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DAMARES LOPES AFONSO

LAND AND DEFORESTATION EMBODIED IN TRADE: AN ANALYSIS FOR BRAZILIAN BIOMES

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Tese apresentada ao programa de Pós-Graduação em Economia da Faculdade de Economia da Universidade Federal de Juiz de Fora, como requisito parcial a obtenção do título de Doutora em Economia. Área de concentração: Economia.

Orientador: Prof. Dr. Fernando Salgueiro Perobelli
Coorientador: Prof. Dr. Weslem Rodrigues Faria

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ABSTRACT

Given the social and ecological importance of Brazilian biomes, which, in addition to providing important environmental services on a global scale, also contribute to the country's income generation in activities linked to agribusiness trade, the objective of this thesis is to evaluate agricultural land and agriculture-caused (AC) deforestation embodied in Brazilian trade, both at the intranational and international levels. To this end, we constructed an inter-regional input-output matrix, named MIP-Biomas, which contains 47 regions, correspondent to the divisions of biomes within their respective federative units, cross-referenced to 36 activities. The MIP-Biomas was built based on the 2015 matrix of the Instituto Brasileiro de Geografia e Estatística (IBGE), considering product-based technology and the Interregional Input-Output Adjustment System (IIOAS) method. This matrix also has the opening of the vector of exports to some of the main Brazilian trading partners, namely, the European Union, the United States, and China, as well as the rest of the world. Combining the monetary data from MIP-Biomas and physical data on direct agricultural land use and AC deforestation taken from satellite images of Mapbiomas, we constructed separate indicators to measure agricultural land content and AC deforestation content embodied in both intranational and international trade. Among the results, at the intranational level, we find that there is a greater concentration of trade with agricultural land content in the Cerrado, Mata Atlântica, and Amazônia biomes, and with AC deforestation in the Amazônia, Caatinga and Cerrado ones. It still stands out the pressure exerted by regions of the Mata Atlântica on land use and deforestation throughout the national territory, with land and deforestation displacement from the South affecting the North of the country, and a concentration of the impacts of the North and Northeast regions in their own territories. At the international level, although trade with land use comes mainly from the Cerrado and Mata Atlântica biomes, the AC deforestation content from the Caatinga and Mata Atlântica biomes is projected. At the sectoral level, in both intranational and international trade, we verify a concentration of agricultural land and AC deforestation content in activities linked to the food sectors, highlighting proteins such as bovines and their meats, milk and its derivatives, in addition to pork and poultry. It is emphasized that there are regional and sectorial variations in these results, as detailed. The results contribute to an evaluation of the sources and destinations of agricultural land use and AC deforestation in Brazilian trade and can serve as a basis for the formulation of national and international policies to fight against deforestation.

Keywords: Land use. Deforestation. Interregional Input-Output Matrix.

RESUMO

Tendo em vista a importância social e ecológica dos biomas brasileiros, os quais além de prover serviços ambientais importantes em escala global também contribuem para a geração de renda do país em atividades ligadas ao comércio agronegócio, o objetivo desta Tese é avaliar o conteúdo de terra e de desmatamento vinculados às atividades agropecuárias e embutidos no comércio brasileiro, tanto ao nível intranacional quanto internacional. Para tanto, construímos uma matriz inter-regional de insumo-produto, nomeada MIP-Biomas, a qual possui 47 regiões, correspondendo às divisões dos biomas em suas respectivas Unidades da Federação, em 36 atividades. A MIP-Biomas foi construída tendo como base a matriz do IBGE para o ano de 2015, considerando a tecnologia baseada no produto e o método IIOAS, e conta ainda com a abertura do vetor de exportações para alguns dos principais parceiros comerciais brasileiros, a saber, a União Europeia, Estados Unidos e China, bem como o restante do mundo. Combinando os dados monetários da MIP-Biomas e dados físicos de uso direto da terra e desmatamento vinculados às atividades agropecuárias provenientes do Mapbiomas, foram construídos indicadores para mensurar o conteúdo de terra e de desmatamento agropecuário no comércio intranacional e internacional, separadamente. Entre os resultados, ao nível intranacional, mostra-se a maior concentração do comércio com conteúdo de terra nos biomas Cerrado, Mata Atlântica e Amazônia e desmatamento na Amazônia, Caatinga e no Cerrado. Destaca-se ainda a pressão exercida por regiões da Mata Atlântica sobre o uso da terra e o desmatamento agropecuário no território nacional, havendo deslocamento de terra e desmatamento do Norte para o Sul do país, e uma concentração dos impactos das regiões Norte e Nordeste em seus próprios territórios. Ao nível internacional, embora o comércio com uso da terra seja predominantemente advindo dos biomas Cerrado e Mata Atlântica, destaca-se o conteúdo de desmatamento agropecuário proveniente dos biomas Caatinga e Mata Atlântica. Setorialmente, tanto no comércio intranacional quanto internacional, é possível verificar a concentração do conteúdo de terra e de desmatamento em atividades vinculadas aos setores alimentícios, destacando-se as proteínas como bovinos e suas carnes, leite e derivados, além de carne de porco e aves. Ressalta-se que há variações regionais e setoriais dos resultados, como detalhado nos resultados dessa Tese. Os resultados contribuem para uma avaliação das origens e destinos do uso da terra e do desmatamento agropecuário no comércio brasileiro, podendo servir de base para a formulação de políticas públicas nacionais e internacionais de combate ao desmatamento.
Palavras-chave: Uso da terra. Desmatamento. Matriz Inter-regional de Insumo-Produto.

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AC deforestation – agriculture-caused (AC) deforestation

APIs – Application Programming Interface

CALF – Complete Agricultural Land Footprint

CTE – Committee on Trade and Environment

EAF – International Agricultural Footprint

EMIT – Environmental Measures and International Trade

EU – European Union

FPNDs – Florestas Públicas Não Destinadas

GATS – General Agreement on Trade and Services

GATT – General Agreement on Tariffs and Trade

GDP – Gross Domestic Product

IBAMA – Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais

IBGE – Instituto Brasileiro de Geografia e Estatística

ICMS – Imposto sobre Circulação de Mercadorias e Serviços

IIOAS – Interregional Input-Output Adjustment System

INPE – Instituto Nacional de Pesquisas Espaciais

IOM – Input-Output Matrix

MEAs – Multilateral Environmental Agreements

MIP – Matriz de Insumo-Produto

NAF – Intranational Agricultural Footprint

NPISH – Non-Profit Institutions Serving Households

PLs – Projetos de Lei

POF – Pesquisa de Orçamento Familiares

PPA – Permanent Preservation Areas

RAIS – Relação Anual de Informações Sociais

Row – Rest of the world

RTAs – Regional Trade Agreements

SPS – Sanitary and Phytosanitary

TBT – Technical Barriers to Trade

TESSD – Trade and Environmental Sustainability Structured Discussions

UF – Federative Units

UN – United Nations

US – United States

WTO – World Trade Organization

ZDCs – Zero Deforestation Commitments

CONTENTS

1 INTRODUCTION

With the expansion of trade and the establishment of global production networks, consumption and production in a country/region transcend its borders; the same can be said for environmental impacts. Thus, there is need for an assessment of the impacts of trade in studies of environmental sustainability in any given location, as is proposed for this thesis by the assessment of land use and deforestation[1] in Brazil.

Brazil, one of the largest countries in forest area in the world, has been suffering from problems linked to deforestation, at the same time that the Brazilian ecological biodiversity is one of the main on the planet (WWF, 2021), distributed among its six biomes, namely, the Amazônia, Caatinga, Cerrado, Mata Atlântica, Pampa, and Pantanal. These biomes provide important ecological services to the ecosystem, such as climate regulation, air and water purification, carbon fixation, where land use and deforestation can have consequences for all forms of life.

According to Mapbiomas (2021), between 2000 and 2020, a 6.33% reduction in the area of forest vegetation was observed in Brazil. Most deforestation, defined here as land use transitions from forest areas[1] to other uses, was done for pasture (55.77%), agriculture (1.75%), forest plantation (1.37%), mosaic of agriculture and pasture[2] (31.97%) and other land uses (9.14%), and the most affected biomes were the Amazônia (60.9%) and Cerrado (31%) (AZEVEDO *et al*., 2021). The Mata Atlântica is, historically, the biome that has undergone the most extensive land use and land cover[3] change in the past, and the Caatinga is the biome that has suffered the greatest environmental impacts from these changes (SOUZA *et al*., 2020).

Despite its negative impacts on the environment, the Brazilian agribusiness sectors play a prominent role in generating income in the country, accounting for 24.80% of the Gross Domestic Product (GDP) in 2022 (CEPEA, 2023). The agricultural[4] activities meet both the

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[1] Correspond to a land use transition, from forest, level 1 of the Mapbiomas 6 collection, which includes forest formation, savanna formation, mangrove and wooded restinga to other uses excluding the forest itself.
[2] Agricultural areas where it was not possible to distinguish between pasture and agriculture (MAPBIOMAS, 2022).
[3] Land cover refers to the vegetative features or man-made constructions on the surface of the land, while land use involves an element of human activity and reflects human decisions about how the land will be used (USDA, 2022a).
[4] Defined here as the set of agricultural cultures, livestock, and forestry products.

broad national consumer market, with over 215 million inhabitants (IBGE, 2023), and the international demand since the country leads the ranking as as the world's third largest exporter of these products (USDA, 2022b). Thus, both intranational and international trade respond to the environmental impacts linked to agricultural activities.

The role of trade as a driver of Brazilian deforestation has been pointed out in empirical studies. Pendrill *et al*. (2019a) address the international trade of commodities that present risks of deforestation. The authors examine how global supply chains for products such as palm oil, soy, beef and cellulose are linked to deforestation in different parts of the world. According to the authors, Brazil is the main consumer of its own products with deforestation content, derived mainly from meat consumption in the domestic market. The country is also one of the most affected by international demand for agricultural products, such as meat and soy, with deforestation content (PENDRILL, *et al*. 2019a; CUYPERS *et al*., 2013; HENDERS; PERSSON.; KASTNER, 2015).

In addition, Pendrill *et al*. (2019a) observed regional and sectoral heterogeneities in the distribution of agricultural production with implications for deforestation in Brazil. However, the modeling employed by the authors, physical-based bilateral trade-model, at national level, does not allow for a regional and sectoral assessment of the direct and indirect effects of trade with deforestation content. In a regional contribution, we highlight Castelani, Guilhoto and Igliori (2013) who, through an interregional input-output matrix with three regions (5 major metropolitan areas, in terms of urbanization, in the Amazônia, rest of the Amazônia and rest of Brazil), estimated how much of Amazônia deforestation is due to the consumption of goods and services by consumers living in the region, compared to deforestation driven by consumers living outside the biome, suggesting that consumption within the Amazônia region, mainly in the Amazônia metropolitan regions, plays a prominent role in the deforestation of that biome.

Seeking to contribute to this evaluation, the main objective of this thesis is to evaluate land and deforestation embodied in Brazilian trade, both at intranational and international levels. It specifically analyzes where agricultural land and agriculture[5]-caused (AC) deforestation in Brazilian biomes comes from and goes to, and also investigates the content of agricultural land and of deforestation present in agricultural, industrial, and service activities.

[5] Defined here as the set of agricultural cultures, livestock, and forestry products.

As for the intranational level, it is aimed to answer the following questions: 1) How much biomes affect each other's agricultural land use and AC deforestation? 2) In what activities does this trade with agricultural land and AC deforestation mainly occur? At the international level, the following question is asked: 3) To what extent do the Brazilian trade patterns (European Union (EU), United States (US), China, and the rest of the world (Row)) contribute to agricultural land use and AC deforestation of Brazilian biomes by trade, and in which activities does this trade most occur?

These questions are answered by combining agriculture land use and deforestation data from Mapbiomas with the Input-Output Matrix (IOM) called MIP[6]-Biomas, which we built for this thesis based on the latest IOM of the Instituto Brasileiro de Geografia e Estatística (IBGE, 2018). The MIP-Biomas is interregional, with a division of Brazilian biomes in their Federative Units (UF), named biomes-UF, and opening the export and import vectors to EU, US, China, and the rest of the world. From these data, we calculate indicators of agricultural land and AC deforestation embodied in intranational and international trade from an end-user perspective, following the methodology present in Fan, Liu and Wang (2022).

The MIP-Biomas, in addition to presenting a broad sectoral opening for agricultural, industrial, and service activities, presents a regional division at the level of biomes-UF, which is in accordance with the different environmental characteristics of Brazilian biomes, in addition to corroborating the fact that each biome has different regulations that impact its land use, such as different percentages of legal reserve. Furthermore, as there are economic disparities within each biome, they have been divided into their UF.

This investigation, still unexplored in the literature, will contribute to the knowledge of the sources and destinations of land use and deforestation in Brazilian biomes. These assessments of the sectors and regions responsible for deforestation in Brazil, besides filling gaps in the literature, also help subsidize a political necessity, since, on the international scene, it is already possible to observe announcements of boycotts of imports with deforestation content by European countries (EU, 2021; FOLHA, 2021, EU, 2022). The results may help the country to articulate an effective public policy to combat deforestation, making the entities

[6]Abbreviation for Matriz de Insumo-Produto (MIP) in Portuguese, called Input-Output Matrix (IOM) in English.

(countries/regions/activities) responsible and converting part of the gains made from trade into actions that are pro-environmental.

In addition to this introduction, this thesis presents four chapters. The second chapter discusses the impact of trade on land use and deforestation, and how environmental regulations have been addressed by federal laws and within the scope of international trade – which may, in turn, impact production and trade. The third chapter presents the empirical strategy adopted in this research, which is divided into three parts, namely, the construction of the MIP-Biomas, the database that measures agricultural land use and AC deforestation, and the indicator that captures embodied land use and deforestation in Brazilian trade. The fourth chapter brings the results, which is divided in terms of appropriation of agricultural land use and AC deforestation content at intranational and international levels. Finally, the sixth section discusses the main conclusions and policy implications of this thesis.

2 RELATING LAND USE AND DEFORESTATION TO TRADE – ENVIRONMENTAL IMPACTS AND REGULATIONS

This chapter is divided into two parts. The first seeks to identify the impacts of trade on land use and deforestation based on theoretical and empirical literature. The second is dedicated to discussing environmental regulations both at national and international level – which may, directly or indirectly, impact production and trade.

2.1 Impacts of trade on land use and deforestation

2.1.1 Theoretical approach

The relationship between trade and environment has been studied in economics in two main groups: environmental economics, which is based on the neoclassical analysis apparatus; and ecological economics (ROMEIRO, 2001). According to Romeiro (2001), in the first, the economic system is seen as sufficiently large and the availability of natural resources is considered as a relative restriction to the system, surmountable by technical and scientific progress. The second group, on the other hand, considers that there is a limit to the expansion of the economic system imposed by global environmental limits themselves. Although the instrument of this thesis is linked to environmental economics, we acknowledge that the indiscriminate use of natural resources brings irreversible damage to the environment, which is already noticeable given the increase in global temperatures and sea level (IPCC, 2021).

The literature that analyzes the impacts of trade on the environment expanded in the mid-twentieth century, following the concern with the environmental issue that was rising at the time (QUEIROZ, 2009). When it comes to natural resources, theoretical models differ in terms of the nature of the resource, whether it is renewable or non-renewable. Land use and deforestation fall within the field of renewable resources.

According to Bulte and Barbier (2005), the theoretical literature on trade and renewable resources stands out for at least three factors, these being: i) the role played by the institutional context that is reflected in the management of these resources; ii) the inherently dynamic nature of their management, such as the size of the resource stock varying over time following the relationship between its rate of use and replenishment; and iii) the environmental concerns associated with the exploitation of this resource, for example, the conversion of habitat and biodiversity.

Theoretical models that are based on renewable resources, especially general equilibrium models derived from classical approaches to international trade such as Ricardo's (1817), Eli Heckscher's (1919) and Bertil Ohlin's (1933), focus on economic welfare (derived from price relationships and market equilibrium) in trade analyses. In general, these models divide countries between North and South – the latter with comparative advantage in the production of the intensive goods in the renewable resource. A trade opening would tend to increase the price of these goods, encouraging their production and, therefore, the exploitation of these resources by the South, which could or not lead to gains in economic welfare depending on the assumptions of the models and the behavior of prices in the market equilibrium (steady state).

Prominent theoretical works in this field include Brander and Taylor (1997a, 1997b, and 1998). Brande and Taylor (1997a) presented a general equilibrium model for an open economy, based on assumptions of comparative advantage and with open access to the renewable resource. The country in question is considered to have fixed labor and produces and consumes two goods, the manufacturing good (M) and the harvesting good (H). Good M uses only the labor factor (L) in its production, while good H is produced by a combination of L and the renewable resource stock defined by a production function of the type Schaefer (1957). In the absence of trade, the ratio r/L, where r is the intrinsic growth rate of the renewable resource, determines the relative prices of the economy. For some sufficiently high r/L ratio compared to the world price, this country is considered as "abundant in resources" and trade openness tends to increase the production of good H in its territory, generating welfare gains initially and losses as the stock of the resource decreases. On the other hand, the country that specializes in M shows welfare gains from trade. The authors concluded that a first-best policy would be to make resource management more efficient. However, since this policy requires institutional changes, they point out that a second-best option could be the reinvestment of the temporary gains by the country exporting good H in other assets with better delineated property rights, what they call the modified Hartwick (1977) rule.

Using the same modeling framework, Brander and Taylor (1997b) studied trade between a country A, with a renewable resource open to its population and a country B, with strict management of this resource. The authors distinguished between two scenarios, in the first, country A uses good H excessively with openness to trade, becoming a net exporter and suffering welfare losses, while country B gains in welfare by becoming a net importer of that good. In the second scenario, if country A uses good H excessively even in the absence of trade, this country tends to become a net importer of H with the opening of trade and B becomes a net exporter of this good; in this case trade provides welfare gains in both countries.

Brander and Taylor (1998) extended the previous models by keeping two countries, the same two goods, M and H, and the assumption of open access to renewable resources. The authors analyzed options for the factor ratio (r/L), including allowing for trade diversification in case of similarity in factor ratios across countries. The results show that the country exporting good H has a lower utility in the steady state compared to that obtained in the absence of trade, even when it diversifies its production. On the other hand, the importing country of good H always gains from trade. As a corrective policy, the authors proposed an import tariff to be applied to importers of good H, benefiting exporters of this good and serving as a pareto improvement (where both countries improve).

Hannesson (2000) modified Brander and Taylor's (1997a, b, 1998) model by allowing for diminishing returns in the manufacturing production sector (M) in a country that is commercially dependent on the renewable resource. This assumption causes this country to show gains from trade openness even when there is open access to the renewable resource and the country is not fully specialized in this good. This occurs given the possibility of importing manufactured goods at a lower price than that obtained in the absence of trade. The author argued that the transition from an open access regime to optimal management of the renewable resource could, or could not, lead to an improvement in welfare, since the production of the resource-intensive good would decrease and, therefore, a portion of the labor factor would be reallocated to the manufacturing sector, affecting the return on this factor.

Regarding the institutional structure, Chichilnisky (1994) built a model of trade between Northern and Southern countries, which are identical in terms of technologies, endowments and preferences, except for the institutional aspect, where the South has poorly defined property rights over environmental resources compared to Northern countries. The environmental resource does not appear in the utility function directly as a consumption good but serves as an input in the production of goods A and B from Leontief type technologies (fixed proportions), with good B being more intensive in the environmental resource. Although neither country has a real comparative advantage in the production of B, the South's lack of property rights leads it to produce and export more of this good. In other words, weak property rights in environmental resource management in the Southern countries grant it an apparent comparative advantage in the production of good B. As a result of trade, there is an excess production of good B in the South and an excess consumption of this good in the North. The author pondered that a policy of taxing the use of environmental resources in the South could lead to an even greater use of it to compensate, economically, for the losses with the tax. Finally, she recommended policies that better define property rights over these resources.

Extensions of Chichilnisky's (1994) work can be found in Karp, Sacheti and Zhao (2001) and Ferreira (2004). Karp, Sacheti and Zhao (2001) showed that in the long run the South does not always lose from trade and the North does not always gain, and that both can win or lose. The scenarios analyzed illustrate the complexity of the long-term relationship between trade and the environment and allow analysts to identify which scenario would likely prevail under specific conditions. Ferreira (2004), like Chichilnisky (1994), constructed an H-O model for trade between Northern and Southern countries exploiting the comparative advantage imposed by open access in the South. However, unlike Chichilnisky (1994) in which prices are dependent on factor endowments, the author exploits the difference between the marginal and average product of the labor factor given by the diminishing returns of this factor.

Still in the institutional context, Hotte, Van Long and Tian (2000) developed a dynamic general equilibrium model of natural resource exploitation in which the enforcement of property rights is an endogenous decision and trade openness can lead to a shift from open access management to a regime where property rights enforcement occurs. However, while this shift increases the stock of resources, it does not necessarily increase welfare due to the costs of enforcing these property rights.

Based on Brander and Taylor's (1997a, 1997b) model for different institutional structures, Copeland and Taylor (2004) have divided renewable resource-rich economies into the Hardin, Ostrom, and Clark categories. The classification varies with respect to the ability to enforce property rights in resource management as world prices vary, so that Hardin always exhibits open access; Ostrom may maintain a limited form of resource management in the presence of higher prices; and Clark may implement fully efficient management and do so when resource prices are sufficiently high. These categories were defined by constraints on the basic model parameters and allowed the authors to evaluate the interaction of world prices and resource management regimes.

There are also models that have incorporated the impacts of trade on habitat and, intrinsically, on biodiversity. Smulders, Van Soest and Withagen (2004) extended Brander and Taylor's (1998) model by introducing economic and ecological interdependencies between the renewable natural resource and agriculture. These interdependencies occur because the loss of habitat for many species of flora and fauna for the expansion of agricultural activity has negative impacts on the very viability of agricultural activity in the long term. The authors identified under what circumstances trade liberalization improves welfare and contributes to nature conservation. They pointed out that the tariff policies recommended by Brander and Taylor (1998) may not lead to conservation of habitat and species diversity in countries where agriculture is an important source of income.

Polasky, Costello, and McAusland (2004) analyzed the effects of trade on land use and indicated its likely effects on biodiversity conservation. Using a two-product, two-country trade model and so-called "species-area curves", the authors observed that trade openness can have adverse consequences for biodiversity by exploiting the comparative advantage resulting from trade specialization. If preferences for biodiversity conservation are high, overall utility may decrease with the movement toward free trade unless corrective conservation policies are applied.

The impact of international trade on biodiversity was also studied in Alam and Van Quyen, (2007) who constructed a North-South trade model with two sectors, agriculture and manufacturing. It is assumed that only the Southern countries have stock of the biodiversity resource and that it is located in their uncultivated land. Furthermore, the South has a comparative advantage in agriculture and the North in manufacturing. The analyses show that free trade, population growth, and a combination of both, lead to the loss of biodiversity in the South. The authors pointed out that demand-side mechanisms, such as preferences sensitive to biodiversity loss, and supply-side mechanisms, like environmentally friendly technologies in agriculture, can slow the depletion of the biodiversity stock, but cannot stop it entirely, warning that more "proactive" measures are needed.

Starting from an optimization model with different assumptions than traditional comparative advantage models and with open access to the renewable resource, Gars and Spiro (2018) point out that trade can lead to the collapse of this resource. The authors take into account two effects. The first one, called the "harvester-preference effect", considers that trade increases the variability of available goods and the countries that export the harvested goods increase production and exports of these products to make possible the purchase of other varieties of products. Since not all countries are able to produce all varieties of products, importers increase their demand for the harvested goods, which leads to an increase in the prices of these goods as a side effect (price effect). The result is an excessive harvest, making the resource even scarcer and more expensive.

In a more optimistic view, Harstad (2020) investigated the impacts of applying a contingent trade agreement that could reverse the negative impacts of open trade on deforestation. The author pointed out that while international trade is often associated with the depletion of renewable resources, the application of contingent agreements could exploit the gains from trade and use these gains to motivate the conservation of the resource rather than its exploitation.

2.1.2 Empirical works

The role of international trade as a driver of deforestation has been pointed out in empirical studies, as is the case of agricultural exports from developing countries (LEBLOIS; DAMETTE; WOLFERSBERGER, 2017), like those from Brazil (FARIA; ALMEIDA, 2016). In addition, the pressure caused by urban demands, such as domestic trade, tends to intensify deforestation (DEFRIES *et al*., 2010).

The literature also present measures of how much trade has contributed to land use and deforestation mainly through what is called “ecological footprints”, in an ex-post analysis,[7] that is, when the trade has already taken place. The impacts found by the authors vary according to the modeling they use. According to Bruckner *et al*. (2015), these data are divided between: i) economic-environmental modeling, usually using input-output matrices and considering the interrelationships among regions/countries in monetary units; ii) physical modeling,

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[7] An ex-ant analysis is the assessment of the impacts of trade before it occurs, see for example Arima *et al*. (2021).

representing global production chains and trade structures in physical units, such as in tons of biomass, and which usually calculates the apparent consumption, that is, production plus imports minus exports; and iii) hybrid modeling that combines physical accounting for products with a low degree of processing and economic-environmental accounting for processed products, for which the conversion to physical units is difficult, as applied by Weinzettel *et al*. (2013) and Tramberend *et al* (2019).

The input-output model has the advantage of revealing the true location and interconnections of ecological footprints, although it is considered that the results derived from these different modeling approaches are not directly comparable (HUBACEK; FENG, 2016). Table 1 summarizes empirical studies that have used input-output and physical modeling in analyses of land use and deforestation, highlighting the geographic scope, analysis period, objective and main results of each study.

There are differences between these articles in relation to the scale of analysis (global, national, regional), the specific focuses of study (deforestation or land footprint) and the methodologies employed to measure the footprints. Furthermore, the metrics used to measure these footprints[8] vary, resulting in different and elaborate results.

From these results, it is possible to note that economic globalization facilitates a scale of forest transition internally by shifting their agricultural demands abroad (MEYFROIDT; RUDEL; LAMBIN, 2010). Countries that absorb these demands, on the other hand, experience agricultural expansion and deforestation. This land displacement and pressure on deforestation occurs mainly from rich to poor countries, with Brazil being one of the most affected (WEINZETTEL *et al*., 2013; QIANG *et al*., 2013, CUYPERS *et al*., 2013; HENDERS; PERSSON.; KASTNER, 2015; PENDRILL *et al*., 2019a,b; HOANG; KANEMOTO, 2021). Domestic demand also impacts land use and deforestation in countries, as is again the case for Brazil (CASTELANI; GUILHOTO; IGLIORI, 2013, PENDRILL *et al*., 2019a).

This thesis contributes to literature by analyzing the agricultural land use and AC deforestation embodied in both intranational and international trade in a broad regional analyze,

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[8] Commonly measured from the producer's and consumer's perspectives. It is also possible to measure shared responsibility, which necessitates to weight the producer and consumer indicators – which may vary by region in the case of an interregional system and be *ad hoc* to apply.

