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An analysis of the deforestation risk associated to the Brazilian domestic consumption of beef products: a Pernambuco case study

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Abbreviations and acronyms

AD	Anno Domini
CO_2	Carbon Dioxide
FRC	Forest Risk Commodity
GDP	Gross Domestic Product
GHG	Greenhouse gas
GTA	Guia de Trânsito Animal
LUC	Land-use Change
LWC	Leather Working Group
MAPA	Ministério da Agricultura, Pecuária e Abastecimento
MPF	Ministério Público Federal
SIE	Selo de Inspeção Estadual
SIF	Selo de Inspeção Federal
SIM	Selo de Inspeção Municipal
TAC	Terms of Adjustment of Conduct
TFA	Tropical Forest Alliance
UF	Unidade Federativa
UPF	Undesignated Public Forest
UPL	Undesigned Public Land
USA	United States of America

Acknowledgement

I would like to use this section to exalt all the people that followed me in the master's period, both in person and by distance. 2 years and a half, three different cities, and many friends on the way, this thesis and the hard work put on the courses would not be possible without the support of all of them.

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Summary

Cattle farming is one of the main drivers of deforestation worldwide. The extensive consumption of beef stresses ecosystems around the world, to expand pasture areas and produce enough to support its demand. In this sense, Brazil arises as one of the main players in both beef production and environmental aspects. The expansion of pasture lands and agricultural areas has been harming different ecosystems in the last decades, principally the Amazon. The domestic market is the main responsible for the beef produced inside the country, about 80% of it. Trace the origin of beef and its subsequent impacts inside Brazil, proved to be an intricate issue, that overlaps in many subjects.

This study aimed to analyze the deforestation risk accruing from the beef marketed in Pernambuco, one of the 26 Federative Unities (UF) of Brazil, associating it with the pasture area required to support the demand and comparing it with the trend of beef exports. The beef marketed in Pernambuco between 2016 and 2019 has an associated total deforestation risk of 1 336 582 ha. Amazon, Pantanal, and Cerrado biomes are associated with 62.5%, 29.12%, and 7.67% of this risk, respectively. Of the 1 271 analyzed products, 44.1% were sourced from the Atlantic Forest biome, 38.6% from the Cerrado one, and 13.6% from the Amazon. 75 meatpacker companies are responsible for supplying beef to 21 municipalities in the state, leaking its associated deforestation towards its market. Demographic aspects of the cities in Pernambuco impose differences in the associated deforestation, and overall sustainability of its beef products. Categorized urban cities are sourced by a wide range of meatpackers and encompass more than 70% of Pernambuco's deforestation risk, although having the biggest sustainability score for its products. This a result of a large income and demand, if compared with rural municipalities.

The demand for beef in the state, and the outsourced deforestation to other biomes and regions, relate to the lack of pasture areas that most states in Brazil face. Pernambuco lacked 2 836 993 ha of pasture area to support beef consumption between 2016 and 2021. Apart from the producing states in the North and Central-West regions, most of the states have a shortage of pasture areas to support their consumption, with the Northeast showing a prominent gap.

1. Introduction

Anthropic actions in the last decades have led the planet into a climatic crisis scenario, with disturbances in the weather, natural cycles, and the capacity to sustain life for many species, including humans themselves (IPCC, 2022). The increasing emissions of Greenhouse gases (GHG), mainly carbon dioxide (CO_2), are the principal source of those changes, with deforestation as one of its main drivers (IPCC, 2012 and 2022; Albuquerque *et al*., 2020).

Forests cover 31% of the globe, approximately 4.06 billion hectares, and act as a home for biodiversity, and a climatic regulator, in addition, to providing goods for the maintenance of life (water, food, minerals, etc.) (FAO and UNEP, 2020). The distribution of forests worldwide doesn't happen uniformly though, with more than 50% of it being present in only five countries (Russian Federation, Brazil, Canada, China, and the United States of America). Brazil, in this context, is the country with the second biggest forested area in the world, after the Russian Federation, representing a share of 12% of its total (FAO and UNEP, 2020).

Brazil is, at the same time, the country with the largest share of biodiversity, regarding the number of species present from each class (plants, mammals, reptiles, etc.) and tropical forested areas in the world (Butler, 2016; UNEP, 2019; Bartaburu, 2021). But it is also the one with some of the highest amounts of deforestation and environmental degradation (Mabee, 2020; Bartaburu, 2021). This Brazilian trend is driven mainly by the expansion of pasture lands, and to a smaller extent, by agriculture (Codeço *et al.*, 2021). The expansion of pasture lands is explained by the economic return that it provides to the sector investors and to the country itself, in the form of beef and dairy sector (Vale *et al.*, 2019).

The beef sector is, on average, responsible for 6% of the Brazilian Gross Domestic Product (GDP) in the last 15 years (CEPEA, 2022a). Also, Brazil is the second biggest beef exporter country, after the USA, corresponding to 13.3% of the international beef market, with expectations of increasing in the following years (Malafaia, Mores, *et al.*, 2021; CEPEA, 2022b).

The expansion of pasture and agriculture over forests is mainly related to the demand for the so-called forest-risk commodities (FRC). Beef is part of the world's "big four" FRCs, together with soybean, palm oil, and timber, but in a Brazilian context is the primary representative (Mammadova, Behagel and Masiero, 2020). The supply chain of FRC commodities is responsible for more than 80% of tropical deforestation, 40% of those correlated only to the "big four" (GEF Secretariat, 2014; Henders, Persson and Kastner, 2015). This trend reflects in an increasing rate of CO_2 emissions and a decrease in its absorption, enhancing the adverse outcomes of climate change. Between 2010 and 2014, for example, it is estimated that there was the emission of 2.6 gigatons of CO_2 ($GtCO_2$) yr^{-1}. This amount was only related to the expansionism of agriculture and its commodities, with a highlight on beef, which was responsible for 0.9 ($GtCO_2$) yr^{-1} of its share (Pendrill *et al.*, 2019).

1.1. Environmental impacts of livestock expansion in a historical perspective

The consumption and development of pastures for cattle ranching are dated between 14,000 and 12,000 years ago, mainly in the Middle East (Aland and Banhazi, 2013). From that period to the Roman Iron Age (1st to 6th century AD), cattle represented 56% of the farmed animal, against 28% of pork and 16% of sheep/goat. This prevalence of cattle against other protein sources affected its value and relevance, costing eight denarii per pound (Roman currency by that time), against chicken which cost 60 denarii, being the most valuable source of protein (Aland and Banhazi, 2013).

During and after the Middle Age (6th to 11th century), 80% of the population were involved with agriculture, being the principal source of income at that time. The expansion of Christianization and the creation of colonies spread this context throughout the newly discovered continents (South America, North America, and Oceania) and subsequent colonies, creating feudal systems to support agricultural expansion.

Since then, the expansion of livestock production entailed a conglomerate of environmental and economic issues, going from cattle health, which decreases productivity, to land conversion into grassland. As stated by CABI (2008), the environmental issues related to cattle farming are mainly GHG emissions, loss in soil and environmental quality, and socio-economic issues. Those specific issues will be further unravelled.

1.1.1. Livestock and GHG emissions

GHG emissions are one of the main drivers of climate change, and the livestock industry is one of the economic sectors bearing the largest responsibility in terms of GHG emissions. The livestock sector, indeed, is responsible for 14.5% of the total GHG emissions, specifically CO_2, CH_4, and N_2O, respectively related to respiration, enteric fermentation, and manure management (Zervas and Tsiplakou, 2012; Rojas-Downing *et al.*, 2017). The increasing amount of GHG emissions, mainly CH_4 and N_2O, accelerate the global warming process, which has as one of its many consequences, the deterioration of productivity and health of many animal supplies (Zervas and Tsiplakou, 2012).

An increase in the temperature rates increases the incidence of heat stress, metabolic disorder, and the propensity for deceases and death of animals (Ali, Carlile and Giasuddin, 2020). The increasing demand for goods followed by the rise in population worldwide presents a threat not only to the environment but to the production itself. Until the end of the 21st century, it is estimated that only through heat stress the livestock sector will lose \$39.94 billion yr^{-1} (Thornton *et al.*, 2022). This economic depletion into the sector attests the fact that the ways of production are feeding its own ruin.

1.1.2. Soil and environment losses

The expansion of livestock, in many locations, require the expansion of pasture-based systems (Greenwood, 2021). Those systems are one of the main drivers of Land Use Change (LUC), together with croplands, causing the deterioration of many ecosystems, mainly in the global south (Gatti *et al.*, 2021; Winkler *et al.*, 2021). Pasture lands intended to livestock production corresponds to 77% of the total agriculture area in the world, and are linked with 80% of deforestation with agriculture purposes (Greenwood, 2021; Skidmore *et al.*, 2021).

Pasture-based systems have predominance of grasses and herbaceous species as its main foundation, and not necessarily imply in loss and environmental quality (CABI, 2008). In the end, pastures present a better soil protection, if compared with arable croplands, only becoming environmentally negative due to the intensive grazing, and overuse of fertilizers/pesticides (CABI, 2008). Pastoral grazing is responsible for increasing the soil erodibility by 6%, and causes 87% of soil loss; Nitrogen and phosphorous are common chemical elements present in fertilizers, when overused they are leached down to the soil, reaching streams, rivers, and ultimately the sea (BUND, 2021; Donovan and Monaghan, 2021). Those previous aspects are enhanced by the physical characteristics of the soils, in terms of its susceptibility to suffer compaction, which is a common consequence of the intensive cattle farming (CABI, 2008; da Silva and Lacher, 2020).

1.1.3. Socio-economic losses

There is an increasing growth in the population and demand for commodities, and beef is not apart from that, but this trend goes against the demographic decrease in the rural population, mainly in the developed countries (CABI, 2008). Even with this trend, the beef sector is responsible for providing the means of livelihood for many communities across the globe, mainly in developing countries (Salmon *et al.*, 2018; Global Witness, 2022).

The beef sector does not get away without some controversy. While it sustains many families and communities, it is one of the sectors with the major incidence of modern slave labor, low remuneration, issues regarding the use of natural resources, mainly water, and land grabbing (Ryschawy *et al.*, 2019; Greenpeace, 2022).

1.2. Brazilian agriculture: developments from a historical perspective

The Brazilian industrial sector has a history of focusing on agriculture, since the Portuguese colonial period. Throughout its colonization process, many different monocultures were introduced to its new colony, with a particular focus on sugar cane, using the knowledge and techniques from Mediterranean and temperate agriculture (De Oliveira and Winiwarter, 2010). By its singularities, the Brazilian economy can be divided into two distinct economic periods, the Mercantile period (1500-1930) and the Industrial period (1930-). The mercantile period itself is subdivided into three principal cycles, the sugar cane (17th century), gold (18th century), and ending between 1930-40 with a coffee and

rubber cycle (Lacerda *et al.*, 2006; Antonio Filho, 2010). The economic and industrial development achieved by the production of the three aforementioned products started declining in 1902, mainly by the international demand, which was not following the offer of products, and the dependence that the country had on few products (Pereira *et al.*, 2012). This trend caused the price of several products to decrease, forcing Brazil to diversify its production and the availability of goods. In this sense, the expansion of pastures for livestock farming took advantage of this degrading scenario and became one of the central exported commodities (Silva Neto and Bacchi, 2014).

The livestock industry started in the 16th century, with the importation of cattle breeds from Asia and Europe, but only became one of the main central large-scale industrial productions in the 18th century (Eastman, 1986; Landau, Simeão and Neto, 2020). Together with sugar, gold, silver, and tobacco, cattle were part of the commodities responsible for sustaining the Brazilian economy at that time (Eastman, 1986). Though most beef production (75-80%) is sold in the domestic market, the cattle sector has become increasingly integrated into international markets – Brazil is the world's largest exporter of beef products, supplying hundreds of international markets.

1.2.1. Central Brazil, 20th century scenario

At the beginning (the 16th century), raising cattle was mainly an economic activity in the Northeast, South, and Southeast region, usually by the coast, and was seen as a secondary type of production. It had a subsistence purpose, mostly for the mining workers, which was the principal type of production at that time (Silva, Boaventura and Fioravanti, 2012). This scenario started a slow shift towards central Brazil through the subsequent centuries because of a gold rush phenomenon, where mines, a source of precious metals, were found in that region, mainly the state of Goiás and Minas Gerais. This discovery caused a migratory flux, where many farmers from all the regions went to central Brazil searching for new opportunities, bringing together with them their livestock production (Silva, Boaventura and Fioravanti, 2012).

The rise of the South African mining market in the 19th century and the stagnation of the technological development of the mining techniques in Brazil caused decay in this sector, opening room for the rise of different ones (Machado and Figueirôa, 2001). The decline of the mining action forced the farmers to find ways to improve their subsistence in the region, which by that time was fully populated. This way, extensive livestock farming was established at the beginning of the 20th as the leading source of income for the state of Goiás (Silva, Boaventura and Fioravanti, 2012).

1.2.2. Establishment on the Amazonian region

Since 1976, there is the transference in the agriculture focus towards the northern region of Brazil (Amazonian area), a situation caused mainly by the fact that 60% of its land is registered as "public land" whereas in the other regions is only 12% (Barona et al., 2010; Azevedo-Ramos et al., 2020). This specific context, together with development incentive policies, facilitated the

action of land-grabbers and land speculation, mainly towards the ‘90s and 2000s (Walker et al., 2009). This fact, together with state subsidies, investment in infrastructure, and increasing international demand, made the Amazonian region an easy target for forest conversion into agricultural land (Barona et al., 2010; Azevedo-Ramos et al., 2020).

This trend is the main responsible for the deforestation rates in the Amazon, and since the start of this agricultural shift, there is already the loss of 18% of its forested area, with 14% of the total deforestation directly related to agriculture, corresponding to an area similar to the state of California (Greenpeace.org, 2018; Gatti *et al.*, 2021). On average, this deforestation percentage means a loss of an area equal to 7.122.673 ha, and in the past 20 years, causing the shift in its status into a carbon net emitter, emitting more C02 than it absorbs (Fisher and Alves, 1989; Harris *et al.*, 2021; Kruid *et al.*, 2021; Brice, Tartar and Rojanasakul, 2022).

1.3. Brazilian deforestation and traceability

As stated before, Brazil is the country with the highest rate of tropical deforestation, having it as its main environmental issue (Mabee, 2020). Recent studies have proved the correlation between deforestation with the increase in droughts, reduction of rain, loss in the soil’s organic matter, the spread of diseases, loss in biodiversity, and many other adverse outcomes (Aragão *et al.*, 2008; Nobre, 2014; MacDonald and Mordecai, 2019). Currently, many of these effects shifted from predictions to reality. In recent years the Amazonian region faced a surgeon malaria cases, a viral disease transmitted by mosquitoes, the increase of droughts in all the Brazilian regions and South American countries, and an overall decrease in biodiversity (MacDonald and Mordecai, 2019; Zanon, 2020; Feng *et al.*, 2021).

In this sense, cattle ranching plays as one of the key drivers of deforestation in Brazil. Brazilian beef domestic market is the main source of Amazonian beef correlated with deforestation, achieving four times the number of deforestation related if compared with the export market (zu Ermgassen *et al.*, 2020). Almost 80% of the beef produced in the country remains inside Brazil, but the lack of traceability and transparency tools hinders the proper analyses of the impacts that this sector brings to the country (USDA, 2022).

The lack of traceability in the Brazilian beef sector has many factors that interfere with its proper operation, going from scarcity of infrastructure to social issues, being a network of aspects that are indivisible from each other. Those aspects became more complex and intricate in the last 4 years (2018-22), with the government of President Jair Bolsonaro, which discredited environmental topics and have an inclination towards agribusiness (Ferrante and Fearnside, 2019; de Area Leão Pereira *et al.*, 2020).

Land grabbing arise as one of the main issues faced by the Amazonian region, happening until nowadays, and more recently at record rates (Kruid *et al.*, 2021). Through political decisions, lack of law enforcement, and the geographic characteristics of the Amazon, which turns monitoring more difficult, land

grabbing became a frequent reality in the region, mainly when is related to agriculture and livestock (Carrero *et al.*, 2022). This fact happens in different ways, for different reasons. The main issue in this sense is the selection and definition of *Undesignated Public land* (UPL), or *Undesignated Public Forest* (UPF), by the Brazilian government, which set the rules for the land that doesn't fit other types of land tenure (e.g., conservation units, rural settlements, military areas, indigenous land, etc.) (Azevedo-Ramos *et al.*, 2020; Carrero *et al.*, 2022).

UPLs don't have a specific purpose, mainly by a lack of investment in the environmental assessment of the area and the building of a strategic plan (Azevedo-Ramos *et al.*, 2020; Mammadova, Behagel and Masiero, 2020). This uncertainty pave the way for land speculation, allowing by the law, under some circumstances, that a person could acquire the ownership of those lands, and reclaim them as their own (Law 11 952 of 2009) (Carrero *et al.*, 2022). The law is strict in this sense, but not the enforcement of it, with lack of access to the area and monitoring, enhanced those previous aspects.

About 14% of the Amazon biome area are occupied by UPL's, an area of approximately 57.5 million ha (Arruda, Lima and Júnior, 2006; Alencar *et al.*, 2021). Until 2020, 18.6 million ha (32%) of the whole UPL's area was illegally declared as private property, and they are responsible for 25% of the total deforested and burnt area in the biome, being the type of land with the highest rate of environmental impacts (Azevedo-Ramos and Moutinho, 2018; Alencar *et al.*, 2021). By law, those areas cannot lose more than 20% of their vegetation, and neither be targeted for agricultural and pecuary purposes, but that is what happens (Stabile *et al.*, 2020; Kruid *et al.*, 2021).

The cattle producers exploit this gap in the system as also the big companies on which they provide their goods. The main examples for that context are the JBS, Minerva, and Marfrig (zu Ermgassen *et al.*, 2020). Those are the three main beef producers/exporters in the Brazilian market, having JBS as the largest meat-packing company in the world, responsible for 40.3% of beef exports originating from the Amazon (Belk *et al.*, 2014; Global Witness, 2020; zu Ermgassen *et al.*, 2020). Those companies signed deals regarding the sustainability of their production and impacts on Amazon. In a way, to avoid a negative reputation and linkage with the degradation of the natural ecosystems. TAC (Terms of Adjustment of Conduct) is one of the two main agreements in this sense. It forbids the purchase from slaughterhouses of cattle from properties inside the Legal Amazon that have relations with illegal deforestation (Armelin *et al.*, 2019; zu Ermgassen *et al.*, 2020). The big three largest cattle companies in Brazil (JBS, Marfrig and Minerva) signed a deal among them, called the G4 Cattle Agreement. This deal has the aim to increase the transparency and traceability of its supply chain, the purchase of cattle only for land that was cleared before 2009 and a without any connections with slave labor, illegal occupation of indigenous areas and deforestation in general (Greenpeace, 2020).

Apart from the two previously cited agreements, those companies are also part of multi-stakeholder initiatives, like the Tropical Forest Alliance (TFA),

Rainforest Alliance, Leather Working Group (LWC), and many others (JBS, 2021; Marfrig, 2022; Minerva, 2022). Despite signing these sustainable procurement commitments more than a decade ago, allegations of deforestation and forced labor continue. Those schemes are usually not legally binding, and susceptible to corruption and misleading, facts that open room for distrust and inefficiency in their actual results (Magalhaes *et al.*, 2022). An example of that is JBS's cattle source, exposed by an article published by Bloomberg (Brice, Tartar and Rojanasakul, 2022), attesting that the company doesn't track properly the origin of the cattle from its slaughterhouse suppliers, only knowing the source from its direct suppliers, missing the indirect ones. This fact prevents the company's complete notion of the extent of its impact, and consequently providing reliable information.

1.4. Supply chain

Supply chain can be roughly defined as "…*a complex network of business entities involved in the upstream and downstream flows of products and/or services, along with the related finances and information*" (Serdarasan, 2013). Its complexity build up over the last decades, as a consequence of globalization, sustainability, customization, outsourcing, innovation, and flexibility, facilitating access to goods all over the world (Serdarasan, 2013; Kagawa et al., 2015; Lima, Gardner and Lathuilliere, 2020; zu Ermgassen et al., 2020; Grabs et al., 2021). The food sector was notably favored by this phenomenon, which on the one hand promoted the rise of local productions to a global scale, but on the other hand, allowed countries (mainly the developed ones) to outsource their production activities, just delocalizing also associated impacts to different locations (Turner, 2014; De Ruiter et al., 2016; Leal and Marques, 2021). The rise in global demand was coupled with globalization allowing new markets to surge and creating a context that favors the appearance of new stakeholders and different sectors (Fearne, 1998; Paciarotti and Torregiani, 2021). For food supply chain, the direct connection between farmers, retailers, and consumers was replaced by a complex system that involves many actors in the process, and together with the market pressure, enhanced the investment in agriculture scientific knowledge and technology, mainly from the 19th century (Johnson, 2002).

Food supply chain and globalization are responsible for causing a shift in the world diet, providing access to products that do not grow in certain localities, and allowing small stakeholders/countries to enter the world trade market and generate income (Johnson, 2002). This system has considerably encouraged the reduction of poverty and hunger worldwide, but not without adverse outcomes (Bukeviciute, Dierx and Ilzkovitz, 2009; Luo *et al.*, 2022).

The democratization of access to information, also enhanced by globalization, brought to the surface the awareness of the adverse consequences of this type of system, i.e., the collapse of biodiversity and ecosystems, poverty, waste of water and resources, etc. (Lowe and Gereffi, 2009; Paciarotti and Torregiani, 2021; Krishnan, Arshinder and Agarwal, 2022). The access to a wider range of products and their features gave society the power to choose the ones that coupled more with its sustainable principles, which in most cases reflects on the

green purchase context (Joshi and Rahman, 2015; Joshi, Uniyal and Sangroya, 2021). This phenomenon explains the fact that consumers in general have a stronger appeal towards sustainable products, with the least possible impacts on the environment, but this fact does not necessarily translate into actual consumption (Joshi and Rahman, 2015; Saitone and Sexton, 2017; Jing *et al.*, 2022; Mehrabi, Perez-Mesa and Giagnocavo, 2022).

