2	24,324	21.1	8,886	7.7	115,027	
2018	79,390	64.5	32,841	26.6	11,028	8.9	123,259	
2019	80,557	67.4	28,783	24.0	10,378	8.6	119,718	
Export								
2010	12,980	44.7	13,676	47.0	2,417	8.3	29,073	Export Tonnage
2011	13,964	42.4	15,960	48.4	3,051	9.2	32,975	
2012	15,396	46.9	14,462	43.9	3,048	9.2	32,906	
2013	23,492	55.0	15,997	37.3	3,307	7.7	42,796	
2014	26,320	57.7	15,796	34.5	3,577	7.8	45,693	
2015	31,406	57.9	17,456	32.1	5,462	10.0	54,324	
2016	28,165	54.7	17,393	33.7	6,024	11.6	51,582	
2017	36,323	53.4	24,017	35.2	7,815	11.4	68,155	
2018	40,975	49.3	32,565	39.1	9,718	11.6	83,258	
2019	36,225	49.1	28,442	38.3	9,406	12.6	74,073	
Domestic								
2010	38,239	96.7	232	0.5	1,145	2.8	39,616	Domestic Tonnage
2011	40,972	96.9	208	0.4	1,168	2.7	42,348	
2012	32,283	96.5	134	0.4	1,060	3.1	33,477	
2013	37,416	96.7	123	0.3	1,165	3.0	38,704	
2014	39,799	98.4	190	0.4	492	1.2	40,481	
2015	42,535	99.5	234	0.5	0.0	0	42,769	
2016	43,243	98.1	273	0.6	600	1.3	44,116	
2017	45,494	97.2	307	0.6	1,071	2.2	46,872	
2018	38,416	96.2	276	0.6	1,310	3.2	40,002	
2019	44,332	97.2	342	0.7	972	2.1	45,646	

Note: Data compiled from the National Land Transport Agency (ANTT); National Land Transport Agency (ANTAQ), Comex-Vis, Ministry of Economy, and National Supply Company (CONAB).
* Short-haul truck shipments refer to the average distance of 440 miles (707 kilometers (km)) from the farm to rail and barge terminals.
Source: Modal share analysis results—calculations by the University of São Paulo, Escola Superior de Agricultura "Luiz de Queiroz," Brazil (ESALQ/USP) and USDA, Agricultural Marketing Service.

Figure 11 presents the Brazil soybean modal share for 2010-19. The use of trucks dropped from 74.7 percent (2010) to 67.4 percent (2019), reducing the dependence on long-distance transportation. On the other hand, rail went from 20.2 percent to 24 percent, while barge increased from 5.1 percent to 8.6 percent—the modal share with the greatest growth in the period.

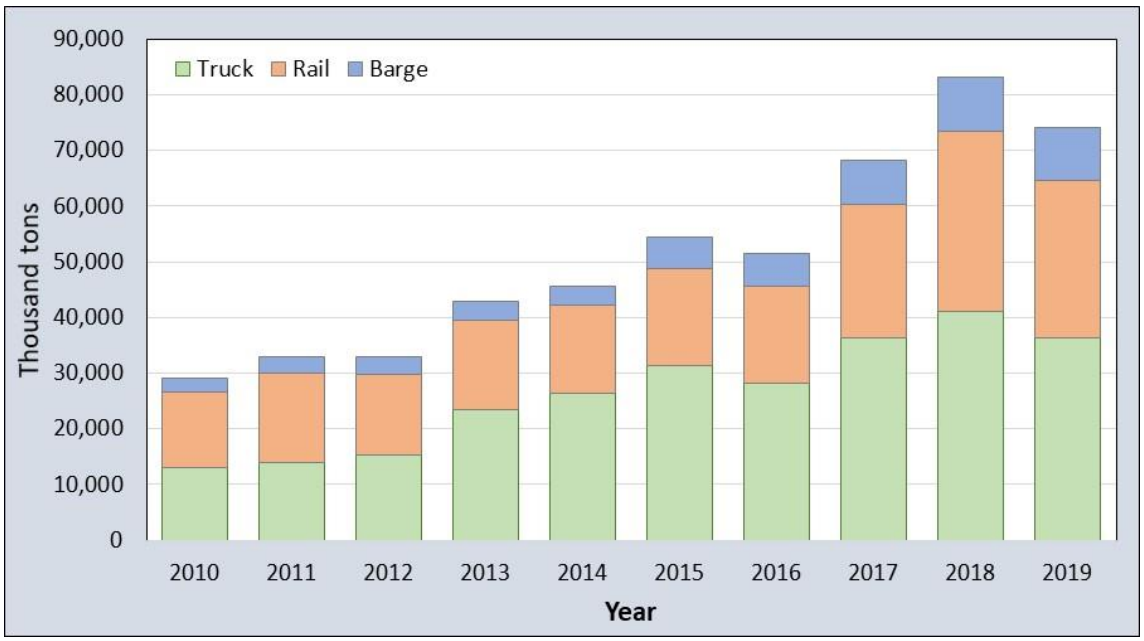
Figure 11: Soybean modal shares, 2010-19



Source: elaborated by the authors based on ANTAQ (2020), ANTT (2020), COMEX-VIS (2020) and CONAB (2020).

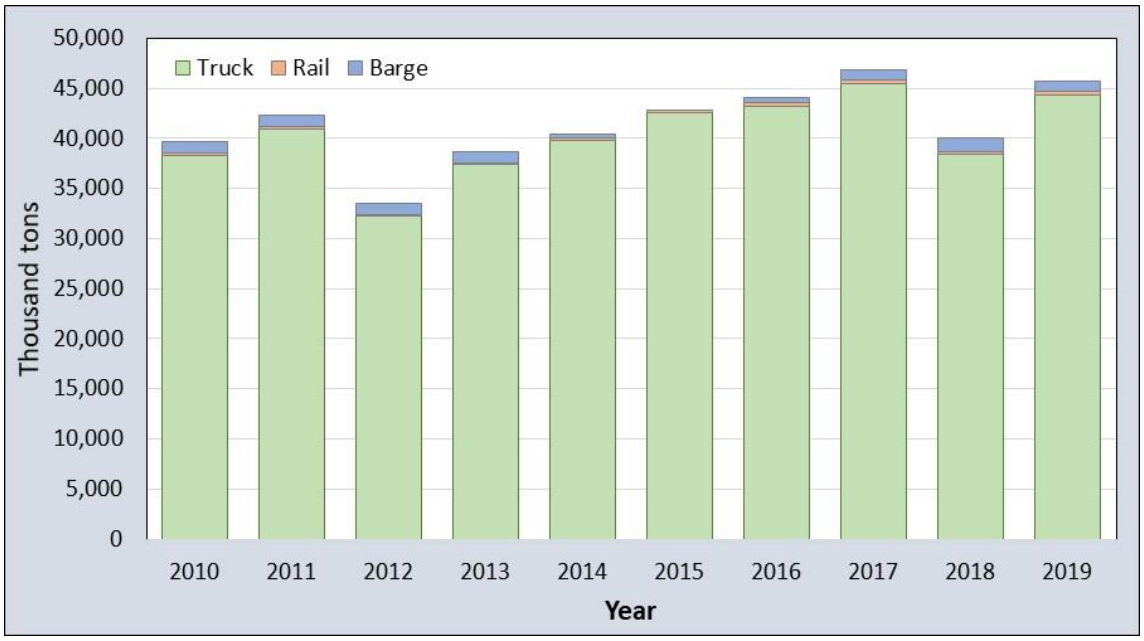
Figure 12 and Figure 13 shows the Brazil soybean export and domestic shipments by mode in the period 2010-19, respectively.