Table 1 – Summary of empirical research that has accounted for land use and deforestation in trade

continues

Authors	Database	Geographical coverage	Period	Objective/Main Results
Zhou and Imura (2011)		China	2000	Applied a regional approach to generate ecological footprints for China's eight regions. The results show substantial cross-regional variation in terms of the amount of land appropriation and the mix of land types.
Olsen *et al.* (2012)		EU countries and their trading partners	2004	Calculated carbon, land, and water footprints for the member states of the EU. Overall, the EU displaced all three types of environmental pressures to the rest of the world. Intra-EU, the UK was the most important displacer overall, while the largest net exporters of embodied environmental pressures were Poland (greenhouse gases), France (land), and Spain (freshwater).
Weinzettel *et al.* (2013)		Global Analysis	2004	Traced the use of land and ocean area through international supply chains to final consumption, showing that there is a net displacement of land use from high-income to low-income countries, even though high-income countries had more land available *per capita* than low-income countries.
Yu, Feng and Hubacek (2013)		Global Analysis	2007	Connected local consumption to global land use through tracking global commodity and value chains via international trade flows. Results show how developed countries consume a large amount of goods and services from both domestic and international markets, and thus impose pressure not only on their domestic land resources, but also displace land in other countries, such as from developing countries.
Cuypers *et al.* (2013)*		EU countries and their trading partners	2004	Showed the countries where EU imports have contributed most to deforestation, among which Brazil stands out.
Castelani, Guilhoto and Igliori (2013)		Brazil (5 major metropolitan areas, in terms of urbanization, in the Amazônia, rest of the Amazônia and rest of Brazil)	2004	Estimated how much of Amazon deforestation is due to consumption of goods and services by households living in the Amazon region itself, compared to deforestation driven by consumers living outside of the Amazon. The results suggest that consumption by households within the Amazon region plays a prominent role in the deforestation of the biome.
Guo *et al.* (2014)		China	1987-2007	Analyzed the impact of domestic consumption and international trade on cultivated land distributions in China. Agriculture and food processing are identified as the two key sectors which contribute with the largest volumes of embodied cultivated land to meet household food demand. In the international trade, agriculture sector is China's largest net importer of cultivated land, in contrast to the textile sector as the largest net exporter.

continue

Authors	Database	Geographical coverage	Period	Objective/Main Results
Chen and Han (2015a)	Input-output modelling	China	2002-2010	Revealed the impacts of domestic demand and international trade on land use distribution of China, mainly due to the land use embodied in the secondary and tertiary industries, China is found as a net exporter of cultivated land use.
Chen and Han (2015b)		Global Analysis	2010	Investigated trade patterns of arable land use in terms of production and consumption. The results show a heavy trade imbalance prevailing not only among countries and regions but also between intermediate products and final goods.
Marselis *et al*. (2017)		Global Analysis	2004, 2007 and 2011	Quantified the amount of agricultural land used for crop production traded among 133 countries and regions. In general, undernourished regions are more likely to export more embodied agricultural land than to import it.
Ali (2017)		EU; Organization for Economic Cooperation and Development (OECD); Brazil, Russia, India and China (BRIC) and the rest of the world	1995-2009	Presented the results of additional analyses of the carbon, water and land footprints for the consumption and production perspective. During the study period, these footprints were higher in the consumer approach for the EU and OECD than in the producer approach. For BRIC and the rest of the world regions, carbon, land and water emissions were higher in the producer approach than in the consumer approach.
Chen *et al*. (2018)		Global Analysis	2012	Simultaneously traced the flows of agricultural land use and freshwater along the global chain. In general, significant pressures from these two resources are identified, from resource-rich and less developed economies to resource-poor and more developed economies.
Han and Chen (2018)		Mainland (China)	2012	Illustrated Mainland's arable land transfers embodied in foreign trade, showing that it exports 27.18 Mha (million hectares) of embodied arable land to other economies, while it imports 48.35 Mha of embodied arable land.
Guo, Jiang and Shen (2019)		China	2000-2015	Examined how pastures in China are used to meet the demands of domestic consumption and international trade. Agriculture and food processing were the two main sectors that contributed the largest volume of embodied pastures in intranational and international trade.
Pendrill *et al*. (2019b)*		Global Analysis	2010-2014	Quantified the carbon emissions associated with deforestation and trace them through global supply chains. Noteworthy among the results is that about 29-39% of deforestation-related emissions were driven by international trade.
Sun *et al*.(2020)		Global Analysis	2006	Identified hotspots (the most significant production regions) for primary crops and livestock driven by international consumption. Observed a large difference in final consumption of primary crops and livestock between high-income and lower-income countries.

continue

Authors	Database	Geographical coverage	Period	Objective/Main Results
Chen, Kang and Han (2021)	Input-output modelling	Global Analysis	-	Assessed environmental inequality for land and water trade. They noted that the environmental cost of developed countries is much lower than that of developing countries compared to their economic gains from global trade.
Franco-Solís and Montanía (2021)		Argentina, Brazil and Paraguay (ABP region) and their trade patterns	2000-2015	Identified the main contributors to agricultural land use growth from Structural Decomposition Analysis applied to multiregional input-output matrices. Results suggest that changes detected within ABP were mainly influenced by shifts in domestic demand and exacerbated by the influence of Brazil within the Mercosur trade agreement. Outside ABP, results show that consumption *per capita* and population expansion in developed and developing economies (the EU28, the US, and China) are major drivers of regional deforestation.
Hoang and Kanemoto (2021)		Global Analysis	2001-2015	Mapped how trade has driven spatial-temporal changes in global deforestation between 2001-2015. They found that while many developed countries, China and India have obtained net forest gains domestically, they have also increased the deforestation embodied in their imports, of which tropical forests are the most threatened biome.
Brulein (2021)*		Belgian and other EU countries	2005-2017	Quantified the environmental impacts embedded in Belgian agricultural and forestry imports and Belgian consumption, then to compare it with other EU countries. The results indicate that Belgium has a high consumption of forest-risk commodities and that the majority of its embedded deforestation area and CO2 emissions are concentrated in seven commodities from a few countries.
Fan, Liu and Wang (2022)		Chinese regions	2017	Constructed a model to estimate the agricultural land transfer embodied in interregional trade by using the agricultural land footprint model and the multi-regional input–output model and applied this method to China regions The results show mainly two patterns: one from North to South and the other from West to East, reflecting the transfer law of movement from the less developed regions to those that were more developed.
Würtenberger, Koellner and Binder (2006)	Physical modelling	Switzerland	2001	Developed a method for quantifying and assessing the land use hidden in the export and import of agricultural goods for the case of Switzerland, focusing on arable crops. With this method, they estimated the overall environmental and socio-economic impacts of an increase in wheat imports to Switzerland.
Bringezu *et al*. (2009)		German	2004	Quantified the land area and related greenhouse gas (GHG) emissions required to meet German consumption of agricultural products for food and non-food use, noting that Germany was already a net importer of agricultural land.

continue

Authors	Database	Geographical coverage	Period	Objective/Main Results
Erb *et al*. (2009)	Physical modelling	Global Analysis	1961-2007	Mapped the spatial disconnect between net producer and net consumer regions of Human Appropriation of Net Primary Production (HANPP). They found that sparsely populated regions are mainly net producers and densely populated regions net consumers, independent of development status.
Meyfroidt, Rudel e Lambin (2010)		Brazil, Bhutan, Cameroon, Chile, China, Costa Rica, El Salvador, France, India, Indonesia, Peru, Vietnam, and trade partners.		Tested whether there is an association over time between a reversal in national deforestation trends and an increase in net imports of wood or agricultural products. Among the results, it is shown that in most countries that have experienced forest transitions, displacement of land-use demand abroad accompanies forest recovery.
Kissinger and Rees (2010)		US	1995-2005	Constructed an analytical method that can locate and measure the ecosystem area embodied in the renewable resource imports of any population, and applied it to the case of the US. The results reveal that the ecosystem land area embodied in US imports of agricultural and forest products is equivalent to the size of Germany, Italy, Spain, and the United Kingdom combined.
Kastner, Kastner and Nonhebel (2011)		Austria	2005	Presented a method that allows to clearly link consumption patterns to the origin of primary products, applying it to the case of land and water use linked to Austria's soy product consumption.
Kastner, Erb and Nonhebel (2011)		Global Analysis	1997–2007	Developed a general typology of how trade in wood products can influence forest change and placed various nations within this framework, showing that wealthy nations with returning forests seem to accelerate this return through importing wood products
Bringezu, O'Brien and Schütz (2012)		EU	2007	Proposed a comprehensive approach to account for the global land use of countries for their domestic consumption and to assess this level with regard to globally acceptable levels of resource use, based on the concept of safe operating space. It is shown that the EU currently uses one-third more cropland than globally available on a *per capita* basis.
Cuypers *et al*. (2013)*		EU	2004	Showed the countries where EU imports have contributed most to deforestation, among which Brazil stands out.
Qiang *et al*. (2013)		China	1986-2009	Measured the impact of China's agricultural imports on the deforestation of its trading partners, showing that this country is a large consumer market for agricultural products with an impact on Brazilian deforestation.

conclusion

Authors	Database	Geographical coverage	Period	Objective/Main Results
Sandström *et al*. (2014)	Physical modelling	Finland	1961–2007	Analyzed the interannual fluctuations and long-term trends in the area needed to produce Finland's imported and exported agricultural products, indicating a growing net deficit between imports and exports systematically in recent decades.
Henders, Persson e Kastner (2015)		Argentina, Bolivia, Brazil, Paraguay, Indonesia, Malaysia, and Papua New Guinea	2000-2011	Quantified the impact of trade on deforestation for specific products and countries. It is noted that the production of the four commodities analyzed in these seven countries was responsible for 40% of the total tropical deforestation and the resulting carbon losses. They also highlighted the growth influence of global markets on the dynamics of deforestation.
Pendrill *et al*. (2019a)		Global Analysis	2005–2013	Quantified deforestation embedded in trade and track it through global supply chains. A large and slightly increasing share of deforestation was attributed to international demand, the bulk of which was exported to countries that either exhibit decreasing deforestation rates or increasing forest coverage, particularly in Europe and Asia.
Pendrill *et al*. (2019b)*		Global Analysis	2010-2014	Quantified the carbon emissions associated with deforestation and traced them through global supply chains. Noteworthy among the results is that about 29-39% of deforestation-related emissions were driven by international trade.
Taherzadeh and Caro (2019)		Global Analysis	2000-2016	Evaluated the virtual water and land trade of the global soybean trade. It is noted that the virtual water and land trade related to the soybean trade shows growth during this period, with animal feed accounting for about three-quarters of the use of this resource.
Brulein (2021)*		Belgian and other EU countries	2005-2017	Quantified the environmental impacts embedded in Belgian agricultural and forestry imports and Belgian consumption, then to compare it with other EU countries. The results indicate that Belgium has a high consumption of forest-risk commodities and the majority of its embedded deforestation area and CO2 emissions are concentrated in seven commodities from a few countries.
Roux *et al*. (2021)		Global Analysis	1986-2011	Examined if recent changes in the origin of agricultural products reduced the HANPP, but the results suggest that the potential of trade to reduce humanity's impact on land ecosystems has not been exploited in the recent past.

Source: Elaborated by the author.

using an interregional matrix disaggregated at biomes-UF in Brazil. Besides to analyze land and deforestation footprints together, this research expands the intraregional analysis of Castelani, Guilhoto and Igliori (2013), and allows the measuring of international trade impacts at the regional level, improving other analyses such as the one done by Pendrill *et al*. (2019a). The thesis also innovates by using national agricultural land use and AC deforestation data with disaggregation for some specific agricultural activities from the Mapbiomas database. This work is also highlights in terms of the applied indicator, we adopted the same methodology applied by Fan, Liu and Wang (2022) to measure land use across Chinese regions from an end-user perspective.

2.2 Environmental regulations on land use, deforestation and trade

This section is divided into two parts. The first part discusses a set of national environmental regulations related to land use and deforestation in Brazil between the 1900s and the early 2000s. These regulations directly influence land use and deforestation in the Brazilian biomes, as the case of the Forest Code, and, in its turn, can have an indirect impact on trade. The second part provides an overview of how environmental regulations have been addressed in the context of international trade in the same period.

2.2.1 National environmental regulations on land use and deforestation

Although there were already environmental regulations in Brazil before the 1900s (PEREIRA, 1950), the protection of forests in the country begins in 1921, with Decree No. 4421 of November 28, which established the "Forest Service of Brazil" under the Ministry of Agriculture. This Decree defined different categories of forests, with emphasis on the so-called protective forests[9] – which are direct predecessors of the permanent preservation areas (PPA) that still exist in Brazilian legislation (ANTUNES, 2014).

The norms established by Decree No. 4421 were in force until the advent of the Forest Code approved by Decree No. 23793 of January 23, 1934. It was with the 1934 Decree that the

[9] These forests: i) “benefit hygiene and public health; ii) ensure the purity and abundance of springs usable for food; iii) balancing the regime of water flows that are intended not only for irrigation of agricultural land but also for those that serve as transport routes and lend themselves to the use of energy; iv) avoid the cursed effects of atmospheric agents, prevent the destruction produced by the winds, prevent the displacement of moved sand as well as landslides, violent erosions, either by rivers or by the sea. and v) assist in the defense of borders”. (Decree No. 4421, 1921, our translation)

concept of legal reserve emerged in the country. The legal reserve guarantees that, even in private properties, some amount of original vegetation cover is to be preserved. In the 1934 Decree, the percentage was fixated at 25% of the area of original vegetation coverage of the properties.

With the advance of agricultural activity in the country, with monocultures, extensive cattle raising, and deforestation, added to environmental pressures from abroad in the 1960s, the Brazilian Forest Code was reformulated in 1965 by Law No. 4771 of September 15. Among the changes brought by the Code were new parameters for legal reserve areas according to Brazilian regions, setting a percentage of 50% in the North and the northern part of the Central-West region and a minimum of 20% in most of the country.

During the effectiveness of the 1965 Forest Code some legislations were created/modified, among which stands out Law No. 6938 of August 31, 1981, that outlines the National Environmental Policy, which defined a process of "greening" of the Brazilian Public Ministry ("*Parquet*") identity and that structured the beginnings of Environmental Law in the country (SARLET; FENSTERSEIFE, 2014).

Environmental Law includes some legal principles, among which we highlight: polluter-pays, user-pays, and protector-receiver. The polluter-pays principle internalizes the negative externalities generated by the production process. Law No. 6938 of 1981 imposes "on the polluter and the predator, the obligation to recover and/or compensate for the damage caused" (LAW No. 6938, 1981, our translation). Other laws fit into the user-pays context, such as the Environmental Crimes Law (Law No. 9605 of February 12, 1998) "which provides on the penal and administrative sanctions derived from conducts and activities that are harmful to the environment" (LAW No. 9605, 1998, our translation), including deforestation. Law No. 6938 of 1981 also imposes the user-payer "of the contribution for the use of environmental resources for economic purposes" (LAW No. 6938, 1981, our translation).

As an example of protector-receiver regulation, we have the ICMS-Ecological tax, a type of tax present in Brazil like the value-added tax in other countries and under the jurisdiction of the Brazilian states. The ICMS-Ecological was implemented in Brazil in the early 1990s, pioneered by the state of Paraná, and directs part of the state's ICMS[10] to municipalities that have land use restrictions in portion of their territory due to the existence of water sources that supply other neighboring municipalities, conservation units, or indigenous lands (LOUREIRO, 2002).

Another advance in Environmental Law was the dedication of a chapter on the 1988 Federal Constitution to the protection of the environment. These normative characters were reinforced with the creation of operational support centers and prosecutors specialized in environmental protection such as the "Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis" (IBAMA), created by Law No. 7735 of February 22, 1989.

Although there were advances in environmental law in the 1990's, the Forest Code of 1965 was in effect for 47 years when it was replaced by the new Forest Code under Law No. 12651 of May 25, 2012. This new Forest Code establishes to legal reserves the following minimums: 80% for Amazônia forests, 35% for Cerrado forests located in the Legal Amazônia,[11] and 20% for the other regions of the country. Thus, it treats the biomes differently and protects the Amazônia further, although other biomes, such as Cerrado, have historically had more alarming rates of deforestation (KLINK; MACHADO, 2005, STRASSBURG; LATAWIEC; BALMFORD, 2016). In the Mata Atlântica biome, the more specific Law No. 11428 of December 22, 2006 (Mata Atlântica Law) overlaps the new Forest Code of 2012, establishing a more restrictive set of rules for the suppression of vegetation in this biome, recognizing that in it are concentrated the largest national economic activities, pressures for infrastructure works, and other urgencies (ANTUNES, 2014).

Even though the new Forest Code of 2012 and the country's environmental legislation should move towards greater protection of nature, it can be said that the opposite has occurred, since there has been a flexibilization of environmental legislation, by giving amnesty to deforestation that occurred prior to July 22, 2008 (called consolidated areas), forgiving fines, and disobliging the recovery of risk areas and native forests (SARLET; FENSTERSEIFE, 2014).

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[10] ICMS is a tax over merchandise circulation, and it is collected by the states.
[11] Political-administrative division that covers nine states: Acre, Amapá, Amazonas, Pará, Rondônia, Roraima and part of Mato Grosso, Tocantins and Maranhão.

Other legislative setbacks have been discussed around the 2020s, as some bills ("Projetos de Lei – PLs"), such as No. 2374 of 2020, that extends the mentioned amnesty deadline from July 22, 2008 to May 25, 2012 for the regularization of the consolidated area in the legal reserve, and PL 311 of 2022, that establishes that Law No. 12651, the new Forest Code, must also be applied to the Mata Atlântica biome throughout the national territory, suppressing the Mata Atlântica Law.

Brazil also deals with land tenures problems, as in the public lands, which are affected by illegal occupation, "grilagem"[12] and speculation (FEARNSIDE, 2001, AZEVEDO-RAMOS, 2020) – and already account for most of the Amazônia deforestation, in the so-called "Florestas Públicas Não Destinadas" (FPNDs) (BRITO, 2022). Regarding land regularization in Brazil, we highlight the Terra Legal Program, established by Law No. 11952 of June 25, 2009, which "Provides for the landholding regularization of occupations incident on lands located in areas of the Union, within the Amazônia Legal" (LAW No. 11952, 2009, our translation), Law No. 13465 of July 11, 2017, which expands landholding regulation beyond the Amazônia Legal, and Decree No. 10592, of December 24, 2020, that regulates Law No. 11952 of 2009. It is indicated that there were environmental setbacks in Decree No. 10592 in relation to the original text of the Law No. 11952 proposed in 2009, such as the loosening of rules on PPA preservation and legal reserve conservation (CPI, 2021).

Although Brazil does not have clear environmental regulations on trade, these regulations on land use and deforestation can have an impact, directly or indirectly, on production and trade. It should be noted that for effective implementation of environmental regulation on trade, it is necessary to understand the main sources and destinations of land use and deforestation in Brazil – as is the objective of this thesis.

2.2.2 International environmental regulations on trade

Environmental regulations came into the international scenario in the 1960's, mainly from middle class people from developed countries, whose basic needs on health, housing, education, and food were met and they were thus ready to change their priorities and modify their way of life in a more sustainable way (LAGO, 2013).

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[12] Consists of falsifying documents to illegally take possession of public or third-party land/buildings.

In 1970’s, with the publication of the study "The Limits to Growth" in 1972, prepared by the Club of Rome, the environmental issue gained greater notability in the international scene. This study presented a pessimistic view of economic growth, which had occurred without considering the limits imposed by natural resources and was published in the same year of the opening of the Stockholm Conference, which was carried out in the framework of the United Nations (UN).

The establishment of environmental regulations with an impact on international trade dates to 1971 when, influenced by preparations for the Stockholm Conference, the General Agreement on Tariffs and Trade (GATT) created the Environmental Measures and International Trade (EMIT) Group. The group was charged with evaluating whether the countries' national policies for the environment were compatible with GATT trade rules (AMARAL JUNIOR, 2011). However, it failed to advance in its objectives, driven mainly by the dilemma faced by developing countries that feared the imposition of restrictions on their imports by developed nations (ZAGO, 2011).

Between 1971 and 1991, environmental policies would have an increasing impact on trade and were even discussed in the GATT negotiation rounds (FERMAN; ANTUNES, 2008). In the Tokyo Round (1973-1979), the Standards Code was established to determine the rules for developing and applying technical regulations. However, the Standards Code was not mandatory, since GATT was a free membership agreement (MACHADO *et al.*, 2003).

In the Uruguay Round (1986-1994), the Standards Code underwent modifications, generating the Technical Barriers to Trade (TBT) and the Sanitary and Phytosanitary (SPS) agreements, in addition to the inclusion of environmental issues in the General Agreement on Trade and Services (GATS) (FERMAN; ANTUNES, 2008). According to Brito (2010), the TBT and SPS agreements are part of a scenario of proliferation of regulations of products and services related to human, animal and plant health, consumer safety and environmental protection, in which it seeks to formulate these processes/standards without harming international trade.

Despite being already discussed by the GATT, the environment and trade topics were more efficiently associated in the constitution of multilateral agreements signed in 1994, with the creation of the World Trade Organization (WTO) – which replaced GATT as an international trade organization. The Committee on Trade and Environment (CTE) was established within the framework of the WTO at the Ministerial Meeting in Marrakech in 1994, representing a specific and permanent body of the WTO to discuss issues related to trade and the environment (SILVA, 2008). Thus, the CTE replaced the EMIT Group created under the GATT.

Still in the 1990s, the United Nations Conference on Environment and Development (RIO-92) stands out, which enshrined the concept of sustainable development and contributed to a broader awareness that environmental damage was mostly the responsibility of developed countries while recognizing the need for developing countries to receive financial and technological support to move towards sustainable development (LAGO, 2013). The conventions resulting from this Earth Summit (RIO-92) had important developments such as the Kyoto Protocol, signed in 1997 in the Japanese city of Kyoto, which established mechanisms to try to contain the greenhouse effect (TANNOUS; GARCIA, 2008). One of the goals of the Kyoto Protocol was to reduce greenhouse gas emissions by 5.2% compared to 1990 in the period between 2008 and 2012.

In 2001 the Doha Round began within the WTO, which had as its contribution the launching of the environmental issue as a priority, under the argument that trade liberalization should be consistent with the sustainable development objectives of the WTO members and with an active participation of the CTE (SILVA, 2008).

It was during the Doha Round that an amendment was approved in Qatar, in 2012, extending the goals of the Kyoto Protocol until the year 2020, when the Paris Agreement would become valid, whose main objective is to reduce greenhouse gas emissions and limit the average global temperature increase to less than 2°C, above pre-industrial levels, reaching a maximum of 1.5% warming.

On November 17, 2020, 50 WTO members announced their intention to "collaborate, prioritize and advance discussions on trade and environmental sustainability" through the initiative called "Trade and Environmental Sustainability Structured Discussions (TESSD)" (WTO, 2020), which was joined by Brazil only in 2022.

In addition to the negotiations under the GATT and later the WTO, the Multilateral Environmental Agreements (MEAs) also stand out as a mechanism for environmental regulation of trade. MEAs are agreements that necessarily involve more than two nations and emerged independently from the trade system (GATT and WTO). Currently, there are 250 MEAs, of which about 20 include provisions that may affect trade (WTO, 2022). According to the WTO (2022), one issue that may arise is whether measures in a multilateral agreement are compatible with WTO rules, for example, a multilateral agreement could authorize trade in a specific product between its parties but prohibit trade in the same product with countries that have not signed the agreement, affecting the WTO's principle of non-discrimination, known as "most-favored-nation treatment," which requires countries to accord equivalent treatment to the same (or "like") products.

There is no consensus in the literature on the impacts of environmental regulations on trade. In this sense, there is a theoretical discussion whether the implementation of corrective environmental policies could lead to competitiveness losses and welfare reduction (e.g. SIEBERT, 1977; BAUMOL; OATES, 1988) or even act as an incentive for firms to innovate, increasing the economy's productivity (PORTER, 1991; PORTER; LINDE, 1995).

Some empirical studies indicate that Regional Trade Agreements (RTAs) with environmental regulations can reduce pollution compared to others agreements that do not have them (BAGHDADI; MARTINEZ-ZARZOSO; ZITOUNA, 2013; ZHOU; TIAN; ZHOU, 2017). For developing countries, Brandi *et al*. (2020) show that including environmental provisions in RTAs can increase their "green exports". The authors point out that the design of trade agreements and the environmental track record of countries, i.e. whether they already have a strong environmental performance, are important factors for the results.

International environment committees can also stimulate national environmental legislation; however, they do not guarantee outcomes, which depend on the effectiveness of such national policies (BRANDI; BLÜMER; MORIN, 2019).

Environmental regulations may also appear from voluntary measures by countries/companies, such as those that occur in the fight against deforestation through the so-called ZDCs (Zero Deforestation Commitments). An example of ZDCs was the Brazilian Soy Moratorium, which had an effect on controlling deforestation in the Amazônia, but the same cannot be said for the Cerrado (ZU ERMGASSEN *et al*., 2020). Developed countries like the EU and the US have voluntarily announced boycotts of Brazilian imports with deforestation content starting in 2020 (EU, 2021; FOLHA, 2021, EU, 2022; VALOR, 2022). In this context, it is important to know the sources and destinations of deforestation embodied in trade in Brazil, at sectoral and regional levels.

3 EMPIRICAL STRATEGY

This section is divided into three parts. The first part presents the databases and the methodology that allows the construction of the MIP-Biomas. The second brings the database on agricultural land and AC deforestation and its connection with the MIP-Biomas data. Subsequently, the indicator built to measure agricultural land and AC deforestation embodied in Brazilian trade, both intranationally and internationally, is presented.

3.1 Construction of the Input-Output Matrix for the Brazilian biomes (MIP-Biomas)

3.1.1 Database

The construction of the MIP-Biomas was based on the IBGE's IOM for the year 2015 (IBGE, 2018), the most recent official Brazilian IOM. The IBGE matrix was converted into a system of 36 activities by 36 activities according to the commodity-by-commodity technology (MILLER; BLAIR, 2009) described in Appendix A, which also presents the classification of the 127 commodities of the IBGE (IBGE, 2018) matrix in the 36 activities of the MIP-Biomas. The commodity-by-commodity technology approach allows for a more detailed investigation of agricultural land use and AC deforestation in economic activities.

The regional dimension of the MIP-Biomas uses the separation of biomes by Federative Units[13] (UF), denominated biomes-UF. This separation occurred at the municipal level. As a given municipality can present forest coverage belonging to more than one biome at the same time, biomes A and B, for example, it was conjectured that this municipality belongs to biome A if more than 50% of its forest coverage, relative to the extent of biomes A and B, belongs to biome A. This classification was carried out with the help of shapefiles from the Instituto Nacional de Pesquisas Espaciais (INPE) and the municipalities' characterization data from the Infosanbas website. In all, 47 biomes-UF regions were obtained.