This fact reduced and put in check the survival of already established companies and ways of production, forcing them to update their food supply chain management in a more sustainable direction. To support this transition, many tools were developed to promote a better understanding of the supply chain outcomes, for the sector itself as its consumers. Traceability and transparency enhancement are the main pillars of this change, but also the creation of environmental certification schemes, eco-labels, voluntary due diligence, access to information and technology, and many others (Lambin *et al.*, 2018; Olsen and Borit, 2018; George *et al.*, 2019; Lima, Gardner and Lathuilliere, 2020; Bager, Persson and dos Reis, 2021).

1.5. Objectives

As stated in the previous sections, tracing the beef supply chain in Brazil is a problematic task. In this sense, this work intends to provide an early study on the deforestation risk arising from the beef available in Pernambuco, one of the ten biggest economic Federative Unities (Unidades Federativas, UF) in Brazil.

As specific objectives, this study will investigate: the main sources of beef in Pernambuco, both in terms of regions, UFs, and biomes (1); the differences between the demographic categories of Pernambuco (2); the associated deforestation risk of biomes, regions, and UFs (3); the trend of consumption of beef in different UFs, and its cattle production area (4); the trend of deforestation of the beef exports, and the regions, UFs, and biomes that support it (5); a comparison between the beef scenario in Pernambuco and the exportation one (6).

1.6. Structure of the thesis

Chapter 1 provide a theoretical background to the research and its objectives, divided in five sub-sections.
Chapter 2 introduces the study area, general and specific, highlighting demographic, social, environmental, and climatic aspects.
Chapter 3 describes the research methodology. The process to collect data and its variations during time, the sample size, and the equations utilized to do the necessary calculations.
Chapter 4 details the results, which are divided in three main subjects.
Chapter 5 provide a discussion of the findings in the results and the comparison between them. Also, analyze the limitations of the study and provide advices for future researches.
Chapter 6 concludes the study with an the main touched points from the previous chapters.

2. Study Area

This chapter reports information about the study area both at the federal (whole Brazil) and state (Pernambuco) level.

2.1. Study Area: Brazil

This work was developed throughout the whole state of Pernambuco, one of the 26 UFs present in Brazil (Figure 1). Brazil is the 5th largest country in the world with an area of 8.515 million km², being the largest in South America, having borders with all South American countries, apart from Chile and Ecuador (IBGE, 2016). It has a vast diversity of ecosystems, climatic zones, topographies, and ethnicities, having a wide range of natural resources, mainly water, and minerals. For those reasons, it is the country with one of the highest potentials in industries and agricultural production (IBGE, 2016).

Brazil has an estimated population of 215 million people, divided into five geo-political regions (i.e., South, Southeast, Central-West, North, and Northeast) based on the type of land use, production, ecosystem, cultural, and political aspects (Figure 1). The inhabitants are mainly concentrated in the Southeast and South regions, or around the coast, with its capital (Brasília) being in the Central West region. Those regions have disparities in dimension, occupation, and quantity of UF's, a consequence of the Portuguese distribution of land in the colonial period, which was called *Hereditary Captaincies*, and the economic development of each area. As an example, the largest region is the North with 3 850 million km², but it has the lowest population amount, approximately 18.7 million, and the lowest share of the national GDP (5.7%) (SEI, 2020; CEDEPLAR, 2022). If compared with the South region, the smallest one (0.58 million km²), which hosts approximately 30.4 million people, and has the second largest share of national GDP (17.2%) (SEI, 2020; CEDEPLAR, 2022).

Brazilian people are the result of centuries of immigration and miscegenation of many ethnicities and races. Most inhabitants identify themselves as white, a consequence of the intense European immigration in the 19th and 20th centuries. This share of immigrants is mainly represented by Portugal, Italy, and Germany, the two latter mainly concentrated in South and Southeast regions. Another significant portion of the population comes from African heritage. Since the 16th century, Portugal promoted one of the largest slavery campaigns in the world, obliging almost 4 million West African citizens to forced labor throughout four centuries. This phenomenon still implies many social issues in the country, making racism a reality in Brazilian society, and increasing the social inequalities between races. To a less extent, there is a share of the population descending from Asia and Middle East countries. Japan, Syria, and Lebanon are the most representative in this sense. Brazil has the largest Japanese population outside Japan and more Lebanon descendants than the inhabitants of its own country.

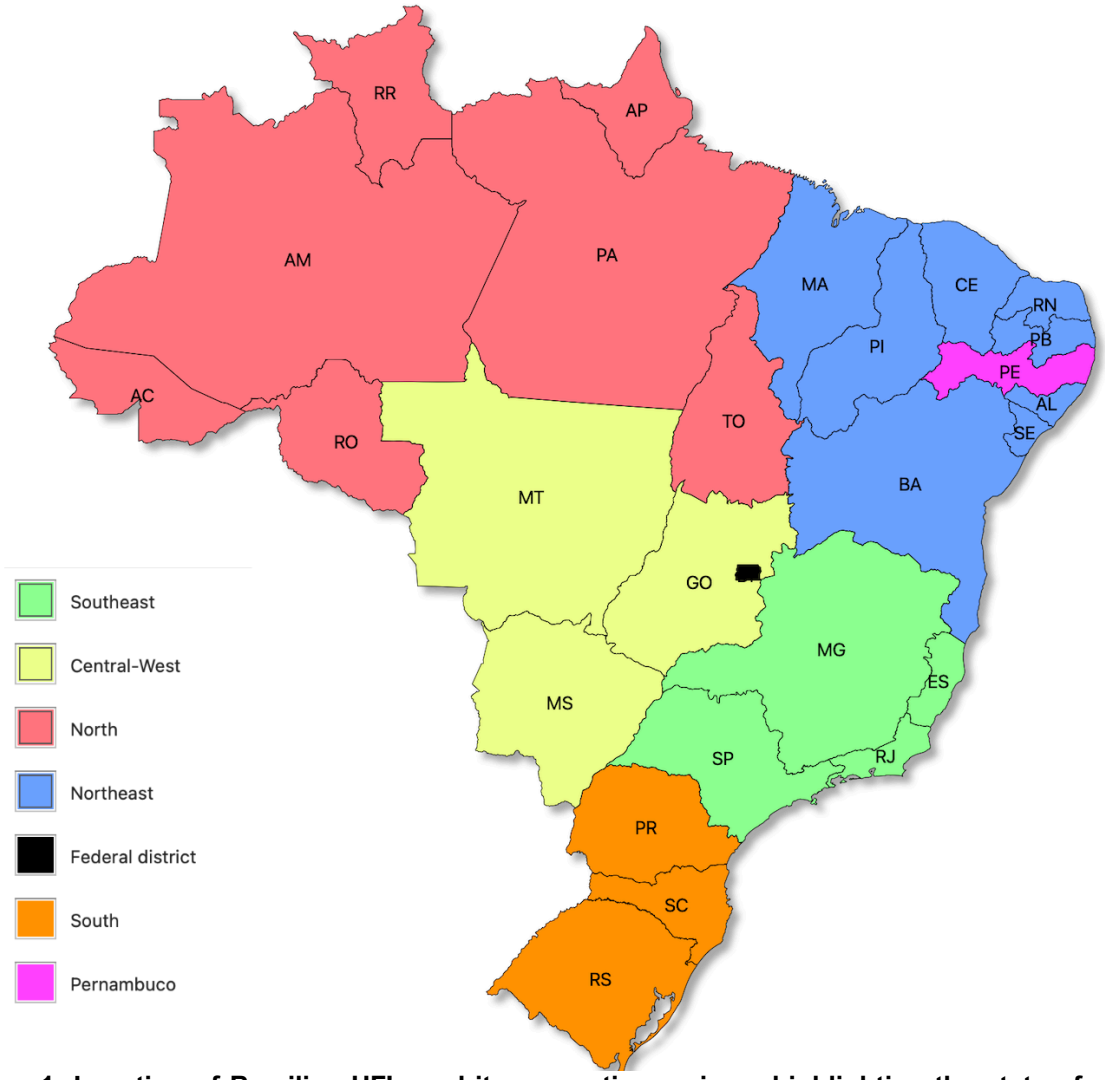

Figure 1: Location of Brazilian UF's and its respective regions, highlighting the state of Pernambuco (PE). Data provided by IBGE and map created with Magic Maps 2 tool.

2.1.1. Brazilian Biomes

Apart from the geopolitical and social division of Brazil, the country can also be fractionated according to its six main biomes (Figure 2):

- **Amazon** is the largest Brazilian biome, covering 7 million km², 49.9% of the national territory, and nine countries, with 60% of its belonging to Brazil, mainly to the North region (IBGE, 2016). It is identified as the largest tropical rainforest in the world, with a vast share of biodiversity, stream systems, minerals, and indigenous communities (Silva, Castro-Gamboa and Bolzani, 2010; Grebner *et al*., 2022). This biome is the main affected by the advance of deforestation and fires, with almost 50% (721 246.73 km²) of its cover being lost because of those drivers (CFR, 2019).
- **Cerrado** is best known as the Brazilian savannah, due to its climatic and vegetation attributes. It is the second largest Brazilian biome, with 2 036.45 km², equivalent to 23,9% of the national territory, also being present in Paraguay and Bolivia to a smaller extent (IBGE, 2016; Genuário *et al.*, 2018). The Central-West region contains most of the Cerrado and

takes advantage of this fact of being the Brazilian region with the largest agricultural production, mainly in the form of cattle pasture, soybean, rice, coffee, and wheat (da Silva and Lacher, 2020). Amazon and Cerrado are the two biomes that are affected the most by the agriculture expansion and are targeted for burnt and deforestation purposes (Grebner *et al.*, 2022). The Cerrado, in particular, is the principal beef exporting and producing region worldwide, representing 48.1% of the total global exports (zu Ermgassen *et al.*, 2020).

- **Pantanal** is described as the largest wetland area in the world, with most of its area being flooded for six months of the year (December to May) (Genuário *et al.*, 2018). It occupies an area of approximately 151 000 km², 1.8% of the national territory, being the second smallest of the six biomes, only behind Pampa, and it is entirely present in the Central-West region (IBGE, 2016; Marques *et al.*, 2021). The hydrology and location of the region turn this biome particular in terms of biodiversity and climate, also having the predisposition to suffer from negative outcomes of climate change, mainly regarding temperature and precipitation (Marques *et al.*, 2021).
- **Atlantic Forest** currently occupies an area of approximately 192 680.73 km², 13% of the national territory, reduced from the 1.1 million km² that it occupied in the 16th century (IBGE, 2016; Ministry of Agriculture, 2019). This constant degradation gave the Atlantic Forest the status of the Brazilian biome with the biggest loss in biodiversity, and endangered species of extinction, being considered one of the three world's biomes more vulnerable to climate change (Fernandez *et al.*, 2017; Rezende *et al.*, 2018). Besides those aforementioned issues, this biome still maintains the status of a biodiversity hotspot, and its degradation provided the means for the economic development of many regions in Brazil (Myers *et al.*, 2000; Rezende *et al.*, 2018). Location-wise, Atlantic Forest covers the east coast of Brazil, crossing three regions (Northeast, Southeast, and South) and being present in 13 UFs.
- **Caatinga** is also a biome with savannah characteristics, but with a low pluviometry rate, being considered for that reason as dryland (Ministry of Agriculture, 2019). It occupies an area of 845 000 km², 9.9% of the national territory, mainly in the Northeast region, with a small portion in the Southeast (IBGE, 2016). The climatic circumstances of the region turn it less productive if compared with the others, mainly by the water deficiency, which causes long dry seasons, and an irregular distribution of rainfall causing floods and destroying cultivations (IBGE, 2016; Alves *et al.*, 2018). This biome, together with Pantanal, has the lowest share in terms of beef production and exportation (zu Ermgassen *et al.*, 2020).
- **Pampa** is the only temperate type of biome in Brazil, with four well-defined seasons, and the smallest in terms of dimensions. It occupies an area of 22 719.69 km², equivalent to 2.1% of the national area, and is present only in the South region, more specifically in the state of Rio Grande do Sul, but also in Argentina and Uruguay (Ministry of Agriculture, 2019). The grass and shrub vegetation of the area provides a favorable environment for livestock production (IBGE, 2016). The biome is responsible for 5% of the total beef production and export in Brazil, even more than bigger biomes like Caatinga and Pantanal.

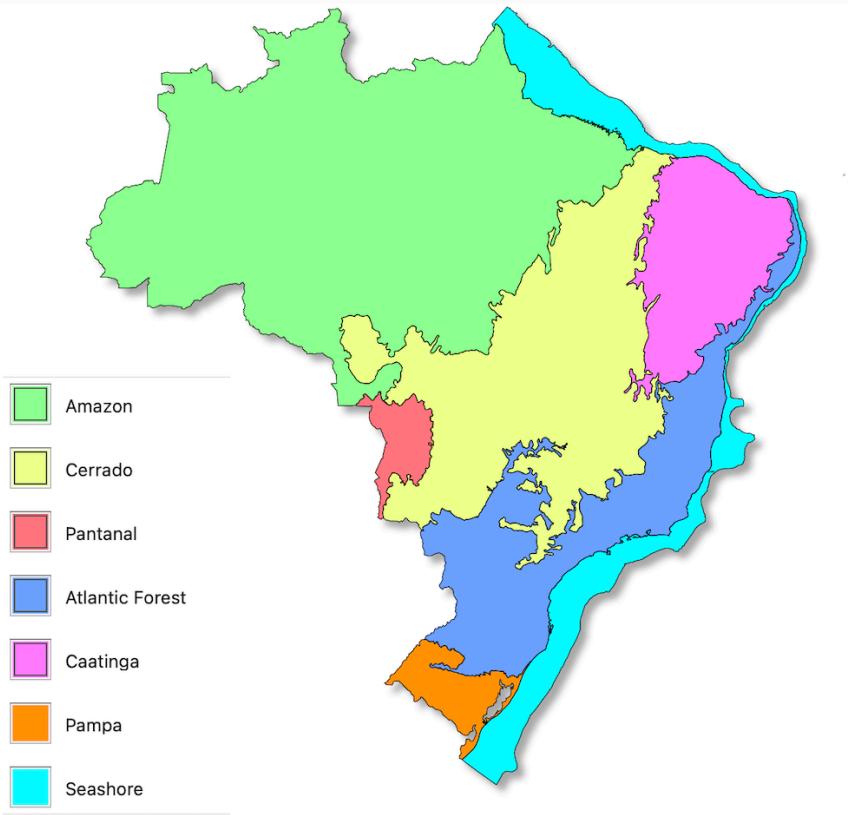

Figure 2: Division of the 6 main biomes in Brazil. Data provided by IBGE and map created with Magic Maps 2 tool.

2.2. Study area: Pernambuco

Pernambuco is located 8° 28' 20.5392" S and 37° 56' 48.3972" W and is part of the Northeastern region, divided into 184 cities, with Recife as its capital (Figure 1) (Lima and Gatto, 2014). Concerning its dimensions and population, Pernambuco covers 98 067.877 km², and is divided into five mesoregions (Sertão Pernambucano, São Francisco Pernambucano, Agreste Pernambucano, Mata Pernambucana, and Metropolitana do Recife) (Figure 3), and hosts a population of 9.6 million inhabitants. It is the 19th largest state in Brazil, in terms of area and the 5th within the Northeast region (IBGE, 2021). It is also the 10th largest economy in Brazil, with 4.2% of its economic sector dedicated to agriculture, 20.3% to industries (sugar cane processing, civil construction, refinery, etc.), and 75.5% to services (tourism, transports, restaurants, etc.) (Landau and Charlotte, 2020).

The territory of Pernambuco was one of the first to be populated and explored by the Portuguese, mainly because of the abundance of Brazilwood (*Paubrasilia echinata*). This tree served as the main traded commodity at the beginning of the colonization period, due to its hard dense wood and source of red dye. The prestige of this tree attracted the attention of other countries during that period. France tried to establish itself in the region and build a port to facilitate the exploration of Brazilwood, but it was defeated by the Portuguese. The Dutch, on other hand, maintained the domain of Recife and Olinda (two of

the biggest cities in Pernambuco) for decades, during the 17th century, but turned to be defeated by Portugal in the end. The Dutch colonization in Pernambuco left marks on the architecture, gastronomy, and infrastructure of the UF.

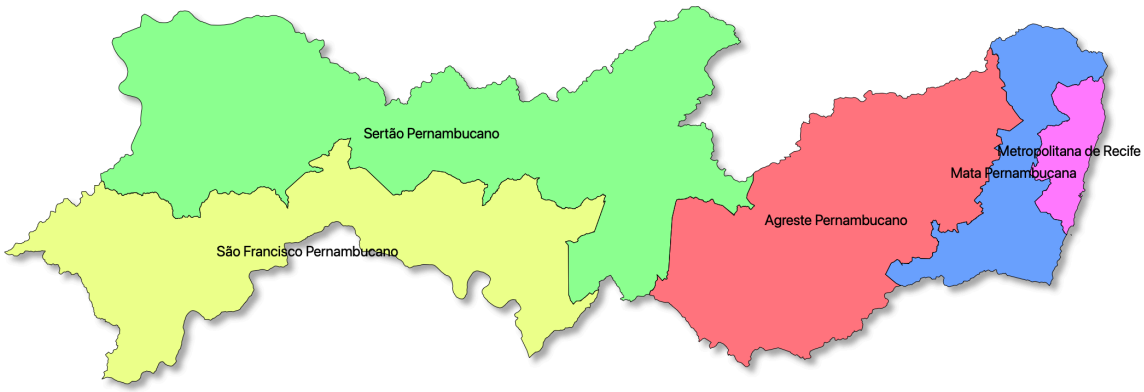

Figure 3: Division of mesoregions in the state of Pernambuco. Data provided by IBGE and map created with Magic Maps 2 tool.

In terms of biome, Pernambuco has the presence of Atlantic Forest, Cerrado, and Caatinga, the latter one dominating most of the state. Caatinga covers 83% of its territory, with the remaining represented by tropical forests and coastal environments, like mangroves (Figure 4) (CONDEPE/FIDEM, 2011). The UF can also be divided in terms of its climatic zones. Following Köppen's classification, Pernambuco has three main climatic zones, being BShw/BShw' (hot semi-arid climate), CS'a/Cw'a (hot-summer Mediterranean climate), and As' (tropical savannah climate) (Figure 5) (CONDEPE/FIDEM, 2011; Mahato, 2021).

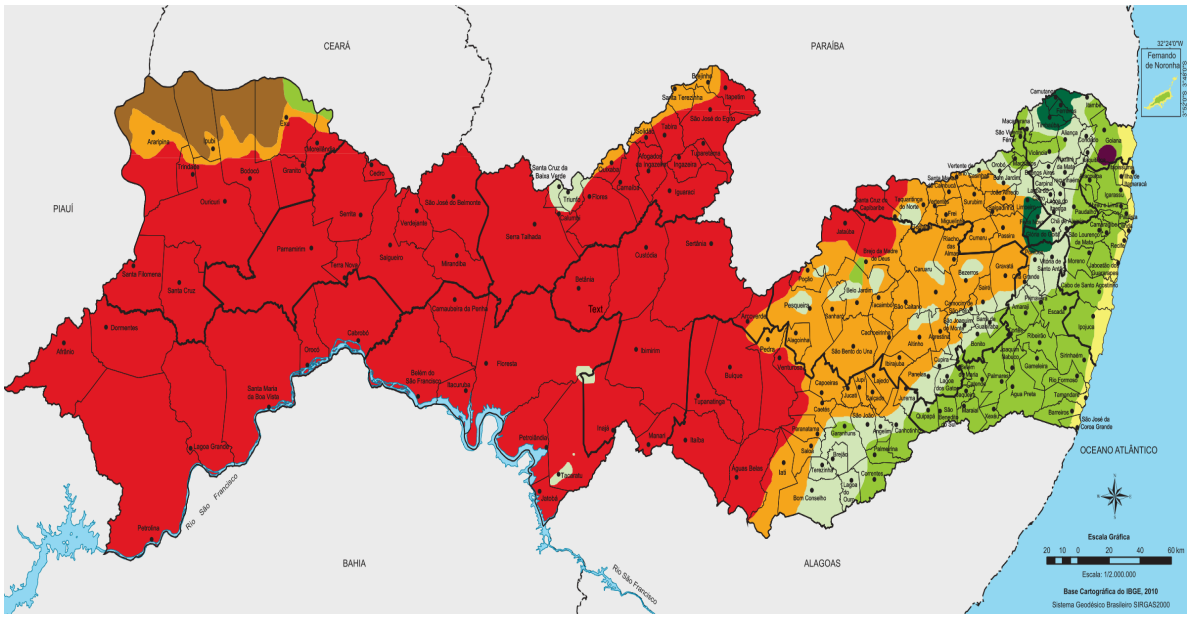

Figure 4: Vegetation division of Pernambuco, following its biome and climatic characteristics. From left to right: Caatinga (red and orange), Atlantic Forest (shades of green), Cerrado (purple), and Coastal environments (light yellow). Source: CONDEPE/FIDEM, 2011

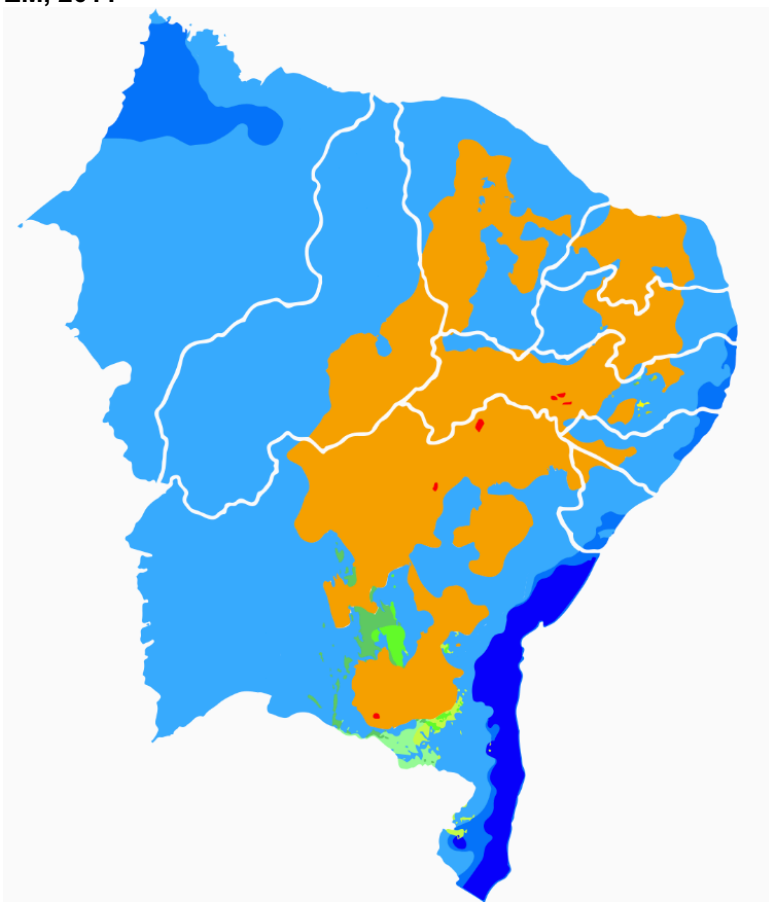

Figure 5: Climatic division of the Brazilian Northeast, following Köppen's classification. Source: Alvares et al., 2014

3. Methodology

To obtain data on deforestation and fire risks related to beef consumption in Pernambuco, the app *Do Pasto ao Prato* was utilized. *Do Pasto ao Prato* means "*From Pasture to a Plate*", and it is an app developed as a joint initiative by TRASE, Stockholm Environment Institute, the Catholique University of Louvain (Université Catholique de Louvain, UCLouvain), and Repórter Brasil, aiming to provide tools for Brazilian consumers to understand environmental and social risks related to beef sold in supermarkets. It works more specifically regarding deforestation and fire risk, but it also covers slave labor and sanitary aspects. An example of the layout and type of data provided by the app can be seen in Figure 6.