Figure 12: Soybean export shipments by mode, 2010-19



Source: elaborated by the authors based on ANTAQ (2020), ANTT (2020), COMEX-VIS (2020) and CONAB (2020).

Figure 13: Domestic soybean shipments by mode, 2010-19



Source: Calculated by the authors based on ANTAQ (2020), ANTT (2020), COMEX-VIS (2020) and CONAB (2020).

Logistical flows of corn and soybean in Brazil

In this section, we present the logistical flows of corn and soybean in Brazil, involving the following analysis:

- Corn and soybeans movements to the main export ports in Brazil by mode: Santos and Paranaguá (2010-19).
- Quantity handled of corn and soybean by rail terminal by mode (2019).
- Distribution of corn shipments by rail terminal (2019).
- Distribution of soybean shipments by rail terminal (2019).
- Quantity handled of corn and soybean by barge terminal (2019).
- Distribution of corn shipments by barge terminal (2019).
- Distribution of soybean shipments by rail terminal (2019).
- Movements of corn and soybean in barge routes (2019).
- Movements of corn and soybean in rail routes (2019).

Table 5 presents the corn and soybean movements to the Ports of Santos and Paranaguá in 2010-19, by mode of transportation.

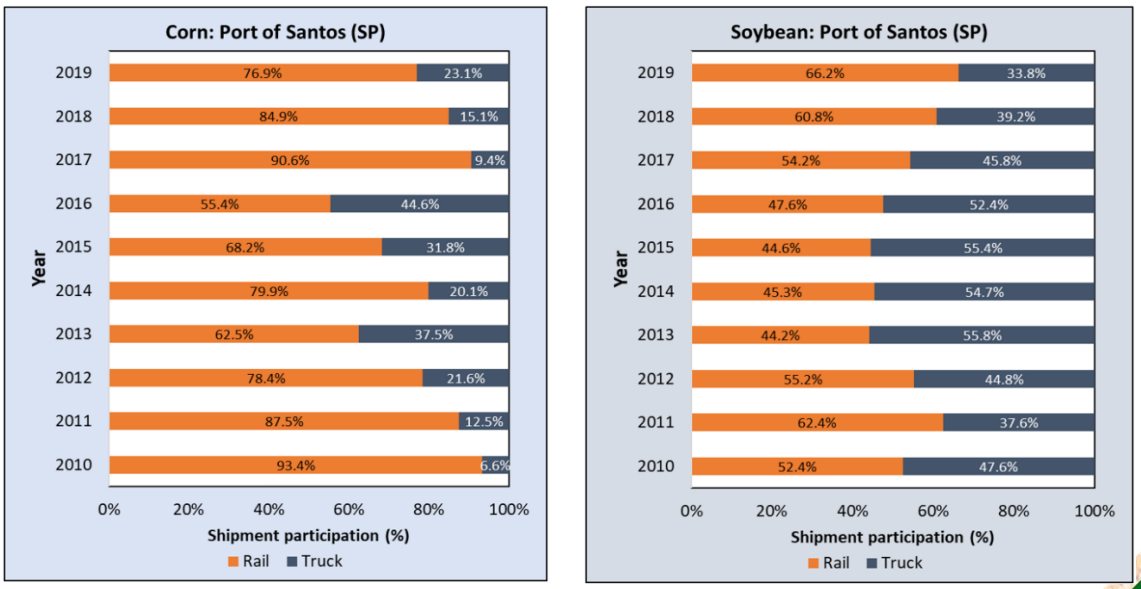
Table 5: Corn and soybeans movements to Ports of Santos and Paranaguá by mode, 2010-19

Year	Corn			Soybean		
	Rail	Barge	Truck	Rail	Barge	Truck
	1,000 tons					
Port of Santos (SP)						
2010	5,159	-	366	4,312	-	3,915
2011	4,222	-	601	5,762	-	3,468
2012	7,186	-	1,976	5,741	-	4,655
2013	7,442	-	4,468	5,698	-	7,195
2014	6,732	-	1,693	5,765	-	6,954
2015	9,030	-	4,210	5,808	-	7,224
2016	6,246	-	5,038	6,893	-	7,583
2017	12,417	-	1,288	8,997	-	7,592
2018	11,242	-	2,003	12,595	-	8,119
2019	14,227	-	4,262	11,307	-	5,779
Port of Paranaguá (PR)						
2010	1,511	-	1,557	1,266	-	4,068
2011	1,071	-	1,461	1,756	-	5,169
2012	1,431	-	3,371	1,586	-	5,368
2013	1,078	-	3,538	1,375	-	6,361
2014	1,108	-	2,925	1,195	-	6,332
2015	1,269	-	2,799	1,065	-	7,454
2016	478	-	2,321	1,499	-	6,658
2017	1,048	-	2,559	2,175	-	9,174
2018	546	-	545	4,289	-	10,583
2019	2,358	-	3,535	2,926	-	8,742

Source: elaborated by the authors based on ANTT (2020) and COMEX-VIS (2020).

Figure 14 shows the evolution of corn and soybeans' movement in the port of Santos by mode of transportation, in terms of the total volume exported. In 2019, rail hauled nearly 77 percent of the total corn delivered to Santos and 66 percent of soybeans. These figures are derived from Table 5.