Table 2 presents the definition of the regions and Table 3 of the activities present in the MIP-Biomas. Figure 1 shows the map of the UF-biomes.

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[13] Also known as “state”.

Table 2 – Regional definition of the MIP-Biomas

Regions		
R1	Amazônia_Acre	Amazônia-AC
R2	Amazônia_Amazonas	Amazônia-AM
R3	Amazônia_Amapá	Amazônia-AP
R4	Amazônia_Maranhão	Amazônia-MA
R5	Amazônia_Mato Grosso	Amazônia-MT
R6	Amazônia_Pará	Amazônia-PA
R7	Amazônia_Rondônia	Amazônia-RO
R8	Amazônia_Roraima	Amazônia-RR
R9	Amazônia_Tocantins	Amazônia-TO
R10	Caatinga_Alagoas	Caatinga-AL
R11	Caatinga_Bahia	Caatinga-BA
R12	Caatinga_Ceará	Caatinga-CE
R13	Caatinga_Minas Gerais	Caatinga-MG
R14	Caatinga_Paraíba	Caatinga-PB
R15	Caatinga_Pernambuco	Caatinga-PE
R16	Caatinga_Piauí	Caatinga-PI
R17	Caatinga_Rio Grande do Norte	Caatinga-RN
R18	Caatinga_Sergipe	Caatinga-SE
R19	Cerrado_Bahia	Cerrado-BA
R20	Cerrado_Distrito Federal	Cerrado-DF
R21	Cerrado_Goiás	Cerrado-GO
R22	Cerrado_Maranhão	Cerrado-MA
R23	Cerrado_Minas Gerais	Cerrado-MG
R24	Cerrado_Mato Grosso do Sul	Cerrado-MS
R25	Cerrado_Mato Grosso	Cerrado-MT
R26	Cerrado_Piauí	Cerrado-PI
R27	Cerrado_Paraná	Cerrado-PR
R28	Cerrado_São Paulo	Cerrado-SP
R29	Cerrado_Tocantins	Cerrado-TO
R30	Mata Atlântica_Alagoas	Mata Atlântica-AL
R31	Mata Atlântica_Bahia	Mata Atlântica-BA
R32	Mata Atlântica_Espírito Santo	Mata Atlântica-ES
R33	Mata Atlântica_Goiás	Mata Atlântica-GO
R34	Mata Atlântica_Minas Gerais	Mata Atlântica-MG
R35	Mata Atlântica_Mato Grosso do Sul	Mata Atlântica-MS
R36	Mata Atlântica_Paraíba	Mata Atlântica-PB
R37	Mata Atlântica_Pernambuco	Mata Atlântica-PE
R38	Mata Atlântica_Paraná	Mata Atlântica-PR
R39	Mata Atlântica_Rio de Janeiro	Mata Atlântica-RJ
R40	Mata Atlântica_Rio Grande do Norte	Mata Atlântica-RN
R41	Mata Atlântica_Rio Grande do Sul	Mata Atlântica-RS
R42	Mata Atlântica_Santa Catarina	Mata Atlântica-SC
R43	Mata Atlântica_Sergipe	Mata Atlântica-SE
R44	Mata Atlântica_São Paulo	Mata Atlântica-SP
R45	Pampa_Rio Grande do Sul	Pampa-RS
R46	Pantanal_Mato Grosso do Sul	Pantanal-MS
R47	Pantanal_Mato Grosso	Pantanal-MT

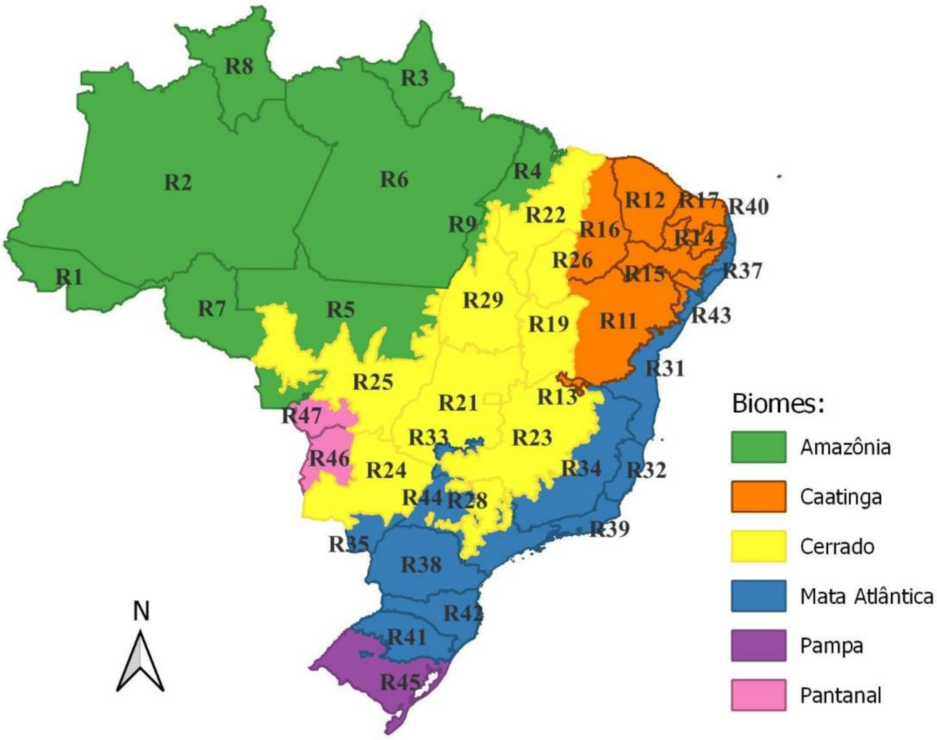
Source: elaborated by the author based on MIP-Biomas.

Table 3 – Sectoral definition of the MIP- Biomas

	Activities
1	Sugarcane
2	Soybeans
3	Other temporary crop products and services
4	Coffee beans
5	Other products from permanent crops
6	Bovine and other live animals, animal products, hunting and services
7	Pigs, poultry and eggs
8	Logging and forestry
9	Fishing and aquaculture
10	Extractive activities
11	Meat of bovine animals and other meat products
12	Pork and poultry
13	Industrialized fish
14	Milk and dairy products
15	Other food products
16	Beverages
17	Tobacco products
18	Manufacture of textiles, clothing and accessories
19	Manufacture of footwear and leather goods
20	Wood products, excluding furniture
21	Cellulose, paper and paper products manufacturing
22	Various industries
23	Petroleum refining and coking plants
24	Manufacture of biofuels
25	Chemical products
26	Fertilizers, pesticides and disinfectants
27	Mineral products, steel, metallurgy and related
28	Machinery and equipment
29	Manufacture of transport vehicles, including parts
30	Furniture
31	Energy, gas, water, sewage, waste management and other utilities
32	Trade
33	Transportation
34	Warehousing and postal services
35	Accommodation and food
36	Various services

Source: elaborated by the author based on MIP-Biomas.

Figure 1 – Regions of the MIP-Biomas



Source: elaborated by the author in QGIS 3.28.

IBGE's IOM was regionalized to create the MIP-Biomas following the IIOAS (Interregional Input-Output Adjustment System), obtaining interregional trade flows from the so-called SHIN tables, following the methodology proposed by Dixon and Rimmer (2004). This procedure has been applied in the literature to estimate interregional trade flows, as found in Faria and Haddad (2014), Haddad *et al*. (2016), Haddad, Gonçalves Júnior, and Nascimento (2017), Haddad, Hattab and Ali (2017), and Haddad *et al*. (2018).

To regionalize, in addition to data from the national input-output system, we use the share of each activity within each of the regions; as well as measures that express the regional shares of the elements of final demand, namely exports, government consumption, total consumption of non-profit institutions serving households[14] (NPISH), household consumption and investment (gross fixed capital formation). All statistics were taken at the municipal level

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[14] Instituições sem fins lucrativos ao serviço das famílias (ISFLSF) in Portuguese.

and then aggregated to the biome-UF level, then regional shares were taken at the biome-UF level according to their participation at the national level.

Specifically, the share of the following information is used as: i) gross value of production (by biome-UF and activity) – GVP^R; ii) exports (by biome-UF and activity) – $TEXP^R$; iii) value added (by biome-UF and activity) – VA^R; iv) total government spending by biome-UF – $TGOV^R$); v) total consumption of NPISH – $TNPISH^R$; vi) total household consumption by biome-UF – THC^R; vii) total investment by biome-UF – $TINV^R$.

Production data (GVP^R) for agricultural activities (activities 1 to 5) come from the value of production according to the 2017 Agricultural Census; for other activities (6 to 36), the wage bill from the Relação Anual de Informações Sociais (RAIS) for 2015 was used. The export data ($TEXP^R$) come from ComexStat in 2015. It should be noted that the export vector is open to the Brazilian trade partners (EU, US, China, and the rest of the world), according to the relative share of each of these countries/regions in the exports of the 47 biomes-UF in the 36 activities. Value added (VA^R) is arrived at by combining the ratio of national value added to national production (value added generator) with the value of regional production (GVP^R).

Government consumption is based on the GDP of the public administration ($TGOV^R$) in 2015 and investment ($TINV^R$) follows total GDP for the same year as the metric. The regional shares of household (THC^R) and NPISH ($TNPISH^R$) consumption are based on the Pesquisa de Orçamentos Familiares (POF) for the years of 2017-2018. The latter are disaggregated at the UF-biome level using the wage bill data from RAIS in 2015, keeping constant the relative participation among UF according to the POF but allowing a different regional measure for each biome-UF cutout. For example, the state of São Paulo (SP) accounts for 31.13% of national consumption according to the 2017-2018 POF and is covered by the Cerrado and Mata Atlântica biomes, with the Mata Atlântica-SP region presenting 88.73% wage share in SP and the rest, 11.27% belonging to the Cerrado-SP region. Thus, combining the POF and RAIS data, these regions represent a share in national household and NPISH consumption of 27.62% and 3.51%, respectively.

Table 4 summarizes the databases used to build MIP-Biomes from of IBGE's IOM (IBGE, 2018). The compatibilization of all these data was possible with the help of translators of the System of National Accounts (SNA) and ComexStat, making the CNAE 2.0 classes of RAIS and export data (SH4) compatible with the activities of IBGE's IOM (IBGE, 2018). The agricultural cultures from the 2017 Agricultural Census were directly made compatible with IBGE's IOM.

Table 4 – Database used for the construction of MIP-Biomas in addition to the IBGE IOM (2015)

	Activities 1 - 6	Other activities (7 - 36)
Intermediate consumption	Agricultural Census (2017)	RAIS (2015)
Government consumptiom	GDP of public administration IBGE (2015)	
NPISH consumption	POF (2017-2018) and RAIS (2015)	
Household consumption	POF (2017-2018) and RAIS (2015)	
Investment	total GDP IBGE (2015)	
Exports and imports	ComexStat (2015)	

Source: elaborated by the author.

Another piece of data necessary for the regionalization process following the IIOAS method is the distance matrix. We used the matrix of road distances, in kilometers, calculated by the Application Programming Interface (APIs) of Google Maps and OpenStreet Maps (CARVALHO, AMARAL, MENDES, 2021).

3.1.2 The Interregional Input-Output Adjustment System (IIOAS) method

Regionalization via IIOAS involves two steps. First, the interregional trade matrices are obtained and, then, the regionalization stage is carried out for the national matrix.

3.1.2.1 Construction of the interstate trade matrices

According to Haddad, Gonçalves Júnior, and Nascimento (2017), to obtain the interregional trade matrices, it is necessary to calculate i) the regional demand for domestic products; ii) the regional demand for imported products and, iii) the total supply of each region, by activity, for the domestic and international markets and by region.

An assumption of the IIOAS method is that the regional demand for domestic products and the regional demand for imported products follow the national pattern for all agents, that is, regional agents share the same technologies and preferences (HADDAD; GONÇALVES

JÚNIOR; NASCIMENTO, 2017). However, given the different trade matrices estimated for each activity, the provenances of intermediate inputs, and final products used in each region will differ.

i. Regional demand for domestic products:

To obtain the regional demand for domestic products ($DOMDEM$), demand-generating coefficient matrices (*DOMGEM*) are constructed for each biome-UF, following the share of each element of the matrix of national uses (activity x activity), considering only the flows of domestic products, in the total of its referred column. For the elements of intermediate consumption and domestic absorption (government consumption, NPISH consumption, household consumption and investments[15]), the share of each element associated with the national demand for domestic products in the total of the respective column is used. So that:

$$SIC_{i\times j}^{DOM} = \frac{Z_{i\times j}^{DOM}}{X_j};\ SGOV_{i\times 1}^{DOM} = \frac{gov_i^{DOM}}{TGOV^N};\ SNPISH_{i\times 1}^{DOM} = \frac{npish_i^{DOM}}{TNPISH^N};\ SHC_{i\times 1}^{DOM} = \frac{hc_i^{DOM}}{THC^N};$$
$$SINV_{i\times 1}^{DOM} = \frac{inv_i^{DOM}}{TINV^N} \quad (1)$$

Where $Z_{i\times j}^{DOM}$ is the matrix of elements of intermediate consumption (IC), and X_j is the vector of gross value of production (GVP) by activity. While gov_i^{DOM}, $npish_i^{DOM}$, hc_i^{DOM} and inv_i^{DOM}, are each element i of the vectors of government consumption, NPISH consumption, household consumption, and investment, respectively, in the national uses matrix and, $TGOV^N$, $TNPISH^N$, THC^N and $TINV^N$ are, respectively, the total values, including taxes, of each element of final demand in the same national matrix.

The regional demand for domestic products is obtained by multiplying the coefficients presented in equation 1 by: i) value of production (by biome-UF and activity) – respectively GVP^R; ii) total government spending by biome-UF – $TGOV^R$; iii) total consumption of NPISH – $TNPISH^R$; iv) total household consumption by biome-UF – THC^R; v) total investment by biome-UF – $TINV^R$ as presented in the equations:

[15] Specifically, the gross fixed capital formation.

$$IC_{i \times j}^{R,DOM} = SIC_{i \times j}^{DOM} * diag(GVP_{i \times 1}^{R}) \qquad \forall\ i, j = 1, ..., 36 \quad \forall\ R = 1, ..., 47 \tag{2}$$

$$GOV_{i \times 1}^{R,DOM} = SGOV_{i \times 1}^{DOM} * TGOV_{1 \times 1}^{R} \qquad \forall\ i, j = 1, ..., 36 \quad \forall\ R = 1, ..., 47 \tag{3}$$

$$NPISH_{i \times 1}^{R,DOM} = SNPISH_{i \times 1}^{DOM} * TNPISH_{1 \times 1}^{R} \qquad \forall\ i, j = 1, ..., 36 \quad \forall\ R = 1, ..., 47 \tag{4}$$

$$HC_{i \times 1}^{R,DOM} = SHC_{i \times 1}^{DOM} * THC_{1 \times 1}^{R} \qquad \forall\ i, j = 1, ..., 36 \quad \forall\ R = 1, ..., 47 \tag{5}$$

$$INV_{i \times 1}^{R,DOM} = SINV_{i \times 1}^{DOM} * TINV_{1 \times 1}^{R} \qquad \forall\ i, j = 1, ..., 36 \quad \forall\ R = 1, ..., 47 \tag{6}$$

$IC_{i \times j}^{R,DOM}$ is the intermediate consumption of domestic products in each region R. $GOV_{i \times 1}^{R,DOM}$, $NPISH_{i \times 1}^{R,DOM}$, $HC_{i \times 1}^{R,DOM}$ are government, NPISH and household consumption of domestic products in each region R, respectively. $INV_{i \times 1}^{R,DOM}$ is the consumption of capital goods produced in the country in each region R. Subsequently, the total demand for domestic products ($DOMDEM$) per biome-UF, is obtained by adding:

$$DOMDEM_{i \times 1}^{R} = \sum_{j=1}^{36} IC_{i \times j}^{R,,DOM} + GOV_{i \times 1}^{R,DOM} + NPISH_{i \times 1}^{R,DOM} + HC_{i \times 1}^{R,DOM} + INV_{i \times 1}^{R,DOM} \tag{7}$$

$$\forall\ i, j = 1, ..., 36 \quad \forall\ R = 1, ...,47$$

It is worth noting that the sum of $DOMDEM_{i \times 1}^{R}$ for all R must be equal to the GVP of each activity in the national use matrix, discounting exports.

ii. Regional demand for imported products:

For the demand for imported products ($IMPDEM$), the calculation procedure is similar to the regional demand for domestic products ($DOMDEM$), while the difference is that the national import matrix is used for the calculations. The demand-generating coefficients for imported products are constructed ($IMPGEN$) from the calculation of the share of each element of the national matrix of imports in the totals of each column of the matrix of national uses (HADDAD; GONÇALVES JÚNIOR; NASCIMENTO, 2017).

Analogous to equation 1, one has:

$$SIC_{i\times j}^{IMP} = \frac{z_{i\times j}^{IMP}}{X_j};\ SGOV_{i\times 1}^{IMP} = \frac{gov_i^{IMP}}{TGOV^N};\ SNPISH_{i\times 1}^{IMP} = \frac{npish_i^{IMP}}{TNPISH^N};\ SHC_{i\times 1}^{IMP} = \frac{hc_i^{IMP}}{THC^N};$$

$$SINV_{i\times 1}^{IMP} = \frac{inv_i^{IMP}}{TINV^N} \qquad (8)$$

To which $z_{i\times j}^{IMP}$ is the matrix of elements of intermediate consumption and gov_i^{IMP}, $npish_i^{IMP}$, hc_i^{IMP} and inv_i^{IMP} are each element i of the vectors of government consumption, NPISH consumption, household consumption, and investment, respectively, in the national import matrix. Like the regional demand for domestic products, the regional demand for imported products is achieved by multiplying the coefficients presented in equation 8 by the total regional values of the matrix elements, as presented in the equations 9 to 13:

$$IC_{i\times j}^{R,IMP} = SIC_{i\times j}^{IMP} * diag(GVP_{i\times 1}^{R}) \qquad \forall\ i, j = 1, ..., 36 \quad \forall\ R = 1, ..., 47 \qquad (9)$$

$$GOV_{i\times 1}^{R,IMP} = SGOV_{i\times 1}^{IMP} * TGOV_{1\times 1}^{R} \qquad \forall\ i, j = 1, ..., 36 \quad \forall\ R = 1, ..., 47 \qquad (10)$$

$$NPISH_{i\times 1}^{R,IMP} = SNPISH_{i\times 1}^{IMP} * TNPISH_{1\times 1}^{R} \qquad \forall\ i, j = 1, ..., 36 \quad \forall\ R = 1, ..., 47 \qquad (11)$$

$$HC_{i\times 1}^{R,IMP} = SHC_{i\times 1}^{IMP} * THC_{1\times 1}^{R} \qquad \forall\ i, j = 1, ..., 36 \quad \forall\ R = 1, ..., 47 \qquad (12)$$

$$INV_{i\times 1}^{R,IMP} = SINV_{i\times 1}^{IMP} * TINV_{1\times 1}^{R} \qquad \forall\ i, j = 1, ..., 36 \quad \forall\ R = 1, ..., 47 \qquad (13)$$

Whither $IC_{i\times j}^{R,IMP}$ is the import for intermediate consumption in each region R. $GOV_{i\times 1}^{R,IMP}$, $NPISH_{i\times 1}^{R,IMP}$ and $HC_{i\times 1}^{R,IMP}$ are, respectively, government, NPISH, and household consumption in imported products and $INV_{i\times 1}^{R,IMP}$ is the import for investment in each region R.

The demand for imported products is then calculated by the sum:

$$IMPDEM_{i\times 1}^{R} = \sum_{j=1}^{36} IC_{i\times j}^{R,IMP} + GOV_{i\times 1}^{R,IMP} + NPISH_{i\times 1}^{R,IMP} + HC_{i\times 1}^{R,IMP} + INV_{i\times 1}^{R,IMP} \qquad (14)$$

$$\forall\ i, j = 1, ..., 36 \quad \forall\ R = 1, ...,47$$

The sum of $IMPDEM^{R}_{i\times 1}$ must be equal to the total imported per activity in the national import matrix.

iii. Total supply from each region:

The domestic supply (*DOMSUP*) is achieved by the difference between the gross value of production (GVP) and exports (EXP) by activity in each biome-UF:

$$DOMSUP^{R}_{i\times 1} = GVP^{R}_{i\times 1} - EXP^{R}_{i\times 1} \qquad \forall \text{ i, j} = 1, ..., 36 \quad \forall \text{ R} = 1, ...,47 \tag{15}$$

Once the domestic demand and supply for the 36 activities per biome-UF are known, an adjustment can be made to the total demand of the country (sum of all the biomes-UF) so that the system is in equilibrium, that is, total domestic demand equals total supply.

Subsequently, matrices of participation in the interregional trade flow (SHIN) are built, representing the participation of each biome-UF in the total of domestic trade for each activity i. The matrices of participation in intraregional $\left(SHIN\ (i,d,d)\right)$ and interregional trade flow $\left(SHIN\ (i,s,d)\right)$ are constructed for each activity i of sources s and destination d, following Dixon and Rimmer (2004). For the intraregional trade flow, we have:

$$SHIN\ (i,d,d) = Min\left\{\frac{DOMSUP_{(i,d)}}{DOMDEM_{(i,d)}}, 1\right\} * F \tag{16}$$

Participation in intraregional trade flow is defined by the relation between supply and demand for the activity i within each biome-UF. If supply is greater than demand, it is then defined that all demand is met internally. Based on Haddad *et al.* (2016), this result is thus multiplied by a factor (*F*) that gives the size of the trade potential of each activity. For agricultural and industrial activities (1 to 30) an *F* factor of 0.50 was used, while for service activities (31 to 36) an *F* equal to 0.95 was considered, as service activities are less tradable.

If domestic demand is greater than supply, it follows that part of the demand is supplied by purchases from other regions through interregional trade, between the different biomes-UF, which is defined by:

$$SHIN\ (i,s,d)\ =\ Min\left\{\frac{1}{imped(s,d)}\cdot\frac{DOMSUP_{(i,s)}}{\sum_{k=1}^{47}DOMSUP_{(i,k)}}\right\}*\left\{\frac{1-SHIN(i,d,d)}{\sum_{j=1,j\neq d}^{47}\frac{1}{imped(j,d)}\cdot\frac{DOMSUP(i,j)}{\sum_{k=1}^{47}DOMSUP(i,k)}}\right\} \tag{17}$$

$SHIN\ (i,s,d)$ is the participation of the trade flow of activity i originating in biome-UF s and destination in biome-UF d; and the impedance, *imped*, is the average road distance between the biomes-UF.

Finally, the trade matrices are obtained by multiplying each $SHIN\ (i,s,d)$ by the respective i-value in the *DOMDEM* matrix:

$$TRADE_i^{sd} = SHIN(i,s,d) * diag[DOMDEM_{i\times R}(i,1{:}R)] \quad \forall\ \mathrm{i} = 1,...,36 \tag{18}$$

$TRADE_i^{sd}$ represents the i trade matrices with origin in the region s and destination in d with i representing each of the 36 activities. According to Haddad, Gonçalves Júnior, and Nascimento (2017), such procedure equals the sum in the columns of each $TRADE_i^{sd}$ to the demand of the respective region d for the region's products s for each activity i. However, the sum of the rows may not be equal to the supply of each activity i from the region s to d, which may become necessary to use the iterative RAS method (MILLER; BLAIR, 2009).

Subsequently to the RAS, one includes in each $TRADE_i^{sd}$ its respective row i of the matrix $IMPDEM_{i\times R}$ including the exterior in the source regions, s.

3.1.2.2 Regionalization stage

The matrices $TRADE_i^{sd}$ indicate how much each of the biomes-UF sells/purchases from the others and purchases from abroad from imports. However, from these matrices, one does not know if the product acquired by a given region was used as intermediate consumption, which activity bought the product or if it was destinated by one of the components of final demand. We then proceed to the second step of the regionalization process to resolve this issue.

One hypothesis adopted, following Chenery (1956) and Moses (1955), is to apply the same regional share to the acquisition of inputs for all activities and the acquisition of final products by final demand users, within each region. The regionalization process is then done in three steps.

First, we construct the matrices SHIN_N, following Dixon and Rimmer (2004):

$$SHIN\_N^{i}_{s \times d} = trade^{sd}_{i} \; * \; \{inv[\, diag(\textstyle\sum_{s=1}^{47} trade^{sd}_{i})]\} \tag{19}$$

Where $trade^{sd}_{i}$ represents each element of the matrix $TRADE^{sd}_{i}$, with s representing the 48 source regions (47 biomes-UF and the external sector) and d being the destination regions (47 biomes-UF).

The second step is to construct the national coefficients of intermediate consumption (ICC^{N}), government consumption ($GOVC^{N}$), NPISH consumption ($NPISHC^{N}$) household consumption (HCC^{N}) and investment ($INVC^{N}$), which are, respectively:

$$ICC^{N}_{i \times j} = Z^{DOM\,+\,IMP}_{i \times j} \; * \; (diag\; TIC^{N}_{1 \times j})^{-1} \tag{20}$$

$$GOVC^{N}_{i \times 1} = \frac{gov^{DOM\,+\,IMP}_{i}}{TGOV^{N}} \tag{21}$$

$$NPISHC^{N}_{i \times 1} = \frac{npish^{DOM\,+\,IMP}_{i}}{TNPISH^{N}} \tag{22}$$

$$HCC^{N}_{i \times 1} = \frac{hc^{DOM\,+\,IMP}_{i}}{THC^{N}} \tag{23}$$

$$INVC^{N}_{i \times 1} = \frac{inv^{DOM\,+\,IMP}_{i}}{TINV^{N}} \tag{24}$$

The subscript DOM + IMP refers to the sum of the matrix of domestic and imported uses and TIC^{N}_{j} represents the vector of total intermediate consumption for each destination activity j, given as the result of the subtraction:

$$TIC^{N}_{1 \times j} = GVP^{N}_{1 \times j} \; - \; VA^{N}_{1 \times j} \tag{25}$$

Being $GVP_{1\times j}^{N}$ and $VA_{1\times j}^{N}$, respectively, the gross value of national production and the national value added for each activity j.