Figure 6: Layout and type of data provided by the Do Pasto ao Prato app. Source: (Do Pasto ao Prato, 2020).

3.1. Functioning of the *Do Pasto ao Prato* app

The app allows consumers to enter the sanitary code printed on products in the supermarket, it then returns to the user information about the sustainability risks embedded in the supply chain of the meat packing facility, based on publicly available information. The sanitary codes are required by law nº 1 283 of 1950, which three types of seals: Selo de Inspeção Federal (SIF), or Federal inspection Seal, Selo de Inspeção Estadual (SIE), or State Inspection seal, and Selo de Inspeção Municipal (SIM), or Town Inspection seal. These seals are present on the packaging of food products, within each seal is possible to trace the original location where the product comes from, as well as the company that produces and distributes it. An example of SIF code is reported in Figure 7.

Figure 7: An example of beef product and how the code is laid out on the package of the product.

For each sanitary code entered, the app returns information about four key sustainability risks in the cattle supply chain: Deforestation, Fires, Slave Labor, and Food Safety. The app attributes a score from 1 to 100 to the analyzed products, 1 referring to the lowest risk possible, and 100 to the highest one. Those values are also represented by the colors green, yellow, and red, with green representing products that are safer, or less impactful, and red representing products with high risks and associated environmental impacts. There are cases where information regarding one or more aspects is unavailable, in those cases grey color is utilized.

3.1.1. App's specific risk methodology

3.1.1.1. Health and animal welfare inspection

To provide health and animal welfare information the app uses a database of fines provided by the Ministério da Agricultura, Pecuária e Abastatecimento (MAPA), i.e., the Ministry of Agriculture, Livestock and Supply. This data, like the other risks provided by the app, refer to the 2016-2019 period.

The app reports the reasons for the fine issuing and the corresponding fine amounts. With this information, they rate the slaughterhouse where each beef product comes from, and consequently the product itself. The score for the companies follows a ranking method where the company that had the largest number of fines will be scored at 100, and the other companies are scored accordingly. Companies can be scored the same, even with a different number of fines, so the score does not address a specific number of fines, just an overall risk. The categories are specified below:

- Green color: there are no fines for that slaughterhouse between 2016 and 2019.
- Yellow color: the slaughterhouse received from 1 to 5 fines between 2016 and 2019.
- Red Color: the slaughterhouse received more than 5 fines between 2016 and 2019.

3.1.1.2. Slave Labor

The majority of modern slave labor in Brazil is related to livestock and beef farming (Repórter Brasil, 2021). The app accounts for the fines that a slaughterhouse has received concerning slave labor, on a list provided by the Ministério Público Federal (MPF) or Public Prosecutor's Office, and combines this information with data reported within Guia de Trânsito Animal (GTA) (SIT, 2022).

The GTA is a public document attesting to the transportation of animals, addressing the date of transport, the aim, the origin, the final destination, and the number of transported animals. The register of each slaughterhouse is analyzed regarding these two data and their sources, and then data are aggregated to provide the slave labor score.

Since some of the slaughterhouses are not directly responsible for the production and processing of the animal, direct and indirect suppliers are also analyzed. In this sense, the supplying farms are also investigated through the GTA and MPF slave labor list.

The rating of the slaughterhouses works according to a logic that is similar to the one described for the previous risk factor and the score ranges from 1 to 100. A color scale is also used:

- Green color: there are no records of slave labor fines related to that slaughterhouse.
- Yellow color: there are farms that have been fined for slave labor, and that indirectly supplies the slaughterhouses.
- Red color: there are farms that have been fined for slave labor, that directly supplies the slaughterhouses.

3.1.1.3. Deforestation

GTA data are taken into consideration also for the deforestation risk, together with datasets for vegetation loss, and pasture expansion. Regarding vegetation loss, the app takes into consideration data from the Atlas Digital das Pastagens Brasileiras (LAPIG), PRODES Amazon and Cerrado, and SOS Atlantic Forest Map (INPE, 2022d, 2022c, 2022a; UFG, 2022). In certain cases where the GTA is not available, data from the Sistema de Informação Gerenciais do Serviço de Inspeção Federal (SIGSIF), or Management Information System of the Federal Inspection Service, is taken into account (MAPA, 2022).

Once the source of cattle is identified, the investigation regarding the new pastures created in the area over the last 5 years, and the deforested area for the same period, starts. This means that the areas in which new pastures were created in 2016 intersected with deforested areas between 2012 and 2016. For the subsequent years the same method is adopted, always using a 5-year range.

If a farm supplies many slaughterhouses the scoring risk takes into consideration the amount of beef that the same place provides to each of them. This means that between two slaughterhouses, or towns, the one that receives more cattle from a certain farm is assigned a lower score by the app, compared with localities that received less. This analysis is done using hectares as the unit for the deforested areas. The scoring and the area exposed to beef-driven deforestation risk are estimations, because the specific location of suppliers and the purchase of cattle from farms may not be publicly available.

The rating of the slaughterhouses works according to a logic consistent with the one described for the previous risk factors. The score ranges from 1 to 100 and is associated with a three colors scale:

- Green color: less than 250 ha of native vegetation was converted to pasture in the supplier area.
- Yellow color: between 251 and 1 700 ha of native vegetation was converted to pasture in the supplier area.
- Red color: more than 1 700 ha of native vegetation was converted to pasture in the supplier area.

3.1.1.4. Fires

The methodology to account for the fires follows the same pattern as the one for deforestation, replacing deforested data with burned ones (INPE, 2022b). It is

necessary to highlight that the app doesn't distinguish burned areas from those with livestock purposes with other purposes, considering all burned areas. The associated risk is reported as follows:

- Green color: less than 10 000 ha of burned area in the supplier area.
- Yellow color: between 10 000 and 60 000 ha were burned in the supplier area.
- Red color: more than 60 000 ha were burned in the supplier area.

3.2. Data Collection

For this work, a total of 1 241 beef products were analyzed from 21 cities in the state of Pernambuco (Figure 8). The cities were chosen based on the city demographic definition, which allows distinguishing four possible categories: Grandes Centro Urbanos (GCU), or Big Urban Centers, Centros Urbanos (CU), or Urban Centers, Intermediario Adjacente (IA), or Intermediate Adjacent areas, and Rural Adjacente (RA), or Rural Adjacent areas. Following the definition by IBGE (2017) and by the law nº 10 527 of 2001, the demographic categories are defined based on the demographic density, population size, and the city GDP. Urban cities are the ones that have more than 100 000 inhabitants, while rural cities have less than 50 000, and intermediate cities can have between 10 000 and 50 000 residents.

Pernambuco has five GCUs, one for each of the five mesoregions of the state (Figure 3). Sertão Pernambucano, São Francisco Pernambucano, Agreste Pernambucano, Mata Pernambucana, and Metropolitana do Recife, host respectively the following GCUs: Garanhuns, Petrolina, Caruaru, Vitória de Santo Antão, and Recife.

To provide a representative sample of the beef market state in Pernambuco, a certain number of products needed to be analyzed for each of the four demographic category types. The amount can be seen as follows:

- GCU – 600 products in at least six different stores per city. Meaning that at least 20 products per store, and 120 products on each GCU (Petrolina, Garanhuns, Caruaru, Vitória de Santo Antão, and Recife) were expected to be collected.
- CU – 270 products in at least four different stores per city. In this case four CU, were chosen, all located in the Metropolitan region of Recife, Jaboatão dos Guararapes, Olinda, Camaragibe, and Paulista. In this case, at least 68 products were expected to be collected in each city, with 17 products per store.
- RA – 180 products in at least four stores per city. The RA for this research was chosen mainly in the Mata Pernambucana region, and Agreste Pernambucano. Three cities were chosen at the beginning (Passira, Riacho das Almas, Vertentes), meaning that 60 products were expected to be collected in each of them, 15 products per store.
- IA – 150 products in at least four different stores per city. The choice for the cities in this demographic category followed the same pattern as RA. The

three cities chosen were Glória do Goitá, Pombos, and Agrestina. 50 products were expected to be collected per city, and 13 products per store.

The above-reported sampling data were defined before starting the field, however, while performing the data collection some changes and deviations occurred. In particular, 21 cities were targeted by the research instead of the 15 originally defined, mainly because of IA and RA cities that in many cases did not have the required number of products. On the contrary, the GCU and CU cities provided the intended amount, so the early chosen cities remained unaltered. The full variation in the methodology is shown in Annex 1.

By the end of the fieldwork, the visited cities were (Figure 8):

- GCU – Petrolina, Garanhuns, Caruaru, Vitória de Santo Antão, and Recife.
- CU - Jaboatão dos Guararapes, Olinda, Camaragibe, and Paulista.
- RA – Passira, Salgadinho, Orobó, Bom Jardim, Cortês, Primavera, and Sairé.
- IA – Glória do Goitá, Pombos, João Alfredo, Bonito, and Chã Grande.

Figure 8: Locality of the 21 cities visited in the state of Pernambuco. Data provided by IBGE and map created with Magic Maps 2 tool.

Changes occurred not only about the targeted cities but also about the stores that should be visited. The supermarket selection was done using Google maps, with stores categorized as sellers of food products, regardless of their size and location within the city. Table 1 shows the number of stores visited and the number of products collected per city, and per demographic category.

As can be noticed, few changes were made to achieve the intended number of products. The transport towards those cities was done mainly by car, except for Petrolina and Garanhuns which required transport by bus.

Table 1: Demographic classification of the visited cities, as the number of stores and collected products.

Cities	Demographic Category	Number of Visited Stores	Total Amount of Collected Products
Petrolina	GCU	6	120
Garanhuns	GCU	10	120
Caruaru	GCU	8	122
Vitória de Santo Antão	GCU	9	122
Recife	GCU	7	120
Jaboatão dos Guararapes	CU	5	69
Olinda	CU	7	71
Camaragibe	CU	5	70
Paulista	CU	4	68
Passira	RA	3	35
Salgadinho	RA	2	17
Orobó	RA	2	23
Bom Jardim	RA	3	35
Cortês	RA	4	33
Primavera	RA	4	41
Sairé	RA	4	23
Glória do Goitá	IA	2	18
Pombos	IA	4	21
João Alfredo	IA	3	37
Bonito	IA	4	37
Chã Grande	IA	5	39
Total	-	101	1 241

3.3. Methodology to calculate Average area and Cattle required to support the consumption demand in Pernambuco

On average, 62% of the carcass becomes proper meat (University of Tennessee, 1822; Gulbe, Melece and Hazners, 2009; Saner and Buseman, 2020). This follows the Dressing Percentage methodology, which takes into consideration the hot carcass, which is the weight of the unchilled carcass after the head, hide, and internal organs have been removed, and the live weight of the animal. Equation 1 exemplifies this method.

$$y = \frac{S*100}{L} \quad (1)$$

y = dressing percentage, %
S = slaughter weight, or hot carcass weight, kg
L = live weight, kg

For calculations, a standard value of 590 kg of live weight per head was utilized, based on the average weight of the slaughtered cattle in Brazil in the year 2020 (Suzuki and Queiroz, 2021).

This methodology was applied together with the average consumption of beef in Brazil, for the analyzed years, the number of cattle heads per UF, slaughtered cattle per UF, and the pasture area per UF. The average consumption of beef in Brazil was 33.075 kg/hab/year, for 2016-19 (CONAB, 2022). This value was applied to the average population of Pernambuco in the time range, equal to 9.4 million inhabitants (IBGE, 2010d, 2010b, 2010c, 2010a).

Equation 2 shows how Pernambuco's share of the yearly national beef production was calculated.

$$PBC = Abc * T * I \quad (2)$$

PBC – Pernambuco beef consumption (kg)
Abc – Average Brazilian Consumption (kg/capita/year) (2016-19)
T – Time range (4 years)
I – Average population of Pernambuco (2016-19)

Pernambuco's share of the national consumption was calculated according to equation 3 data, which utilized data from the amount of cattle heads in the time range (2016-19), the number of slaughtered cattle per year, and pasture area (ABIEC, 2017, 2018, 2019, 2021; IBGE, 2022a; UFG, 2022).

$$PC = \frac{PBC}{\{\lfloor(\sum Sc)*0.8\rfloor*590\}*0.62} * 100 \quad (3)$$

PC – Pernambuco's consumption share of the total produced beef in the time range (2016-19) (%)
Sc – Slaughtered cattle in the country per year
0.8 – Percentage of beef that remains in the internal market
590 – Weight of cattle when slaughtered (kg)
0.62 – Dressing percentage, conversion of cattle's carcass in meat (kg)
PBC – Pernambuco's beef consumption.

The required area and cattle to support the demand for beef in Pernambuco were calculated via equations from 4 to 6:

$$Nc = 365{,}8 * PBC \quad (4)$$

NC – Number of cattle required to support the demand
365.8 – Average weight of beef (kg) produced by one carcass
PBC – Pernambuco's beef consumption

$$Ac = \frac{\sum Ch}{\sum Pa} \quad (5)$$

$$Ra = Nc * Ac \quad (6)$$

Ac – Average cattle head per pasture area (head/hectare)
Ch – Total number of cattle heads per year
Pa – Pasture area per year (ha) (UFG, 2022)
Ra – Required area to produce the amount of demanded cattle (ha)
Nc – Number of cattle required to support the demand

4. Results

4.1. Deforestation Risk associated with beef in Pernambuco

Within this sub-chapter, results about the Deforestation Risk associated with beef in Pernambuco, according to the Do Pasto ao Prato app elaborations, will be presented in detail.

4.1.1. Geographic and Deforestation Aspects of UFs and Regions

As stated before, the estimation of deforestation risk from the app uses different sources and types of data to score beef products. In the end, it provides an approximation of the actual deforested area, based on deforestation rates in the municipalities where each meat packer sourced their cattle, since higher resolution data are not publicly available i.e., the exact location of the farms that directly and indirectly supply slaughterhouses. In addition, in some cases, beef products did not have information about deforestation, fires, or their origin. That was the case in about 358 (29%) of the records, where at least one of the risks, or its origin, was missing.

The beef sold in Pernambuco has an average risk corresponding to 65.72 (on a scale from 1 to 100), which in the *Do Pasto ao Prato* app configures the UF the status of Regular in terms of risk, corresponding to a yellow color - full risk scores on Annex 2. The UF has an average deforested area per beef equal to 2 531.22 ha through the period between 2016-19, having as origin mainly Southeast (35%), Central West (22%), and Northeast (20%) regions (Figure 9).

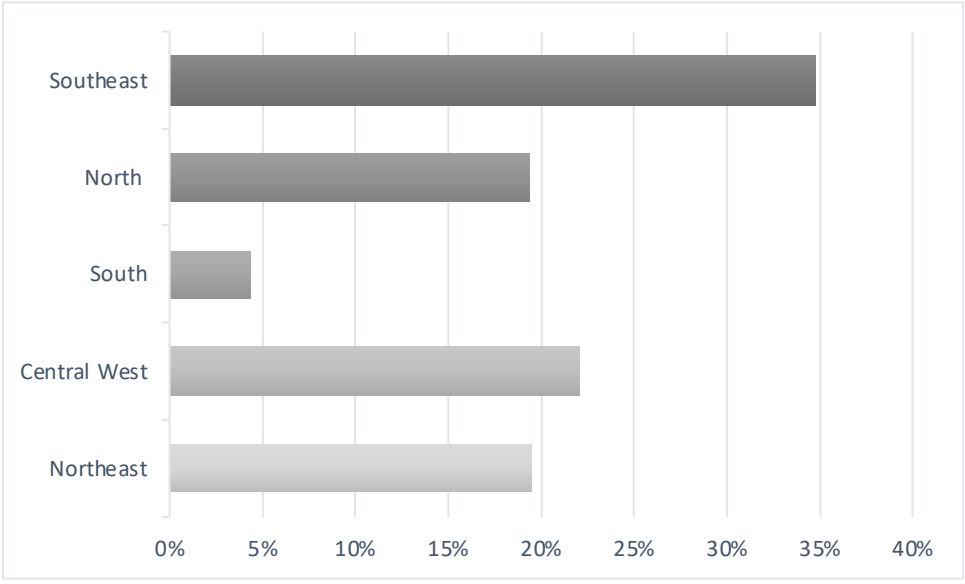

Figure 9: Beef sourcing for Pernambuco from different Brazilian regions. Source: own elaboration.

As can be seen, the principal supplier regions are the Southeast, North, and Central-West regions, which corresponds to Brazilian states being more affected by deforestation, with a focus on the state of Pará (INPE, 2021) (Table 2). In the period covered by our analysis 3 250 500 ha were deforested in the Amazon, and the Pará state covers 38% of this deforested amount, followed by Mato Grosso (19.2%) and Rondônia (16%). This trend is not followed by the meatpacker supplier. In this case, they are mainly located in the Southeast, corresponding to 35% of the total number of companies. Figures 10 and 11 show an overview of beef supplies to Pernambuco per Brazilian state (UF).

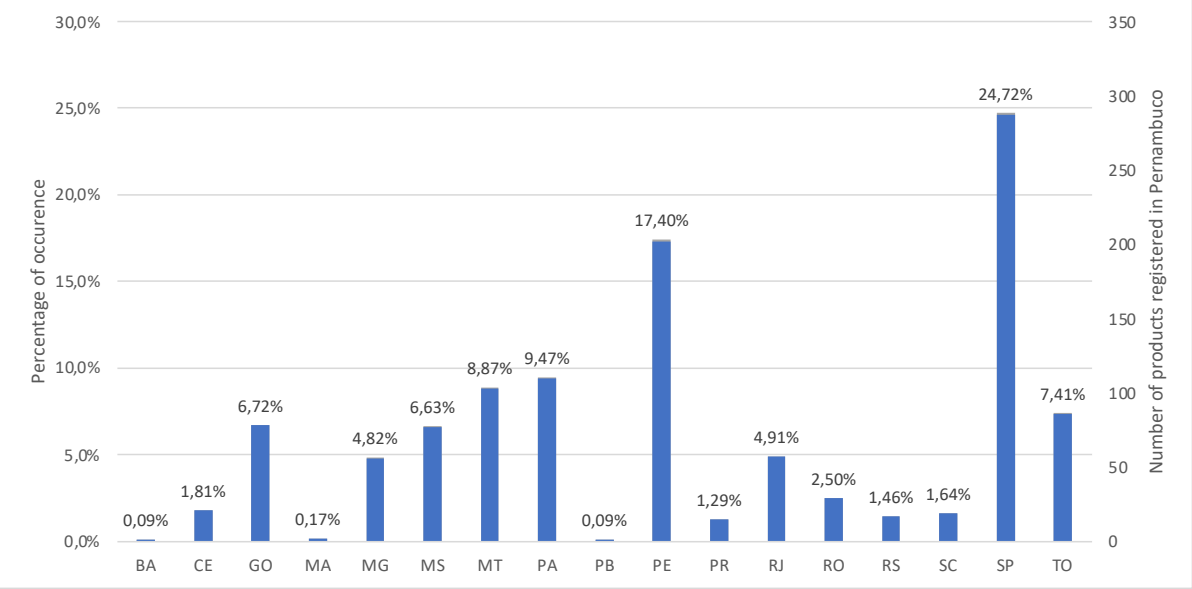

Figure 10: Number of beef products supplied to Pernambuco, split per state of origin where the meatpackers locate. The abbreviations mean, from left to right: Bahia (BA), Ceará (CE), Goiás (GO), Maranhão (MA), Minas Gerais (MG), Mato Grosso do Sul (MS), Mato Grosso (MT), Pará (PA), Paraíba (PB), Pernambuco (PE), Paraná (PR), Rio de Janeiro (RJ), Rondônia (RO), Rio Grande do Sul (RS), Santa Catarina (SC), São Paulo (SP), and Tocantins (TO). Source: own elaboration.