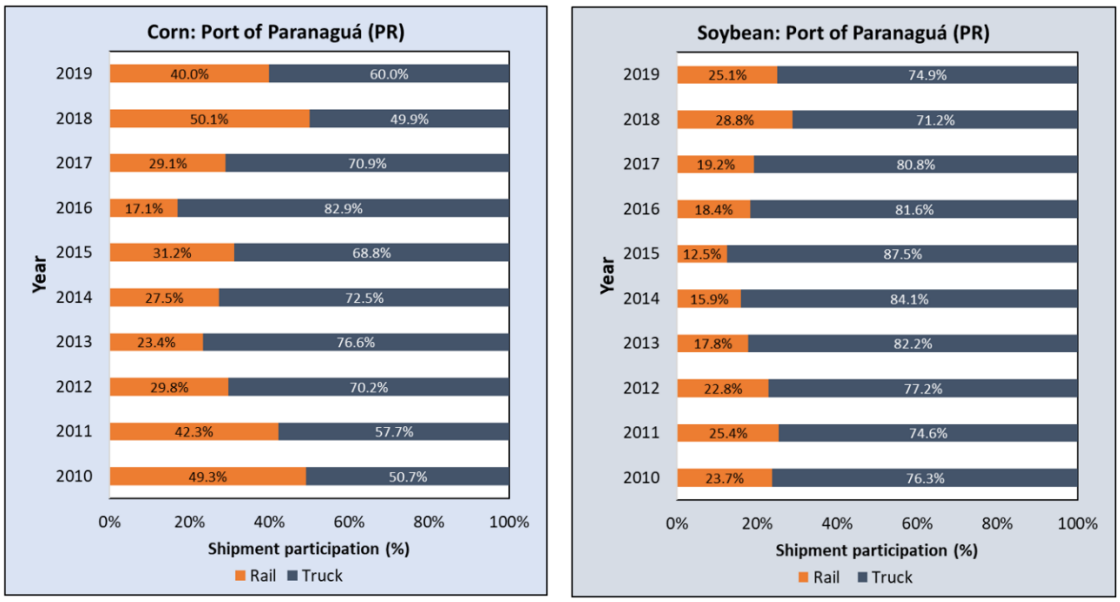
Figure 14: Corn and soybean movements to Port of Santos (SP) by rail and truck (%), 2010-19



Source: elaborated by the authors based on ANTT (2020) and COMEX-VIS (2020).

Figure 14 shows the evolution of corn and soybeans' movement in the port of Paranaguá by mode of transportation, in terms of the total volume exported. In 2019, trucks delivered 60 percent of corn exports and rail delivered 40 percent to the Port of Paranaguá,. Trucks delivered nearly 75 percent of soybeans to the Port of Paranaguá and rail hauled 25 percent. These figures are derived from Table 5.

Figure 15: Corn and soybean movements to the Port of Paranaguá by rail and truck (%), 2010-19



Source: elaborated by the authors based on ANTT (2020) and COMEX-VIS (2020).

Table 6 shows the amounts of corn and soybeans (in tons) and shares of the totals rail terminals handled in 2019.

For example, the largest rail terminal in the country in 2019 was in Rondonópolis (MT), which handled 44 percent of all corn and 19 percent of all soybeans.

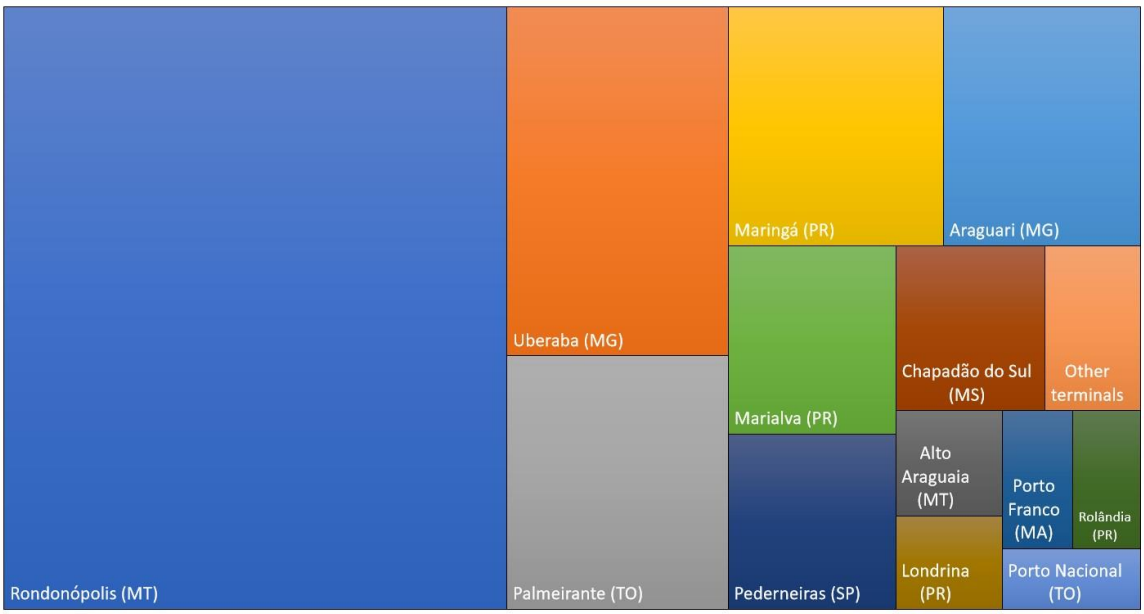
Table 6: Quantity handled by rail terminal, 2019

Rail Terminal	Quantity handled - 2019 (1,000 tons)		Relative quantity handled - 2019 (percent of total)	
	Corn	Soybean	Corn	Soybean
Rondonópolis (MT)	9,398.5	5,649.3	44.2	19.6
Uberaba (MG)	2,394.9	3,085.2	11.3	10.7
Araguari (MG)	1,462.0	3,536.4	6.9	12.3
Palmeirante (TO)	1,740.6	2,447.8	8.2	8.5
Maringá (PR)	1,598.0	2,184.7	7.5	7.6
Marialva (PR)	974.4	1,411.4	4.6	4.9
Cruz Alta (RS)	80.6	1,936.4	0.4	6.7
Porto Franco (MA)	302.0	1,428.2	1.4	5.0
Porto Nacional (TO)	261.9	1,386.1	1.2	4.8
Pederneiras (SP)	911.8	725.9	4.3	2.5
Chapadão do Sul (MS)	759.1	801.6	3.6	2.8
Pirapora (MG)	0.0	790.9	0.0	2.7
Itiquira (MT)	83.8	609.1	0.4	2.1
Cascavel (PR)	127.9	512.5	0.6	1.8
Rolândia (PR)	291.4	321.0	1.4	1.1
Londrina (PR)	309.1	289.3	1.5	1.0
Alto Araguaia (MT)	347.3	237.9	1.6	0.8
Cacequi (RS)	25.8	327.3	0.1	1.1
Júlio de Castilhos (RS)	5.5	312.4	0.0	1.1
Ponta Grossa (PR)	0.0	253.3	0.0	0.9
Campinas (SP)	98.8	68.0	0.5	0.2
Santa Luzia (MG)	0.0	137.6	0.0	0.5
Santo Ângelo (RS)	13.2	85.6	0.1	0.3
Sarandi (PR)	42.0	42.4	0.2	0.1
Tupanciretã (RS)	0.0	84.1	0.0	0.3
Ijuí (RS)	9.6	52.0	0.0	0.2
Alegrete (RS)	0.0	29.9	0.0	0.1
Pradópolis (SP)	0.0	29.9	0.0	0.1
Guarapuava (PR)	0.1	5.5	0.0	0.0
Rio Grande (RS)	1.4	0.0	0.0	0.0
Guarujá (SP)	0.0	1.1	0.0	0.0
Serra (ES)	0.0	0.2	0.0	0.0
São Francisco do Sul (SC)	0.0	0.1	0.0	0.0

Source: elaborated by the authors based on ANTT (2020).