The third and last step consists of constructing the regional coefficients. The 36 matrices SHIN_N are transformed into 48 matrices SHIN_S (equivalent to the 47 biomes-UF plus the external sector) of dimensions 36 × 47. The final regional coefficients of intermediate consumption ($ICRC_{i\times j}^{sd}$), government consumption ($GOVRC_{i\,x\,1}^{sd}$), NPISH consumption ($NPISHRC_{i\,x\,1}^{sd}$), household consumption ($HCRC_{i\times 1}^{sd}$) and investment ($INVRC_{i\times 1}^{sd}$) are expressed by:

$$ICRC_{i\times j}^{sd} = diag\,(SHIN\_S(1\!:i;d)) * ICC_{i\times j}^{N} \qquad \forall\ d = 1, ..., 47;\ \forall\ s = 1,..., 48 \quad (26)$$

$$GOVRC_{i\times 1}^{sd} = diag\,(SHIN\_S(1\!:i;d)) * GOVC_{i\times 1}^{N} \qquad \forall\ d = 1, ..., 47;\ \forall\ s = 1,..., 48 \quad (27)$$

$$NPISHRC_{i\times 1}^{sd} = diag\,(SHIN\_S(1\!:i;d)) * NPISHC_{i\times 1}^{N} \qquad \forall\ d = 1, ..., 47;\ \forall\ s = 1,..., 48 \ (28)$$

$$HCRC_{i\times 1}^{sd} = diag\,(SHIN\_S(1\!:i;d)) * HCC_{i\times 1}^{N} \qquad \forall\ d = 1, ..., 47;\ \forall\ s = 1,..., 48 \ (29)$$

$$INVRC_{i\times 1}^{sd} = diag\,(SHIN\_S(1\!:i;d)) * INVC_{i\times 1}^{N} \qquad \forall\ d = 1, ..., 47;\ \forall\ s = 1,..., 48 \ (30)$$

The transformation of the regional coefficients into monetary flows is done by multiplying these coefficients by the regional values, so that we have:

$$RIC_{i\times j}^{sd} = ICRC_{i\times j}^{sd} * diag(TRIC_{1\times j}^{d}) \qquad \forall\ d = 1, ..., 47;\ \forall\ s = 1, ..., 48 \ (31)$$

Where $RIC_{i\times j}^{sd}$ is the regional intermediate consumption for each pair of regions s × d and $TRIC_{1\times j}^{d}$ is the total regional intermediate consumption – expressed by the difference between the regional gross production value and the regional value added.

For the final demand components:

$$RGOV_{i\times 1}^{sd} = GOVRC_{i\times 1}^{sd} * RTGOV_{1\times 1}^{d} \qquad \forall\ d = 1, ..., 47;\ \forall\ s = 1,..., 48 \quad (32)$$

$$RNPISH^{sd}_{i \times 1} = NPISHRC^{sd}_{i \times 1} * RTNPISH^{d}_{1 \times 1} \qquad \forall\, d = 1, ..., 47; \forall\, s = 1,..., 48 \quad (33)$$

$$RHC^{sd}_{i \times 1} = HCRC^{sd}_{i \times 1} * RTHC^{d}_{1 \times 1} \qquad \forall\, d = 1, ..., 47; \forall\, s = 1,..., 48 \quad (34)$$

$$RINV^{sd}_{i \times 1} = INVRC^{sd}_{i \times 1} * RTINV^{d}_{1 \times 1} \qquad \forall\, d = 1, ..., 47; \forall\, s = 1,..., 48 \quad (35)$$

The final right-hand elements in each equation, $RTGOV^{d}_{1 \times 1}$, $RTNPISH^{d}_{1 \times 1}$, $RTHC^{d}_{1 \times 1}$ e $RTINV^{d}_{1 \times 1}$ correspond to the total regional values of each component of final demand – following the participation of each biome-UF in the national total according to the data detailed in section 3.1.1.

One can also construct regional indirect tax coefficients from the tax matrices following the same logic described above for intermediate consumption, obtaining the matrix of indirect taxes levied on regional intermediate consumption, $RIT^{sd}_{i \times j}$. In the MIP-Biomas, national and imported taxes are added together. The taxes applied on the final demand components are also regionalized according to the share of each component by biome-UF in the national total.

Since exports abroad are known, their values only need to be allocated in the interregional system. However, this thesis presents the breakdown of the vector of exports to EU, US, China, and the rest of the world according to the shares of these countries/regions in regional exports by activity i from the ComexStat data[16]. To close the interregional system only the elements of regional value added are missing, RVA^{sd}_{j}, which are also known. Finally, the regional gross value of production, GVP^{R} must be equal to the total demand of each region TD^{R}. The gross value of regional production is given by:

$$GVP^{R}_{j} = \sum_{i=1}^{36} RIC^{sd}_{i \times j} + \sum_{i=1}^{36} RIT^{sd}_{i \times j} + RVA^{sd}_{j} \qquad (36)$$

[16] Participation in service activities (from 31 to 36) follows participation in activity 36, the general one, due to lack of service data in ComexStat.

In which $RIC_{i \times j}^{sd}$ is the regional intermediate consumption matrix, $RIT_{i \times j}^{sd}$ is the matrix of indirect taxes on regional intermediate consumption, and RVA_j^{sd} is the regional value added for each activity j.

The total regional demand can be written as:

$$TD_i^R = \sum_{j=1}^{36} RCI_{i \times j}^{sd} + RGOV_i^{sd} + RNPISH_i^{sd} + RHC_i^{sd} + RINV_i^{sd} \quad (37)$$

Since there is the presence of stock variation (*SV*), it is assumed that:

$$SV_i^R = GVP^{R\prime} - TD^R \quad (38)$$

The consistency of the values of the *SV* and other components of the matrix is guaranteed at the national level, specifically, based on IBGE's national matrix for the year of 2015.

Appendix B brings an overview of the MIP-Biomas, focus on the breakdown of regional production based on the origin of final demand, and the distribution of GDP and economic activities by biome-UF.

3.2 Agricultural land and agriculture-caused deforestation data in Brazil

The data, in physical terms, of land use and of deforestation were taken from collection 6 of the Mapbiomas project, which presents 36 years (1985-2020) of mapping for 25 land cover classes and land use transitions. The methodology employed by Mapbiomas consists of obtaining and processing Landsat satellite images, with a resolution of 30 × 30 meters per pixel. The images are processed using the Google Earth Engine platform and machine learning algorithms (machine learning and deep learning). The processing of the images occurs by Brazilian biome (Amazônia, Caatinga, Cerrado, Mata Atlântica, Pampa and Pantanal); subsequently, these images are reclassified into other geographic units, such as municipalities and biomes by UF.

The Mapbiomas data, beyond its spatial disaggregation, details the areas of land use and land use transition by classes of agriculture, pasture, forest plantation and the mosaic areas of agriculture and pasture. Mapbiomas collection 6 also provides disaggregation of agriculture (level 4) for the classes: rice, coffee, sugar cane, citrus, soybean, other temporary crops and other perennial crops (also called permanent crops). These sectoral and regional breakdowns make the Mapbiomas database more suitable to be compatible with MIP-Biomas than other nationally available data – without taking away the merits of the other sources.

From the land use transition data of Mapbiomas, one can characterize AC deforestation in a direct way. In this work, we count only primary deforestation, which is given by the land use transitions from Forest areas (level 2) to the different classes of agriculture cultures (rice, coffee, sugar cane, citrus, soybean, other temporary crops, other perennial crops), pasture, forest plantation, and the mosaic areas of agriculture and pasture. Another advantage of Mapbiomas database considers as forest any forest formation, savanna formation, mangrove and wooded restinga, which can characterize the forest formation present in all Brazilian biomes.

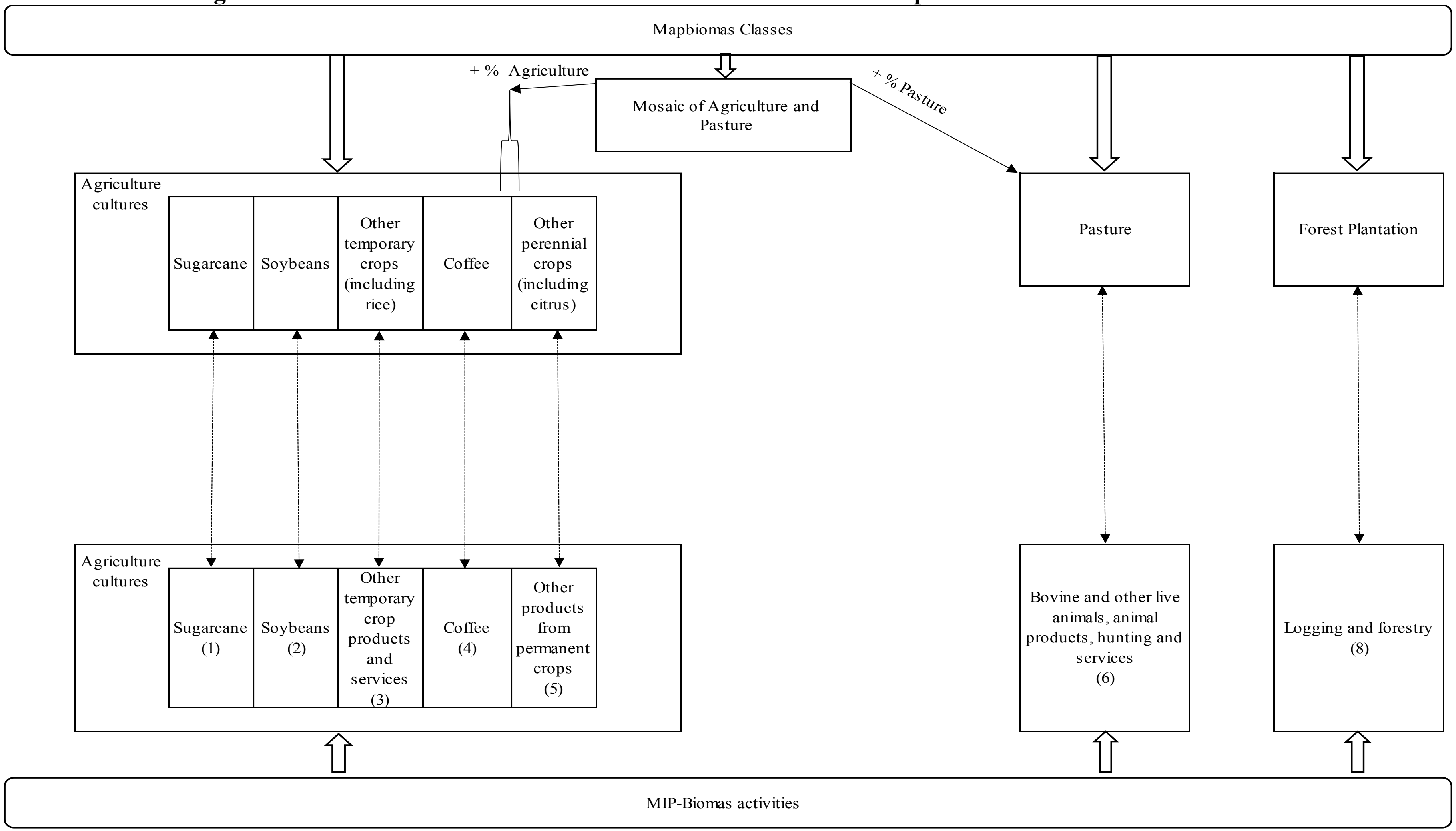
The classes referring to agriculture cultures, pasture, and forest plantation were made compatible with the MIP-Biomas activities (1 to 6 and 8), as shown in Figure 2, both in the land use and deforestation (land use transition) data.

It is possible to directly match the agricultural classes of Mapbiomas collection 6 with the MIP-Biomas activities, except for the rice and citrus classes,[17] which were aggregated to the other temporary crops and other perennial crops classes, respectively. In addition, all the pasture area of Mapbiomas was used in MIP-Biomas activity 6 (Bovine and other live animals, animal products, hunting and services), following other articles that present pasture allocated to cattle (Pendrill 2019a,b), and the area related to forest plantation was allocated to activity 8 (Logging and forestry).

We distributed the areas of land use and deforestation of the mosaic class of agriculture and pasture proportionally among the classes of agriculture and pasture to maintain the proportionality of these uses already presented in each biome-UF. Exemplifying, for the land use in the Amazônia-Amapá (Amazônia-AP) region, the agriculture and pasture areas correspond, respectively, to 15.08% and 84.92% of the total land use of these areas added

[17] Initially, it was thought to make the rice and citrus classes compatible with the activities "Rice, wheat and other cereals" and "Orange", present in the IBGE IOM (IBGE, 2018), however, because a concise compatibility was not possible, it was decided not to disaggregate these activities in the MIP-Biomas.

Figure 2 – Attribution of land use and deforestation data from Mapbiomas to MIP-Biomas activities



Source: elaborated by the author.

together. Therefore, 15.08% of the mosaic areas are designated for agriculture and 84.92% for pasture. Subsequently, the mosaic areas destined for agriculture are employed in the agricultural sub-classes following the percentage of their uses. Deforestation of the mosaic areas was also allocated using the observed percentage of deforestation in agriculture and pasture as a reference.

For a more accurate characterization of land use and deforestation in the most recent period, we adopted the average land use in the years 2013-2015 and a 5-year average deforestation period from 2010-2015, as adopted by authors such as Pendrill *et al*. (2019a,b) and Zu Ermgassen *et al*. (2020). We also performed a robustness check of the results for the period 2015-2017 for land use and 2012-2017 for deforestation, which gave similar results as showed in Appendix F of this thesis.

3.3 Quantifying land and deforestation embodied in Brazilian trade

In this thesis, we start from measuring the content of land and of deforestation present in Brazilian trade relations through the combination of agricultural land and AC deforestation data, in physical terms, with an interregional input-output modeling.

At the intranational level, indicators are constructed that track the content of agricultural land and AC deforestation embodied in trade relations between biomes-UF, as well as the allocation of content of land and of deforestation in the various activities present in the MIP-Biomas, according to the methodology applied in Fan, Liu and Wang (2022).

For international trade, the export vector is open for EU, US, China, and the rest of the world (Row) to assess the regional effects of each of these countries/regions on agricultural land and AC deforestation in Brazilian biomes. Together, EU, US, and China accounted for 44.49% of Brazil's exports in 2015 and the rest of the world for 55.51%, according to data from MIP-Biomas.

3.3.1 Basic assumptions of the interregional input-output model with agricultural land use and deforestation

Input-output modeling makes it possible to measure the interdependence between the final use of products and the acquisition of intermediate inputs; interregional models, such as MIP-Biomas, also capture as interregional linkages between economic activities in different regions and between agents of final demand (MILLER; BLAIR, 2009).

To facilitate the explanation of the analysis techniques, Figure 3 is considered as a synthesis of the MIP-Biomas, consisting of its n regions (biomes-UF) each with m activities and t elements of final demand. Where z_{ij}^{sd} represents the monetary value of the purchased goods or services of the activity i in the region s for the intermediate use of the activity j in the region d. f_{it}^{sd} represents the monetary value of the goods or services coming from the activity i in the region s for the region d to be used as final demand t and consumed domestically. e_i^s represents the component of final demand exported abroad, disaggregated by country/region, g_i^s is the stock variation by activity i and region s and y_i^s is the sum of final demand. p and c represents the vectors of imports and taxes, respectively. w_j^d is value added. x_i^d is the total production of the activity i in the region d. r_j^d represents the direct land or deforestation footprint by the activity j in the region d. All these measurements are in monetary units, except r_j^d which are in hectares (ha).

The intersectoral flows of the input-output model can be represented as follows: a) the equilibrium expressed by total demand, equation 39, which represents the sum of intermediate demand (z) and domestic (f) and exported (e) components of final demand; b) the equilibrium given by total supply, with the sum of intermediate consumption plus value added, imports, and taxes, as shown in equation 40.

$$x_i^s = \sum_{s=1}^{n} \sum_{j=1}^{m} z_{ij}^{sr} + f_i^s + e_i^s \tag{39}$$

$$x_j^d = \sum_{s=1}^{n} \sum_{i=1}^{m} z_{ij}^{sd} + p_j^d + c_j^d + w_j^d \tag{40}$$

Where total demand, equation 39, is equal to total supply, equation 40, in the model. Coefficients of production are assumed to be fixed, that is, the output of each product is a function of a fixed combination of the intermediate input components:

Figure 3 – Representation of the MIP-Biomas

<table>
<tr><td colspan="3" rowspan="3">Output
Input</td><td colspan="7">Intermediate consumption</td><td colspan="9">Domestic final demand</td><td colspan="4" rowspan="2">Exports</td><td rowspan="3">Stock variation</td><td rowspan="3">Total final demand</td><td rowspan="3">Total demand</td></tr>
<tr><td colspan="3">Economy 1</td><td rowspan="2">...</td><td colspan="3">Economy n</td><td colspan="4">Economy 1</td><td rowspan="2">...</td><td colspan="4">Economy n</td></tr>
<tr><td>Activity 1</td><td>...</td><td>Activity m</td><td>Activity 1</td><td>....</td><td>Activity m</td><td>Government consumption 1</td><td>NPISH consumption 1</td><td>Household consumption 1</td><td>Investment 1</td><td>Government consumption n</td><td>NPISH consumption n</td><td>Household consumption n</td><td>Investment 1</td><td>China</td><td>US</td><td>EU</td><td>Row</td></tr>
<tr><td rowspan="7">Intermediate consumption</td><td rowspan="3">Economy 1</td><td>Activity 1</td><td colspan="7" rowspan="7">z_{ij}^{sd}</td><td colspan="9" rowspan="7">f_{it}^{sd}</td><td colspan="4" rowspan="7">e_i^s</td><td rowspan="7">g_i^s</td><td rowspan="7">y_i^s</td><td rowspan="7">x_i^s</td></tr>
<tr><td>⋮</td></tr>
<tr><td>Activity m</td></tr>
<tr><td colspan="2">⋮</td></tr>
<tr><td rowspan="3">Economy n</td><td>Activity 1</td></tr>
<tr><td>⋮</td></tr>
<tr><td>Activity m</td></tr>
<tr><td colspan="3">Imports</td><td colspan="7">p_{ij}^d</td><td colspan="9">p_i^d</td><td colspan="4">p_i^d</td><td>p_i^d</td><td>p_i^d</td><td>p_i^d</td></tr>
<tr><td colspan="3">Taxes</td><td colspan="7">c_j^d</td><td colspan="9">c_j^d</td><td colspan="4">c_j^d</td><td>c_j^d</td><td>c_j^d</td><td>c_j^d</td></tr>
<tr><td colspan="3">Value added</td><td colspan="7">w_j^d</td></tr>
<tr><td colspan="3">Total output</td><td colspan="7">x_j^d</td></tr>
<tr><td colspan="3">Land use /deforestation factor</td><td colspan="7">r_j^d</td></tr>
</table>

Source: elaborated by the author.

$$a_{ij} = \frac{z_{ij}}{X_j} \tag{41}$$

Whither technical coefficients represent the quantity of activity inputs i required to produce one unit of the activity's output j. Substituting equation 41 in equation 39, and considering the system in matrix form, we have:

$$x_i^s = \sum_{s=1}^{n} \sum_{j=1}^{m} a_{ij}^{sr} X_j + f_i^s + e_i^s \tag{42}$$

$$X = AX + Y \tag{43}$$

The solution for total output is a function of the Leontief inverse ($L = (I - A)^{-1}$) and the total final demand (Y) which is exogenous to the model.

$$X = (I - A)^{-1} Y \tag{44}$$

This system indicates the output required, directly and indirectly, in each activity i when final demand increases by one monetary unit. In addition to these equations from the traditional model, the economic-environmental modeling makes use of $h,$ a coefficient of direct agricultural land use/deforestation footprint per unit of product, x, by activity j in the region of origin d:

$$h_j^d = \frac{r_j^d}{x_j^d} \tag{45}$$

The interpretation of h_j^d, in the case of land use, refers to how much unit of land is used to produce one monetary unit of total output produced in each activity j. Regarding deforestation, an equivalent interpretation can be thought of, with h_j^d telling us how much deforestation activity j produces per monetary unit of output produced in this activity. Only agricultural cultures, livestock, and logging and forest activities are referred to agricultural land use and deforestation in this research[18], the direct agricultural land/deforestation footprints, r_j^d, of all industries other than these are zero – the same occur with the coefficient h_j^d.

[18] These activities are activities 1 to 6 and 8, as shown in Figure 3 and in Table 2.

3.3.2 Measuring agricultural land and agriculture-caused deforestation embodied in Brazilian intranational and international trade

We calculate the agricultural land and AC deforestation embodied in Brazilian intranational and international trade following the measure of complete agricultural land footprint (CALF) present in Fan, Liu, and Wang (2022). This measure takes the sum of all direct agricultural land use caused by the end-use activities in an area, where the direct agricultural land footprint is redistributed to different end-users according to the demand–supply chain (FAN; LIU; WANG, 2022). The agricultural land (or, also, deforestation in our case) footprint of one area that is allocated to part of the complete agricultural land (deforestation) footprint of another area is considered the agricultural land (deforestation) footprint embodied in trade, inherent to the links in the demand-supply chain.

Different from the CALF indicator, in this thesis, end-users were disaggregated between national users and international users to separately verify the effects of intranational and international trade, separately.

Considering the n regions and m activities present in the MIP-Biomas shown in Figure 3 and according to the basic formulations of the input-output system, we have:

$$X = (I - A)^{-1}(\sum f^s + \sum e^s) \tag{46}$$

In which X denotes the total output, A is the direct consumption coefficient matrix between the domestic regions; f^s denotes the national final use in region s (government consumption, NPISH consumption, household consumption and investment), known as domestic absorption; and e^s denotes the international final use given by exports of region s. Replacing the Leontief matrix as $b = (I - A)^{-1}$, the equation 46 becomes:

$$X = b(\sum f^s + \sum e^s) \tag{47}$$

Taking the direct agricultural land or AC deforestation footprint as the vector r_j^d and dividing it by the total output produced in each activity j, x_j^d, we have the total land or deforestation by one monetary unit, h_j^d, as seen in equation 45. With h^d we can calculate the intranational agricultural footprint (NAF) as:

$$NAF = h * X = h * b * \left(\sum f^i\right) \tag{48}$$

$$h * X = (h^1 \dots h^s \dots h^n) * \begin{bmatrix} b^{11} & \cdots & b^{1n} \\ \vdots & \ddots & \vdots \\ b^{n1} & \cdots & b^{nn} \end{bmatrix} * \left(\sum f^s\right) \tag{49}$$

Where b^{sd} denotes the block matrix in the Leontief inverse matrix. The NAF in area s is then expressed by:

$$NAF^s = \ h^s * \sum_l \sum_i b^{si} f^{il} \tag{50}$$

Which represents the agricultural land or deforestation footprint of region s caused by the national final consumption of government, NPISH, households, and also investment (gross fixed capital formation), being i the activities and l the regions.

In the same way, we have the international agricultural footprint (EAF):

$$EAF = h * X = h * b * \left(\sum e^i\right) \tag{51}$$

$$EAF^s = h^s * \sum_k b^{sk} e^k \tag{52}$$

The EAF represents the agricultural land or deforestation footprint in region s caused by exports from EU, US, China, and the rest of the world (Row), separately.

In intranational trade, we also measure the bilateral impacts of agricultural land or deforestation footprint in region s caused by region d, named BNAF, which can be expressed as:

$$BNAF^{sd} = \ h^s * \sum_i b^{si} f^{id} \tag{53}$$

Simetrically, the agricultural land or deforestation footprint in region d caused by region s is:

$$BNAF^{ds} = h^{d} * \sum_{i} b^{di} f^{is} \tag{54}$$

The net agricultural land or deforestation footprint $(NBNAF)$ of region s caused by area d can thus be expressed as:

$$NBNAF^{sd} = BNAF^{sd} - BNAF^{ds} \tag{55}$$

According Fan, Liu and Wang (2022), we can also obtain agricultural land/deforestation embodied in each activity at the national level, dividing the data of each activity by the national gross agricultural land/deforestation footprint. The same procedure can be performed for regional analysis.

4 RESULTS

This section is subdivided into three parts. The first explores physical data on agricultural land use and deforestation. In the second, the agricultural land and AC deforestation embodied in intranational Brazilian trade is observed, evaluating this content between regions and in each activity. The third part presents the results of international trade.

4.1 Exploring land use and deforestation data

Tables 5-8 show the national distribution of agricultural land use and AC deforestation, respectively, in hectares and percentage terms across the 47 UF-biomes. It can be seen that the Mata Atlântica and the Cerrado dominate land use and deforestation for sugarcane, soybeans, other temporary crops, coffee, and forest plantation. The Pampa biome stands out in land use of other temporary crops with 20.44% of the national total, a class that includes rice production in which this biome is characterized as a national producer. In the Caatinga and Cerrado, land use and deforestation of permanent crops predominate, representing, respectively, 57.20% and 25.06% of national land use and 68.68% and 24.29% of deforestation. The Caatinga attracts attention for presenting high deforestation derived from pasture, 30.97% of the national total.

Figures 4-7 show the distribution of agricultural land use and AC deforestation of sugarcane, soybeans, other temporary crops, coffee and other permanent crops, pasture and forest plantation in the biomes-UF – which represent the direct agricultural footprints, r_j^d. In general, there is a congruence between land use and deforestation patterns, and it can be said that the distribution of deforestation in the national territory follows the land use in the evaluated activities, even though not in the same proportions as shown in Tables 5-8.

Some cases can be emphasized where the proportion of land use is greater than the proportion of deforestation, such as the other temporary crops activity in the Cerrado-BA areas with corresponding 7.06% of national land use and 0.56% of deforestation and logging, and forest in Pampa-RS, which presents 7.60% of land use and 1.03% of deforestation. In some activities the opposite occurs, with a higher percentage of deforestation compared to land use, as occurs with sugarcane activity in Cerrado-PI, which presents a 5.75% participation in deforestation and 0.09% in land use, and pasture in Caatinga-CE, a share of 8.10% participation in national deforestation and 1.59% in land use.