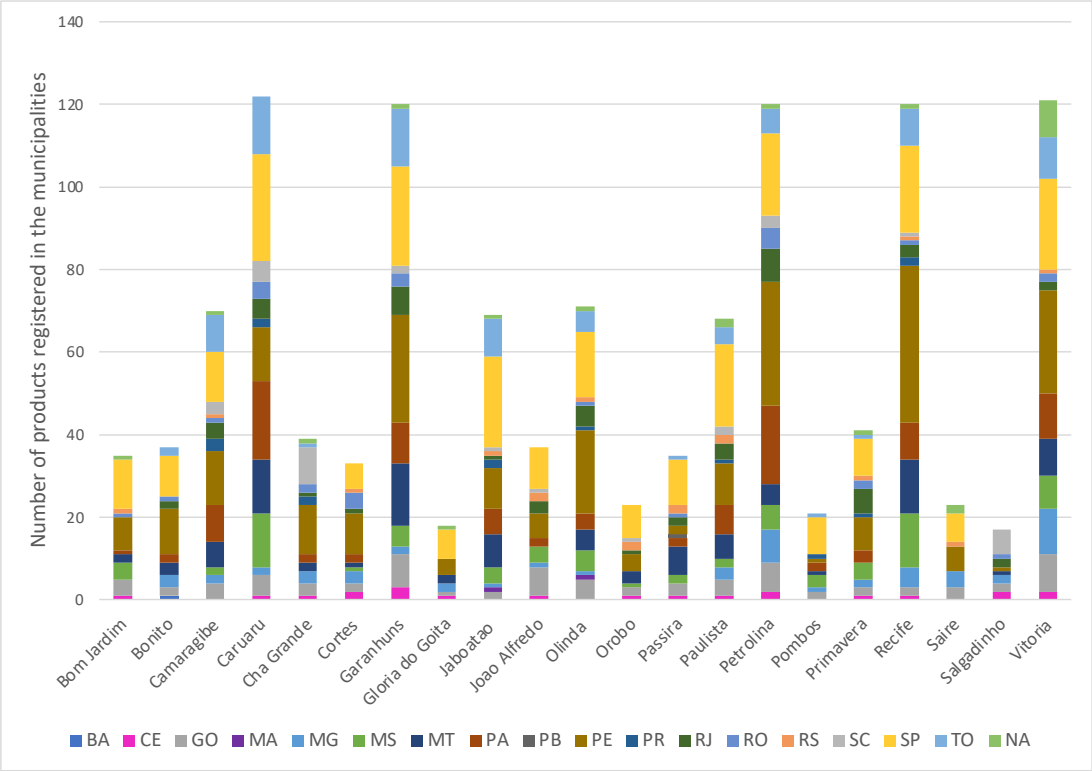

Figure 11: State-of-origin that sources beef to Pernambuco, and its subsequent share of the supply for each analyzed municipality. Source: own elaboration.

Table 2: Extent of deforestation in the UF's compound the Amazonian biome area. Source:(INPE, 2022).

UF	Deforestation area (ha)				
	2016	**2017**	**2018**	**2019**	**Total**
Acre (AC)	37 200	25 700	44 400	68 200	175 500
Amazonas (AM)	112 900	100 100	104 500	143 400	460 900
Amapá (AP)	1 700	2 400	2 400	3 200	9 700
Maranhão (MA)	25 800	26 500	25 300	23 700	101 300
Mato Grosso (MT)	148 900	156 100	149 000	170 200	624 200
Pará (PA)	299 200	243 300	274 400	417 200	1 234 100
Rondônia (RO)	137 600	124 300	131.600	125 700	519 200
Roraima (RR)	20 200	13 200	19 500	59 000	111 900
Tocantins (TO)	5 800	3 100	2 500	2 300	13 700
Total	789 300	694 700	753 600	1 012 900	3 250 500

It is necessary to note that Pernambuco is just behind São Paulo regarding meatpacker suppliers, but it is at the same time the state with the most unavailable data in terms of origin and risks of the beef (72%). This shows that the database behind the *Do Pasto ao Prato* initiative is not uniformly complete – future work should extend the underlying data to cover meat pack facilities across the country. Also, even with 35% of the beef coming from the Southeast region, the largest accumulated deforestation risk comes from the North region (85%) (Table 3).

The accumulated deforestation refers to the sum of the deforestation risk of all the beef products collected coming from the targeted region, and the deforestation risk itself is the sum of the associated deforestation risk of distinct products and origins. So, the region of origin of beef has more influence on the environmental risks than the traded amount itself.

Table 3: Regional statistics of the collected data per Region in Brazil. Columns with the the "Occurrence by regions" regard the number of times that a product has the targeted region as its origin, and only counts products that have information regarding its origin.

Region	Number of products	Percentage of Occurrence (%)	Sum of deforestation risk area (ha)	Sum of Accumulated deforestation risk area (ha)	Percentage of Accumulated deforestation risk (%)
Northeast	226	19%	1 055	2 116	0.01%
Central West	256	22%	110 621	735 754	2.52%
South	51	4%	532	784 579	2.69%
North	225	19%	245 951	2 4871 466	85.14%
Southeast	403	35%	14 833	2 819 611	9.65%
Total	1 161	100%	372 992	29 213 526	100%

4.1.2. Pernambuco's demographic aspects

Inside Pernambuco, the beef produced locally is mainly present in GCU municipalities (51%), followed by CU (21%), RA (15%), and IA (12%). 21% of the total amount of analyzed beef have Pernambuco as its origin. If considering the total amount of analyzed beef per municipality the pattern suffers a slight change. GCU municipalities remain to have the largest share of beef products coming from Pernambuco, with an average of 21.9%. In this case, it is followed by IA municipalities (20.7%), and then CU (19%), and RA (18.2%). In Figure 12 it is possible to see the relation between the aforementioned parameters.

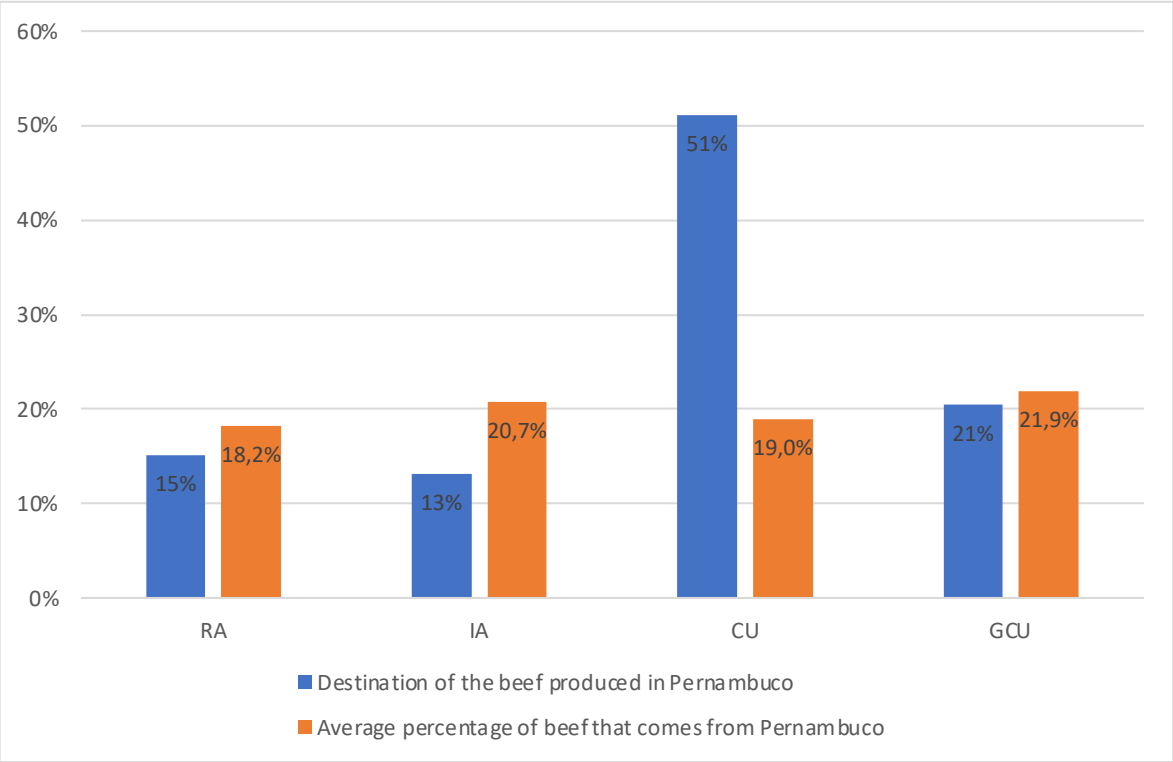

Figure 12: Comparison between the destination of beef produced in Pernambuco per demographic category, with the average share of beef that has Pernambuco as its origin in each municipality.

Figures 13 and 14 show the relation between the demographic category and their deforestation score. Population and GDP were the parameters chosen for these analyses.

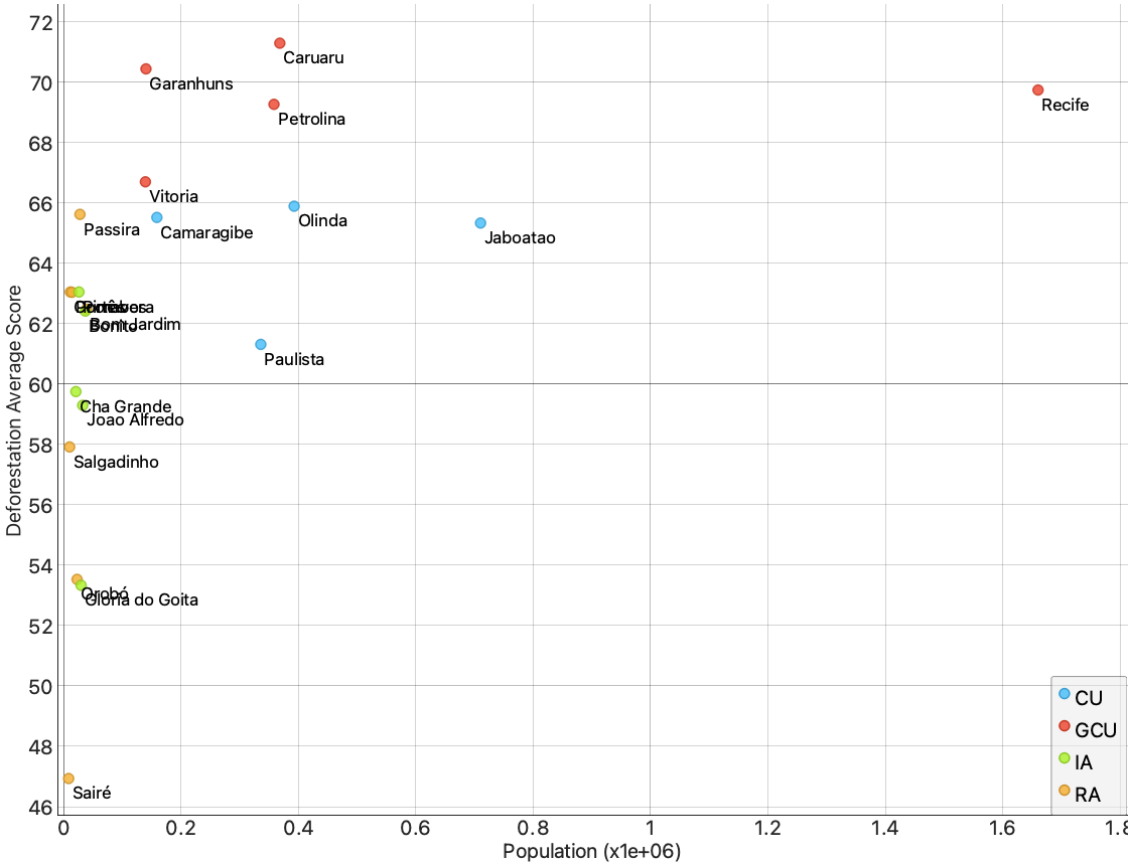

Figure 13: Deforestation Score and Population relation for the Demographic Categories of the 22 visited cities in Pernambuco. Data adapted from the app and IBGE, using Orange3 software.

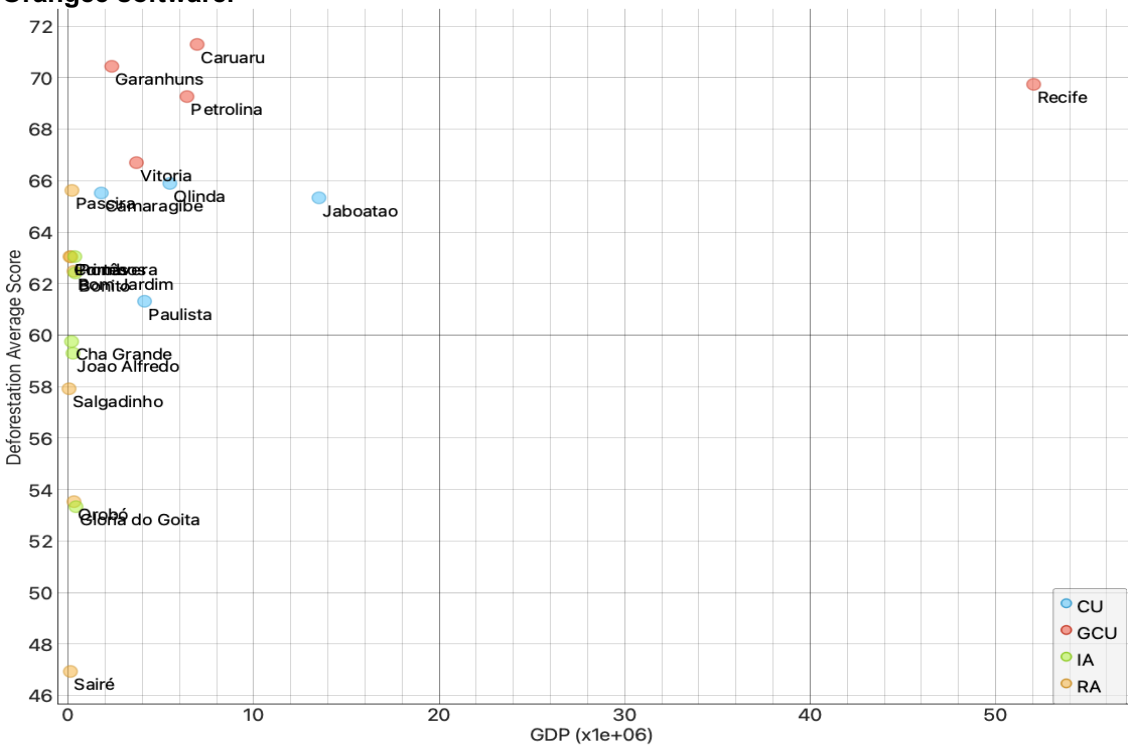

Figure 14: Deforestation Average Score and GDP relation for the Demographic Categories of the 22 visited cities in Pernambuco. GDP is measured in R$ (Brazilian currency). Data adapted from the app and IBGE, using Orange3 software.

The municipalities categorized as GCU present the highest sustainability score, being 90.7% bigger than the last score (IA) (Figures 15 and 16). In terms of average deforestation risk, GCU municipalities are also the 1st in the rank, followed by CU, IA, and RA (Figure 15). In this last case, GCU municipalities present an average risk of deforestation 49.8% bigger than RA.

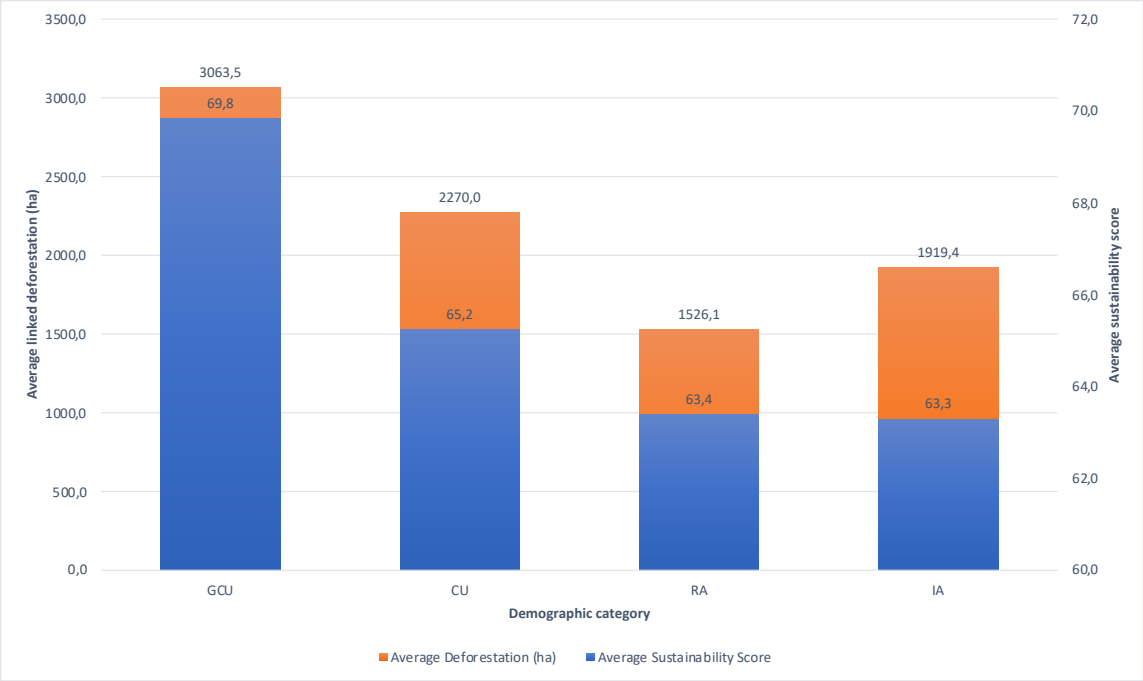

Figure 15: Average linked deforestation and sustainability score correlated to the demographic category of the analyzed municipalities. Source: own elaboration.

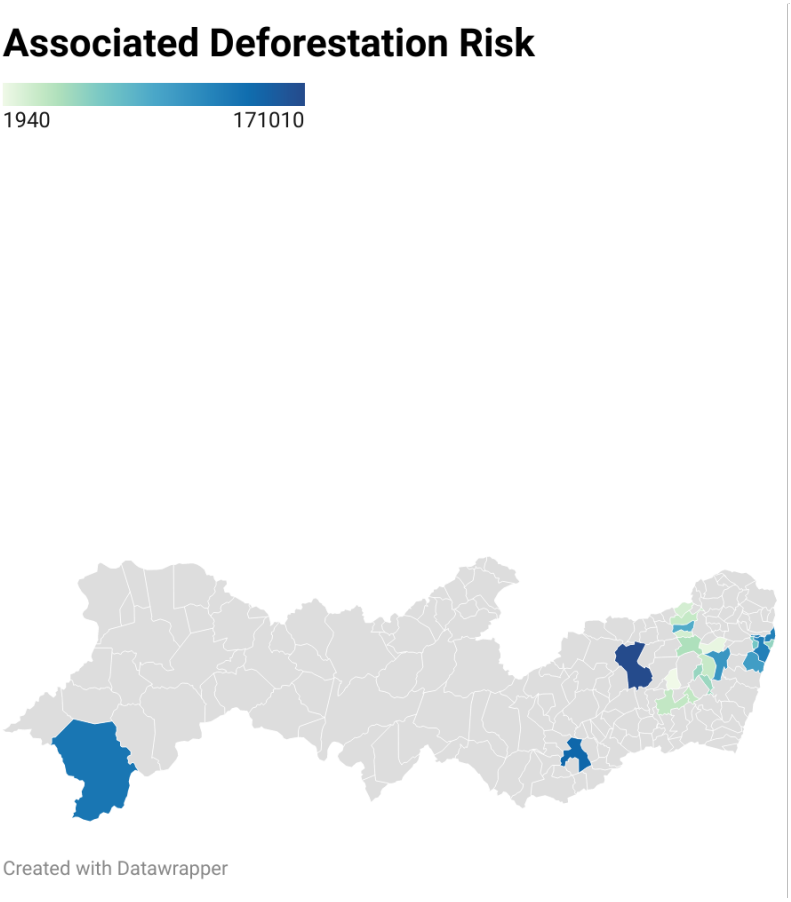

Figure 16: Average associated deforestation risk of the analyzed municipalities of Pernambuco. Source: own elaboration.

4.1.3. Geographic and deforestation aspects of biomes

The trend of beef supply in Pernambuco also supports the pattern of deforestation and exploitation of resources from the Amazon, Cerrado, and Atlantic Forest biomes (Figures 17 and 18). Those three biomes are responsible for providing 13.6%, 38.6%, and 44.1%, respectively of the total amount of collected beef (Table 4).

The expansion of land grabbing and pasture areas in the Amazon can be seen through the results in Table 4, through the extent of its deforestation risk. The biome is in the 3rd place, in terms of beef provision to Pernambuco, being 64% less than the 2nd place, Cerrado. Furthermore, it is in the 1st place in accumulated deforestation risk, 126% bigger than the same 2nd place, even if it supplies less beef. Full dataset can be seen in Annex 3.

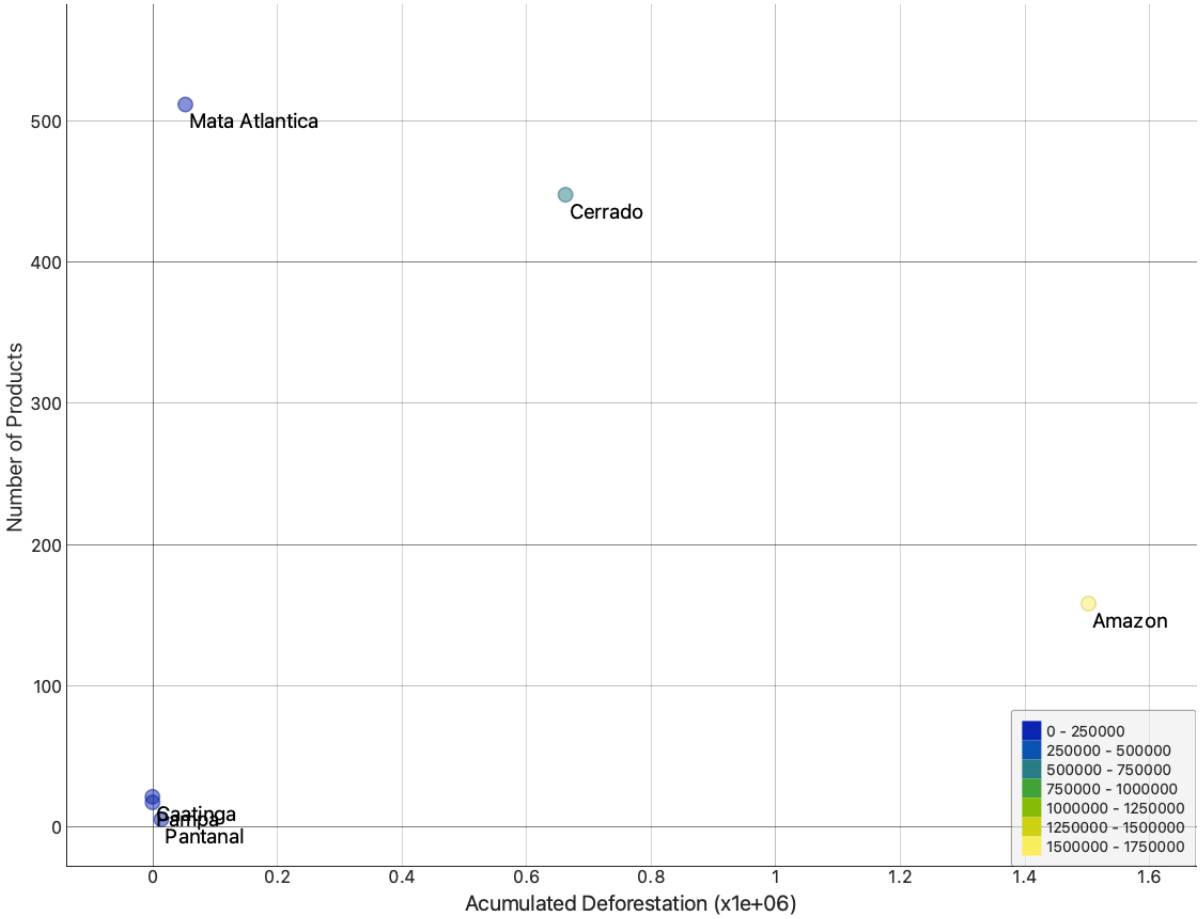

Figure 17: Relation between the number of products that originates from one of the biomes and their subsequent average linked deforestation. Data correlated to Pernambuco. Source: own elaboration.