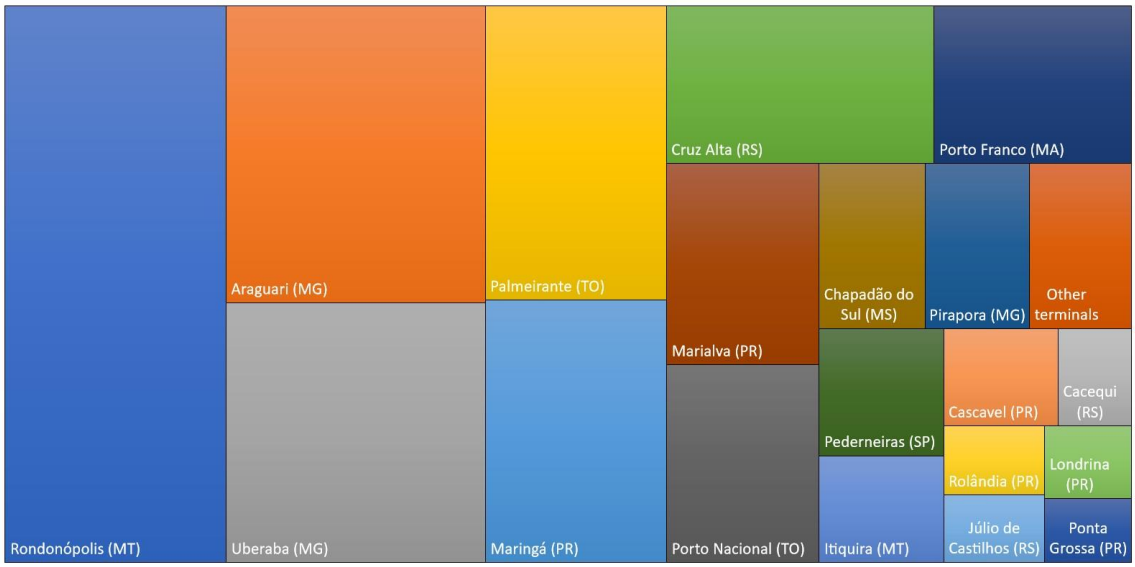
Figure 16 and Figure 17 present the data in Table 6 visually, illustrating the concentration of movements by rail terminal for both corn and soybeans.

Figure 16: Distribution of corn shipments by rail terminal, 2019



Note: figure illustrating the information presented in Table 8.
Source: elaborated by the authors based on ANTT (2020).

Figure 17: Distribution of soybean shipments by rail terminal, 2019



Note: figure illustrating the information presented in Table 8.
Source: elaborated by the authors based on ANTT (2020).

Table 7 shows the amounts of corn and soybeans (in tons) and shares of the totals barge terminals handled in 2019.

For example, the largest barge terminal in the country in 2019 was Itaituba (PA), which handled nearly 59 percent of all corn transported by barge; almost 45 percent of all soybeans moved by barge.

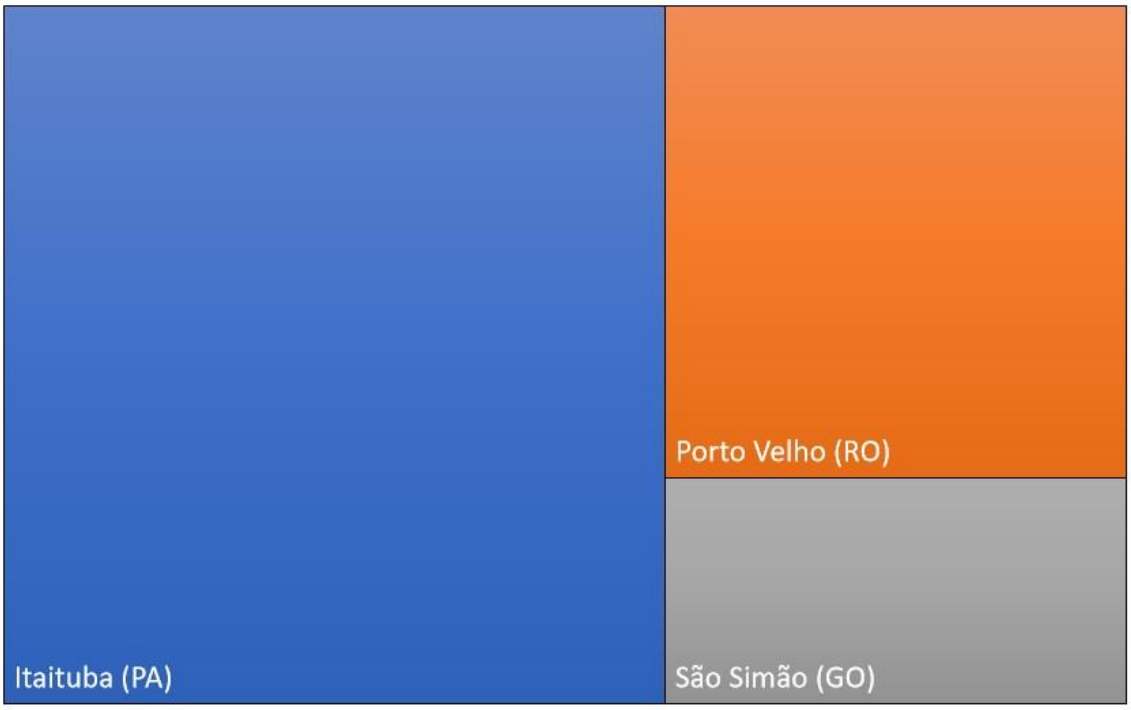
Table 7: Quantity handled by barge terminal, 2019

Barge Terminal	Quantity handled – 2019 (1,000 tons)		Relative quantity handled – 2019 (percent of total)	
	Corn	Soybean	Corn	Soybean
Itaituba (PA)	5,688.2	4,656.9	58.9	44.9
Porto Velho (RO)	2,682.1	4,317.5	27.8	41.6
São Simão (GO)	1,279.6	860.5	13.3	8.3
Porto Alegre (RS)	0.0	279.0	0.0	2.7
Canoas (RS)	0.0	225.9	0.0	2.2
Pelotas (RS)	0.0	38.2	0.0	0.4

Source: elaborated by the authors based on ANTAQ (2020).