Table 5 – Agricultural land use by regions (2013-2015 average) – values in hectares

Regions/Activities	Sugarcane	Soybeans	Other temporary crops	Coffee	Other permanent crops	Pasture	Forest plantation
Amazônia-AC	0.00	0.00	1.97	0.00	0.00	1909445.74	0.00
Amazônia-AM	4360.59	3.10	2410.05	0.00	0.00	1828309.73	0.00
Amazônia-AP	0.00	1947.81	30782.34	0.00	0.00	184377.37	94132.69
Amazônia-MA	0.00	9221.97	39061.60	0.00	0.00	5082333.88	40552.88
Amazônia-MT	70893.25	3014517.35	702321.86	0.00	0.00	12902117.59	8922.73
Amazônia-PA	0.00	135977.13	105504.69	0.00	118933.97	19746933.71	79086.25
Amazônia-RO	0.00	116642.69	86469.91	0.00	0.00	8076360.44	0.00
Amazônia-RR	0.00	11619.87	6202.27	0.00	0.00	778111.82	1741.93
Amazônia-TO	0.00	340.83	4033.35	0.00	0.00	1714545.36	131.82
Caatinga-AL	5870.81	0.00	992.56	0.00	51.46	889826.09	0.00
Caatinga-BA	24127.69	44.79	91127.17	8530.16	61924.13	11789884.69	17007.05
Caatinga-CE	0.00	3.66	235566.97	0.00	472386.96	2906990.86	0.00
Caatinga-MG	143.35	62.37	2031.37	165.73	1839.40	333757.99	91.72
Caatinga-PB	10038.58	0.00	254.12	0.00	137.85	2195761.57	0.00
Caatinga-PE	6298.86	0.00	53450.48	0.00	78683.34	3012903.71	0.00
Caatinga-PI	3629.93	796.99	105504.96	0.00	6277.38	1831403.56	2631.30
Caatinga-RN	4725.84	0.00	438046.59	0.00	70106.19	1528769.54	0.00
Caatinga-SE	0.00	0.00	17584.15	0.00	0.00	771071.41	0.00
Cerrado-BA	0.00	1219892.56	1120292.03	25149.20	14978.91	1781288.11	1595.98
Cerrado-DF	0.00	104786.91	21058.97	225.48	0.00	125706.50	1604.33
Cerrado-GO	582350.41	3228650.19	827616.47	10499.52	0.00	15406207.93	86076.28
Cerrado-MA	26228.74	586726.24	226878.58	0.00	0.00	2427925.69	23077.24
Cerrado-MG	801673.75	1330122.29	783869.67	308540.60	13774.06	14088184.15	1200033.38
Cerrado-MS	371613.31	1432780.01	162290.50	0.00	0.00	13377999.39	520821.03
Cerrado-MT	36624.52	5116122.49	735741.19	0.00	0.00	7658317.69	52567.71
Cerrado-PI	11058.89	657831.41	481336.07	0.00	0.00	38824.14	979.41
Cerrado-PR	0.00	13872.95	3882.60	48.10	0.08	17777.76	56645.76
Cerrado-SP	3796314.34	376459.30	158176.33	58434.94	274187.01	1332477.02	402384.92
Cerrado-TO	6510.42	416960.07	240408.59	0.03	0.00	4998772.46	1629.90
Mata Atlântica-AL	458335.01	0.00	9.81	0.00	0.00	736807.24	0.53
Mata Atlântica-BA	41.11	0.00	113.88	21006.25	0.00	6227153.83	351861.70
Mata Atlântica-ES	79.65	0.00	75592.78	36873.46	0.00	2957795.75	154114.05
Mata Atlântica-GO	176679.02	43582.19	61822.89	36.70	0.00	558305.64	1119.51
Mata Atlântica-MG	168417.15	59391.88	520238.97	369461.80	0.00	13511210.21	444414.63
Mata Atlântica-MS	245498.73	941687.91	197594.62	0.00	0.00	2303404.13	8257.31
Mata Atlântica-PB	116230.97	0.00	2.06	0.00	0.00	220837.82	0.00
Mata Atlântica-PE	358268.50	0.00	2713.83	0.00	0.00	969625.82	0.00
Mata Atlântica-PR	825942.44	6083145.20	1444523.77	45042.22	0.00	3957803.96	889245.38
Mata Atlântica-RJ	22.66	0.00	155795.81	0.21	0.00	2441552.53	5013.01
Mata Atlântica-RN	41093.81	0.00	15056.07	0.00	0.00	85516.33	0.00
Mata Atlântica-RS	0.00	3729455.06	1431771.75	0.00	0.00	523750.34	231443.20
Mata Atlântica-SC	0.00	840082.43	1366721.69	0.00	0.00	1483420.37	892940.32
Mata Atlântica-SE	12036.02	0.00	432.44	0.00	0.00	833812.16	189.20
Mata Atlântica-SP	4219240.36	385061.42	662449.63	61058.14	95417.50	5628278.68	402084.55
Pampa-RS	0.00	2463733.68	3243085.70	0.00	0.00	32576.17	491889.01
Pantanal-MS	0.29	590.58	545.38	0.00	0.00	967762.75	444.70
Pantanal-MT	1359.14	4770.20	8332.48	0.00	0.00	1171380.87	6081.13
Total	12385708.13	32326883.50	15869700.98	945072.52	1208698.22	183347380.52	6470812.56

Source: elaborated by the author based on Mapbiomas database

Table 6 – Regional share of agricultural land use (2013-2015 average) – percentage values

Regions/Activities	Sugarcane	Soybeans	Other temporary crops	Coffee	Other permanent crops	Pasture	Forest plantation
Amazônia-AC	0.00	0.00	0.00	0.00	0.00	1.04	0.00
Amazônia-AM	0.04	0.00	0.02	0.00	0.00	1.00	0.00
Amazônia-AP	0.00	0.01	0.19	0.00	0.00	0.10	1.45
Amazônia-MA	0.00	0.03	0.25	0.00	0.00	2.77	0.63
Amazônia-MT	0.57	9.33	4.43	0.00	0.00	7.04	0.14
Amazônia-PA	0.00	0.42	0.66	0.00	9.84	10.77	1.22
Amazônia-RO	0.00	0.36	0.54	0.00	0.00	4.40	0.00
Amazônia-RR	0.00	0.04	0.04	0.00	0.00	0.42	0.03
Amazônia-TO	0.00	0.00	0.03	0.00	0.00	0.94	0.00
Caatinga-AL	0.05	0.00	0.01	0.00	0.00	0.49	0.00
Caatinga-BA	0.19	0.00	0.57	0.90	5.12	6.43	0.26
Caatinga-CE	0.00	0.00	1.48	0.00	39.08	1.59	0.00
Caatinga-MG	0.00	0.00	0.01	0.02	0.15	0.18	0.00
Caatinga-PB	0.08	0.00	0.00	0.00	0.01	1.20	0.00
Caatinga-PE	0.05	0.00	0.34	0.00	6.51	1.64	0.00
Caatinga-PI	0.03	0.00	0.66	0.00	0.52	1.00	0.04
Caatinga-RN	0.04	0.00	2.76	0.00	5.80	0.83	0.00
Caatinga-SE	0.00	0.00	0.11	0.00	0.00	0.42	0.00
Cerrado-BA	0.00	3.77	7.06	2.66	1.24	0.97	0.02
Cerrado-DF	0.00	0.32	0.13	0.02	0.00	0.07	0.02
Cerrado-GO	4.70	9.99	5.22	1.11	0.00	8.40	1.33
Cerrado-MA	0.21	1.81	1.43	0.00	0.00	1.32	0.36
Cerrado-MG	6.47	4.11	4.94	32.65	1.14	7.68	18.55
Cerrado-MS	3.00	4.43	1.02	0.00	0.00	7.30	8.05
Cerrado-MT	0.30	15.83	4.64	0.00	0.00	4.18	0.81
Cerrado-PI	0.09	2.03	3.03	0.00	0.00	0.02	0.02
Cerrado-PR	0.00	0.04	0.02	0.01	0.00	0.01	0.88
Cerrado-SP	30.65	1.16	1.00	6.18	22.68	0.73	6.22
Cerrado-TO	0.05	1.29	1.51	0.00	0.00	2.73	0.03
Mata Atlântica-AL	3.70	0.00	0.00	0.00	0.00	0.40	0.00
Mata Atlântica-BA	0.00	0.00	0.00	2.22	0.00	3.40	5.44
Mata Atlântica-ES	0.00	0.00	0.48	3.90	0.00	1.61	2.38
Mata Atlântica-GO	1.43	0.13	0.39	0.00	0.00	0.30	0.02
Mata Atlântica-MG	1.36	0.18	3.28	39.09	0.00	7.37	6.87
Mata Atlântica-MS	1.98	2.91	1.25	0.00	0.00	1.26	0.13
Mata Atlântica-PB	0.94	0.00	0.00	0.00	0.00	0.12	0.00
Mata Atlântica-PE	2.89	0.00	0.02	0.00	0.00	0.53	0.00
Mata Atlântica-PR	6.67	18.82	9.10	4.77	0.00	2.16	13.74
Mata Atlântica-RJ	0.00	0.00	0.98	0.00	0.00	1.33	0.08
Mata Atlântica-RN	0.33	0.00	0.09	0.00	0.00	0.05	0.00
Mata Atlântica-RS	0.00	11.54	9.02	0.00	0.00	0.29	3.58
Mata Atlântica-SC	0.00	2.60	8.61	0.00	0.00	0.81	13.80
Mata Atlântica-SE	0.10	0.00	0.00	0.00	0.00	0.45	0.00
Mata Atlântica-SP	34.07	1.19	4.17	6.46	7.89	3.07	6.21
Pampa-RS	0.00	7.62	20.44	0.00	0.00	0.02	7.60
Pantanal-MS	0.00	0.00	0.00	0.00	0.00	0.53	0.01
Pantanal-MT	0.01	0.01	0.05	0.00	0.00	0.64	0.09
Total	100	100	100	100	100	100	100

Source: elaborated by the author based on Mapbiomas database

Table 7 – Agriculture-caused deforestation by regions (2010-2015 average) – values in hectares

Regions/Activities	Sugarcane	Soybeans	Other temporary crops	Coffee	Other permanent crops	Pasture	Forest plantation
Amazônia-AC	0.00	0.00	0.00	0.00	0.00	35499.06	0.00
Amazônia-AM	7.52	0.00	235.12	0.00	0.00	110886.34	0.00
Amazônia-AP	0.00	0.32	1044.55	0.00	0.00	19543.00	74.30
Amazônia-MA	0.00	0.13	2971.65	0.00	0.00	170389.98	29.91
Amazônia-MT	68.96	566.30	3293.13	0.00	0.00	247373.71	0.55
Amazônia-PA	0.00	51.40	3871.05	0.00	39.48	605297.30	131.44
Amazônia-RO	0.00	16.01	1531.42	0.00	0.00	112806.65	0.00
Amazônia-RR	0.00	0.13	700.57	0.00	0.00	43782.24	1.21
Amazônia-TO	0.00	0.23	117.98	0.00	0.00	31569.41	0.00
Caatinga-AL	3.35	0.00	1.39	0.00	3.18	26651.74	0.00
Caatinga-BA	38.37	0.10	199.77	480.16	620.83	444623.03	118.29
Caatinga-CE	0.00	0.00	4638.44	0.00	23652.24	302348.04	0.00
Caatinga-MG	0.00	1.56	31.82	52.55	70.30	9951.75	4.34
Caatinga-PB	101.15	0.00	0.92	0.00	0.56	99556.08	0.00
Caatinga-PE	4.25	0.00	512.03	0.00	600.95	96418.76	0.00
Caatinga-PI	126.65	9.57	1075.73	0.00	212.81	102182.00	0.66
Caatinga-RN	49.94	0.00	20918.08	0.00	1330.69	53505.81	0.00
Caatinga-SE	0.00	0.00	9.89	0.00	0.00	21078.49	0.00
Cerrado-BA	0.00	258.47	1668.68	3504.77	4891.41	67371.70	68.29
Cerrado-DF	0.00	52.95	264.31	259.79	0.00	1079.64	22.97
Cerrado-GO	503.35	1623.23	4086.12	3088.23	0.00	137365.48	1605.25
Cerrado-MA	527.15	372.25	2562.91	0.00	0.00	71611.53	7.99
Cerrado-MG	296.97	446.67	1845.13	7866.02	130.01	169063.80	12645.56
Cerrado-MS	215.39	1268.06	1825.38	0.00	0.00	70083.33	1961.93
Cerrado-MT	222.31	3872.99	11842.23	0.00	0.00	123140.53	43.60
Cerrado-PI	666.14	724.81	20373.97	0.00	0.00	5064.12	0.05
Cerrado-PR	0.00	35.35	165.03	7.77	0.00	446.84	474.13
Cerrado-SP	5083.37	599.56	2644.26	3378.35	4348.49	11582.99	1808.08
Cerrado-TO	24.92	350.76	2664.61	0.02	0.00	84092.39	0.84
Mata Atlântica-AL	331.08	0.00	0.00	0.00	0.00	9928.94	0.16
Mata Atlântica-BA	0.00	0.00	0.25	975.16	0.00	123294.85	3611.59
Mata Atlântica-ES	0.00	0.00	2953.05	142.41	0.00	20740.26	3189.91
Mata Atlântica-GO	60.75	20.46	227.96	21.11	0.00	2342.86	24.16
Mata Atlântica-MG	20.88	13.69	4997.78	10793.62	0.00	141516.06	9241.27
Mata Atlântica-MS	16.00	1428.20	1131.86	0.00	0.00	5896.11	197.03
Mata Atlântica-PB	67.83	0.00	0.00	0.00	0.00	8688.69	0.00
Mata Atlântica-PE	38.18	0.00	0.04	0.00	0.00	17811.59	0.00
Mata Atlântica-PR	410.15	12633.91	74421.11	1309.46	0.00	18333.50	8584.45
Mata Atlântica-RJ	0.00	0.00	516.43	0.13	0.00	15162.78	225.86
Mata Atlântica-RN	8.74	0.00	114.83	0.00	0.00	3585.30	0.00
Mata Atlântica-RS	0.00	5076.32	44840.98	0.00	0.00	3124.45	497.80
Mata Atlântica-SC	0.00	1853.00	38588.33	0.00	0.00	21980.38	10764.33
Mata Atlântica-SE	1.12	0.00	0.69	0.00	0.00	12775.26	0.77
Mata Atlântica-SP	2694.83	300.79	24192.11	3513.81	2670.35	27623.87	3864.39
Pampa-RS	0.00	2762.91	13837.94	0.00	0.00	147.15	616.45
Pantanal-MS	0.00	3.85	1.09	0.00	0.00	10059.08	15.56
Pantanal-MT	0.61	2.79	78.34	0.00	0.00	16779.60	0.22
Total	11589.98	34346.75	296998.98	35393.36	38571.29	3734156.48	59833.37

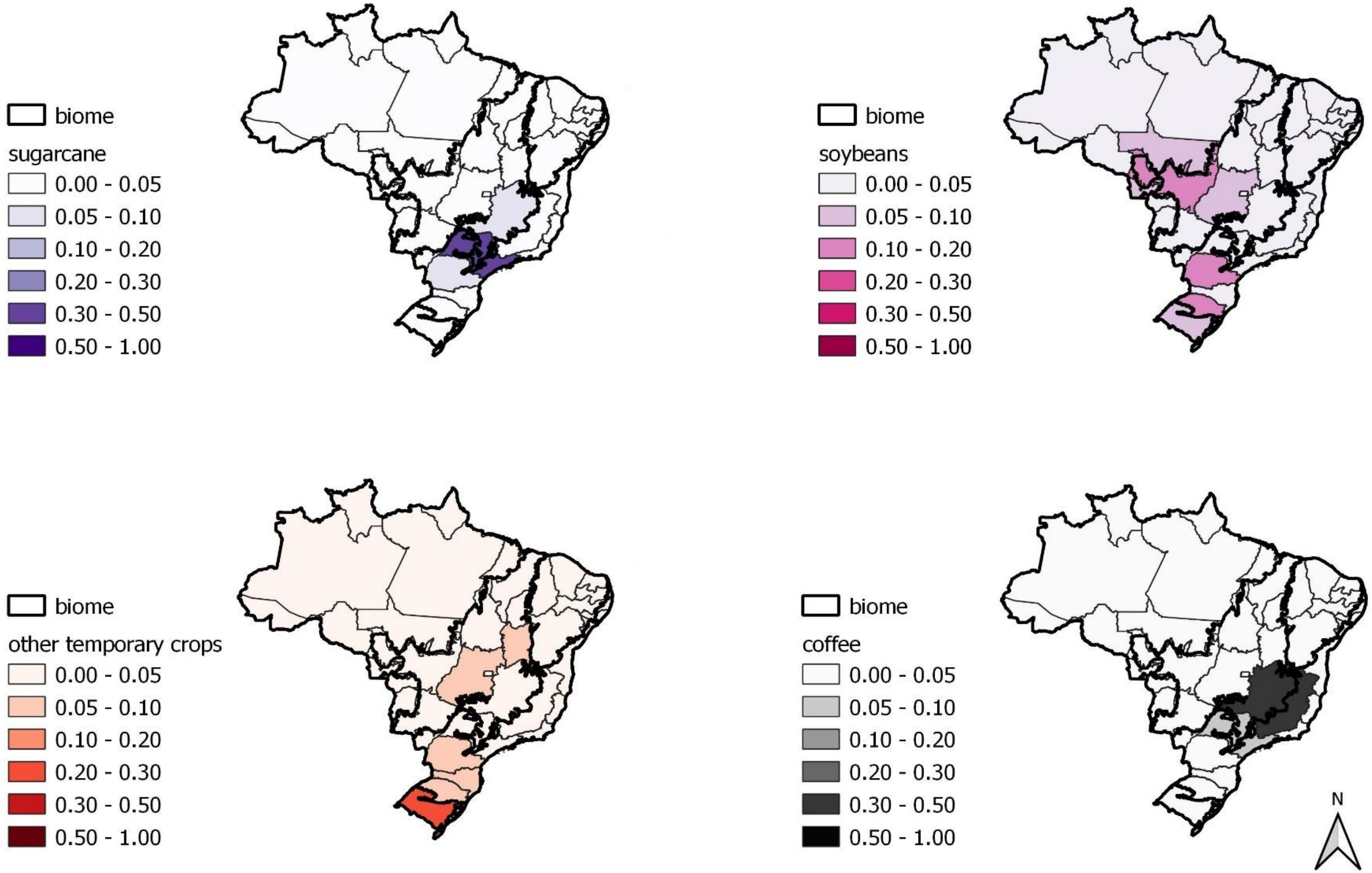
Source: elaborated by the author based on Mapbiomas database

Table 8 – Regional share of agriculture-caused deforestation (2010-2015 average) – percentage values

Regions/Activities	Sugarcane	Soybeans	Other temporary crops	Coffee	Other permanent crops	Pasture	Forest plantation
Amazônia-AC	0.00	0.00	0.00	0.00	0.00	0.95	0.00
Amazônia-AM	0.06	0.00	0.08	0.00	0.00	2.97	0.00
Amazônia-AP	0.00	0.00	0.35	0.00	0.00	0.52	0.12
Amazônia-MA	0.00	0.00	1.00	0.00	0.00	4.56	0.05
Amazônia-MT	0.59	1.65	1.11	0.00	0.00	6.62	0.00
Amazônia-PA	0.00	0.15	1.30	0.00	0.10	16.21	0.22
Amazônia-RO	0.00	0.05	0.52	0.00	0.00	3.02	0.00
Amazônia-RR	0.00	0.00	0.24	0.00	0.00	1.17	0.00
Amazônia-TO	0.00	0.00	0.04	0.00	0.00	0.85	0.00
Caatinga-AL	0.03	0.00	0.00	0.00	0.01	0.71	0.00
Caatinga-BA	0.33	0.00	0.07	1.36	1.61	11.91	0.20
Caatinga-CE	0.00	0.00	1.56	0.00	61.32	8.10	0.00
Caatinga-MG	0.00	0.00	0.01	0.15	0.18	0.27	0.01
Caatinga-PB	0.87	0.00	0.00	0.00	0.00	2.67	0.00
Caatinga-PE	0.04	0.00	0.17	0.00	1.56	2.58	0.00
Caatinga-PI	1.09	0.03	0.36	0.00	0.55	2.74	0.00
Caatinga-RN	0.43	0.00	7.04	0.00	3.45	1.43	0.00
Caatinga-SE	0.00	0.00	0.00	0.00	0.00	0.56	0.00
Cerrado-BA	0.00	0.75	0.56	9.90	12.68	1.80	0.11
Cerrado-DF	0.00	0.15	0.09	0.73	0.00	0.03	0.04
Cerrado-GO	4.34	4.73	1.38	8.73	0.00	3.68	2.68
Cerrado-MA	4.55	1.08	0.86	0.00	0.00	1.92	0.01
Cerrado-MG	2.56	1.30	0.62	22.22	0.34	4.53	21.13
Cerrado-MS	1.86	3.69	0.61	0.00	0.00	1.88	3.28
Cerrado-MT	1.92	11.28	3.99	0.00	0.00	3.30	0.07
Cerrado-PI	5.75	2.11	6.86	0.00	0.00	0.14	0.00
Cerrado-PR	0.00	0.10	0.06	0.02	0.00	0.01	0.79
Cerrado-SP	43.86	1.75	0.89	9.55	11.27	0.31	3.02
Cerrado-TO	0.22	1.02	0.90	0.00	0.00	2.25	0.00
Mata Atlântica-AL	2.86	0.00	0.00	0.00	0.00	0.27	0.00
Mata Atlântica-BA	0.00	0.00	0.00	2.76	0.00	3.30	6.04
Mata Atlântica-ES	0.00	0.00	0.99	0.40	0.00	0.56	5.33
Mata Atlântica-GO	0.52	0.06	0.08	0.06	0.00	0.06	0.04
Mata Atlântica-MG	0.18	0.04	1.68	30.50	0.00	3.79	15.45
Mata Atlântica-MS	0.14	4.16	0.38	0.00	0.00	0.16	0.33
Mata Atlântica-PB	0.59	0.00	0.00	0.00	0.00	0.23	0.00
Mata Atlântica-PE	0.33	0.00	0.00	0.00	0.00	0.48	0.00
Mata Atlântica-PR	3.54	36.78	25.06	3.70	0.00	0.49	14.35
Mata Atlântica-RJ	0.00	0.00	0.17	0.00	0.00	0.41	0.38
Mata Atlântica-RN	0.08	0.00	0.04	0.00	0.00	0.10	0.00
Mata Atlântica-RS	0.00	14.78	15.10	0.00	0.00	0.08	0.83
Mata Atlântica-SC	0.00	5.39	12.99	0.00	0.00	0.59	17.99
Mata Atlântica-SE	0.01	0.00	0.00	0.00	0.00	0.34	0.00
Mata Atlântica-SP	23.25	0.88	8.15	9.93	6.92	0.74	6.46
Pampa-RS	0.00	8.04	4.66	0.00	0.00	0.00	1.03
Pantanal-MS	0.00	0.01	0.00	0.00	0.00	0.27	0.03
Pantanal-MT	0.01	0.01	0.03	0.00	0.00	0.45	0.00
Total	100	100	100	100	100	100	100

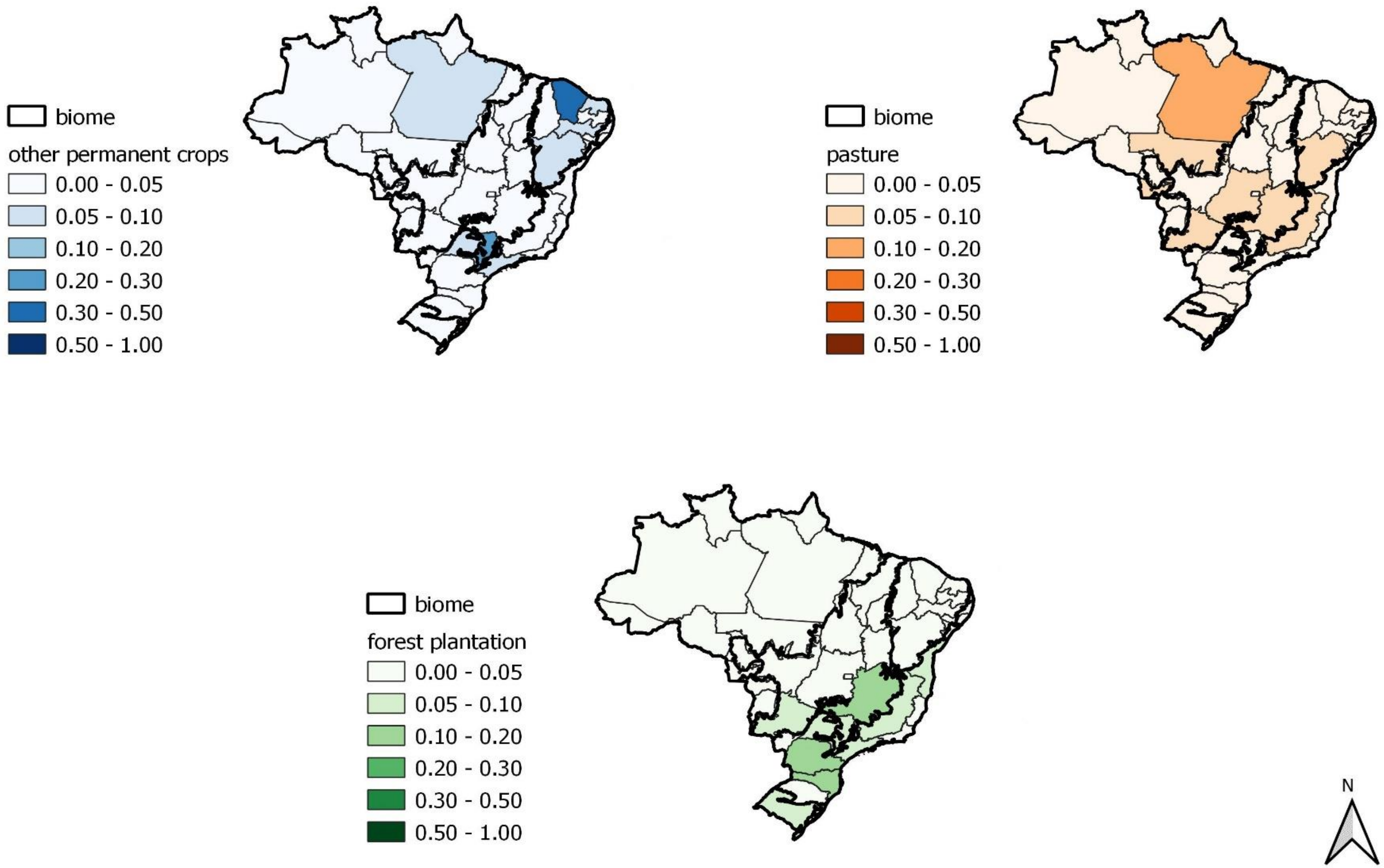
Source: elaborated by the author based on Mapbiomas database

Figure 4 – Regional share of agricultural land use – 2013-2015 average



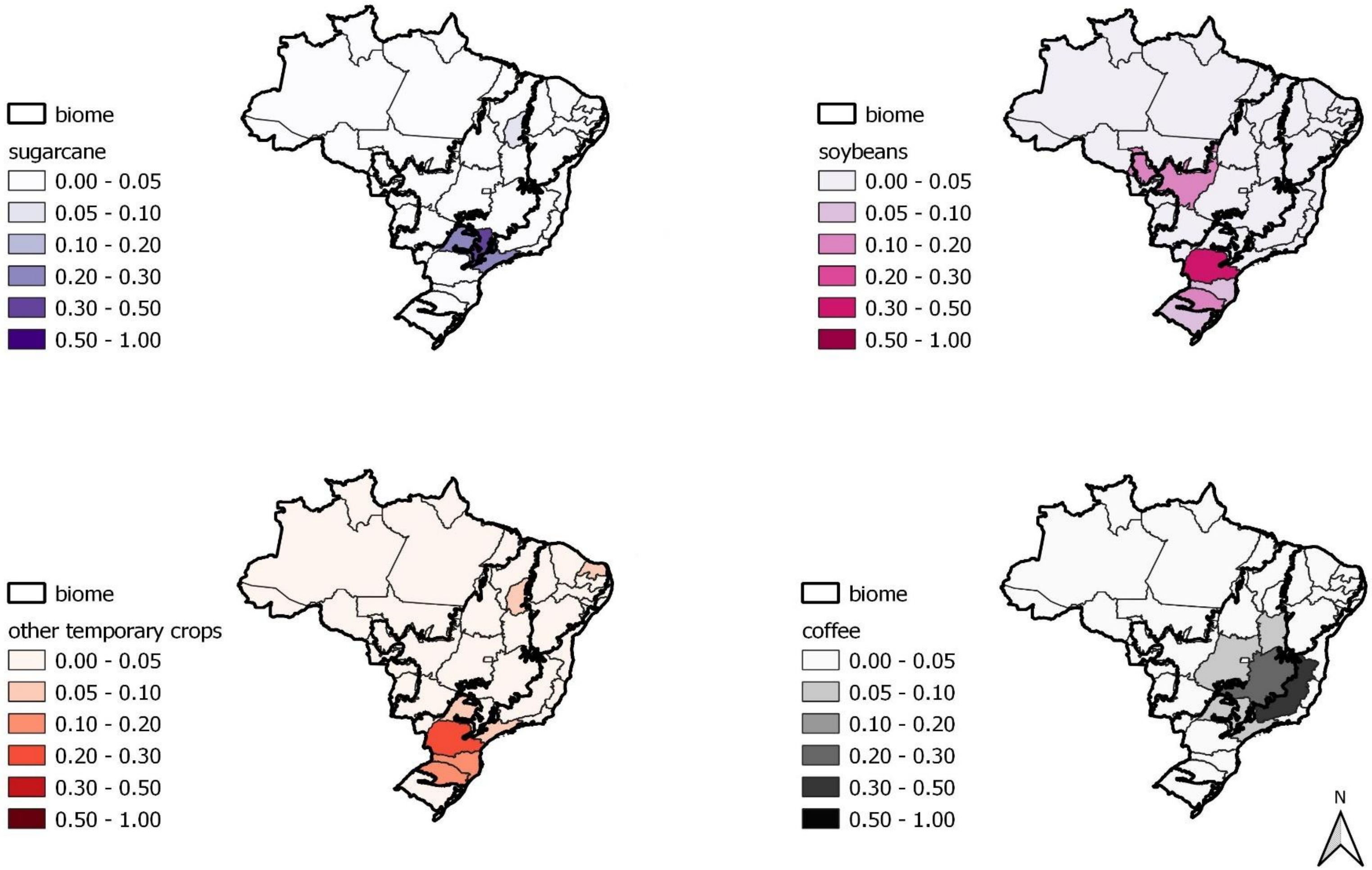
Source: elaborated by the author in QGIS 3.28.