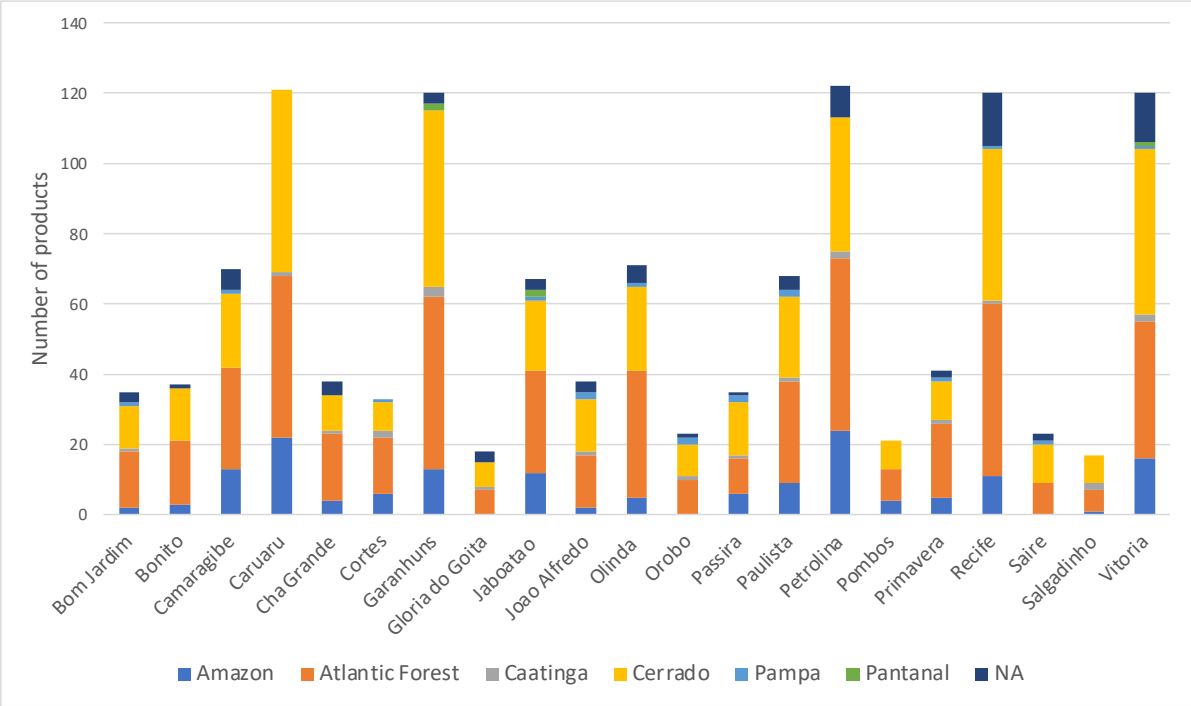

Figure 18: Relation between the number of products that originates from a certain biome and their subsequent average linked deforestation. Data correlated with each of the analysed municipalities. Source: own elaboration.

Table 4: Biome statistics of Occurrence and Deforestation Risk. Source: Do Pasto ao Prato, adapted by the author.

Biome	Number of beef products	Occurrence (%)	Average Deforestation Risk (ha)	Percentage of Risk (%)
Amazon	158	13.6	12 464	62.5
Cerrado	448	38.6	1 540	7.67
Atlantic Forest	512	44.1	204	1.02
Caatinga	21	1.8	na	na
Pampa	17	1.5	10	0.05
Pantanal	5	0.4	5 868	29.21
Total	1 161	100	20 086	100

Na: Not available

4.1.4. Brands and distributor companies

The top 10 meatpacker suppliers responsible for the beef sourced to Pernambuco were JBS, Frigol, Vale Grande Industria, Frigorifico Redentor, Irmãos Goncalves Comercio E Industria, Ativo Alimentos Exportadora E Importadora, and Big Charque Industria E Comercio, with JBS appearing four times. Table 5 shows an overview of the beef scenario in Pernambuco, focusing on the top 10 brands and their origin, sustainability, and deforestation-correlated aspects. The complete dataset can be seen in Appendix 6.

Table 5: Overview of the Beef Scenario in Pernambuco. The data is displayed taking into consideration the largest deforestation risk to the lowest.

Brand	Meatpacker supplier	Frozen or Fresh Beef (Majority)	Origin	State	Region	Deforestation Risk (ha)	Score	Beef Classification
Bordon, Friboi, and Masterboi	JBS	Frozen	Porto Velho	Rondônia (RO)	North	69 235	100	Bad
Frigol	Frigol	Frozen	São Felix Do Xingu	Pará (PA)	North	65 472	100	Bad
Frialto	Vale Grande Industria E Comercio De Alimentos	Frozen	Matupá	Mato Grosso (MT)	Central West	19 704	99	Bad
Frigoara	Frigorifico Redentor	Frozen	Guarantã do Norte	Mato Grosso (MT)	Central West	16 418	99	Bad
Friboi, Friboi Maturatta, Reserva Friboi	JBS	Fresh	Santana Do Araguaia	Pará (PA)	North	15 140	98	Bad
Frigon	Irmãos Goncalves Comercio E Industria	Fresh	Jaru	Rondônia (RO)	North	14 863	98	Bad
Friboi	JBS	Frozen	Anastácio	Mato Grosso do Sul (MS)	Central West	10 912	98	Bad
Mafrinorte	Ativo Alimentos Exportadora E Importadora	Frozen	Castanhal	Pará (PA)	North	10 721	98	Bad
Friboi	JBS	Frozen	Marabá	Pará (PA)	North	9 498	97	Bad
Chrque Rio Mar	Big Charque Industria E Comercio	Fresh	Cacoal	Rondônia (RO)	North	9 460	96	Bad

Figures 19 to 24 show the pattern of meatpackers' distribution, in terms of the municipalities that they supply, and its associated deforestation risk. The figures were divided into six, following the alphabetical order of the meatpackers, having 11 meatpackers each. Meatpackers on which the data for the risk were not available, are not included in the figures.

The size of the flows varies according to the deforestation risk that the meatpackers are correlated with. This was done in a way to favour a better visualization of the trend. The specific data from the following figures are summarized in Annex 4.

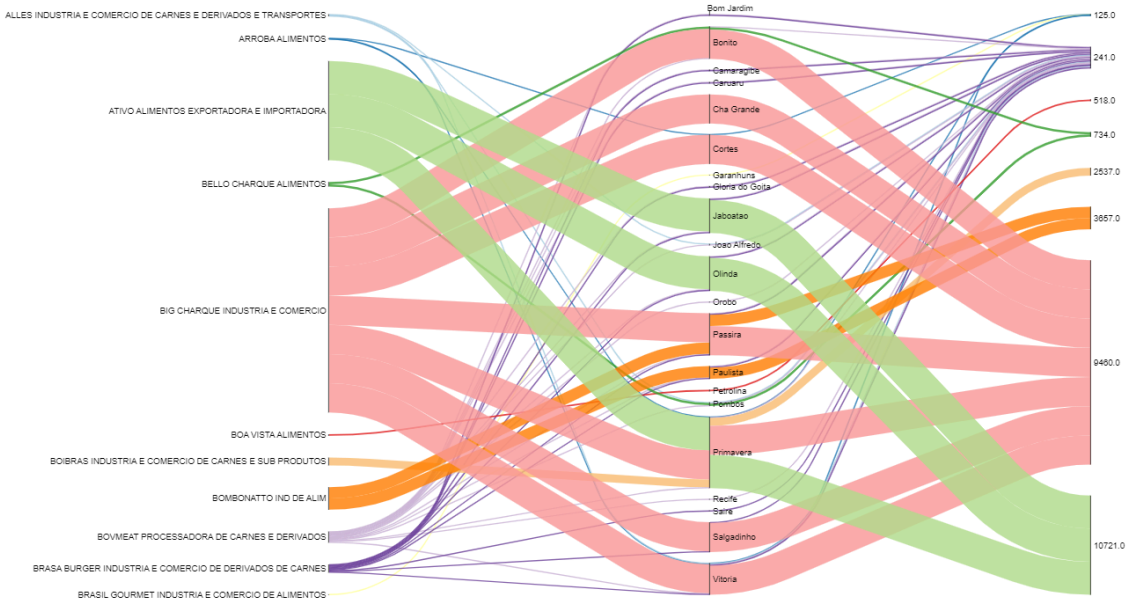

Figure 19: Sankey Diagram of meatpackers and its correlated supplied municipality and deforestation risk. From 1st to 11th meatpacker in alphabetical order. Source: own elaboration, using Python.

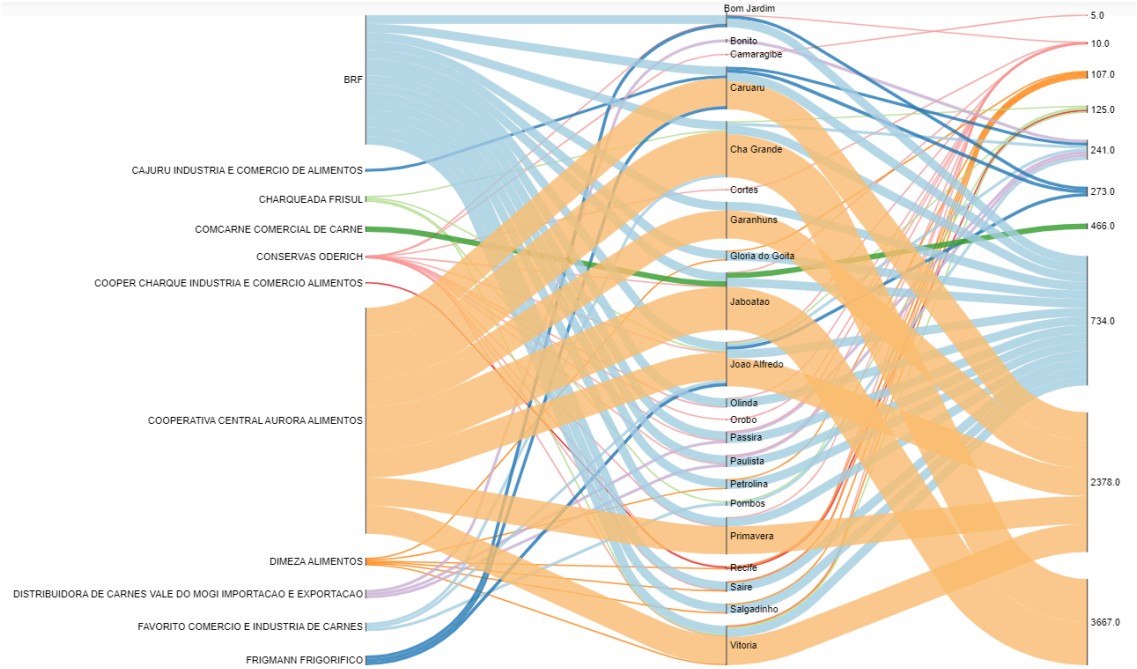

Figure 20: Sankey Diagram of meatpackers and its correlated supplied municipality and deforestation risk. From 12th to 22nd meatpacker in alphabetical order. Source: own elaboration, using Python.

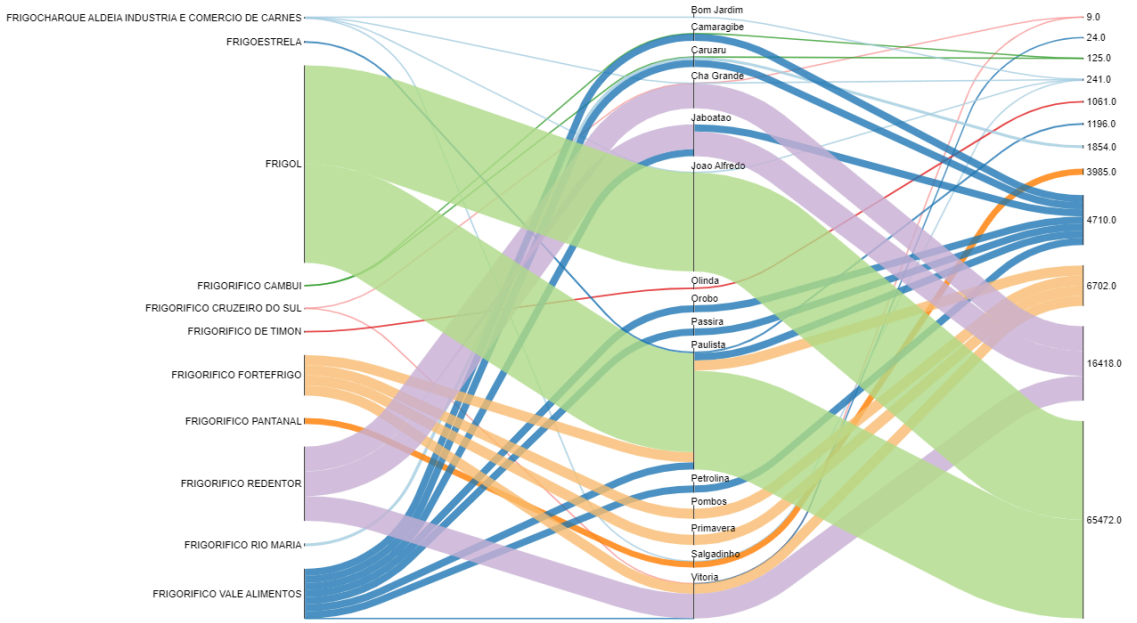

Figure 21: Sankey Diagram of meatpackers and its correlated supplied municipality and deforestation risk. From 23rd to 33rd meatpacker in alphabetical order. Source: own elaboration, using Python.

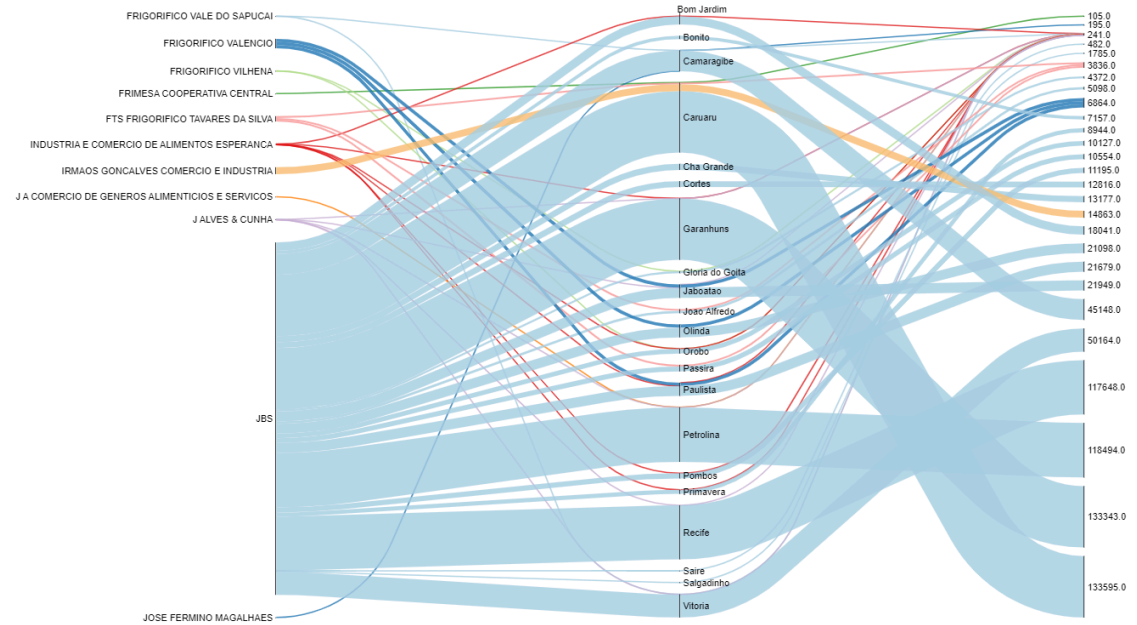

Figure 22: Sankey Diagram of meatpackers and its correlated supplied municipality and deforestation risk. From 34th to 44th meatpacker in alphabetical order. Source: own elaboration, using Python.

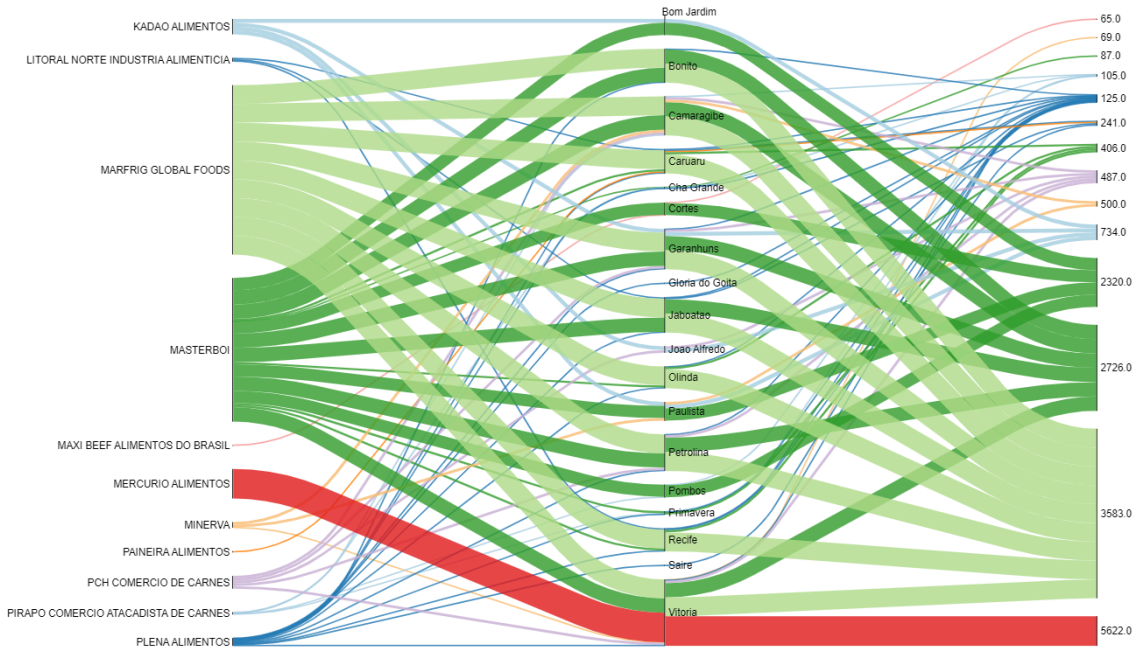

Figure 23: Sankey Diagram of meatpackers and its correlated supplied municipality and deforestation risk. From 45th to 55th meatpacker in alphabetical order. Source: own elaboration, using Python.

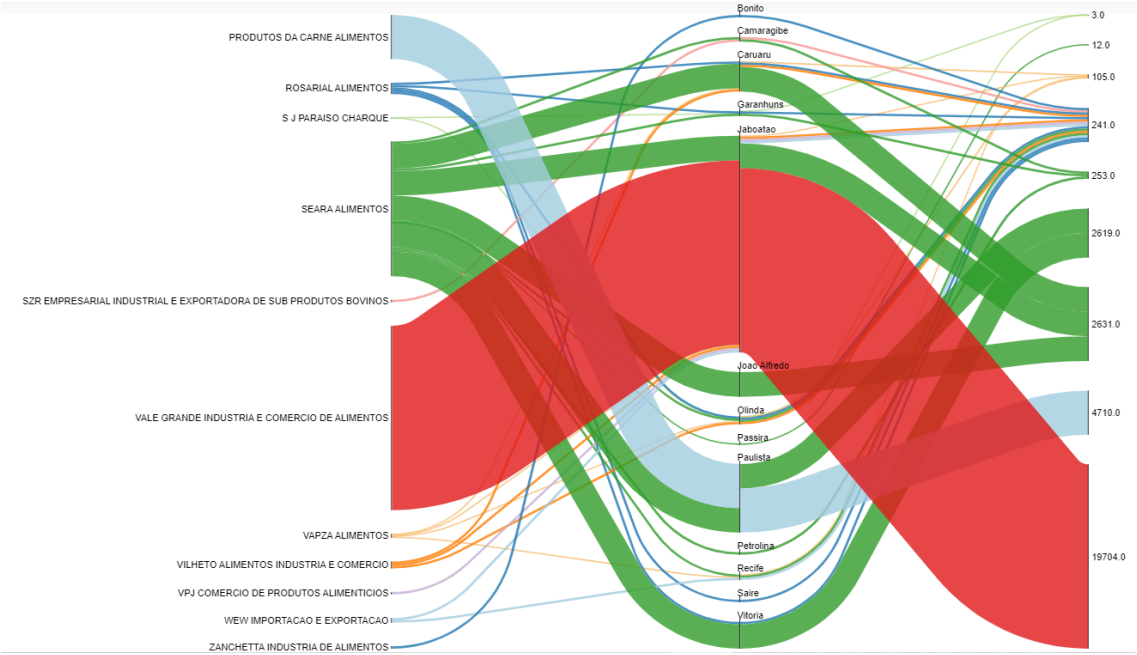

Figure 24: Sankey Diagram of meatpackers and its correlated supplied municipality and deforestation risk. From 56th to 66th meatpacker in alphabetical order. Source: own elaboration, using Python.