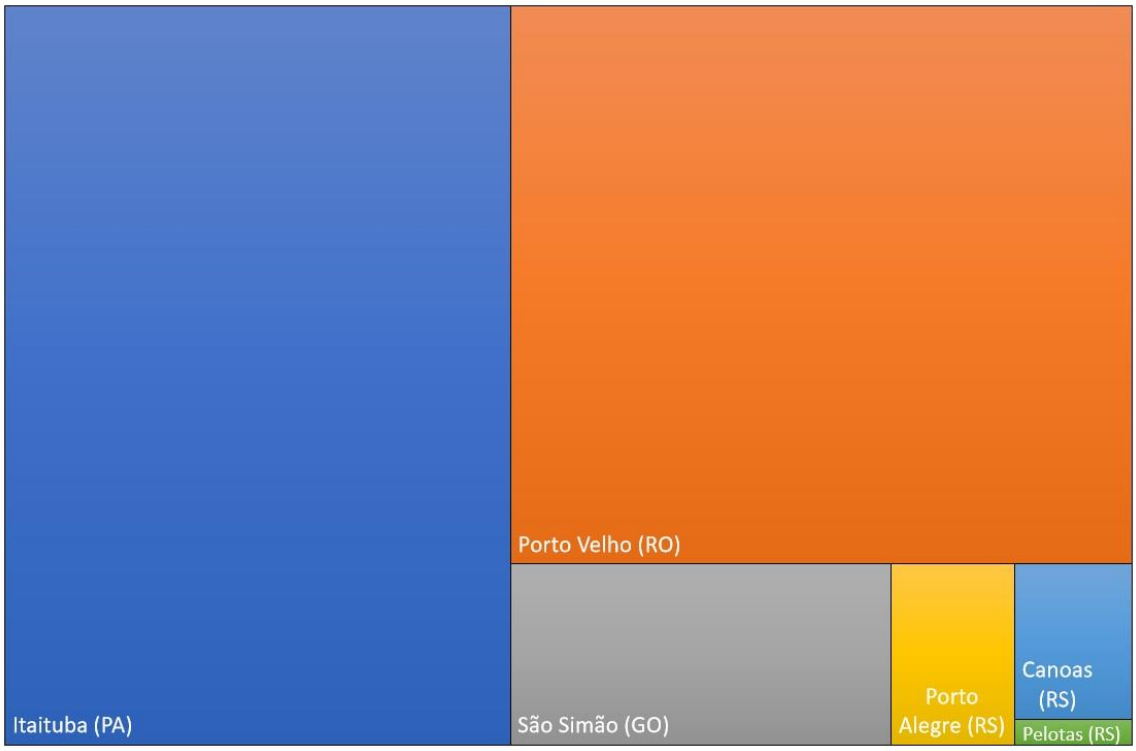
Figure 18 and Figure 19 present the data in Table 7 visually, illustrating the concentration of movements by barge terminal for both corn and soybeans, respectively.

Figure 18: Distribution of corn shipments by barge terminal, 2019



Note: Figure illustrates the information presented in Table 9.
Source: elaborated by the authors based on ANTAQ (2020).

Figure 19: Distribution of soybean shipments by barge terminal, 2019



Note: Figure illustrates the information presented in Table 9.
Source: elaborated by the authors based on ANTAQ (2020).

Table 8 presents barge movements between origin-destination (routes) pairs in Brazil for corn and soybeans in 2019. The main logistic flow of barges in the country for corn and soybean was from the Itaituba (PA) terminal to the Barcarena (PA) export terminal.

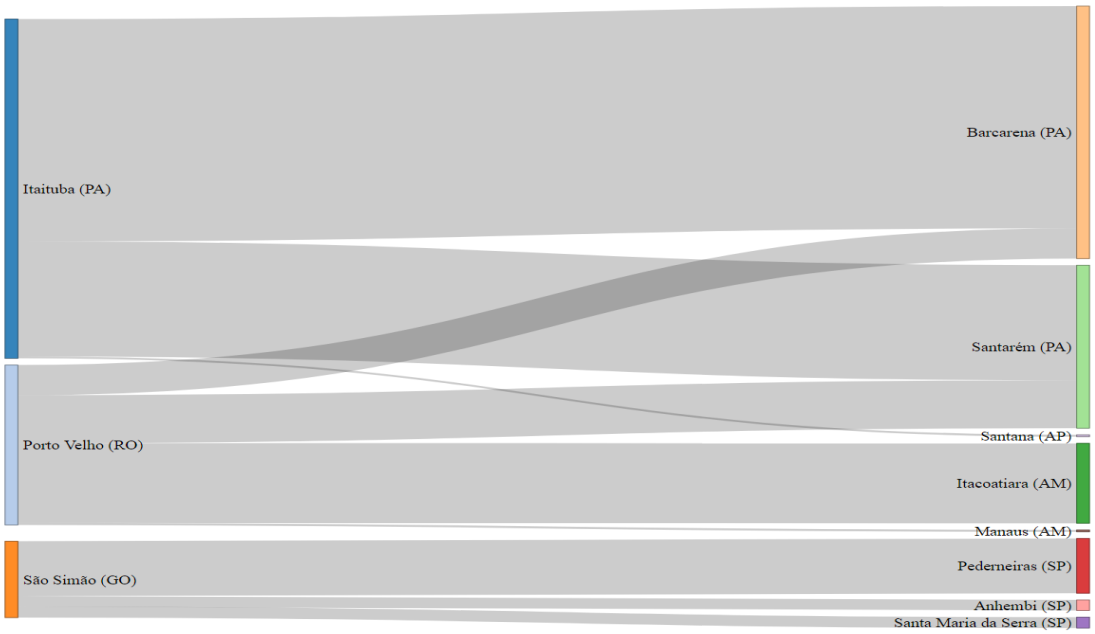
Table 8: Movements of corn and soybean in barge routes, 2019

Barge routes		Quantity shipped - 2019 (1,000 tons)		Relative quantity shipped - 2019 (percent of total)	
Origin	Destination	Corn	Soybean	Corn	Soybean
Itaituba (PA)	Barcarena (PA)	3,727.0	3,048.5	38.6	29.4
Porto Velho (RO)	Itacoatiara (AM)	1,340.4	2,886.8	13.9	27.8
Itaituba (PA)	Santarém (PA)	1,929.5	1,496.9	20.0	14.4
Porto Velho (RO)	Santarém (PA)	802.4	1,000.8	8.3	9.6
São Simão (GO)	Pederneiras (SP)	919.1	780.0	9.5	7.5
Porto Velho (RO)	Barcarena (PA)	506.5	429.8	5.2	4.1
Porto Alegre (RS)	Rio Grande (RS)	0.0	278.9	0.0	2.7
São Simão (GO)	Anhembi (SP)	177.5	80.4	1.8	0.8
Canoas (RS)	Rio Grande (RS)	0.0	225.8	0.0	2.2
São Simão (GO)	Santa Maria da Serra (SP)	182.9	0.0	1.9	0.0
Itaituba (PA)	Santana (AP)	31.6	111.4	0.3	1.1
Pelotas (RS)	Rio Grande (RS)	0.0	38.2	0.0	0.4
Porto Velho (RO)	Manaus (AM)	32.7	0.0	0.3	0.0

Source: elaborated by the authors based on ANTAQ (2020).