Figure 5 – Regional share of agricultural land use – 2013-2015 average



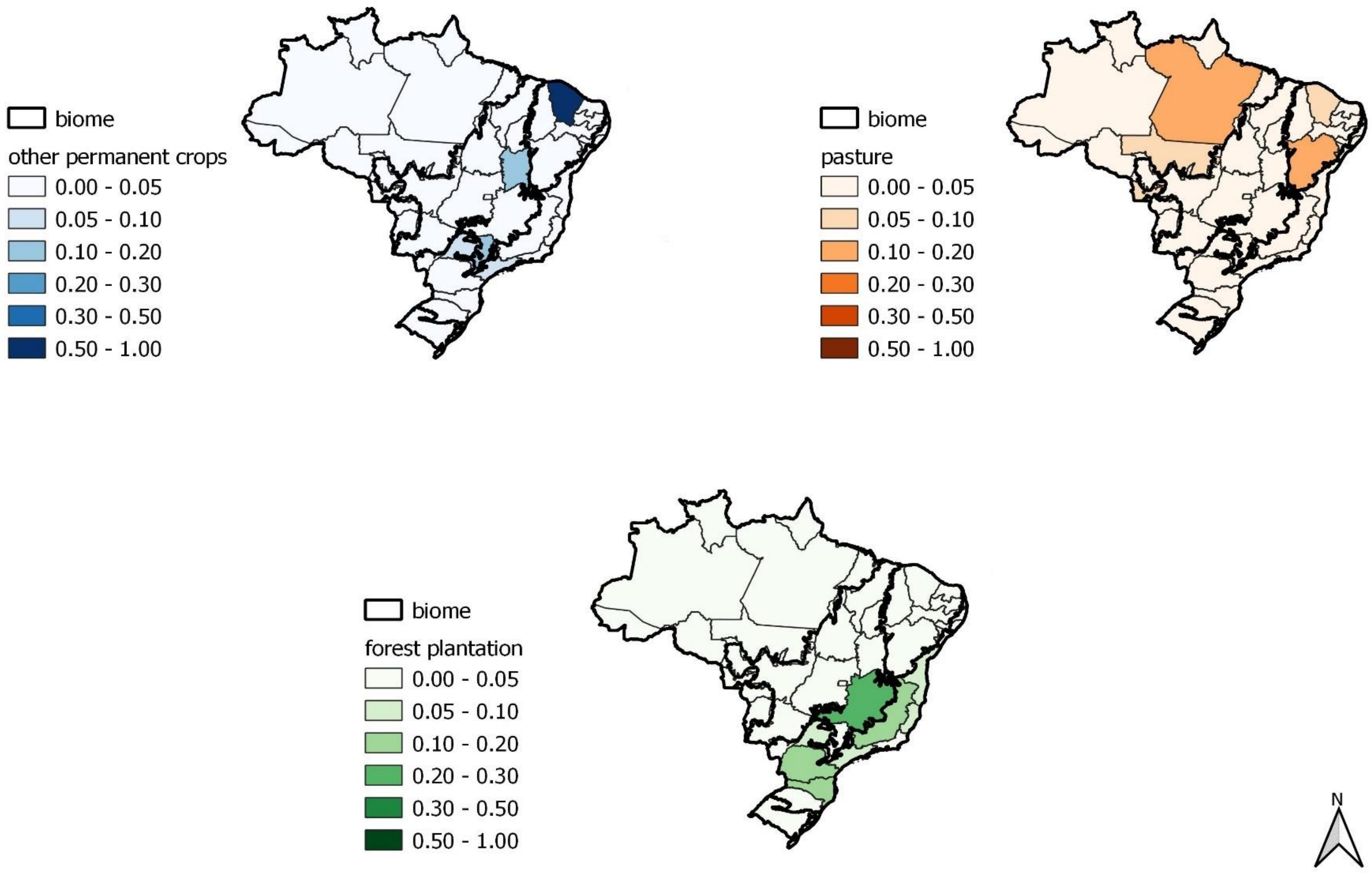
Source: elaborated by the author in QGIS 3.28.

Figure 6 – Regional share of agriculture-caused deforestation – 2010-2015 average



Source: elaborated by the author in QGIS 3.28.

Figure 7 – Regional share of agriculture-caused deforestation – 2010-2015 average



Source: elaborated by the author in QGIS 3.28.

4.2 Land and deforestation embodied in Brazilian intranational trade

This subsection is subdivided into two subsections, where the first presents the agricultural land and AC deforestation embodied in bilateral intranational trade, and the second indicates which activities absorb most of the land content and of deforestation content.

4.2.1 Agricultural land and agriculture-caused deforestation transfer patterns

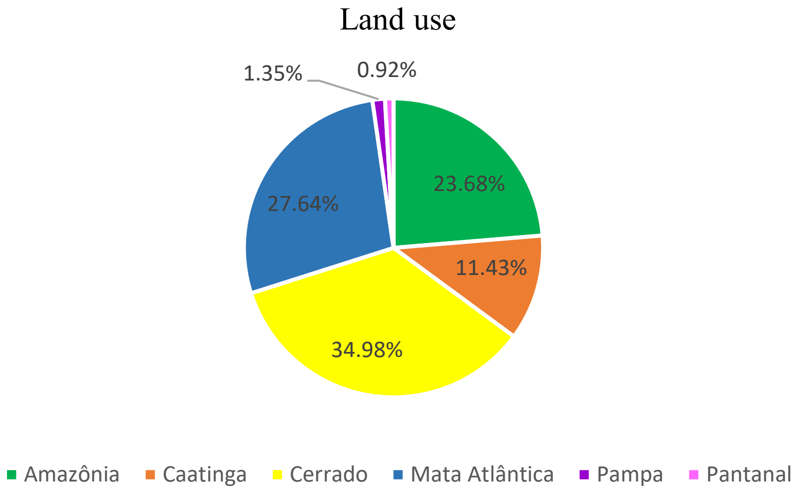
Altogether, the content of agricultural land and AC deforestation embodied in intranational trade corresponds to 178595327.46 and 3072132.04 million (reais) ha, respectively. Figure 8 details the total agricultural land and AC deforestation embodied in Brazilian intranational trade by Brazilian biome.

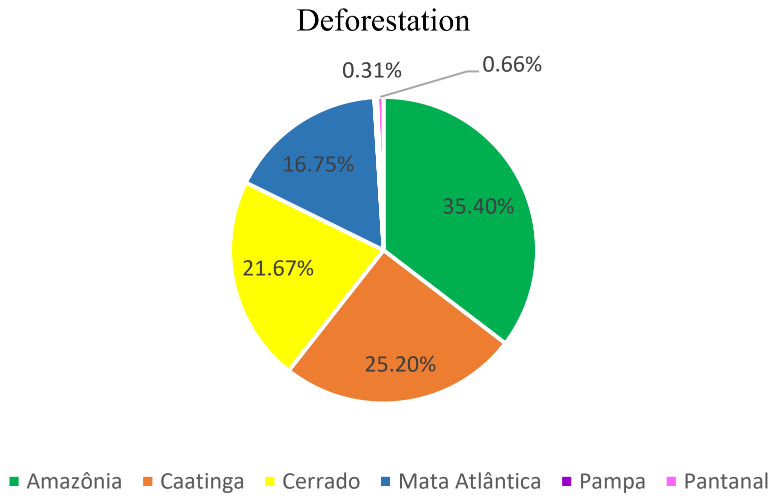
The Amazônia is the third biome that contributed the most to trade with agricultural land content in the average of the period 2013-2015, with 23.68% of the total, behind the Cerrado (34.98%) and the Mata Atlântica (27.64%), while it was the biome most affected by trade with deforestation content, on average between 2010-2015, corresponding to 35.40% of the national total.

The Caatinga stands out for occupying the second national position in terms of trade with deforestation content with a participation of 25.20% of the national total but corresponding to 11.43% of the trade with land content. The opposite occurs in the Cerrado, Mata Atlântica, Pampa, and Pantanal biomes, where the land content present in intranational trade is greater than the deforestation content. However, national legislation does not impose stricter restrictions on deforestation in the Caatinga, as is the case of specific values of the legal reserves for the Amazônia and the Cerrado.

Tables 9 and 10 show the bilateral patterns of trade with content of agricultural land and of AC deforestation between Brazilian biomes, with consumption reading from the row under the column. The patterns of the agricultural land and AC deforestation embodied in trade are similar, even though they do not occur in the same proportions.

Figure 8 – Agricultural land use and agriculture-caused deforestation embodied in intranational trade by biome





Source: elaborated by the author based on the results.

In general, each biome accounts for most of the land use and deforestation within its own territory, which can be seen in the main diagonal of the matrices in Tables 9 and 10. Considering the sum of the whole territory, for land use, the percentages of internal consumption in the Amazônia, Caatinga, Cerrado, Mata Atlântica and Pampa are, respectively, 53.87%, 61.72%, 49.74%, 84.16% and 62.60%. In the case of deforestation, these percentages are, in the same order, 58.49%, 62.61%, 54.65%, 86.77 and 62.96%.

The Pantanal biome stands as an exception since the agricultural land and AC deforestation embodied in trade with the Mata Atlântica and Cerrado exceed its internal consumption. In addition to the Pantanal, the internal consumption of agricultural land and AC deforestation in the Amazônia and Cerrado are lower than those in the Mata Atlântica, Caatinga and Pampa. This fact indicates that the Pantanal, Amazônia and Cerrado provide more agricultural land content and AC deforestation from their territories to other biomes compared to the Mata Atlântica, Pampa and Caatinga.

Table 9 – Embodied agricultural land in intranational trade between Brazilian biomes – percentage values

		Receptor					
		Amazônia	Caatinga	Cerrado	Mata Atlântica	Pampa	Pantanal
consumer	Amazônia	53.87	1.59	3.11	1.29	0.59	6.32
	Caatinga	4.42	61.72	2.45	2.30	0.62	1.30
	Cerrado	12.54	5.32	49.74	10.28	5.76	23.35
	Mata Atlântica	27.74	30.84	43.23	84.16	30.42	43.56
	Pampa	1.35	0.52	1.40	1.95	62.60	2.25
	Pantanal	0.07	0.01	0.07	0.03	0.02	23.22
	Total	100	100	100	100	100	100

Source: elaborated by the author based on the results.

Table 10 – Embodied agricultural deforestation in intranational trade between Brazilian biomes – percentage values

		Receptor					
		Amazônia	Caatinga	Cerrado	Mata Atlântica	Pampa	Pantanal
consumer	Amazônia	58.49	1.62	3.75	1.08	0.55	6.83
	Caatinga	4.69	62.61	3.26	2.85	0.60	1.33
	Cerrado	10.97	5.24	54.65	7.80	5.84	24.05
	Mata Atlântica	24.58	30.01	37.04	86.77	30.05	42.79
	Pampa	1.21	0.51	1.24	1.47	62.96	2.22
	Pantanal	0.06	0.01	0.06	0.02	0.02	22.78
	Total	100	100	100	100	100	100

Source: elaborated by the author based on the results.

The Mata Atlântica is the biome that puts the most pressure on land use and deforestation in the other Brazilian biomes, followed by the Cerrado. In contrast, the Amazônia, Caatinga, Pampa and Pantanal do not have above average agricultural land and AC deforestation consumption coming from any other biome than their own territories.

A highlight point is the heterogeneity in the consumption of agricultural land and AC deforestation internally and externally to the biomes as presented in Table 11, emphasizing that the external consumption is that absorbed by regions other than the biome-UF itself, that is, the part that is destinated to the trade. The Amazônia and Caatinga are placed as examples, presenting UF-biomes with high percentages of internal consumption and low external consumption in agricultural land and AC deforestation as Amazônia-AM, Amazônia-AP and Caatinga-CE, and others with high external consumption in detriment of internal consumption, as observed in Amazônia-MT, Amazônia-TO and Caatinga-MG. In addition, despite differing in percentage terms, the internal and external trade of agricultural land and AC deforestation follow the same pattern in the biomes-UF.

For a better understanding of the interregional flows, Figures 9 and 10 bring, respectively, the matrix of participation of interregional trade with content of agricultural land and of AC deforestation between the biomes-UF. The data are in percentages and range from 0% to 32.18% for land use and 0 to 27.97% for deforestation. The matrices do not account for internal consumption within each UF-biome. For the purpose of reading this matrix, we consider the rows as consumers of land use and deforestation and the columns as suppliers of these consumptions.

Following that presented by the relationships between biomes in Tables 9 and 10, there is congruence in the pattern presented by the interregional matrices of trade with agricultural land and AC deforestation content, although the percentages differ. The pressure exerted by the Mata Atlântica biomes-UF on land use and deforestation in Brazil is striking, as is the case for Mata Atlântica-SP, Mata Atlântica-PE, Mata Atlântica-PR, Mata Atlântica-RS and Mata Atlântica-MG. Consumption with land content and deforestation content in Mata Atlântica-SP and Mata Atlântica-PR, for example, spreads all over the national territory.

The consumption presented by Mata Atlântica-PE, on the other hand, is concentrated in the Caatinga and Mata Atlântica areas in Northeastern regions close to the state of Pernambuco, including its own Caatinga-PE region.

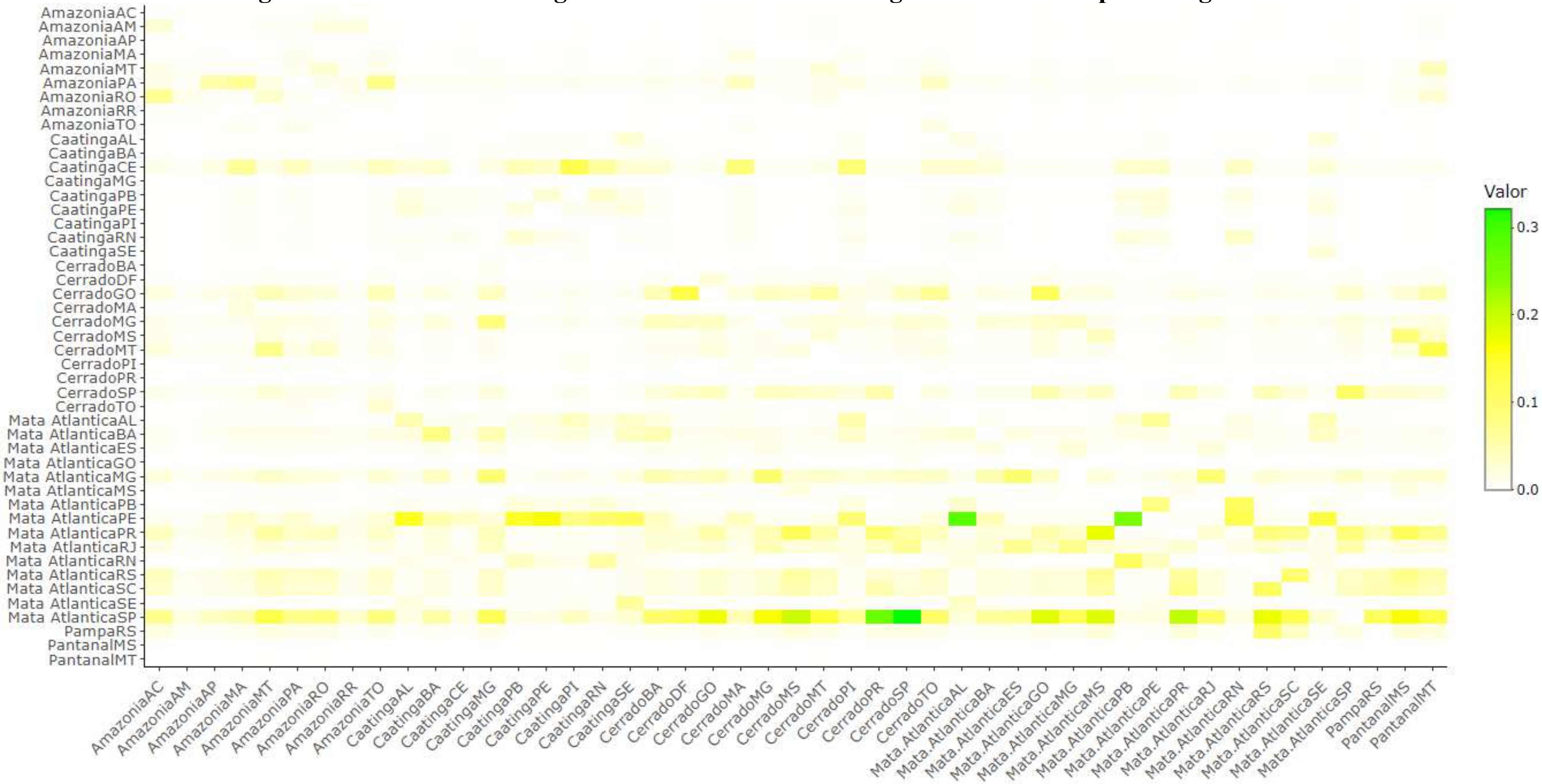
The Caatinga-CE region also stands out for its deforestation consumption from neighboring regions such as Cerrado-MA, Amazônia-MA, Caatinga-RN and Caatinga-PI. It is also possible to observe the high internal trade with content of agricultural land and of AC deforestation in the Amazônia region, as occurs with Amazônia-PA under Amazônia-MA, Amazônia-MT, and Amazônia-TO, and Amazônia-RO on Amazônia-AC.

Table 11 – Internal and external content of agricultural land and of agriculture-caused deforestation content by region – percentage values

Regions		land use		deforestation	
		Intra	Inter	Intra	Inter
R1	Amazônia-AC	42.01	57.99	49.33	50.67
R2	Amazônia-AM	86.57	13.43	86.59	13.41
R3	Amazônia-AP	71.20	28.80	72.89	27.11
R4	Amazônia-MA	50.10	49.90	50.14	49.86
R5	Amazônia-MT	31.90	68.10	34.93	65.07
R6	Amazônia-PA	50.09	49.91	49.87	50.13
R7	Amazônia-RO	53.53	46.47	53.60	46.40
R8	Amazônia-RR	78.14	21.86	78.61	21.39
R9	Amazônia-TO	38.80	61.20	38.83	61.17
R10	Caatinga-AL	56.21	43.79	56.44	43.56
R11	Caatinga-BA	49.46	50.54	49.32	50.68
R12	Caatinga-CE	79.09	20.91	77.81	22.19
R13	Caatinga-MG	30.94	69.06	31.05	68.95
R14	Caatinga-PB	59.10	40.90	59.23	40.77
R15	Caatinga-PE	58.99	41.01	58.82	41.18
R16	Caatinga-PI	51.86	48.14	54.05	45.95
R17	Caatinga-RN	60.72	39.28	60.35	39.65
R18	Caatinga-SE	46.94	53.06	46.79	53.21
R19	Cerrado-BA	38.81	61.19	42.57	57.43
R20	Cerrado-DF	47.74	52.26	56.24	43.76
R21	Cerrado-GO	38.96	61.04	43.47	56.53
R22	Cerrado-MA	51.90	48.10	51.99	48.01
R23	Cerrado-MG	38.38	61.62	39.40	60.60
R24	Cerrado-MS	31.76	68.24	33.67	66.33
R25	Cerrado-MT	38.12	61.88	43.77	56.23
R26	Cerrado-PI	37.17	62.83	60.09	39.91
R27	Cerrado-PR	32.94	67.06	36.65	63.35
R28	Cerrado-SP	26.33	73.67	44.88	55.12
R29	Cerrado-TO	37.90	62.10	37.81	62.19
R30	Mata Atlântica-AL	39.04	60.96	51.08	48.92
R31	Mata Atlântica-BA	54.60	45.40	54.47	45.53
R32	Mata Atlântica-ES	59.63	40.37	60.80	39.20
R33	Mata Atlântica-GO	30.67	69.33	35.71	64.29
R34	Mata Atlântica-MG	54.44	45.56	54.70	45.30
R35	Mata Atlântica-MS	26.26	73.74	31.20	68.80
R36	Mata Atlântica-PB	41.61	58.39	53.12	46.88
R37	Mata Atlântica-PE	56.91	43.09	68.31	31.69
R38	Mata Atlântica-PR	43.40	56.60	56.35	43.65
R39	Mata Atlântica-RJ	61.45	38.55	61.65	38.35
R40	Mata Atlântica-RN	54.43	45.57	65.36	34.64
R41	Mata Atlântica-RS	32.32	67.68	55.57	44.43
R42	Mata Atlântica-SC	53.87	46.13	57.35	42.65
R43	Mata Atlântica-SE	50.21	49.79	50.58	49.42
R44	Mata Atlântica-SP	47.71	52.29	59.54	40.46
R45	Pampa-RS	62.60	37.40	62.96	37.04
R46	Pantanal-MS	25.88	74.12	25.89	74.11
R47	Pantanal-MT	20.98	79.02	20.85	79.15

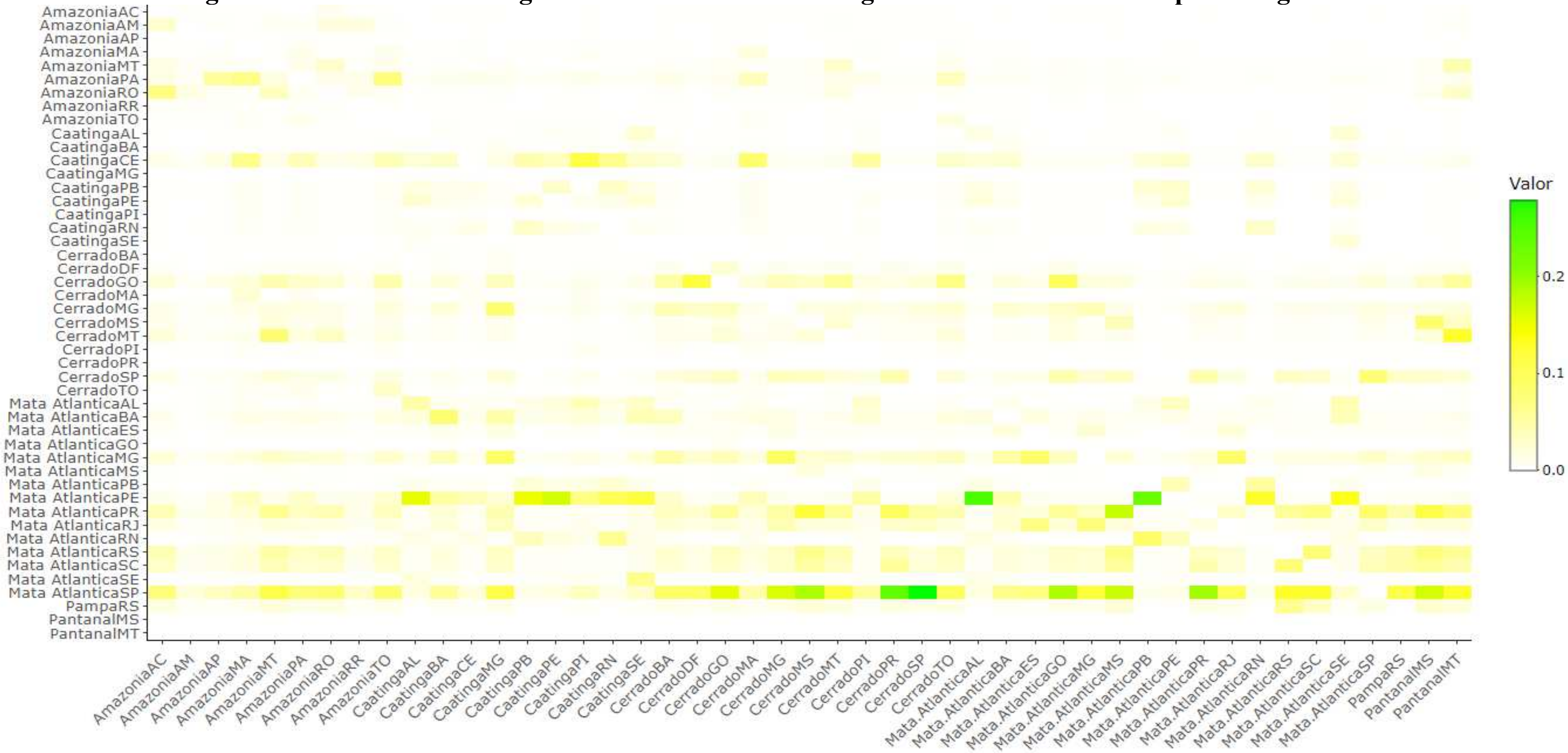
Source: elaborated by the author based on the results.