As can be seen, the meatpackers are randomly spread across the municipalities, only with JBSs as a common denominator between them. Municipalities have, on average, five different meatpackers supplying their supermarkets. Pernambuco is dominated by JBS and Masterboi products, with those brands responsible for 363 and 261 products, respectively. JBS, for instance, has nine UFs as the source for its cattle, in four different regions (North, Northeast, Central-West, and Southeast), while Masterboi has three states as the source for its beef (Pará, Tocantins, and Pernambuco). As stated

in the previous section, GCU, CU, IA, and RA municipalities, are ranked in the order of largest deforestation risk, with the same trend happening for the average number of brands present in them. GCU has on average 22 meatpackers supplying its supermarkets, with CU having the same average. IA has 13 meatpackers, and RA has 11 (Figures 25 and 26).

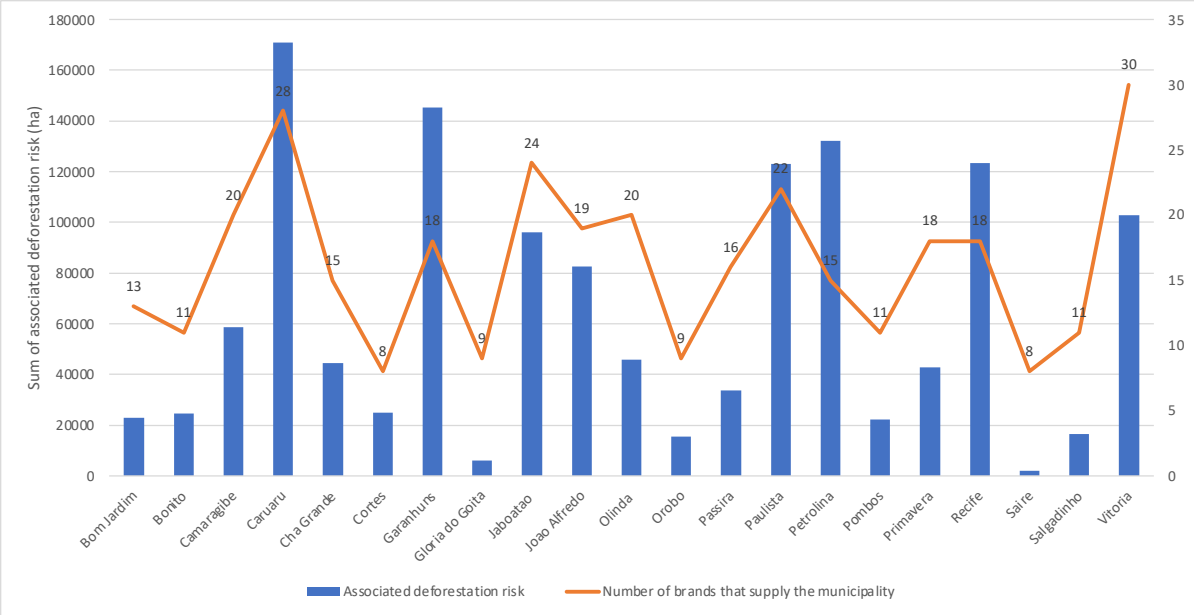

Figure 25: Relation between the sum of the associated deforestation risk of the brands that supply a certain municipality, and the number of meatpackers that proceed with this action. Source: own elaboration.

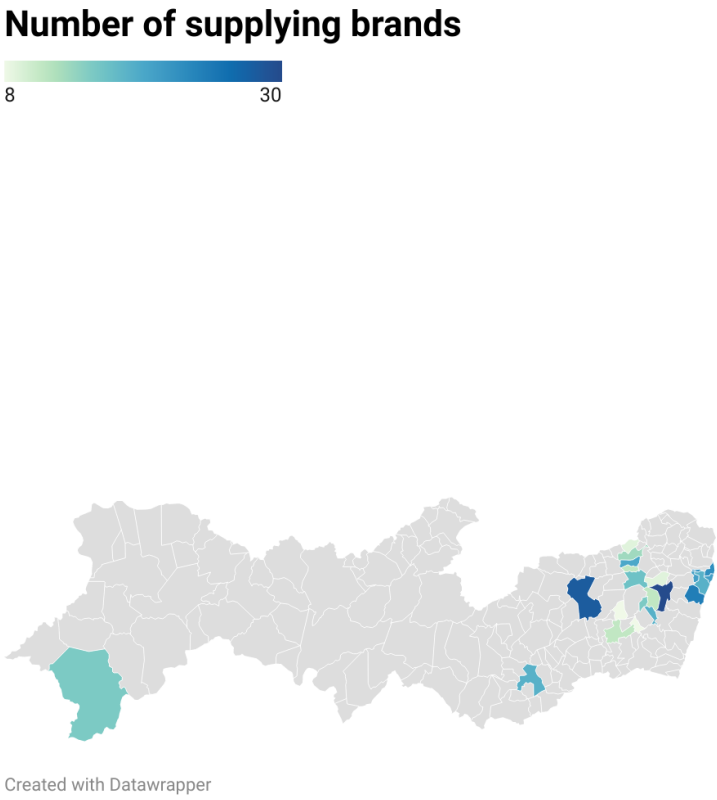

Figure 26: Number of supplying brands per analyzed municipality in Pernambuco. Source: own elaboration.

4.2. Pernambuco's consumption and deforestation

The average consumption of a food product is cyclical, and changes based on (among others) economic, social, and health matters. Brazil is, at the same time, one of the largest beef producers and one of the largest beef consumers. Table 6 shows the relation between the consumption (demand), amount of cattle, and the associated deforestation required to support the demand in Brazil (average reference figures) and Pernambuco (total figures).

Table 6: Beef consumption and associated deforestation in Brazil and Pernambuco. Source: own elaboration.

Average Consumption of beef (kg/hab/year)	Average weight of cattle when slaughtered (kg)	Dressing Percentage (%)	Percentage of beef that remains in Brazil (%)	Total Amount of cattle heads (2016-21)	Total Amount of Slaughtered Cattle (2016-21)	Pasture Area (ha)	Average Area to Produce one cattle head (ha)
33.075	590	62	80	1 229 549 881	180 938 041	172 327 571	1.3
Pernambuco							
Average Population (2016-21)	**Average Consumption of beef (kg)**	**Average Amount of Cattle Heads**	**Slaughtered Amount**	**Pasture Area (ha) (2016-21)**	**Share of Consumption in the country (%)**	**Number of cattle heads require to fulfill the demand**	**Required area to produce the demanding cattle (ha)**
9 526 463	178 906 981	1 749 991	1 592 160	3 171 66	4,6	4 890 841	6 008 660

In the time range of the analyses (2016-21), Pernambuco was responsible for 4.6% of the consumption of the total volume of produced beef, also considering beef targeted for exports. Distribution and demand for cattle meat in Brazil differ according to the UFs and regions. Although, production and consumption don't go hand to hand. Center West and North are the two regions with the largest amount of beef production but are also the least consuming ones (Figure 25). They are respectively responsible for 7.7% and 8.7% of the national beef consumption, against the Southeast, which represents 42.1% of the total average consumption. (Figures 25 and 26) (IBGE, 2020).

Pernambuco in conjunction with most of the Brazilian states, requires a bigger pasture area to produce enough beef for their consumption, than the one it has (Figure 27). The state requires 4 428 510 ha of pasture area to produce enough beef to support its consumption, an area equivalent to the state of Rio de Janeiro. But it only owns 71.5% of this area (3 166 525), requiring other states to supplement its lack of territory (Figure 28). The total surplus/shortage area and average consumption can be seen in Annex 7.

Figure 27: Average consumption of beef per state in Brazil, from 2016-2021. Source: IBGE, 2020a.

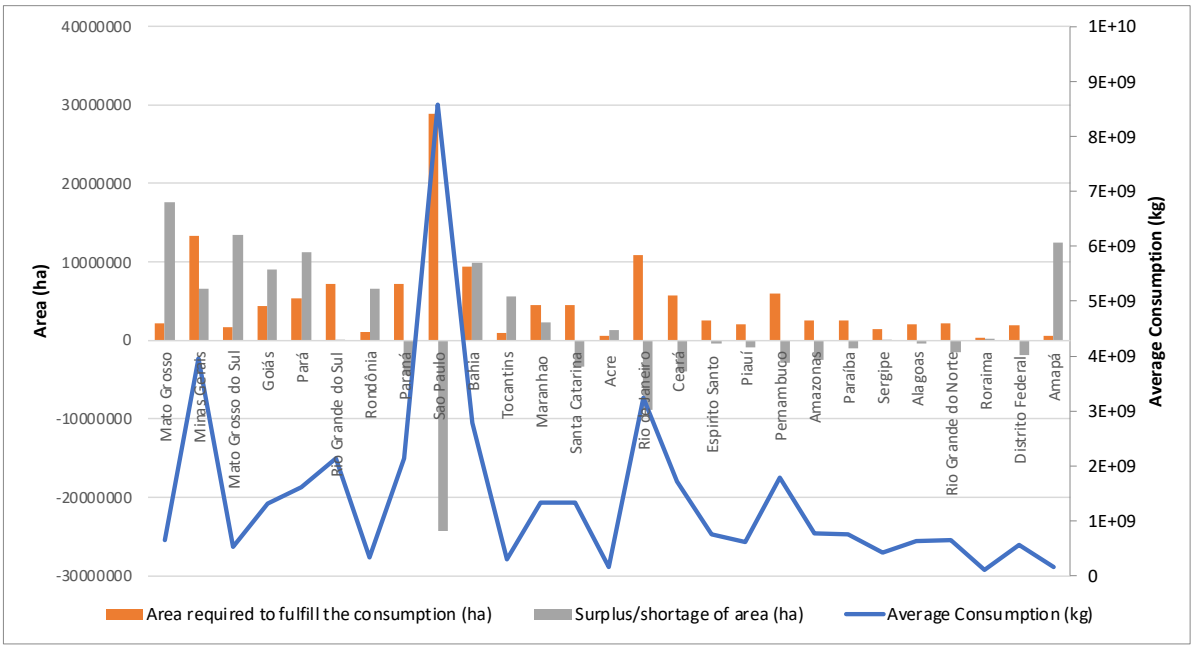

Figure 28: Surplus or shortage of pasture area required to support the internal consumption of beef for each Brazilian UF, correlated to its average consumption (2016-21). Source: (ABIEC, 2017, 2018, 2019, 2020, 2021, 2022; IBGE, 2022a; UFG, 2022), adapted by the author.

4.3. Brazilian beef export scenario

The origin of the beef, in both regional, UF, or biome levels, is not enough robust information to trace a distribution pattern. This means that the most relevant UFs, in terms of supply, are the same for both internal and external markets. Pernambuco, which receives on average 3.45% of the produced beef in Brazil, has as the biggest source the same biomes and, to a certain extent, UFs that supply the external market.

Pernambuco, as the 16th UF with the largest beef production in Brazil, mostly relies on the supply of beef from other UFs to address domestic consumption (see Table 6). The UF produced 33% of the total amount of domestically consumed beef between 2016 and 2019. This aspect resembles the scenario of many countries worldwide that require the import of beef to address their demand, depending on the Brazilian production for this. As addressed by zu Ermgassen *et al.* (2020) and TRASE, the beef international market imposes significant pressure on the Brazilian biomes, with around 20% of its Brazilian beef production being designated for exports.

The main importers of Brazilian beef products between 2016 and 2019 include China (importing about 2.6% of total beef production), Hong Kong (2.1%), Egypt (1.4%), Iran (0.8%), and Chile (0.7%) (Figure 29). Appendix 3 shows the total beef product exports from Brazil - in kg and U$ - and the share of each destination market/country.

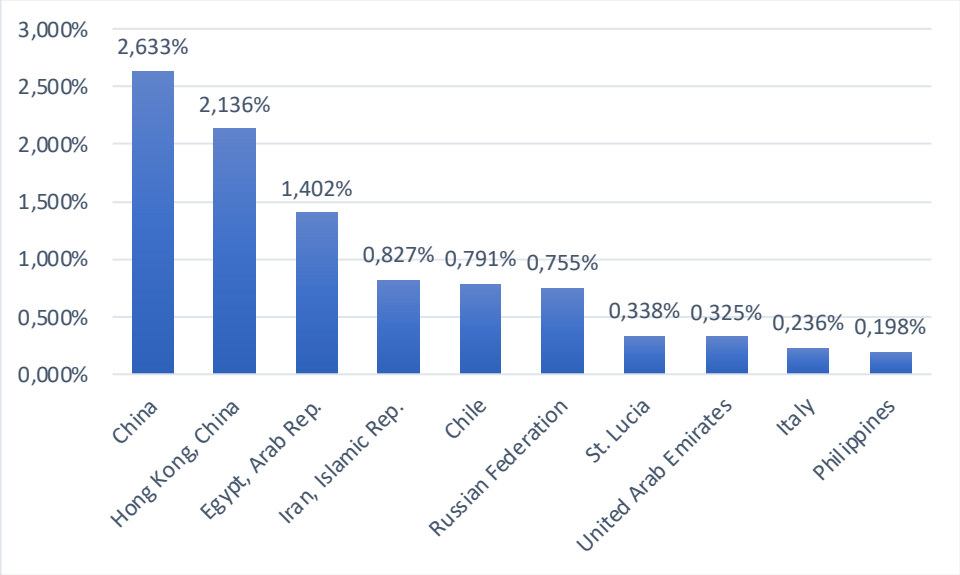

Figure 29: Share of beef exports per country (2016-19), highlighting the top 10 importers. Source :(WITS, 2020), adapted by the author.

The beef products exported from Brazil mainly originate from the Cerrado and Amazon biomes. As reported by zu Ermgassen *et al.*, (2020), between 2015 and 2017, 44% of the exported beef had as origin municipalities in the Cerrado region, followed by the Amazon with 24%, while Caatinga is the biome with the least representative amount of beef exports, with 0.14% of the total (Figure 30).

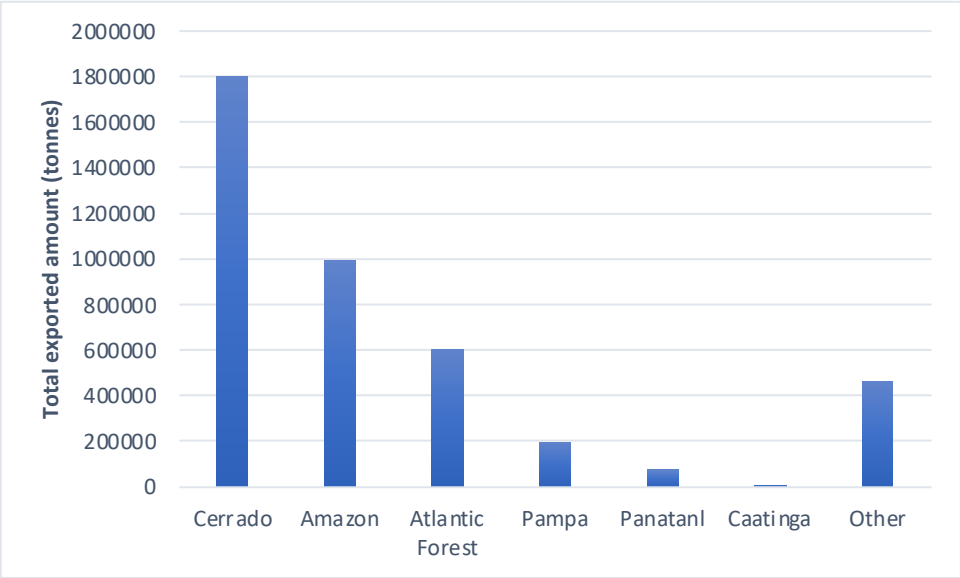

Figure 30: Origin of the exported beef per biome (2015-17). Source: (Trase, 2020).

Exports are mainly concentrated in the UFs of the Southeast, Central West, and North regions. UFs that are responsible for the largest amount of beef exports include Sao Paulo and Mato Grosso, responsible for 22% and 19% of total exports, respectively. UFs in the Northeast and South, apart from Rio Grande do Sul, which emerge as a relevant player, correspond together to just 4% of the total amount of exports (Figure 31).

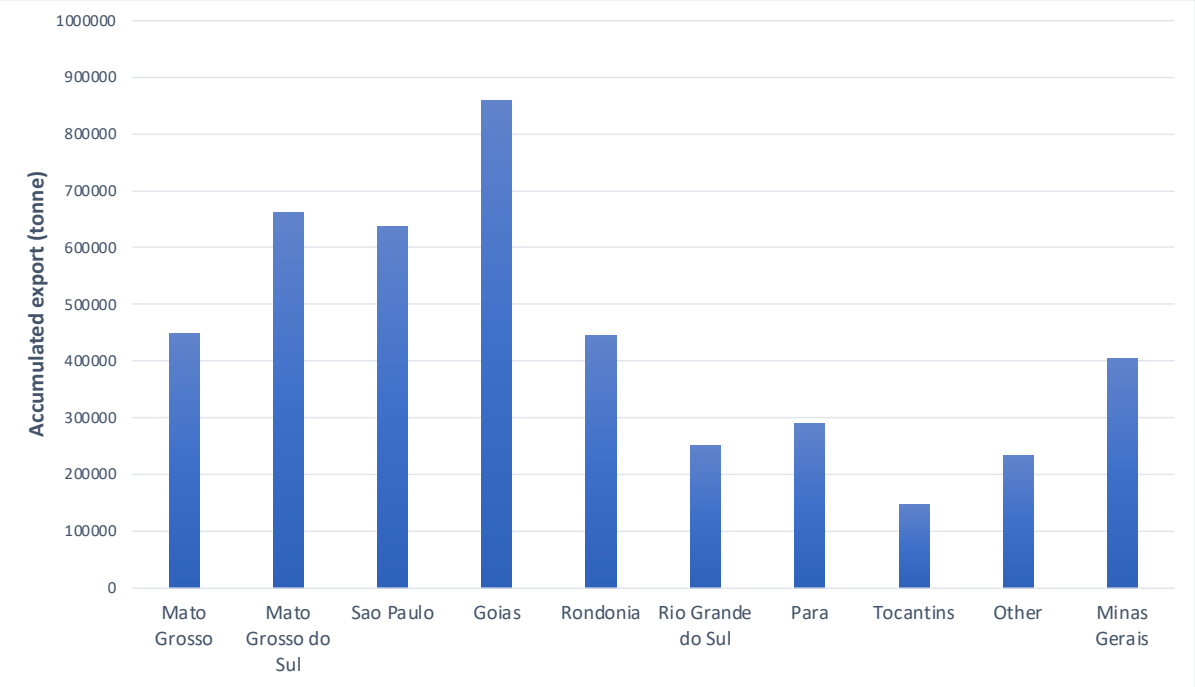

Figure 31: Origin of the exported beef per UF (2015-17). Source: (Trase, 2020).

The product type and the sanitary and environmental requirements of the country/market of destination are linked to the region and risks for the supplied

beef (zu Ermgassen *et al.*, 2020). As an example, the USA and UK mainly buy processed beef from Brazil, which is mostly produced in the South and Southeast regions (zu Ermgassen *et al.*, 2020).

5. Discussion

5.1. Pernambuco's deforestation risk

Pernambuco's deforestation risk is determined based on the amount of deforestation generated in the area where the meatpackers are located. The deforestation risk associated with a particular municipal area in Pernambuco is directly related to the meatpackers that supply beef to the local market. Seventy-five meatpackers were responsible for providing beef to twenty-one cities in the state of Pernambuco.

As detailed in Section 3.1., the main region sourcing beef for Pernambuco is the Southeast (35%), the richest in Brazil. This fact is not surprising since the Southeast region has been, for centuries, the economic powerhouse of Brazil, the region with the largest number of inhabitants, where the larger Brazilian companies are based, and where technological development is at its peak (IBGE, 2016). Those factors are also supported by the fact that São Paulo, the richest UF in Brazil, has one of the main ports to export commodities in the country, causing many of the goods to have this state as the main destination and subsequently transport products to other regions, both internally and externally (Malafaia *et al.*, 2021).

Trends in deforestation risk do not follow the one of supply. Southeast supplies most of the beef to Pernambuco but presents the 3rd largest deforestation risk (14 592 ha) (Table 3). In 2021, the region had 17% of the total pasture area in the country, against 27% from the North, and 28% from the Central-West regions (UFG, 2022). The economic and technological development of the region, associated with the cattle-farming focus on the North and Central-West regions, explains the 3rd place in the deforestation risk. Nevertheless, in many other environmental analyses, the Southeast is negatively accommodated in the 1st position, i.e., use of pesticides, energy consumption, CO_2 emissions, etc. (Hersen *et al.*, 2019; Ciotta, Silva and Musarra, 2022).

From a biome perspective, the same trends have already been presented before. Since the Atlantic Forest biome remains mainly concentrated in the Southeast region, the number of products sourced from it, and the deforestation risk towards Pernambuco is the same as the region it belongs to, 512 and 6 541 ha, respectively. Differently from the Amazon and Cerrado biomes, the Atlantic Forest already lost more than 87% of its original area and is the most exploited and degraded biome since the colonial period (Scarano and Ceotto, 2015). This fact implies that, differently from the Cerrado and Amazon biomes, still largely unexploited, nowadays there is a small room for expansion in this biome.

This study suffered from a lack of information in some of the analyzed products, as stated before, particularly when regarding Atlantic Forest and the Northeast region. Recife was the municipality where most of the beef originated from (156 products), with none of its products having information regarding their risks. In total, 219 products deriving from this biome were missing some information. This fact significantly affects the proper deforestation risk accruing from this biome, but also the Northeast region. The choice to invest in traceability makes

more sense when targeting the regions with the largest deforestation status and the expansion of cattle farming. Perhaps that explains why for the Cerrado and the Amazon all the products have their risks perfectly reported, but this is not the case for the Atlantic Forest and Caatinga biomes.