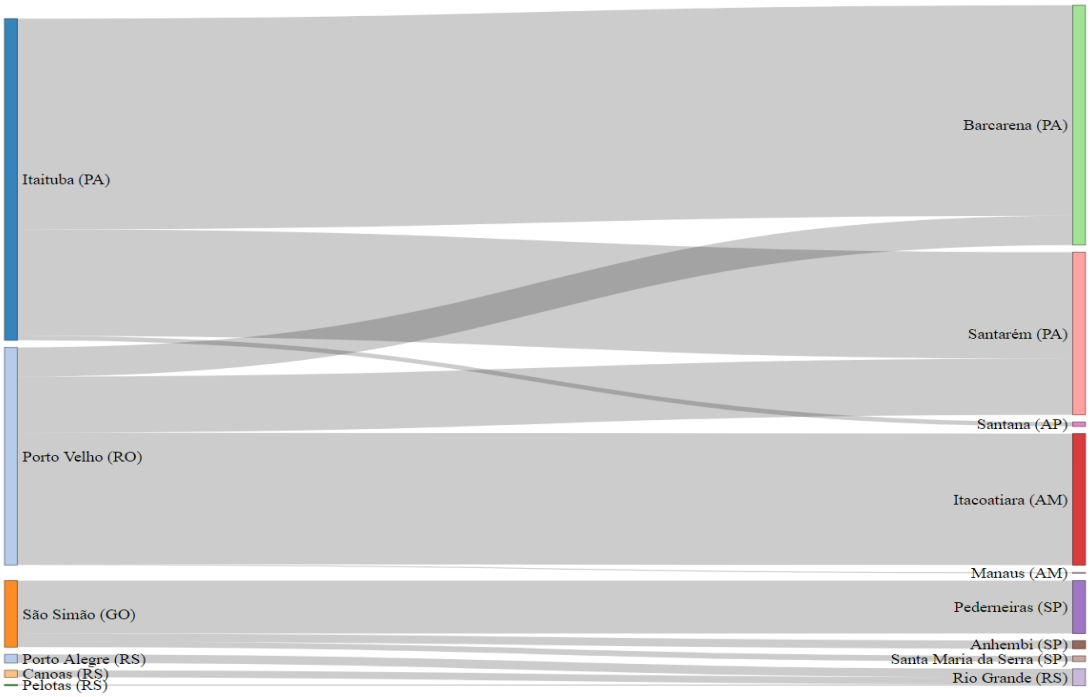
Figures 20 and Figure 21 illustrate the routes (origin-destination pairs) of barge presented in Table 8 for corn and soybeans in 2019, respectively.

Figure 20: Distribution of corn barge routes, 2019



Note: Figure illustrates the information presented in Table 10.
Source: elaborated by the authors based on ANTAQ (2020).

Figure 21: Distribution of soybean barge routes, 2019



Note: Figure illustrates the information presented in Table 8.
Source: elaborated by the authors based on ANTAQ (2020).

Table 9 presents rail movements between origin-destination (routes) pairs in Brazil for corn and soybeans in 2019. The main logistic flow of rail in the country for corn and soybean was from the Rondonópolis (MT) terminal to the Santos (MT) export terminal.

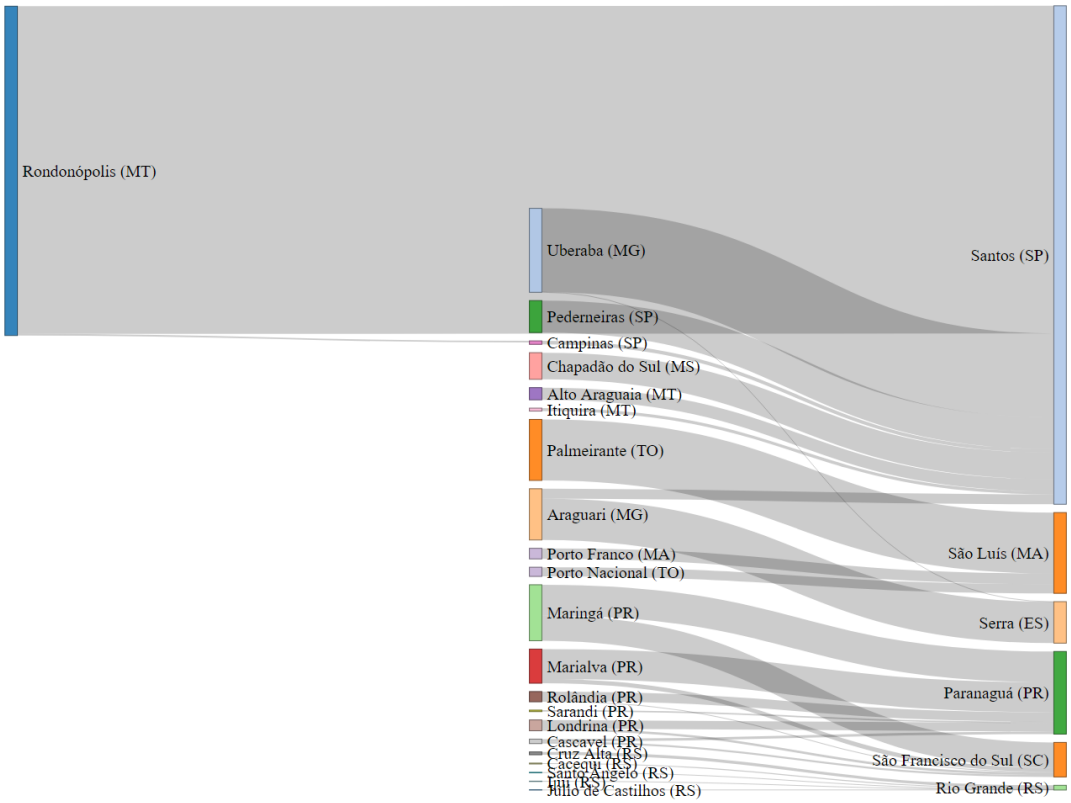
Table 9: Movements of corn and soybean in rail routes, 2019