Figure 9 – Matrix of interregional trade with embodied agricultural land – percentage values



Source: elaborated by the author in R software.

Figure 10 – Matrix of interregional trade with embodied agricultural deforestation – percentage values



Source: elaborated by the author in R software.

The results show the pressure exerted by trade with the biomes-UF from the Southeast and South of the country on land use and deforestation both in their territory and in others, and the concentration of the impacts of trade with biomes-UF from the North and Northeast in their regions, without wide spreading to the national territory. There is thus a displacement of agricultural land and AC deforestation from the North to the South of the country – regions that concentrate a large part of the national population and economic activities.

4.2.2 Content of agricultural land and agriculture-caused deforestation by activity

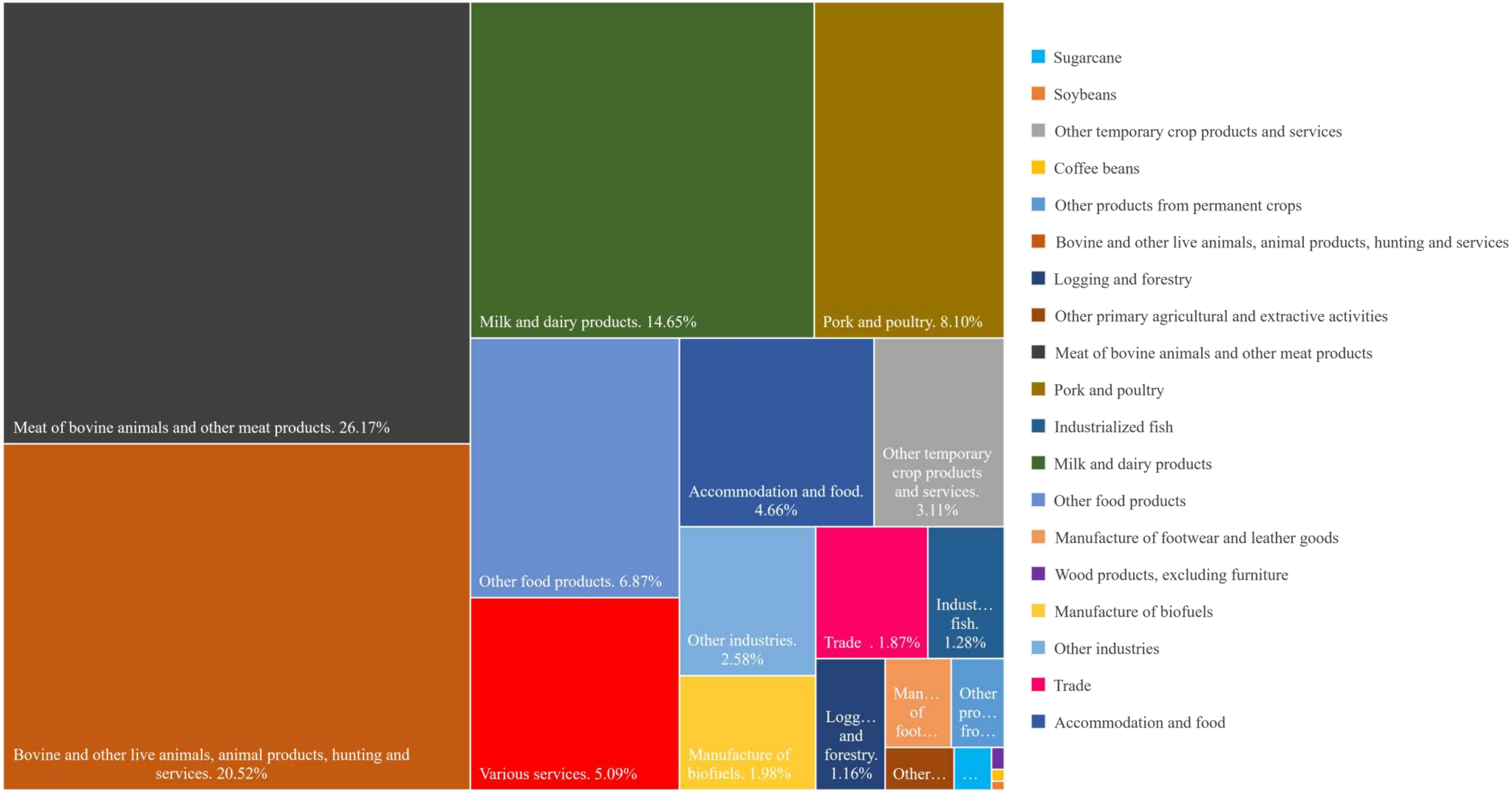
Regarding the sectoral pattern of the agricultural land and AC deforestation footprint, Figures 11 and 12[19], it can be seen that activities directly linked to cattle, such as bovine and other live animals, animal products, hunting and services (activity 6) and meat of bovine animals and other meat products (activity 11) account for 46.69% of the land footprint and 53.80% of the deforestation footprint of Brazilian biomes. This result is in line with other works in the literature, such as Pendrill *et al*. (2019a), who observed the dominance of cattle meat in the embodied deforestation in Brazil. However, it should be noted that the percentages are not directly comparable since the data used in this work are detailed at the regional level, by biome-UF, the indicators are built taking into account final consumption using an input-output matrix instead of a physical-based bilateral trade-model as used by the authors, besides having more detailed data on land use and deforestation.

Other activities with high content of proteins such as pork and poultry meat and milk and dairy products also stand out representing, together, 22.75% of the land footprint and 23.54% of deforestation footprint. Appendix C brings the corresponding percentage of each of the 36 activities.

There are regional variations in terms of the agricultural land and AC deforestation footprint among activities depending on the productive structure of the regions, as shown in Appendix D, which highlights the higher-than-average participation among the 36 activities analyzed in each of the 47 biomes-UF. Examples are the land footprint in the manufacture of footwear and leather goods in Caatinga-CE, a state characterized as one of the largest producers

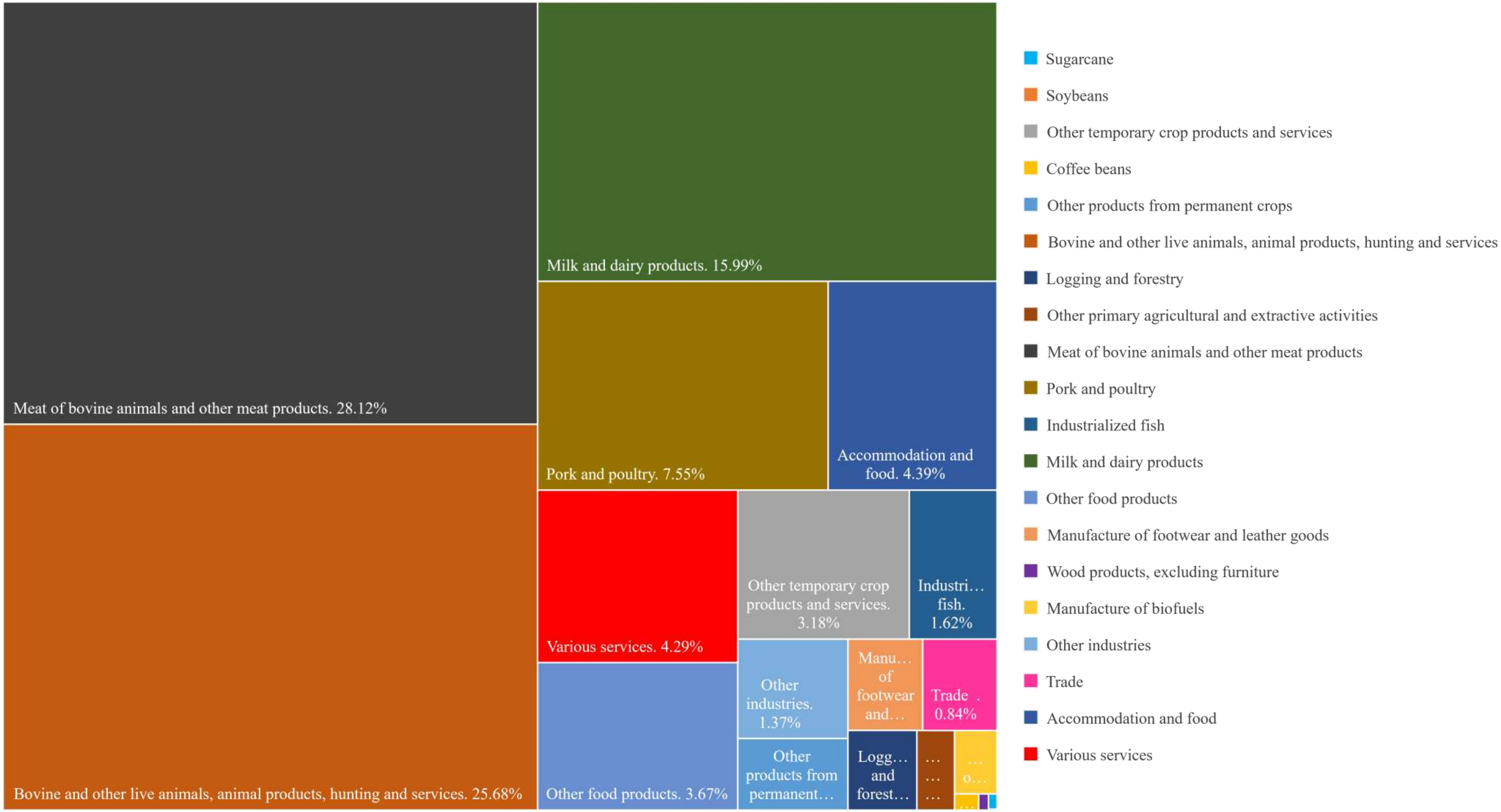
[19] For visualization purposes, the 36 activities (Table 2) were simplified into 20. Other primary agricultural and extractive activities corresponds to the sum of activities 7, 9, and 10; Other industries represents the sum of activities 16, 17, 18, 21, 22, 23, 25, 26, 27, 28, 29 and 30, and Various services includes activities 31, 33, 34, and 36.

Figure 11 – Embodied agricultural land by activities



Source: elaborated by the author based on the results.

Figure 12 – Embodied agricultural deforestation by activities



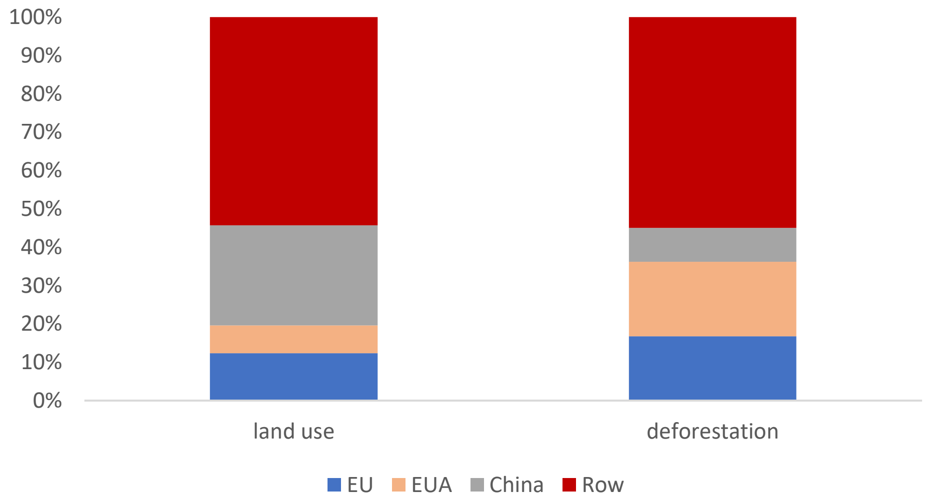
Source: elaborated by the author based on the results.

of footwear in the country, land and deforestation footprints in petroleum refining and coking plants in Mata Atlântica-RJ, state with a prominent petroleum industry, and the footprints in the manufacture of biofuels in Cerrado-GO, Mata Atlântica-GO, and Mata Atlântica-MS, which occupy leading positions in the production of biofuels in Brazil.

4.3 Land and deforestation embodied in Brazilian international trade

The total value of agricultural land and AC deforestation embodied in international trade are, in that order, 74831573 and 1298227 million (reais) ha, less than in intranational trade. Figure 13 shows the distribution of land and deforestation embodied in the trade with the EU, US, China, and the rest of the world (Row). Together, the EU, US and China account for 45.71% of the land use and 45.01% of the AC deforestation present in exports from Brazilian biomes, respectively – justifying the disaggregation of these countries and regions and the analysis of their impacts separately on Brazilian trade. The following subsections provide detailed analyses for agricultural land and AC deforestation in Brazilian international trade.

Figure 13 – Distribution of trade with agricultural land and agriculture-caused deforestation by countries/regions



Source: elaborated by the author based on the results.

4.3.1 Embodied agricultural land

Except for the US, where the Caatinga accounts for 63.19% of trade with agricultural land content, followed by the Mata Atlântica with 28.58%; in the EU, China, and the rest of the world, the Mata Atlântica followed by the Cerrado are the biomes most affected by trade with land content, as shown in Figure 14, which presents the distribution of trade with land content by biome and countries. The percentages for the Mata Atlântica and Cerrado are 37.51% and 29.12% respectively in trade with the EU, 50.12% and 30.32% with China and 50.84% and 20.89% with the rest of the world (Row).

Table 12 breaks down the percentages by biome-UF, highlighting the shares above 5%. Altogether, of the 47 biomes-UF, 11 stand out for presenting part of the agricultural land content in Brazilian trade destined for some specific country/region: Amazônia-PA, Caatinga-CE, Caatinga-PI, Cerrado-MT, Cerrado-SP, Mata Atlântica-MG, Mata Atlântica-PR, Mata Atlântica-RS, Mata Atlântica-SC, Mata Atlântica-SP and Pampa-RS.

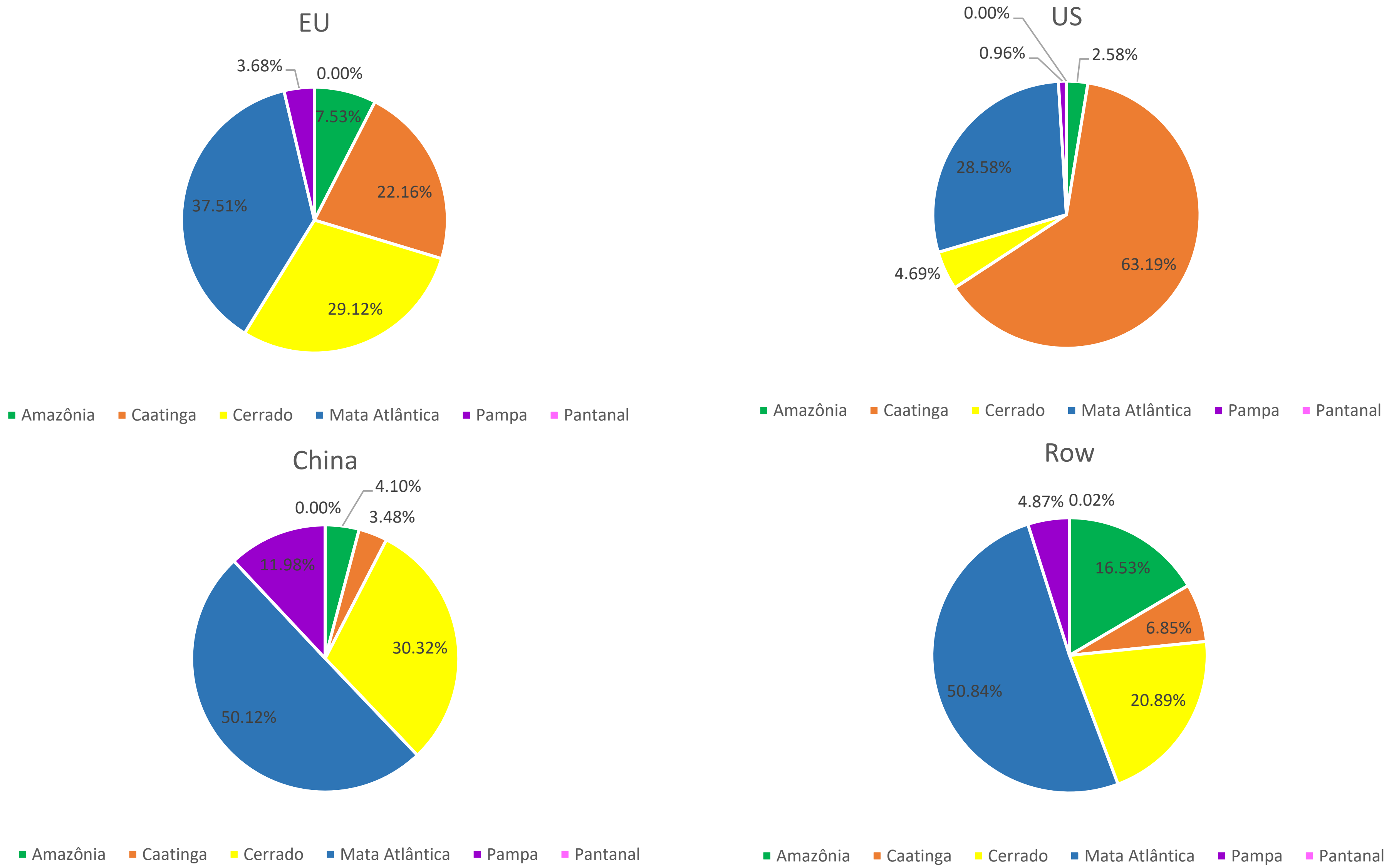
In sectoral terms, trade with agricultural land content is concentrated in the food sectors, as observed in Table 13. As in domestic trade, activities linked to bovines and their meats (activities 6 and 11) together account for most of the trade with agricultural land content, this percentage being 43.94% in the case of the EU, 72.68% with the US, and 37.76% with the rest of the world. Except for China, where most of the land content is tied to soybeans, 83.03%.

Other activities stand out in trade with the EU, which are: soybeans (18.50%), coffee (7.34%) and other food products (14.45%). In the case of trade with China, we can also highlight the pork and poultry meat activity (5.31%) – activity that holds most of the land content in the trade with the rest of the world (27.95% of the total). In the rest of the world, other temporary crops (7.11%) and other food products (8.05%) also stand out.

The land content embodied in proteins trade, whether in bovines (activities 6 and 11, respectively), pork and poultry meat, and even industrialized fish purchased by the US (3.11%), draws attention.

It should be noted that these results, although they are linked to the export structure of the countries, as occurs with typical cases such as the significant export of soy to China and coffee to the EU as shown in Appendix E, are not limited to this trade structure. These results are also linked to trade interrelationships between Brazilian regions and the physical land use (and deforestation) in these regions. Thus, the importance of an interregional economic-environmental modeling in this type of analysis is highlighted.

Figure 14 – Distribution of trade with agricultural land content by biome and country/region



Source: elaborated by the author based on the results.

Table 12 – Distribution of trade with agricultural land content by countries/regions and biome-UF – percentage values

	Regions	EU	US	China	Row
R1	Amazônia-AC	0.00	0.00	0.00	0.00
R2	Amazônia-AM	0.02	0.02	0.00	0.21
R3	Amazônia-AP	0.72	0.13	0.00	0.43
R4	Amazônia-MA	0.12	0.11	0.01	0.86
R5	Amazônia-MT	4.62	0.06	3.47	2.66
R6	Amazônia-PA	1.30	2.24	0.59	7.98
R7	Amazônia-RO	0.75	0.02	0.03	3.64
R8	Amazônia-RR	0.00	0.00	0.00	0.00
R9	Amazônia-TO	0.00	0.00	0.00	0.75
R10	Caatinga-AL	0.00	0.00	0.00	0.00
R11	Caatinga-BA	0.27	0.28	0.01	0.08
R12	Caatinga-CE	8.18	15.68	1.91	1.86
R13	Caatinga-MG	0.00	0.00	0.00	0.00
R14	Caatinga-PB	0.04	0.02	0.00	0.05
R15	Caatinga-PE	0.32	0.08	0.00	0.08
R16	Caatinga-PI	11.96	46.93	1.55	4.07
R17	Caatinga-RN	1.38	0.20	0.00	0.72
R18	Caatinga-SE	0.00	0.00	0.00	0.01
R19	Cerrado-BA	1.81	0.05	2.93	1.10
R20	Cerrado-DF	0.01	0.00	0.09	0.39
R21	Cerrado-GO	4.43	0.43	3.20	3.92
R22	Cerrado-MA	2.46	0.13	2.59	0.45
R23	Cerrado-MG	2.60	0.64	2.26	3.17
R24	Cerrado-MS	1.52	0.11	1.90	2.06
R25	Cerrado-MT	8.88	0.10	12.78	6.37
R26	Cerrado-PI	0.35	0.00	0.91	0.20
R27	Cerrado-PR	0.00	0.03	0.00	0.01
R28	Cerrado-SP	5.29	3.19	2.40	2.72
R29	Cerrado-TO	1.77	0.00	1.25	0.48
R30	Mata Atlântica-AL	0.14	0.19	0.04	0.29
R31	Mata Atlântica-BA	0.65	1.06	0.28	0.56
R32	Mata Atlântica-ES	0.78	1.41	0.08	0.35
R33	Mata Atlântica-GO	0.35	0.00	0.26	0.09
R34	Mata Atlântica-MG	5.08	3.96	0.27	1.58
R35	Mata Atlântica-MS	0.33	0.06	0.81	0.95
R36	Mata Atlântica-PB	0.02	0.07	0.00	0.01
R37	Mata Atlântica-PE	0.14	0.18	0.00	0.19
R38	Mata Atlântica-PR	9.43	2.18	24.23	13.88
R39	Mata Atlântica-RJ	0.32	3.24	0.17	0.76
R40	Mata Atlântica-RN	0.01	0.04	0.00	-0.01
R41	Mata Atlântica-RS	1.94	0.65	6.26	4.21
R42	Mata Atlântica-SC	10.06	3.75	5.71	13.46
R43	Mata Atlântica-SE	0.19	0.01	0.00	0.01
R44	Mata Atlântica-SP	8.08	11.78	12.01	14.49
R45	Pampa-RS	3.68	0.96	11.98	4.87
R46	Pantanal-MS	0.00	0.00	0.00	0.02
R47	Pantanal-MT	0.00	0.00	0.00	0.00

Source: elaborated by the author based on the results.

The relationship between the regional and sectorial shares of trade with agricultural land content is also noteworthy. For example, the activity bovine and other live animals, animal products, hunting and services (activity 6) corresponds to 64.50% of the trade with agricultural land content destined for the US, which is related to the fact that the regions most impacted by the trade with this country are large producers of this activity, namely Caatinga-PI and Caatinga-CE. Another example is China, in which 83.03% of the trade with land content is concentrated in soybeans, affecting large producing regions in this segment such as Mata Atlântica-PR and Cerrado-MT.

Table 13 – Distribution of trade with agricultural land content by country/region and activity – percentage values

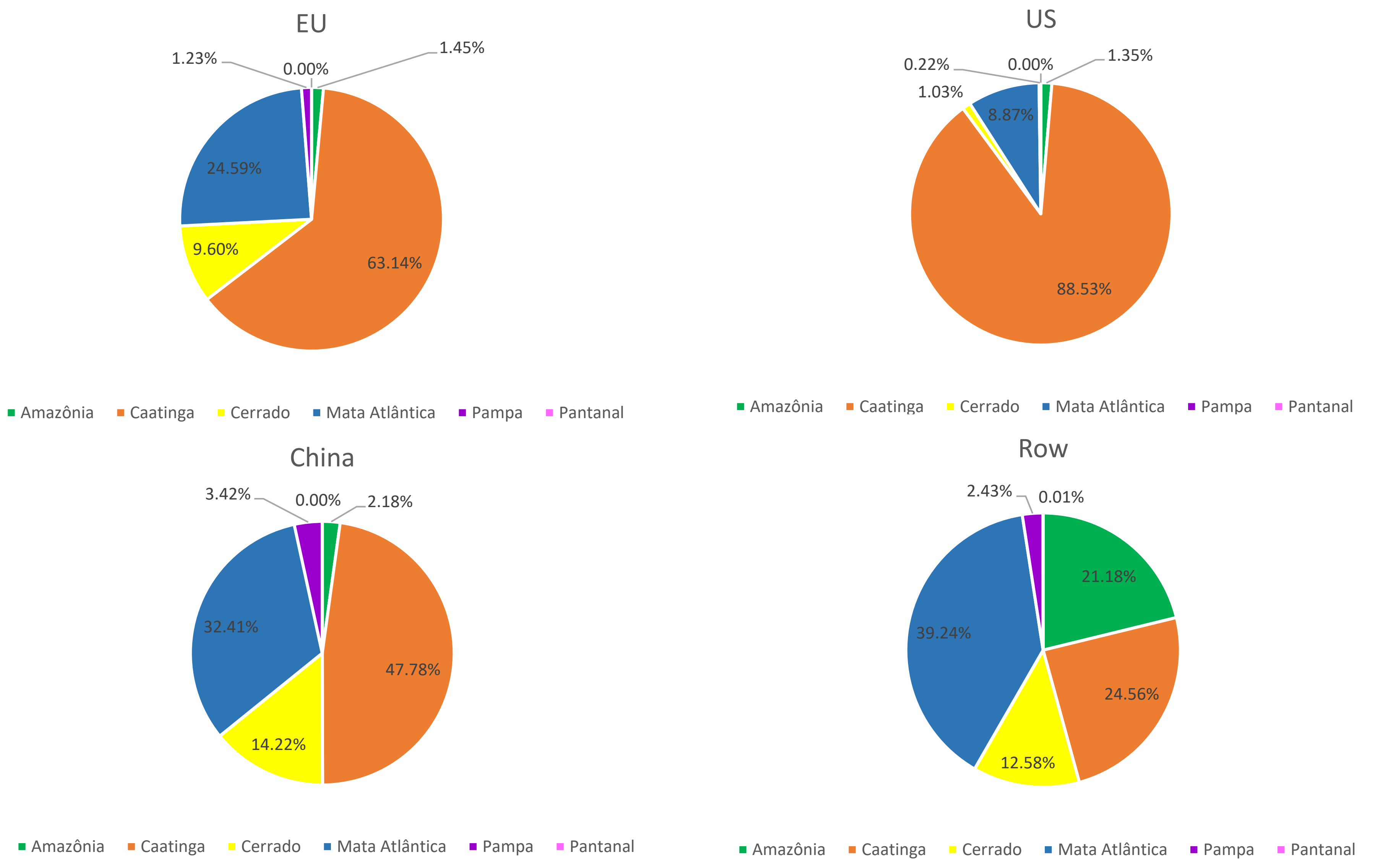
	Activities	EU	US	China	Row
1	Sugarcane	0.00	0.00	0.00	0.00
2	Soybeans	18.50	0.01	83.03	7.70
3	Other temporary crop products and services	3.93	0.99	0.49	7.11
4	Coffee beans	7.34	4.84	0.02	0.86
5	Other products from permanent crops	0.35	0.56	0.02	0.09
6	Bovine and other live animals, animal products, hunting and services	19.89	64.50	3.44	12.76
7	Pigs, poultry and eggs	0.00	0.00	0.00	0.08
8	Logging and forestry	1.48	0.43	0.28	1.26
9	Fishing and aquaculture	0.01	0.12	0.00	0.01
10	Extractive activities	0.37	0.33	0.44	0.22
11	Meat of bovine animals and other meat products	24.05	8.18	3.86	25.00
12	Pork and poultry	2.96	0.04	5.31	27.95
13	Industrialized fish	0.47	3.11	0.24	0.68
14	Milk and dairy products	0.01	0.11	0.00	0.86
15	Other food products	14.45	4.63	1.42	8.05
16	Beverages	0.02	0.47	0.02	0.06
17	Tobacco products	0.43	0.17	0.01	1.40
18	Manufacture of textiles, clothing and accessories	0.03	0.08	0.01	0.07
19	Manufacture of footwear and leather goods	1.57	1.42	0.54	0.63
20	Wood products, excluding furniture	0.53	2.34	0.03	0.30
21	Cellulose, paper and paper products manufacturing	1.34	1.24	0.59	0.38
22	Various industries	0.06	0.25	0.00	0.15
23	Petroleum refining and coking plants	0.40	0.47	0.00	0.35
24	Manufacture of biofuels	0.49	0.33	0.03	0.89
25	Chemical products	0.54	0.80	0.07	0.60
26	Fertilizers, pesticides and disinfectants	0.00	0.01	0.00	0.03
27	Mineral products, steel, metallurgy and related	0.41	1.34	0.10	0.34
28	Machinery and equipment	0.11	0.43	0.02	0.17
29	Manufacture of transport vehicles, including parts	0.11	0.99	0.02	0.24
30	Furniture	0.01	0.05	0.00	0.02
31	Energy, gas, water, sewage, waste management and other utilities	0.00	0.00	0.00	0.00
32	Trade	0.00	0.00	0.00	0.21
33	Transportation	0.00	0.00	0.00	0.13
34	Warehousing and postal services	0.00	0.00	0.00	0.03
35	Accommodation and food	0.00	0.00	0.00	1.14
36	Various services	0.12	1.71	0.01	0.22

Source: elaborated by the author based on the results.