The lack of information on the risks deriving from Recife not only affects the biome and regional analyses. The supply inside the state follows a trend where the bigger cities (GCU) have access to a wider range of products, which was expected. But what wasn't expected is that those municipalities would present both the highest value for their average sustainability score and deforestation risk (Figure 16). It was expected that GCU municipalities, due to their economic power, would have lower scores in all the risks. 21% of the products in GCU cities have Recife as their origin, but 51% of the products in CU municipalities had the same origin. With proper knowledge of the risks deriving from Recife, CU municipalities could surpass the GCU ones in terms of deforestation risk, ranking in 1st place.

5.2. Meatpackers' supply pattern

When taking the brands as a unit of analysis, supply trends do not follow any pattern. The suppliers that are more dominant in terms of number of supplied products and the number of supplied municipalities are widespread across all the demographic categories, the same happens with the meatpackers that are present in less than three municipalities. Similarly, the origin of the meatpackers, in terms of state, biome, and region doesn't follow a specific trend.

The actual correlated risk of single meatpackers also suffered from the lack of information, mainly considering a dominant meatpacker as Masterboi. In total, eight meatpackers did not have any information about their risks, except for those regarding their origin, and three of those are present in more than ten municipalities (Frinense Alimentos, Icane Industria E Comercio De Alimentos Do Nordeste, and Fipel Frigorifico Industrial Pernambucano). Even with that information available, JBS would remain undefeated as the meatpacker with the largest number of sources and associated deforestation risk.

JBS, as the largest meatpacker company in the world, has its movement "better" traced, if we compare it with the other companies. With more in-depth analyses it is possible to see that all the municipalities have different deforestation risks related to JBS, since the company's multiple sources of beef present different deforestation risks.

5.3. Consumption and Deforestation

In general, beef consumption, income, and GDP have a strong correlation with each other, meaning that when one of the parameters increases, or is high, the others follow the trend (Diacon and Maha, 2015). This pattern can be seen in the consumption of beef in Brazil, at least for the six highest-ranked consumer UFs (Figures 19 and 20). São Paulo (SP), Minas Gerais (MG), Rio de Janeiro (RJ), Bahia (BA), Paraná (PR), and Rio Grande do Sul (RS), are in that order, the UFs with the largest average of beef consumption, and are also some of the

states with the highest GDP in Brazil (IBGE, 2022b). This confirms a general trend observed within existing literature: meat consumption tends to go hand in hand with high GDP values, at least to a certain extent (Whitton *et al.*, 2021).

Beyond the six aforementioned UFs, the analyses become more intricate. The 7th highest average consumption of beef belongs to Pernambuco, a UF that does not have a widespread pecuary production and neither GDP if we compare for example with Mato Grosso (MT), which has one of the highest GDPs in Brazil and one the highest cattle farming production. The subsequent ranked UFs do not follow a pattern of consumption too.

Without a proper qualitative analysis (interviews, surveys, et.) in those regions, it is difficult to give a concrete answer on the reasons for the different consumption patterns. Furthermore, some recent studies try to shed light on the main factors influencing the variation in beef consumption. A common factor emerging from many studies is the growing awareness of environmental and animal welfare aspects (Henchion *et al.*, 2014; Henchion, McCarthy and Resconi, 2017; Mottin *et al.*, 2019; Eugênio Spers, Carvalho Burnier and Lucchese-Cheung, 2021).

North and Central-West regions are the largest producer regions in Brazil, as well as the ones with the largest deforestation rates and the lowest average beef consumption. Living nearby the degradation of many natural environments implies that its inhabitants/customers suffer the negative outcomes of the cattle expansion to a larger extent if we compare with Northeast and South regions for example, which in a way can reduce their propensity to consume beef. This aspect is also supported by the surplus and shortage of pasture areas per UF (Figure 20). The only UFs that have a surplus of pasture area to support their consumption are the ones from the North and Central-West regions, except for Bahia (Northeast), Minas Gerais (Southeast), and Maranhão (Northeast). Those regions not only provide the land and resources for supplying the demand within other UFs but internationally too. In total, the country has 40.3 million ha of surplus pasture area, with 36% and 40% of this share being respectively represented by the North and Central-West.

Apart from sustainability aspects, income is the highest limiting factor in terms of consumption (Henchion *et al.*, 2014). This can explain the lack of consumption in regions like the North and Northeast and the prevalence of the South and Southeast. Cultural aspects in terms of culinary can also be limiting factors, and the South takes advantage in this sense. Even if the “churrasco” culture (Brazilian barbecue) is widely spread in all the regions, it is particularly strong in the South. So, in terms of average beef consumption, sustainability and welfare can be limiting aspects mainly for the Central-West and North regions; income affects mainly North and Northeast, favouring the South and Southeast; and cultural aspects mainly favor the South over the other regions.

5.4. Brazil’s Exports

The beef that remains inside the country and the ones that are being exported, do not present any technical difference. The origin of both biome and

geographic region can be, in certain cases, comparable. Pernambuco, and many other Brazilian UFs, that rely on the production of other states to support their demand, have the same pattern of origin as the beef that goes to China for example. The only difference is that while UFs in Brazil produce and transport a wide range of beef products, the international market is divided in terms of the products that they purchase from the country.

In some cases, certain countries only import a specific type of beef product from Brazil, different from what happens in the domestic market. This implies that the origin of the beef, and consequently the risks associated with it, are focused on specific UFs and regions. Each country have a specific purchase characteristic, buying specific products in a specific amount. Angola, for example, is the main importer of dried salted beef, which has its origin most focused in the Pampa biome, while Italy imports mainly boneless beef that comes mostly from the Cerrado and the Amazon.

The particularities of each foreign market make it complex to compare these markets with a UF like Pernambuco, even more, if traceability is addressed. The trend of volume, types of products, consumption, and traceability disfavor the comparisons of UFs with the international market.

5.5. Limitations of the study and suggestions for future research

Many adjustments and simplifications - in terms of fieldwork activities as well as variables and data sources - were needed to make this study possible. The analysis of beef trade flows within Brazil and associated impacts face huge obstacles, and this research provides an early path for future research to develop the same study in other UFs compared to those considered here. As addressed before, Brazil has twenty-seven UFs, and this research only addresses one of them.

In terms of the fieldwork, there is a clear difference in Pernambuco between big cities and the small rural ones, in terms of the available beef. On many occasions, in the smaller cities, the available beef was found in a “fresh” state, the way they are presented in butcher stores. This fresh state is more appealing to most customers, but in smaller cities, they did not have any sort of package or track of the origin of that meat. In certain cases, employees said that the beef came from the surroundings, without any type of inspection, while the opposite scenario is observed in the bigger cities. All in all, this makes it difficult to study beef trade and associated deforestation risks in rural areas.

Also, this research focused only on the deforestation risk, but as attested before, the app *Do Pasto ao Prato* provides four risks in total. Using the entirety of the collected data should provide a more precise result of the beef context in Pernambuco, but each of the risks brings with it different sorts of implications and parameters, making it complex to address and tie all of them together. Deforestation and Fire risks, for example, encompass more of an environmental scope, while slave labor and sanitary aspects are more social and health oriented.

The fieldwork for the data collection had to be adjusted several times to fit the range of intended products. Apart from that, many sources were utilized to provide the means for some calculations and estimations. This process implies a certain level of uncertainty, which could be further reduced by other different methodologies. Monte Carlo simulation could be one of them, mainly related to the consumption and pasture area of the states. Samples of pasture areas, cattle heard, population, and consumption could be done this way to reduce uncertainties.

The app itself attests that some of the methods and values it relies on are estimated. With the advance in traceability and technologies, the results from the app will likely be more accurate. The app also encompasses a short time range of just four years, from 2016 to 2019, meaning that this is a work in constant development.

6. Conclusion

Over the last few decades, deforestation and its adverse consequences have harmed the planet at unprecedented levels. The destruction of the environment, global warming, and climate abnormalities, among other negative consequences, has sparked a global response.

The beef industry has proven to have a central role in the deforestation processes. Brazil, in this sense, is a key area, not only in terms of its extensive beef production but also because of its environmental significance. The country has the largest biodiversity and hosts the largest forest area in the world, the Amazon. In the last decades, this biome has been targeted as a land provider for the expansion of agricultural activities, with a focus on cattle farming.

This research showed evidence of the connection between the deforestation in the principal Brazilian biomes and the beef that is supplied to the domestic and international markets, with a focus on the state of Pernambuco. 1 271 products were analyzed throughout 21 municipalities within the state, divided into four demographic categories. This study also addresses the required pasture area for supplying the demanded beef per state and the pattern of origin of the beef products. The app *Do Pasto ao Prato* was the main tool utilized to identify risks accruing from the beef available in the state, along with the meatpacker supplier and its city of origin.

Pernambuco is mostly supplied by meatpacker companies that are correlated with deforestation of the Amazon biome (62.5% of the total deforestation risk) and has the Southeast as the region with the largest number of supplied products (35%). This aspect shows that a small number of beef products deriving from the Amazon biome can have a much higher risk (and impacts) than a number of products from other Brazilian biomes, states and regions. This can also be observed in beef deriving from the Pantanal biome. The average deforestation risk associated to a beef product sourced from the Amazon or the Pantanal is, respectively, 12 464 ha and 5 868 ha. Although being the main supplying biomes, the Atlantic Forest and the Cerrado have lower deforestation risks, i.e., 204 ha and 1 504 ha, respectively.

The amount of beef that is supplied to a state is depends on its consumption patterns, therefore the deforestation associated with beef also correlates with consumption. The Brazilian states that are the main beef producers are also the ones with the lowest rate of beef consumption. With few exceptions, all the states outside the Central-West and North regions lack enough pasture area to support the domestic consumption of beef by its inhabitants, and this in particular the case of the Northeast. The geographical distance from the extensive cattle farming and economic/cultural aspects are the main factors that explain the current rate of consumption in a certain state.

As for the international market, the characteristics of the supplied beef are comparable with the Brazilian states that needs to purchase beef products from other regions and biomes. Pernambuco, in this sense, lacks 2 836 993 ha of

pasture area to support its domestic consumption, therefore it must procure beef from the same regions and biomes that feed export flows to supply the international markets, i.e., the Cerrado, the Atlantic Forest, and the Amazon biomes.

This study considered and analyzed only one of the risks that relate to beef products, i.e., deforestation. Aspects regarding fires, slave labor, and sanitary aspects can be further unraveled in future research. The research, moreover, can benefit from the constant update of the *Do Pasto ao Prato* app, both in terms of origin and meatpackers, and with regard to the associated risks. As stated before, the traceability of beef inside Brazil faces some obstacles, and the lack of information on some of the targeted products is a consequence of this.

The state of the global climate and environment require an extensive analysis of drivers of the adverse outcomes, and strategies to cope with them. Brazil arose as one of the main players in the climatic/environmental field, having the potential to direct the future of the planet toward a more sustainable context. Protecting the Amazon, the lungs of the world, could be nominated as one of the most urgent goals for our society, but the rate of degradation of this biome suggests a movement in the opposite direction. Investments in the traceability of the main deforestation-correlated commodities (beef, soybean, palm oil, and timber) supply chain, together with increasing society's awareness about them and their impacts, are key actions towards a future that values and protects the World's forests, and promotes sustainable supply chains.

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Annexes

Annex 1 - Approach to fieldwork methodology, before and after the start

Previous Established Methodology					
Demographic Category	Number of Cities	Number of Stores	Products per Store	Amount of Products per City	Total Amount of Products per demographic category
GCU	5 (Petrolina, Garanhuns, Caruaru, Vitória de Santo Antão, and Recife)	6	20	120	600
CU	4 (Jaboatão dos Guararapes, Olinda, Camaragibe, and Paulista)	4	17	68	270
RA	3 (Passira, Riacho das Almas, Vertentes)	4	15	60	180
IA	3 (Glória do Goitá, Pombos, and Agrestina)	4	13	50	150
After Fieldwork Starting Methodology					
GCU	5 (Petrolina, Garanhuns, Caruaru, Vitória de Santo Antão, and Recife)	6	20	120	604
CU	4 (Jaboatão dos Guararapes, Olinda, Camaragibe, and Paulista)	4	17	68	278
RA	7 (Passira, Salgadinho, Orobó, Bom Jardim, Cortês, Primavera, and Sairé)	3	8	24	174
IA	5 (Glória do Goitá, Pombos, João Alfredo, Bonito, and Chã Grande)	4	9	36	154

Annex 2 – Average score for the four possible risks per municipalities

Average Risks Score						
Demographic Category	**City**	**Slave Labor**	**Sanitary Inspection**	**Fires**	**Deforestation**	**Average**
GCU	Caruaru	30.96	81.16	72.68	71.29	64.02
GCU	Garanhuns	26.79	80.48	72.10	70.44	62.45
GCU	Petrolina	43.30	75.51	70.46	69.27	64.63
GCU	Recife	21.90	85.34	72.51	69.74	62.37
GCU	Vitória de Santo Antão	27.59	78.15	68.96	66.70	60.35
CU	Jaboatão dos Guararapes	35.84	76.11	66.11	65.33	60.85
CU	Camaragibe	30.47	73.58	65.71	65.52	58.82
CU	Olinda	18.68	78.68	68.65	65.52	57.88
CU	Paulista	35.41	73.44	63.22	61.31	58.34
RA	Passira	17.5	67.44	67.55	65.62	54.53
RA	Salgadinho	1	64.65	57.67	57.92	45.31
RA	Orobó	1	74.68	55.76	53.53	46.24
RA	Bom Jardim	10.9	64.47	64.28	62.48	50.53
RA	Cortês	25.63	66.45	64.2	63.05	54.83
RA	Primavera	49.67	70.05	63.68	63.04	61.61
RA	Sairé	1	90.86	49.4	46.93	47.05
IA	Glória do Goitá	1	84.2	55.58	53.33	48.53
IA	Pombos	28.86	74.86	63.9	63.05	57.67
IA	João Alfredo	1	66.44	61.89	59.30	47.16
IA	Bonito	23	78.44	63.46	62.42	56.83
IA	Chã Grande	37.5	65.63	59.63	59.75	55.63

Annex 3 – Total Deforestation risk of municipalities in Pernambuco

Municipalities	Associated deforestation risk (ha)	Number of supplying brands	Average deforestation risk of beef products (ha)	Demographic category
Bom Jardim	23 076	13	1 775	RA
Bonito	24 508	11	2 228	IA
Camaragibe	58 801	20	2 940	CU
Caruaru	171 010	28	6 108	GCU
Chã Grande	44 389	15	2 959	IA
Cortês	24 796	8	3 100	RA
Garanhuns	145 214	18	8 067	GCU
Glória do Goitá	6 061	9	673	IA
Jaboatão dos Guararapes	96 100	24	4 004	CU
João Alfredo	82 742	19	4 355	IA
Olinda	45 915	20	2 296	CU
Orobó	15 570	9	1 730	RA
Passira	33 696	16	2 106	RA
Paulista	122 871	22	5 585	CU
Petrolina	132 219	15	8 815	GCU
Pombos	22 145	11	2 013	IA
Primavera	42 729	18	2 374	RA
Recife	123 314	18	6 851	GCU
Sairé	1 940	8	243	RA
Salgadinho	16 553	11	1 505	RA
Vitória de Santo Antão	102 933	30	3 431	GCU
Total	1 336 582	-	-	-

Annex 4 - Average Consumption of beef in each Brazilian state (2016-21)

Rank	State	Region	Consumption (tonnes) (2016-21)
1	São Paulo	Southeast	8 585 789
2	Minas Gerais	Southeast	3 962 672
3	Rio de Janeiro	Southeast	3 231 839
4	Bahia	Northeast	2 786 968
5	Paraná	South	2 138 896
6	Rio Grande do Sul	South	2 131 736
7	Pernambuco	Northeast	1 789 070
8	Ceará	Northeast	1 709 610
9	Pará	North	1 606 980
10	Santa Catarina	South	1 336 825
11	Maranhão	Northeast	1 324 846
12	Goiás	Central-West	1 308 984
13	Amazonas	North	772 199
14	Paraíba	Northeast	752 513
15	Espirito Santo	Southeast	750 208
16	Rio Grande do Norte	Northeast	655 874
17	Mato Grosso	Central-West	650 279
18	Alagoas	Northeast	625 263
19	Piauí	Northeast	613 676
20	Distrito Federal	Central-West	561 848
21	Mato Grosso do Sul	Central-West	518 878
22	Sergipe	Northeast	429 728
23	Rondônia	North	331 844
24	Tocantins	North	293 704
25	Acre	North	164 423
26	Amapá	North	157 255
27	Roraima	North	110 773

Annex 5 - Slaughtered amount of cattle per state (2016-21)

Slaughtered Amount of Cattle							
State	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**Total**
Mato Grosso	4 577 459	4 804 611	5 219 350	5 649 896	5 076 288	4 456 596	29 784 200
Minas Gerais	2 469 873	2 766 901	2 800 782	2 846 455	2 684 585	2 610 507	16 179 103
Mato Grosso do Sul	3 292 279	3 436 886	3 293 548	3 585 067	3 238 912	2 955 535	19 802 227
Goiás	2 821 463	3 179 805	3 207 705	3 008 205	2 793 131	2 969 595	17 979 904
Pará	2 731 398	2 637 185	2 609 298	2 407 912	2 210 994	2 258 687	14855474
Rio Grande do Sul	1 897 834	1 929 178	2 134 308	1 966 444	1 897 236	1 602 392	11 427 392
Rondônia	2 155 315	2 259 982	2 414 392	2 392 309	2 179 717	1 862 407	13 264 122
Paraná	1 198 329	1 283 978	1 441 473	1 452 174	1 443 827	1 210 093	8 029 874
São Paulo	2 792 350	2 912 755	3 045 988	3 326 168	3 120 469	2 891 690	18 089 420
Bahia	1 140 385	1 176 495	1 192 229	1 196 050	958 899	924 693	6 588 751
Tocantins	1 022 512	980 048	1 066 984	1 032 557	894 811	949 944	5 946 856
Maranhão	776 772	738 542	712 944	687 455	566 989	567 263	4 049 965
Santa Catarina	407 877	431 830	476 147	536 299	595 824	533 622	2 981 599
Acre	453595	427 923	425 104	416 498	372 495	325 075	2 420 690
Rio de Janeiro	150 625	175 134	182 603	183 725	157 599	137 514	987 200
Ceará	200 079	172 889	156 437	152 141	128 709	114 748	925 003
Espirito Santo	309 559	296 784	273 365	284 115	238 723	189 404	1 591 950
Piauí	127 806	134 131	137 992	128 573	107 128	76 857	712 487
Pernambuco	299 853	273 069	294 386	273 234	236 913	214 705	1 592 160
Amazonas	253 446	257 559	241 531	247 259	211 634	155 079	1 366 508
Paraíba	81 731	54 022	50 582	57 044	59 366	55 516	358 261
Sergipe	87 027	92 363	116 162	X	X	X	295 552
Alagoas	152 882	148 132	132 972	114 001	104 884	104 417	757 288
Rio Grande do Norte	90 277	81 671	83 897	86 239	78 130	63 997	484 211
Roraima	63 854	67 319	76 985	82 553	87 692	89 441	467 844

Distrito Federal	X	X	X	X	X	X	X
Amapá	X	X	X	X	X	X	X

Annex 6 – Municipalities deforestation risk and supplying meatpackers

Meatpacker	Supplied municipalities	Deforestation associated risk (ha)	Demographic category
ALLES INDUSTRIA E COMERCIO DE CARNES E DERIVADOS E TRANSPORTES	João Alfredo	241	IA
	Pombos	241	IA
	Vitória de Santo Antão	241	GCU
ARROBA ALIMENTOS	Cortês	125	RA
	Primavera	125	RA
	Vitória de Santo Antão	125	GCU
ATIVO ALIMENTOS EXPORTADORA E IMPORTADORA	Jaboatão dos Guararapes	10 721	CU
	Olinda	10 721	CU
	Primavera	10 721	RA
BELLO CHARQUE ALIMENTOS	Bonito	734	IA
	Pombos	734	IA
BIG CHARQUE INDUSTRIA E COMERCIO	Bonito	9 460	IA
	Chã Grande	9 460	IA
	Cortês	9 460	RA
	Passira	9 460	RA
	Primavera	9 460	RA
	Salgadinho	9 460	RA
	Vitória de Santo Antão	9 460	GCU
BOA VISTA ALIMENTOS	Petrolina	518	GCU
BOIBRAS INDUSTRIA E COMERCIO DE CARNES E SUB PRODUTOS	Primavera	2 537	RA
BOMBONATTO IND DE ALIMENTOS	Passira	3 657	RA
	Paulista	3 657	CU
BOVMEAT PROCESSADORA DE CARNES E DERIVADOS	Bom Jardim	241	RA
	Bonito	241	IA
	Camaragibe	241	CU
	Caruaru	241	GCU
	Glória do Goitá	241	IA
	Jaboatão dos Guararapes	241	CU
	João Alfredo	241	IA
	Olinda	241	CU
	Orobó	241	RA
	Passira	241	RA
	Paulista	241	CU
	Pombos	241	IA
	Primavera	241	RA
	Recife	241	GCU
	Vitória de Santo Antão	241	GCU
BRASA BURGER INDUSTRIA E COMERCIO DE	Bom Jardim	241	RA
	Camaragibe	241	CU
	Caruaru	241	GCU