Rail routes		Quantity shipped - 2019 (1,000 tons)		Relative quantity shipped – 2019 (percent of total)	
Origin	Destination	Corn	Soybean	Corn	Soybean
Rondonópolis (MT)	Santos (SP)	9,353.4	5,580.8	44.0	19.4
Uberaba (MG)	Santos (SP)	2,389.8	2,975.1	11.3	10.3
Araguari (MG)	Serra (ES)	1,179.1	3,257.7	5.6	11.3
Palmeirante (TO)	São Luís (MA)	1,740.6	2,447.8	8.2	8.5
Maringá (PR)	São Francisco do Sul (SC)	718.8	1,399.0	3.4	4.9
Marialva (PR)	Paranaguá (PR)	854.0	1,182.4	4.0	4.1
Cruz Alta (RS)	Rio Grande (RS)	80.6	1,936.4	0.4	6.7
Porto Franco (MA)	São Luís (MA)	302.0	1,428.2	1.4	5.0
Maringá (PR)	Paranaguá (PR)	879.2	785.7	4.1	2.7
Porto Nacional (TO)	São Luís (MA)	261.9	1,386.1	1.2	4.8
Pederneiras (SP)	Santos (SP)	911.8	725.9	4.3	2.5
Chapadão do Sul (MS)	Santos (SP)	759.1	801.6	3.6	2.8
Pirapora (MG)	Serra (ES)	0.0	790.9	0.0	2.7
Itiquira (MT)	Santos (SP)	83.8	609.1	0.4	2.1
Alto Araguaia (MT)	Santos (SP)	347.3	237.9	1.6	0.8
Araguari (MG)	Santos (SP)	282.8	278.7	1.3	1.0
Londrina (PR)	Paranaguá (PR)	244.0	252.8	1.1	0.9
Rolândia (PR)	Paranaguá (PR)	265.5	225.4	1.3	0.8
Cacequi (RS)	Rio Grande (RS)	25.8	327.3	0.1	1.1
Marialva (PR)	São Francisco do Sul (SC)	120.4	229.0	0.6	0.8
Júlio de Castilhos (RS)	Rio Grande (RS)	5.5	312.4	0.0	1.1
Cascavel (PR)	Guarapuava (PR)	0.0	271.9	0.0	0.9
Cascavel (PR)	Paranaguá (PR)	73.1	183.9	0.3	0.6
Ponta Grossa (PR)	Paranaguá (PR)	0.0	253.3	0.0	0.9
Campinas (SP)	Santos (SP)	98.8	68.0	0.5	0.2
Santa Luzia (MG)	Serra (ES)	0.0	137.6	0.0	0.5
Rolândia (PR)	São Francisco do Sul (SC)	25.9	95.6	0.1	0.3
Uberaba (MG)	Serra (ES)	5.1	110.2	0.0	0.4
Rondonópolis (MT)	Campinas (SP)	45.1	68.5	0.2	0.2
Cascavel (PR)	São Francisco do Sul (SC)	54.8	56.7	0.3	0.2
Londrina (PR)	São Francisco do Sul (SC)	65.1	36.5	0.3	0.1
Santo Ângelo (RS)	Rio Grande (RS)	13.2	85.6	0.1	0.3
Sarandi (PR)	Paranaguá (PR)	42.0	42.4	0.2	0.1
Tupanciretã (RS)	Rio Grande (RS)	0.0	84.1	0.0	0.3
Ijuí (RS)	Rio Grande (RS)	9.6	52.0	0.0	0.2
Alegrete (RS)	Rio Grande (RS)	0.0	29.9	0.0	0.1
Pradópolis (SP)	Santos (SP)	0.0	29.9	0.0	0.1
Guarapuava (PR)	São Francisco do Sul (SC)	0.0	5.5	0.0	0.0

Source: elaborated by the authors based on ANTT (2020).

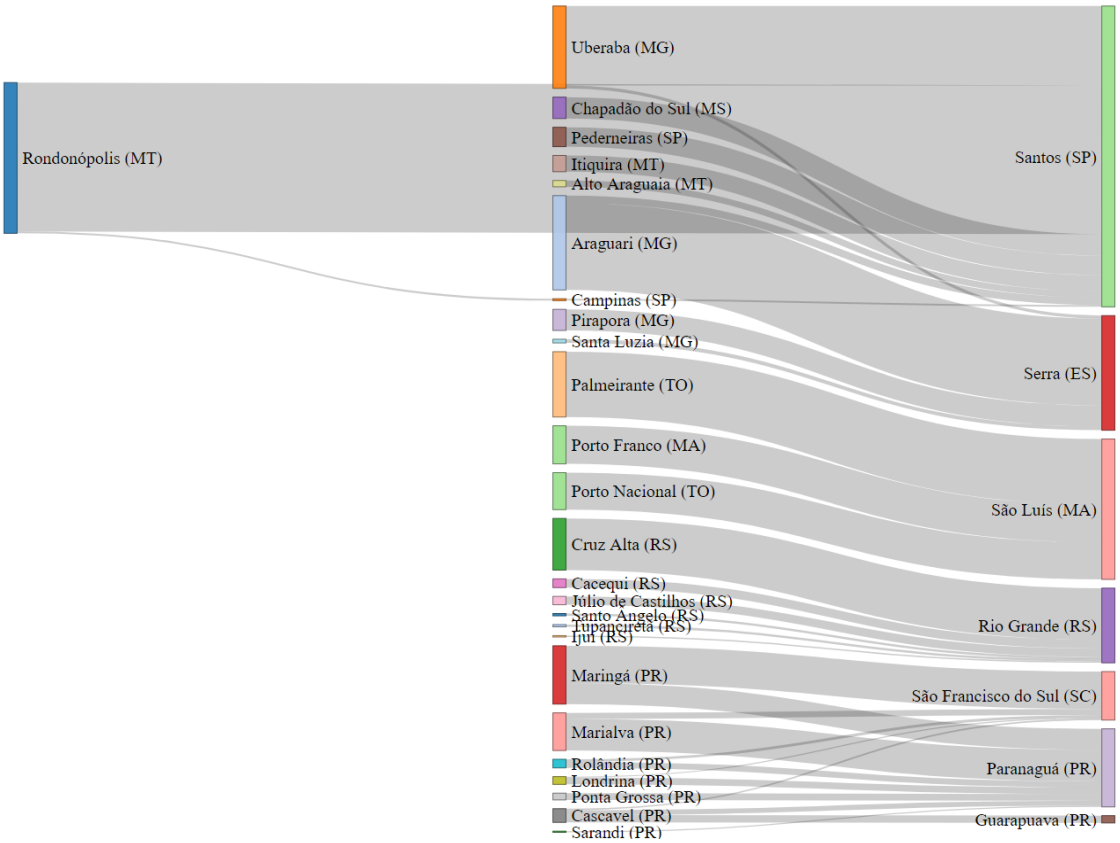
Figures 22 and Figure 23 illustrate the routes (origin-destination pairs) of rail presented in Table 9 for corn and soybeans in 2019, respectively.

Figure 22: Distribution of corn rail routes - 2019



Note: Figure illustrates the information presented in Table 9.
Source: elaborated by the authors based on ANTT (2020).