DERIVADOS DE CARNES	Glória do Goitá	241	IA
	Jaboatão dos Guararapes	241	CU
	Olinda	241	CU
	Passira	241	RA
	Paulista	241	CU
	Sairé	241	RA
	Salgadinho	241	RA
	Vitória de Santo Antão	241	GCU
BRASIL GOURMET INDUSTRIA E COMERCIO DE ALIMENTOS	Garanhuns	125	GCU
BRF	Bom Jardim	734	RA
	Caruaru	734	GCU
	Chã Grande	734	IA
	Garanhuns	734	GCU
	Glória do Goitá	734	IA
	Jaboatão dos Guararapes	734	CU
	João Alfredo	734	IA
	Olinda	734	CU
	Passira	734	RA
	Paulista	734	CU
	Petrolina	734	GCU
	Primavera	734	RA
	Sairé	734	RA
	Salgadinho	734	RA
	Vitória de Santo Antão	734	GCU
CAJURU INDUSTRIA E COMERCIO DE ALIMENTOS	Caruaru	241	GCU
CARANGOLA DISTRIBUIDORA DE ALIMENTOS	Camaragibe	NA	CU
	Caruaru	NA	GCU
	Garanhuns	NA	GCU
	João Alfredo	NA	IA
	Primavera	NA	RA
CHARQUE 2000 ITAPERUNA INDUSTRIA COMERCIO E DISTRIBUICAO DE CARNES E CHARQUES	Caruaru	NA	GCU
	Jaboatão dos Guararapes	NA	CU
	Orobó	NA	RA
	Passira	NA	RA
	Paulista	NA	CU
	Salgadinho	NA	RA
	Vitória de Santo Antão	NA	GCU
CHARQUE 500 INDUSTRIA E COMERCIO	Olinda	NA	CU
	Paulista	NA	CU
	Recife	NA	GCU
CHARQUEADA FRISUL	Chã Grande	125	IA
	João Alfredo	125	IA
	Pombos	125	IA
	Vitória de Santo Antão	125	GCU
COMCARNE COMERCIAL DE	Jaboatão dos Guararapes	466	CU

CARNE			
CONSERVAS ODERICH	Bom Jardim	10	RA
	Camaragibe	5	CU
	Cortês	10	RA
	Jaboatão dos Guararapes	10	CU
	João Alfredo	10	IA
	Olinda	10	CU
	Orobó	10	RA
	Passira	10	RA
	Paulista	10	CU
	Primavera	10	RA
	Recife	10	GCU
	Sairé	10	RA
	Vitória de Santo Antão	10	GCU
COOPER CHARQUE INDUSTRIA E COMERCIO ALIMENTOS	Recife	125	GCU
COOPERATIVA CENTRAL AURORA ALIMENTOS	Caruaru	2 378	GCU
	Chã Grande	3 667	IA
	Garanhuns	2 378	GCU
	Jaboatão dos Guararapes	3 667	CU
	João Alfredo	2 378	IA
	Primavera	2 378	RA
	Vitória de Santo Antão	2 378	GCU
CSP NORDESTINA INDUSTRIA E COMERCIO DE ALIMENTOS	Passira	NA	RA
DIMEZA ALIMENTOS	Glória do Goitá	107	IA
	Petrolina	107	GCU
	Recife	107	GCU
	Sairé	107	RA
	Salgadinho	107	RA
	Vitória de Santo Antão	107	GCU
DISTRIBUIDORA DE CARNES VALE DO MOGI IMPORTACAO E EXPORTACAO	Bonito	241	IA
	Passira	241	RA
	Paulista	241	CU
FAVORITO COMERCIO E INDUSTRIA DE CARNES	Chã Grande	241	IA
	João Alfredo	241	IA
	Pombos	241	IA
FIPEL FRIGORIFICO INDUSTRIAL PERNAMBUCANO	Bom Jardim	NA	RA
	Camaragibe	NA	CU
	Caruaru	NA	GCU
	Chã Grande	NA	IA
	Olinda	NA	CU
	Orobó	NA	RA
	Pombos	NA	IA
	Primavera	NA	RA
	Recife	NA	GCU
	Vitória de Santo	NA	GCU

	Antão		
FRIGMANN FRIGORIFICO	Bom Jardim	273	RA
	Caruaru	273	GCU
	João Alfredo	273	IA
FRIGOCHARQUE ALDEIA INDUSTRIA E COMERCIO DE CARNES	Bom Jardim	241	RA
	Chã Grande	241	IA
	João Alfredo	241	IA
	Salgadinho	241	RA
FRIGOESTRELA	Paulista	1196	CU
FRIGOL	João Alfredo	65 472	IA
	Paulista	65 472	CU
FRIGORIFICO CAMBUI	Camaragibe	125	CU
	Caruaru	125	GCU
FRIGORIFICO CRUZEIRO DO SUL	Chã Grande	9	IA
	Vitória de Santo Antão	9	GCU
FRIGORIFICO DE TIMON	Olinda	1 061	CU
FRIGORIFICO FORTEFRIGO	Paulista	6 702	CU
	Pombos	6 702	IA
	Primavera	6 702	RA
	Vitória de Santo Antão	6 702	GCU
FRIGORIFICO PANTANAL	Salgadinho	3895	RA
FRIGORIFICO REDENTOR	Chã Grande	16 418	IA
	Jaboatão dos Guararapes	16 418	CU
	Vitória de Santo Antão	16 418	GCU
FRIGORIFICO RIO MARIA	Caruaru	1 854	GCU
FRIGORIFICO VALE ALIMENTOS	Camaragibe	4 710	CU
	Caruaru	4 710	GCU
	Jaboatão dos Guararapes	4 710	CU
	Orobó	4 710	RA
	Passira	4 710	RA
	Paulista	4 710	CU
	Petrolina	4 710	GCU
	Vitória de Santo Antão	24	GCU
FRIGORIFICO VALE DO SAPUCAI	Camaragibe	241	CU
	Vitória de Santo Antão	241	GCU
FRIGORIFICO VALENCIO	Jaboatão dos Guararapes	6 864	CU
	Olinda	6 864	CU
	Paulista	6 864	CU
FRIGORIFICO VILHENA	Glória do Goitá	241	IA
	Orobó	241	RA
FRIMESA COOPERATIVA CENTRAL	Caruaru	105	GCU
FRINENSE ALIMENTOS	Bonito	NA	IA
	Camaragibe	NA	CU
	Caruaru	NA	GCU
	Cortês	NA	RA

	Garanhuns	NA	GCU
	João Alfredo	NA	IA
	Olinda	NA	CU
	Passira	NA	RA
	Petrolina	NA	GCU
	Primavera	NA	RA
	Recife	NA	GCU
	Salgadinho	NA	RA
	Vitória de Santo Antão	NA	GCU
FTS FRIGORIFICO TAVARES DA SILVA	Caruaru	3 836	GCU
	João Alfredo	3 836	IA
	Passira	3 836	RA
ICANE INDUSTRIA E COMERCIO DE ALIMENTOS DO NORDESTE	Bom Jardim	NA	RA
	Caruaru	NA	GCU
	Chã Grande	NA	IA
	Cortês	NA	RA
	Garanhuns	NA	GCU
	Glória do Goitá	NA	IA
	João Alfredo	NA	IA
	Orobó	NA	RA
	Passira	NA	RA
	Paulista	NA	CU
	Petrolina	NA	GCU
	Primavera	NA	RA
	Recife	NA	GCU
	Salgadinho	NA	RA
	Vitória de Santo Antão	NA	GCU
INDUSTRIA E COMERCIO DE ALIMENTOS ESPERANCA	Bom Jardim	241	RA
	Camaragibe	NA	CU
	Garanhuns	241	GCU
	Orobó	241	RA
	Paulista	241	CU
	Pombos	241	IA
	Primavera	241	RA
IRMAOS GONCALVES COMERCIO E INDUSTRIA	Caruaru	14 863	GCU
J A COMERCIO DE GENEROS ALIMENTICIOS E SERVICOS	Petrolina	241	GCU
J ALVES & CUNHA	Garanhuns	241	GCU
	Jaboatão dos Guararapes	241	CU
	Petrolina	241	GCU
	Recife	241	GCU
	Vitória de Santo Antão	241	GCU
JBS	Bom Jardim	18 041	RA
	Bonito	7 157	IA
	Camaragibe	45 148	CU
	Caruaru	133 595	GCU
	Chã Grande	13 177	IA
	Cortês	12 816	RA
	Garanhuns	133 343	GCU

	Glória do Goitá	4 372	IA
	Jaboatão dos Guararapes	21 949	CU
	João Alfredo	5 098	IA
	Olinda	21 098	CU
	Orobó	10 127	RA
	Passira	10 554	RA
	Paulista	21 679	CU
	Petrolina	118 494	GCU
	Pombos	11 195	IA
	Primavera	8 944	RA
	Recife	117 648	GCU
	Sairé	482	RA
	Salgadinho	1 785	RA
	Vitória de Santo Antão	50 164	GCU
JOSE FERMINO MAGALHAES	Camaragibe	195	
KADAO ALIMENTOS	Bom Jardim	734	RA
	Garanhuns	734	GCU
	João Alfredo	734	IA
	Paulista	734	CU
LITORAL NORTE INDUSTRIA ALIMENTICIA	Caruaru	241	GCU
	Jaboatão dos Guararapes	241	CU
	Recife	241	GCU
MARFRIG GLOBAL FOODS	Bonito	3 583	IA
	Camaragibe	3 583	CU
	Caruaru	3 583	GCU
	Garanhuns	3 583	GCU
	Jaboatão dos Guararapes	3 583	CU
	Olinda	3 583	CU
	Petrolina	3 583	GCU
	Recife	3 583	GCU
	Vitória de Santo Antão	3 583	GCU
MASTERBOI	Bom Jardim	2 320	RA
	Bonito	2 726	IA
	Camaragibe	2 726	CU
	Caruaru	406	GCU
	Chã Grande	87	IA
	Cortês	2 320	RA
	Garanhuns	2 726	GCU
	Glória do Goitá	NA	IA
	Jaboatão dos Guararapes	2 726	CU
	João Alfredo	NA	IA
	Olinda	406	CU
	Passira	NA	RA
	Paulista	2 320	CU
	Petrolina	2 726	GCU
	Pombos	2 320	IA
	Primavera	406	RA
	Recife	406	GCU
	Sairé	NA	RA
	Salgadinho	NA	RA
	Vitória de Santo	2 726	GCU

	Antão		
MAXI BEEF ALIMENTOS DO BRASIL	Cortês	65	RA
MERCURIO ALIMENTOS	Vitória de Santo Antão	5 622	GCU
MINERVA	Camaragibe	500	CU
	Paulista	500	CU
	Vitória de Santo Antão	69	GCU
PAINEIRA ALIMENTOS	Caruaru	241	GCU
PCH COMERCIO DE CARNES	Camaragibe	487	CU
	Garanhuns	487	GCU
	João Alfredo	487	IA
	Petrolina	487	GCU
	Vitória de Santo Antão	487	GCU
PIRAMBU COMERCIO DE CARNES	Bonito	NA	IA
	Chã Grande	NA	IA
PIRAPO COMERCIO ATACADISTA DE CARNES	Camaragibe	105	CU
	Chã Grande	105	IA
	Pombos	105	IA
	Primavera	105	RA
PLENA ALIMENTOS	Bonito	125	IA
	Caruaru	125	GCU
	Chã Grande	125	IA
	Garanhuns	125	GCU
	Glória do Goitá	125	IA
	Jaboatão dos Guararapes	125	CU
	Olinda	125	CU
	Petrolina	125	GCU
	Primavera	125	RA
	Recife	125	GCU
	Sairé	125	RA
	Vitória de Santo Antão	125	GCU
PRODUTOS DA CARNE ALIMENTOS	Paulista	4 710	CU
ROSARIAL ALIMENTOS	Caruaru	241	GCU
	Garanhuns	241	GCU
	Olinda	241	CU
	Sairé	241	RA
	Vitória de Santo Antão	241	GCU
S J PARAISO CHARQUE	Garanhuns	3	GCU
	Olinda	3	CU
SEARA ALIMENTOS	Camaragibe	253	CU
	Caruaru	2 631	GCU
	Garanhuns	253	GCU
	Jaboatão dos Guararapes	2 631	CU
	João Alfredo	2 631	IA
	Olinda	241	CU
	Passira	12	RA
	Paulista	2 619	CU

	Petrolina	253	GCU
	Recife	241	GCU
	Vitória de Santo Antão	2 619	GCU
SZR EMPRESARIAL INDUSTRIAL E EXPORTADORA DE SUB PRODUTOS BOVINOS	Camaragibe	241	CU
VALE GRANDE INDUSTRIA E COMERCIO DE ALIMENTOS	Jaboatão dos Guararapes	19 704	CU
VAPZA ALIMENTOS	Caruaru	105	GCU
	Jaboatão dos Guararapes	105	CU
	Olinda	105	CU
	Recife	105	GCU
VILHETO ALIMENTOS INDUSTRIA E COMERCIO	Caruaru	241	GCU
	Jaboatão dos Guararapes	241	CU
	Olinda	241	CU
VIVA ALIMENTOS	Bom Jardim	NA	RA
	Camaragibe	NA	CU
	Caruaru	NA	GCU
	Garanhuns	NA	GCU
	Jaboatão dos Guararapes	NA	CU
	Olinda	NA	CU
	Paulista	NA	CU
	Petrolina	NA	GCU
	Recife	NA	GCU
	Vitória de Santo Antão	NA	GCU
VPJ COMERCIO DE PRODUTOS ALIMENTICIOS	Jaboatão dos Guararapes	241	CU
WEW IMPORTACAO E EXPORTACAO	Jaboatão dos Guararapes	241	CU
	Recife	241	GCU
ZANCHETTA INDUSTRIA DE ALIMENTOS	Bonito	241	IA

Annex 7 – Surplus and shortage of area per state

Ufs	Average Consumption (kg)	Area required to support the demand (ha)	Surplus/shortage of area (ha)
Mato Grosso	650 279 034	2 183 987,44	17 565 126,6
Minas Gerais	3 962 671 834	13 308 787,5	6 619 095,47
Mato Grosso do Sul	518 878 223	1 742 672,7	13 461 807,3
Goiás	1 308 984 248	4 396 274,52	9 070 809,48
Pará	1 606 979 904	5 397 104,53	11 283 653,5
Rio Grande do Sul	2 131 736 173	7 159 518,87	100 165,126
Rondônia	331 843 883	1 114 510,59	6 625 844,41
Paraná	2 138 896 392	7 183 566,75	-4 484 438,7
Sao Paulo	8 585 789 005	28 835 706,4	-24 228 489
Bahia	2 786 968 307	9 360 141,49	9 901 143,51
Tocantins	293 703 675	986 415,22	5 642 260,78
Maranhao	1 324 845 836	4 449 546,28	2 3175 68,72
Santa Catarina	1 336 825 003	4 489 778,78	-3 300 288,8
Acre	164 423 282	552 221,99	1 292 175,01
Rio de Janeiro	3 231 839 057	10 854 257,2	-8 897 889,2
Ceará	1 709 610 194	5 741 792,35	-3 946 260,4
Espirito Santo	750 208 260	2 519 603,63	-456 583,63
Piauí	613 675 813	2 061 054,09	-852 291,09
Pernambuco	1 789 069 814	6 008 660,58	-2 836 993,6
Amazonas	772 199 170	2 593 460,96	-2 436 051
Paraíba	752 512 566	2 527 342,73	-1 039 323,7
Sergipe	429 727 966	1 443 258,09	86 208,906
Alagoas	625 262 509	2 099 968,46	-441 239,46
Rio Grande do Norte	655 874 066	2 202 778,57	-1 451 548,6
Roraima	110 773 048	372 035,59	167 241,41
Distrito Federal	561 848 177	1 886 988,96	-1 886 989
Total	39 302 680 209	131 999 581	40327990,4

Annex 8 – Contribution of countries in the beef exports between 2016-19

Country	Total export (U$)	Total export (kg)	Export share on total production (%)
China	5 804 134.78	1 196 025 337	2.633%
Hong Kong. China	3 631 494	970 430 289	2.136%
Egypt. Arab Rep.	2 024 033.81	636 737 028	1.402%
Iran. Islamic Rep.	1 480 684.05	375 603 699	0.827%
Chile	2 168 092.4	359 183 871	0.791%
Russian Federation	1 087 773.96	342 972 588	0.755%
St. Lucia	572 142.95	153 378 684	0.338%
United Arab Emirates	573 539.03	147 464 806	0.325%
Italy	661 644.55	107 245 786	0.236%
Philippines	269 827	90 042 686	0.198%
Israel	354 853.12	75 076 015	0.165%
Singapore	274 849.89	70 519 224	0.155%
Netherlands	522 017.55	65 448 312	0.144%
Algeria	232 307.66	60735328	0.134%
Lebanon	281 804.04	60 602 042	0.133%
Jordan	221 190.79	59 104 413	0.130%
Angola	213 008.89	56 895 482	0.125%
Uruguay	173 300.61	48 663 581	0.107%
Turkey	128 950.09	35 312 549	0.078%
Spain	193 856.55	32 507 236	0.072%
Argentina	61 974.22	25 664 328	0.057%
Germany	210 308.82	25 489 132	0.056%
Occ.Pal.Terr	94 138.56	25 464 401	0.056%
Venezuela	136 341.39	23 459 055	0.052%
Libya	67 040.92	20 942 500	0.046%
Malaysia	64 431.02	18 220 839	0.040%
Vietnam	54 755.56	15 495 589	0.034%
United States	61 477.39	14 673 709	0.032%
United Kingdom	78 129.42	13 237 002	0.029%
Albania	39 982.54	12 518 024	0.028%
Serbia. FR(Serbia/Montenegro)	30 087.6	11 102 588	0.024%
Gabon	26 723.33	10 130 337	0.022%

Iraq	35 963.14	9 990 593	0.022%
Georgia	20 305.63	9 628 547	0.021%
Paraguay	23 603.87	8 539 131	0.019%
Qatar	35 308.76	7 871 081	0.017%
Niger	42 237.16	7 045 392	0.016%
Sweden	75 959.49	7 020 635	0.015%
Tunisia	17 761.53	4 978 027	0.011%
Oman	17 918.69	4 766 434	0.010%
Peru	18 701.95	4 620 015	0.010%
Aruba	20 677.11	4 390 235	0.010%
Thailand	7 857.22	4 171 336	0.009%
South Africa	9 319.86	3 684 561	0.008%
Curaçao	16 226.9	3 590 690	0.008%
Indonesia	15 269	3 552 843	0.008%
France	9 476.24	2 668 239	0.006%
North Macedonia	7 866.39	2 662 869	0.006%
Cote d'Ivoire	3 617.76	2 368 730	0.005%
Cuba	13 716.11	2 275 045	0.005%
Portugal	18 086.44	2 224 976	0.005%
Comoros	5 942.31	2 043 152	0.004%
Armenia	3 479.19	1 974 741	0.004%
Bahrain	8 671.65	1 866 492	0.004%
Belgium	15 853.42	1 664 722	0.004%
Azerbaijan	4 311.93	1 592 015	0,004%
Korea. Dem. Rep.	6 149.64	1 346 144	0.003%
Switzerland	13 739.87	1 272 761	0.003%
Turkmenistan	2 594.33	1 095 930	0.002%
Bahama. The	3 182.51	945 622	0.002%
Morocco	3 943.99	939 806	0.002%
Mauritius	3 356.57	924 906	0.002%
Greece	3 717.54	912 174	0.002%
Finland	9 378.14	872 007	0.002%
Cape Verde	4 804.23	861 277	0.002%
Maldives	4 610.12	833 194	0.002%
Liberia	2 586.48	800 404	0.002%
Moldova	1 615.39	719 633	0.002%
Congo. Dem. Rep.	1 782.62	717 276	0.002%
Seychelles	3 097.33	702 165	0.002%
Senegal	2 591.66	622 422	0.001%

Ghana	964.88	617 023	0.001%
Bermuda	2 422.47	612 752	0.001%
Bolivia	1 244.56	535 659	0.001%
Denmark	5 105.66	531 689	0.001%
Equatorial Guinea	2 468.82	528 726	0.001%
Norway	6 187.03	458 132	0.001%
Montenegro	1 337.4	415 252	0.001%
Other Asia. nes	1 718.73	366 309	0.001%
Congo. Rep.	509.04	278 915	0.001%
Ukraine	675.45	268 532	0.001%
Kyrgyz Republic	335.34	210 103	0.000%
Grenada	570.92	191 078	0.000%
Myanmar	422.27	188 370	0.000%
Tajikistan	382.03	165 745	0.000%
Australia	440.5	124 533	0.000%
Kuwait	1 328.99	113 971	0.000%
Ireland	262.72	111 042	0.000%
Namibia	162.49	108 094	0.000%
Kazakhstan	317.81	107 483	0.000%
Brunei	89.07	102 200	0.000%
Panama	438.72	79 276	0.000%
Tanzania	444.69	79 198	0.000%
Marshall Islands	440.95	77 423	0.000%
Canada	211.35	64 847	0.000%
Sri Lanka	376.4	60 546	0.000%
Saint Maarten (Dutch part)	192.96	58 621	0.000%
India	194.52	57 040	0.000%
Haiti	192	54 531	0.000%
Malta	303.07	54 052	0.000%
Mexico	89.82	49 500	0.000%
Mozambique	90.93	41 006	0.000%
Guinea	206.82	39 668	0.000%
Cyprus	232.28	39 113	0.000%
Antigua and Barbuda	112.62	38 417	0.000%
Cameroon	85.75	27 662	0.000%
Honduras	99.88	27 146	0.000%
Macao	102.14	27 008	0.000%
Dominican Republic	56.04	26 999	0.000%
Lithuania	62.19	24 997	0.000%

Sierra Leone	132.18	22 811	0.000%
Japan	97.51	21 257	0.000%
Djibouti	157	20 439	0.000%
Lao PDR	23.1	17 500	0.000%
Mali	60.86	13 112	0.000%
San Marino	29.57	8 660	0.000%
Iceland	11.19	2 260	0.000%
Sao Tome and Principe	9.1	2 238	0.000%
Cayman Islands	9.24	1 570	0.000%
Barbados	4.96	1 065	0.000%
Gibraltar	4.63	865	0.000%
Latvia	2.95	510	0.000%
Belize	3.07	462	0.000%
Tuvalu	1.41	378	0.000%
Bunkers	1.82	258	0.000%
Falkland Island	1.44	229	0.000%
Bosnia and Herzegovina	0.76	140	0.000%
Romania	0.83	123	0.000%
Colombia	0.87	111	0.000%
Guyana	0.19	100	0.000%
St. Vincent and the Grenadines	0.5	41	0.000%
Bulgaria	0.31	40	0.000%
Madagascar	0.21	30	0.000%
Kiribati	0.12	20	0.000%
Luxembourg	0.07	5	0.000%