Figure 23: Distribution of soybean rail routes - 2019



Note: Figure illustrates the information presented in Table 9.
Source: elaborated by the authors based on ANTT (2020).

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Appendix A: Modal Share Methodology

Indicators of relationships between movements of rail and barge modes and production of the evaluated products were defined by equations (1) and (2).

$$\text{Ratio of rail shipments and production}_{p,t} = \frac{\text{Rail}_{p,t}}{\text{Production}_{p,t}} \quad (1)$$

$$\text{Ratio of barge shipments and production}_{p,t} = \frac{\text{Barge}_{p,t}}{\text{Production}_{p,t}} \quad (2)$$

Where:

- $\text{Ratio of rail shipments and production}_{p,t}$ is a ratio of rail shipments and production of product *p* at time *t*
- $\text{Ratio of barge shipments and production}_{p,t}$ is a ratio of barge shipments and production of product *p* at time *t*
- $\text{Rail}_{p,t}$ is a rail shipments of the product *p* at time t in tons
- $\text{Barge}_{p,t}$ is a barge shipment of the product *p* at time *t* in tons
- $\text{Production}_{p,t}$ is a production of product *p* at time *t* in tons

Equations (3) and (4) show the method of calculating the average annual distances traveled in Brazil for handling corn and soybeans in the Brazilian rail and barge.

$$\text{ARDISTANCE}_{p,t} = \frac{\left(\sum_o \sum_d \text{Rail}_{o,d,p,t} \text{ x Rail Distance}_{o,d,p,t}\right)}{\sum_o \sum_d \text{Rail}_{o,d,p,t}} \quad (3)$$

$$\text{AWDISTANCE}_{p,t} = \frac{\left(\sum_o \sum_d \text{Barge}_{o,d,p,t} \text{ x Barge Distance}_{o,d,p,t}\right)}{\sum_o \sum_d \text{Barge}_{o,d,p,t}} \quad (4)$$

Where:

- $\text{ARDISTANCE}_{p,t}$ is an average rail distance of product *p* at time *t* in miles
- $\text{AWDISTANCE}_{p,t}$ is an average barge distance of product *p* at time *t* in miles
- $\text{Rail}_{o,d,p,t}$ is a rail trip from terminal *o* to final terminal *d* of product *p* at time *t* in tons
- $\text{Rail Distance}_{o,d,p,t}$ is a rail distance from terminal *o* to final terminal *d* of product *p* at time *t* in miles

- Barge $_{o,d,p,t}$ is a barge trip from terminal *o* to final terminal *d* of product *p* at time *t* in tons
- Barge Distance$_{o,d,p,t}$ is a barge distance from terminal *o* to final terminal *d* of product *p* at time *t* in miles

Equations (5) to (8) show the receipt of movements in the two largest Brazilian corn and soybeans export ports, Santos (SP) and Paranaguá (PR). As previously noted, there is no option to use barge to move corn and soybeans products to these two seaports, so there are no barge movements for these ports.

$$\text{Rail to Paranaguá Port}_{p,t}(\%) = \frac{\text{Rail to Paranaguá Port}_{p,t}}{\text{Paranaguá Exports}_{p,t}} \quad (5)$$

$$\text{Truck to Paranaguá Port}_{p,t}(\%) = 1 - \frac{\text{Rail to Paranaguá Port}_{p,t}}{\text{Paranaguá Exports}_{p,t}} \quad (6)$$

$$\text{Rail to Santos Port}_{p,t}(\%) = \frac{\text{Rail to Santos Port}_{p,t}}{\text{Santos Exports}_{p,t}} \quad (7)$$

$$\text{Truck to Santos Port}_{p,t}(\%) = 1 - \frac{\text{Rail to Santos Port}_{p,t}}{\text{Santos Exports}_{p,t}} \quad (8)$$

Where:

- Rail to Paranaguá Port$_{p,t}$ (%) is a rail movement to Paranaguá Port of product *p* at time t, in %
- Truck to Paranaguá Port$_{p,t}$ (%) is a truck movement to Paranaguá Port of product *p* at time t, in %
- Rail to Santos Port$_{p,t}$ (%) is a rail movement to Santos Port of product *p* at time t, in %
- Truck to Santos Port$_{p,t}$ (%) is a truck movement to Santos Port of product *p* at time t, in %
- Rail to Paranaguá Port$_{p,t}$ is a rail movement to Paranaguá Port of product *p* at time t, in tons
- Rail to Santos Port$_{p,t}$ is a rail movement to Santos Port of product *p* at time t, in tons
- Paranaguá Exports$_{p,t}$ is a Paranaguá Exports of product *p* at time *t* in tons
- Santos Exports$_{p,t}$ is a Santos Exports of product *p* at time *t* in tons

In the modal share analysis, we account for only tonnages of long-haul truck movements, which cover the long distances between the production regions and destinations (ports or domestic market). More specifically, because of Brazil's vastness and the low density of the rail and waterway terminals, transportation from the production regions to the terminals occurs exclusively by short-haul trucks. Such movements represent the shortest segment of a long route to reach the port or domestic market, according to the method adopted by Chang et al. (2019). In this way, we estimated the modal share for corn and soybeans, based on three types of movements.

Rail transport's share in the modal is calculated by equation (9).

$$\text{Rail Share}_{p,t} = \frac{\text{Rail}_{p,t}}{\text{Tonnages}_{p,t}} \quad (9)$$

Equation (10) calculates a barge share:

$$\text{Barge Share}_{p,t} = \frac{\text{Barge}_{p,t}}{\text{Tonnages}_{p,t}} \quad (10)$$

Equation (11) accounts for truck as production less barge and rail movements. This equation refers to a residual because is no data available for the truck.

$$\text{Truck}_{p,t} = \text{Production}_{p,t} - \text{Rail}_{p,t} - \text{Barge}_{p,t} \quad (11)$$

Truck transport's share is calculated by expression (12).

$$\text{Truck Share}_{p,t} = \frac{\text{Truck}_{p,t}}{\text{Tonnages}_{p,t}} \quad (12)$$

The quantification of the total volume handled in the system, which is the denominator of the modal share calculation, is applicable by the expression (13).

$$\text{Tonnages}_{p,t} = \text{Rail}_{p,t} + \text{Barge}_{p,t} + \text{Truck}_{p,t} \quad (13)$$

Where:

- Rail $\text{Share}_{p,t}$ is rail transport's share in the modal share of product *p* at time *t*, in %
- Barge $\text{Share}_{p,t}$ is barge transport's share in the modal share of product *p* at time *t*, in %
- Truck $\text{Share}_{p,t}$ is truck transport's share in the modal share of product *p* at time *t*, in %
- $\text{Truck}_{p,t}$ is truck transport of product *p* at time *t*, in tons
- $\text{Tonnages}_{p,t}$ is total tonnage of product *p* at time *t*, in tons