4.3.2 Embodied agricultural deforestation

Figure 15 shows the panorama of trade with AC deforestation content by biome and country/region. The Caatinga is the biome most affected by trade with AC deforestation

Figure 15 – Distribution of trade with agriculture-caused deforestation content by biome and country/region



Source: elaborated by the author based on the results.

content, accounting, respectively, for 63.14% of the deforestation content present in trade with the EU, 88.53% with the US and 47.78% with China. The biomes-UF Caatinga-CE and Caatinga-PI concentrate most of this percentage as shown in Table 14, together accounting for 59.95%, 88.20% and 47.74% of the trade with deforestation content destined for the EU, US and China, respectively.

The Mata Atlântica is the second most affected biome by trade with embodied deforestation destined for the EU, US and China and the first most impacted biome by trade with the rest of the world, with emphasis on four of its UF-biomes: Mata Atlântica-MG, Mata Atlântica-PR, Mata Atlântica-SC and Mata Atlântica-SP (Table 14). In the trade with the rest of the world, the region that stands out the most is Amazônia-PA, which is responsible for 13.32% of the total trade with AC deforestation content.

In general terms, the Mata Atlântica and Cerrado dominate the land use for the majority of the countries/regions analyzed in international trade, and the Caatinga scenario is the worst in the trade with deforestation content. However, international concerns turn to other biomes, mainly to the Amazônia, which receives preservation resources (FUNDO AMAZÔNIA, 2023). This result is even more worrying if we consider studies that predict that the Caatinga may be the biome most affected by zero deforestation policies in the Amazônia (SOUZA, 2022).

Sectorally, the deforestation content is mainly derived from trade of bovine and other live animals, animal products, hunting, and services activity, as shown in Table 15 – highlighting the values above 5%. This activity corresponds to 59.10% of the trade with the EU, 87.70% with the US, 47.53% with China, and 34.51% with the rest of the world. Meat of bovine animals and other meat products stand out in the EU (14.54%), China (9.41%), and the Row (22.79%). Meat of pork and poultry also shows high deforestation content in trade with China (12.12%) and the rest of the world (22.14%).

Also noteworthy are the deforestation content present in coffee purchased by the EU (9.87%) and the US (3.14%), soybeans by China (22.75%), and other temporary crops in the rest of the world (8.02%) and the EU (4.79%).

The relationship between sectoral and regional deforestation content is intrinsic, explaining the high deforestation content present in the bovine activity (6) and the concentration of regional effects in the Caatinga regions, as well as other examples, such as the coffee trade with deforestation content for the EU and the effects of this block on regions such as Mata Atlântica-MG, a major producer of this activity.

Table 14 – Distribution of trade with agriculture-caused deforestation content by country/regions and biomes-UF – percentage values

	Regions	EU	US	China	Row
R1	Amazônia-AC	0.00	0.00	0.00	0.00
R2	Amazônia-AM	0.02	0.01	0.00	0.26
R3	Amazônia-AP	0.05	0.06	0.00	0.04
R4	Amazônia-MA	0.07	0.04	0.03	1.56
R5	Amazônia-MT	0.87	0.01	0.45	1.87
R6	Amazônia-PA	0.40	1.22	1.66	13.32
R7	Amazônia-RO	0.04	0.01	0.04	3.17
R8	Amazônia-RR	0.00	0.00	0.00	0.00
R9	Amazônia-TO	0.00	0.00	0.00	0.94
R10	Caatinga-AL	0.00	0.00	0.00	0.00
R11	Caatinga-BA	0.23	0.14	0.03	0.12
R12	Caatinga-CE	31.69	31.77	32.97	9.92
R13	Caatinga-MG	0.00	0.00	0.00	0.00
R14	Caatinga-PB	0.04	0.01	0.00	0.07
R15	Caatinga-PE	0.19	0.02	0.01	0.08
R16	Caatinga-PI	28.26	56.44	14.77	12.91
R17	Caatinga-RN	2.72	0.15	0.00	1.46
R18	Caatinga-SE	0.00	0.00	0.00	0.01
R19	Cerrado-BA	0.41	0.04	0.72	0.15
R20	Cerrado-DF	0.00	0.00	0.01	0.30
R21	Cerrado-GO	2.30	0.10	2.71	2.79
R22	Cerrado-MA	0.27	0.03	0.72	0.14
R23	Cerrado-MG	1.44	0.24	0.54	2.24
R24	Cerrado-MS	0.59	0.02	1.11	1.16
R25	Cerrado-MT	2.45	0.03	4.97	3.75
R26	Cerrado-PI	0.05	0.00	0.41	0.24
R27	Cerrado-PR	0.00	0.01	0.00	0.00
R28	Cerrado-SP	1.83	0.57	2.68	1.35
R29	Cerrado-TO	0.26	0.00	0.35	0.45
R30	Mata Atlântica-AL	0.07	0.05	0.08	0.21
R31	Mata Atlântica-BA	0.38	0.26	0.57	0.38
R32	Mata Atlântica-ES	0.49	0.40	0.15	0.23
R33	Mata Atlântica-GO	0.09	0.00	0.05	0.02
R34	Mata Atlântica-MG	5.18	1.92	0.39	1.51
R35	Mata Atlântica-MS	0.10	0.01	0.40	0.47
R36	Mata Atlântica-PB	0.01	0.02	0.00	0.01
R37	Mata Atlântica-PE	0.06	0.06	0.01	0.15
R38	Mata Atlântica-PR	4.73	0.48	14.18	10.12
R39	Mata Atlântica-RJ	0.09	0.83	0.23	0.37
R40	Mata Atlântica-RN	0.00	0.01	0.00	-0.01
R41	Mata Atlântica-RS	0.80	0.15	2.28	3.73
R42	Mata Atlântica-SC	6.06	1.04	6.54	11.10
R43	Mata Atlântica-SE	0.09	0.00	0.00	0.01
R44	Mata Atlântica-SP	6.42	3.62	7.54	10.93
R45	Pampa-RS	1.23	0.22	3.42	2.43
R46	Pantanal-MS	0.00	0.00	0.00	0.01
R47	Pantanal-MT	0.00	0.00	0.00	0.00

Source: elaborated by the author based on the results.

Table 15 – Distribution of trade with agriculture-caused deforestation content by country/region and activity – percentage values

	Activities	EU	US	China	Row
1	Sugarcane	0.00	0.00	0.00	0.00
2	Soybeans	1.03	0.00	22.75	0.63
3	Other temporary crop products and services	4.79	0.41	1.20	8.02
4	Coffee beans	9.87	3.14	0.09	1.42
5	Other products from permanent crops	0.36	0.44	0.05	0.15
6	Bovine and other live animals, animal products, hunting and services	59.10	87.70	47.53	34.51
7	Pigs, poultry and eggs	0.00	0.00	0.00	0.06
8	Logging and forestry	0.25	0.05	0.24	0.21
9	Fishing and aquaculture	0.01	0.04	0.00	0.01
10	Extractive activities	0.16	0.05	0.64	0.11
11	Meat of bovine animals and other meat products	14.54	2.38	9.41	22.79
12	Pork and poultry	1.74	0.01	12.12	22.14
13	Industrialized fish	0.32	1.96	1.16	0.97
14	Milk and dairy products	0.01	0.03	0.00	0.66
15	Other food products	4.80	0.95	1.69	3.63
16	Beverages	0.01	0.06	0.01	0.02
17	Tobacco products	0.30	0.08	0.04	1.32
18	Manufacture of textiles, clothing and accessories	0.02	0.03	0.02	0.06
19	Manufacture of footwear and leather goods	1.24	0.56	1.58	0.64
20	Wood products, excluding furniture	0.21	0.48	0.05	0.16
21	Cellulose, paper and paper products manufacturing	0.58	0.31	1.00	0.20
22	Various industries	0.02	0.05	0.01	0.08
23	Petroleum refining and coking plants	0.06	0.04	0.00	0.07
24	Manufacture of biofuels	0.05	0.02	0.01	0.13
25	Chemical products	0.24	0.20	0.14	0.44
26	Fertilizers, pesticides and disinfectants	0.00	0.00	0.00	0.01
27	Mineral products, steel, metallurgy and related	0.16	0.28	0.18	0.19
28	Machinery and equipment	0.04	0.07	0.04	0.08
29	Manufacture of transport vehicles, including parts	0.04	0.19	0.03	0.12
30	Furniture	0.00	0.01	0.00	0.01
31	Energy, gas, water, sewage, waste management and other utilities	0.00	0.00	0.00	0.00
32	Trade	0.00	0.00	0.00	0.07
33	Transportation	0.00	0.00	0.00	0.04
34	Warehousing and postal services	0.00	0.00	0.00	0.02
35	Accommodation and food	0.00	0.00	0.00	0.87
36	Various services	0.06	0.43	0.02	0.15

Source: elaborated by the author based on the results.

Intranational and international trade results are not sensitive to the time of land use and deforestation, as shown at Appendix F section.

5 CONCLUSIONS

This thesis aimed to evaluate the agricultural land and AC deforestation embodied in Brazilian trade relations with a focus on the impacts on the six biomes in the country: the Amazônia, Caatinga, Cerrado, Mata Atlântica, Pampa and Pantanal. The analysis was done both at the intranational level, observing how the regions (biomes-UF) relate to each other in this trade, and at the international level, focusing on Brazil's trading partners, namely the EU, US, China, and the rest of the world (Row). In addition to the spatial dimension, we observed which economic activities most contribute to trade with agricultural land and AC deforestation.

To achieve the purpose of this thesis, some steps were fundamental to understand the research problem and the methodological strategy to be employed. To contextualize how the impacts of trade on land use and deforestation have been addressed in the literature, chapter 2 presents a survey of theoretical and empirical works. In addition, this chapter discusses how national regulations have been addressed on land use and deforestation, which can indirectly affect trade, and also examines international environmental regulations that can directly affect international trade.

Chapter 3 presents the methodological scope of the thesis, composed by the construction of an interregional input-output matrix called MIP-Biomas, which has an opening for 47 regions and 36 activities, and was built especially for the purposes of this thesis' analysis based on the IBGE matrix (2015) and data from other sources, such as RAIS, POF, IBGE, and ComexStat, which helped in the regionalization process of this matrix using the IIOAS method.

This research innovates by combining MIP-Biomas data with detailed satellite imagery data from the Mapbiomas platform – which has spatial detail for municipalities (at the lowest level) and sectoral detail for specific agricultural cultures, pasture and forestry. Thus, this thesis fits into the literature that evaluates land and deforestation footprints by combining physical data on agricultural land use and AC deforestation with monetary data from the input-output matrix, within the scope of economic-environmental modeling, and consisting of the first disaggregated analysis for the Brazilian case covering the entire national territory.

The thesis also distinguishes itself from others presented in the literature by making use of the indicator proposed by Fan, Liu, and Wang (2022) to measure land and deforestation content in trade for an end-user assessment, which has been disaggregated in this research for the assessments of intranational and international trade separately.

Chapter 4 shows the results, divided into three subsections. The first consists of an exploratory analysis of data on land use and deforestation in agricultural activities analyzed using data from Mapbiomas. The second and third sections present, respectively, the impacts of intranational and international trade on land use and deforestation in Brazilian biomes.

It was shown that most of the content of agricultural land and of AC deforestation comes from Brazilian domestic demand, corroborating the findings of Pendrill *et al*. (2019a). At the intranational level, the Mata Atlântica biome stands out for the impacts presented on its own territory and on the other Brazilian biomes. The Cerrado, Mata Atlântica, and Amazônia biomes together account for 86.30% of trade with agricultural land content, and the Amazônia, Caatinga, and Cerrado biomes account for 82.27% of trade with AC deforestation content. It was observed that trade with agricultural land and AC deforestation from North and Northeast regions is concentrated in their own territories, differently from what occurs with the biomes-UF of the South and Southeast regions, with greater spreading of their impacts in the national territory. In general, it can be said that there is a displacement of land and deforestation from the North to the South of the country.

In terms of international trade, the Mata Atlântica and the Cerrado stand out in terms of trade with agricultural land content destined for the EU, China, and the rest of the world; in the case of the US, the Caatinga accounts for 63.19% of this trade. The Caatinga is also placed as the biome most impacted by trade with AC deforestation content, except for trade with the rest of the world, where the Mata Atlântica ranks first, followed by the Caatinga.

In sectorial terms, both at the intranational and international levels, it is observed that a large part of the content of agricultural land and of AC deforestation comes from the food sectors directly and indirectly linked to land use and deforestation, especially bovines and their meats, as well as other proteins such as milk and dairy products, poultry and pork. Thus, policies for better land use in these activities, such as increased productivity, and mitigation of deforestation without prejudice to the protein quality of the diet of Brazilians are necessary.

The patterns found by this thesis are not sensitive to the time of land use and deforestation as shown in the sensitivity analysis. The results found here should be considered by environmental policy makers since national conservation efforts have been concentrated mainly in the Amazônia biome, which has the largest area of legal reserve. This biome also captures a large part of the international conservation resources However, other biomes have been affected by trade, as is the case of deforestation from the Caatinga. In addition, countries like the EU have signaled the possibility of barriers to trade with deforestation content, and it is important to know the source of this content.

The analytical framework presented in this study, which is accessible to the public, has the potential to be applied to various aspects of policy analysis. Although the analysis cannot be performed separately for legal and illegal deforestation due to data limitations, it is expected that the identification of the problem, main regions/countries and activities that most influence land use and deforestation in Brazilian trade, will provide valuable information for policy makers.

It is important to acknowledge that the accuracy of the MIP-Biomas and the associated indicators of agricultural land and AC deforestation embodied in trade depend on the quality and availability of input data, including input-output tables, land use and deforestation datasets, trade data, and other relevant sources. Continuous efforts should be made to update and improve these data sources, enhancing the accuracy of indicators and supporting informed decision-making regarding sustainable land use and trade practices in Brazil.

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APPENDIX A[20] – Definition of the MIP-Biomas activities

A.1 Commodity-by-Commodity approach

In traditional n-sector input-output models, each element of the matrix Z= $[z_{ij}]$, nxn, represents the value of purchases of industry (sector) i produced by industry j. In addition, there is an n-element vector representing the total industry output X= $[x_{ij}]$, where:

$$X_i = z_{i1} + \ldots + z_{in} + Y_i \quad \text{A.1}$$

and Y are the sales to final demand. In matrix form, we have:

$$X = Z + Y \quad \text{A.2}$$

The technical coefficients, A= $[a_{ij}]$, are given by:

$$A = Z\hat{X}^{-1} \quad \text{A.3}$$

Isolating Z and substituting A.3 into A.2 we have the traditional system, where the output X is presented as:

$$\mathrm{X} = AX + Y \quad \text{A.4}$$

In the commodity-by-industry framework, the matrix of intersectoral transactions, Z, is initially replaced by the use matrix, U= $[u_{ij}]$ where u_{ij} is the value of purchases of commodity i by industry j. U is known as the absorption matrix and the intuition behind this matrix is that industries use commodities to produce commodities. Compared to equation A.1, the corresponding commodity output is:

$$Q_i = u_{i1} + u_{i2} + \cdots + E_i \quad \text{A.5}$$

[20] This section is based on chapter 5 by Miller and Blair (2009).

which means that the total production of a commodity is the sum of all the amounts of that commodity consumed by industries in the economy plus any sales of that commodity to final customers (E).

Consider another basic identity from the general input-output model, the sum of all interindustry inputs to a production process, plus any value-added inputs, is equal to the value of the total output of that industry, namely:

$$X_j = z_{1j} + z_{2j} + \dots + z_{nj} + W_j \quad \text{A.6}$$

In the context of commodity-by-industry this is translate to the sum of all commodity inputs plus any value-added inputs is equal to the value of that industry's total output, that is,

$$X_j = u_{1j} + u_{2j} + \dots + u_{mj} + W_j \quad \text{A.7}$$

In parallel to the matrix of technical coefficients, A, we have the matrix B, which is given by:

$$B = U\hat{X}^{-1} \quad \text{A.8}$$

The dimension of B[21] is usually commodity-by-industry. However, from this system one can reach commodity-by-commodity, industry-by-industry and industry-by-commodity dimensions. The make matrix, V, also known as the production matrix, is an important way to arrive at these varied dimensions. Each element in V, v_{ij}, shows the value of the output of commodity j produced by industry i, in one industry-by-commodity dimension. In matrix V both the total output of the industry, x, and the total output of commodities, q, are accounted for.

The total production of any industry is found in the sum of all commodities produced by that industry. This total is the sum of the row of V:

[21] Not to be confused with the Leontief matrix used in the empirical strategy sections.

$$X_j = v_{j1} + \cdots + v_{jm}$$ A.9

Or: $X = V_i$ A.10

Similarly, total output of any commodity can be found by summing over all industries that produce the commodity. These totals are the columns sums of V:

$$Q_j = v_{1j} + \cdots + v_{nj}$$ A.11

$$Q' = i'V$$ A.12

$$Q = (V')i$$ A.13

To derive alternative requirements matrices, we can start with equation A.5, which in matrix terms gives us:

$$Q = U_i + E$$ A.14

Considering equation A.8 after post-multiplying by $\hat{X}$[22], it becomes:

$$U = BX$$ A.15

Substituting A.15 into A.14, we have:

$$Q = BX_i + E$$ A.16

This equation is analogous to the basic identity in the traditional Leontief model presented in A.4. However, B is not invertible, not being able to generate the Leontief inverse for the impact analyses. To do so, the system in A.16 needs to undergo a transformation of the Make matrix into a commodity-by-commodity matrix, as used in this thesis.

[22] Considering that $\hat{X} = X$ (MILLER; BLAIR, 2009).

Taking V as the supply matrix, with commodity-by-industry dimension, the matrix of the industry's production proportions is given by:

$$C = V'\hat{X}^{-1} \tag{A.17}$$

$$CX = V'_i \tag{A.18}$$

Substituting A.13 into A.19 and isolating X, we have:

$$X = C^{-1}Q \tag{A.19}$$

And yet, substituting A.19 into A.16, we obtain a system that can be worked out at the commodity-by-commodity level:

$$Q = B\,(C^{-1}Q) + E = (I - BC^{-1})^{-1}E \tag{A.20}$$

A.2 Products classification

Table A.1 brings the classification used in the transformation of the 127 products of the IBGE IOM (2015) into the activities of the MIP-Biomas.

Table A.1 - Classification of products in MIP-Biomas

continue

127 produtos		Classificação MIP-Biomas	
1	Rice, wheat and other cereals	3	Other temporary crop products and services
2	Grain maize	3	Other temporary crop products and services
3	Herbaceous cotton, other temporary tillage fibers	3	Other temporary crop products and services
4	Sugarcane	1	Sugarcane
5	Soybeans	2	Soybeans
6	Other products and services of temporary crops	3	Other temporary crop products and services
7	Orange	5	Other products from permanent crops
8	Coffee beans	4	Coffee beans
9	Other permanent crops	5	Other products from permanent crops
10	Bovine and other live animals, animal products, hunting and services	6	Bovine and other live animals, animal products, hunting and services
11	Milk from cows and other animals	14	Milk and dairy products
12	Pigs	7	Pigs, poultry and eggs
13	Poultry and eggs	7	Pigs, poultry and eggs
14	Products of forestry and logging	8	Logging and forestry

continue

	127 produtos		Classificação MIP-Biomas
15	Fisheries and aquaculture (fish, crustaceans and molluscs)	9	Fishing and aquaculture
16	Mineral coal	10	Extractive activities
17	Non-metallic minerals	10	Extractive activities
18	Petroleum, natural gas and support services	10	Extractive activities
19	Iron ore	10	Extractive activities
20	Non-ferrous metallic minerals	10	Extractive activities
21	Meat of bovine animals and other meat products	11	Meat of bovine animals and other meat products
22	Pork	12	Pork and poultry meat
23	Poultry meat	12	Pork and poultry meat
24	Industrialized fish	13	Industrialized fish
25	Chilled, sterilised and pasteurised milk	14	Milk and dairy products
26	Other dairy products	14	Milk and dairy products
27	Sugar	15	Other food products
28	Canned fruit, leguminous, other vegetables and fruit juices	15	Other food products
29	Vegetable and animal oils and fats	15	Other food products
30	Processed coffee	15	Other food products
31	Processed rice and products derived from rice	15	Other food products
32	Products derived from wheat, manioc or maize	15	Other food products
33	Balanced animal feeds	15	Other food products
34	Other food products	15	Other food products
35	Drinks	16	Beverages
36	Smoke products	17	Tobacco products
37	Processed textile yarn and fibres	18	Manufacture of textiles, clothing and accessories
38	Fabrics	18	Manufacture of textiles, clothing and accessories
39	Household and other textile articles	18	Manufacture of textiles, clothing and accessories
40	Articles of apparel and accessories	18	Manufacture of textiles, clothing and accessories
41	Footwear and leather products	19	Manufacture of footwear and leather products
42	Wooden products, except furniture	20	Wood products, excluding furniture
43	Cellulose	21	Cellulose, paper and paper products manufacturing
44	Paper, paperboard, packaging and paper products	21	Cellulose, paper and paper products manufacturing
45	Printing and reproduction services	22	Various industries
46	Aviation fuels	23	Petroleum refining and coking plants
47	Gasoalcohol	23	Petroleum refining and coking plants
48	Naphthas for petrochemicals	23	Petroleum refining and coking plants
49	Fuel Oil	23	Petroleum refining and coking plants
50	Diesel – biodiesel	23	Petroleum refining and coking plants
51	Other products of petroleum refining	23	Petroleum refining and coking plants
52	Ethanol and other biofuels	24	Manufacture of biofuels
53	Inorganic Chemicals	25	Chemical products
54	Fertilizers	26	Fertilizers, pesticides and disinfectants
55	Organic Chemicals	25	Chemical products
56	Resins, elastomers and man-made fibres	25	Chemical products
57	Agricultural pesticides and household disinfectants	26	Fertilizers, pesticides and disinfectants
58	Miscellaneous chemical products	25	Chemical products
59	Paints, varnishes, lacquers and varnishes	25	Chemical products
60	Perfumery, toilet soaps and cleaning products	25	Chemical products
61	Pharmaceutical products	25	Chemical products

continue

	127 produtos		Classificação MIP-Biomas
62	Rubber articles	22	Various industries
63	Plastic articles	22	Various industries
64	Cement	27	Mineral products, steel, metallurgy and related
65	Articles of cement, plaster or similar materials	27	Mineral products, steel, metallurgy and related
66	Glass, ceramic and other non-metallic mineral products	27	Mineral products, steel, metallurgy and related
67	Pig iron and ferro-alloys	27	Mineral products, steel, metallurgy and related
68	Semi-finished, flat rolled, long rolled and steel tubes	27	Mineral products, steel, metallurgy and related
69	Products of non-ferrous metallurgy	27	Mineral products, steel, metallurgy and related
70	Castings of steel and non-ferrous metals	27	Mineral products, steel, metallurgy and related
71	Metal products, excluding machinery and equipment	27	Mineral products, steel, metallurgy and related
72	Electronic componentes	28	Machinery and equipment
73	Office machinery and computer equipment	28	Machinery and equipment
74	Electronic material and communications equipment	28	Machinery and equipment
75	Measuring, test and control equipment, optical and electromedical	28	Machinery and equipment
76	Electrical machinery, apparatus and equipment	28	Machinery and equipment
77	Appliances	28	Machinery and equipment
78	Tractors and other agricultural machinery	28	Machinery and equipment
79	Machinery for mineral extraction and construction	28	Machinery and equipment
80	Other machinery and mechanical equipment	28	Machinery and equipment
81	Cars, vans and utility vehicles	29	Manufacture of transport vehicles, including parts
82	Trucks and buses, including cabin, coaches and trailers	29	Manufacture of transport vehicles, including parts
83	Parts and accessories for motor vehicles	29	Manufacture of transport vehicles, including parts
84	Aircraft, ships and other transport equipment	29	Manufacture of transport vehicles, including parts
85	Furniture	30	Furniture
86	Products of various industries	22	Various industries
87	Maintenance, repair and installation of machinery and equipment	36	Various services
88	Electricity, gas and other utilities	31	Energy, gas, water, sewage, waste management and other utilities
89	Water, sewage, recycling and waste management	31	Energy, gas, water, sewage, waste management and other utilities
90	Buildings	36	Various services
91	Infrastructure works	36	Various services
92	Specialised services for construction	36	Various services
93	Wholesale and retail trade	32	Trade
94	Inland freight transport	33	Transportation
95	Passenger land transport	33	Transportation
96	Waterborne transport	33	Transportation
97	Air transport	33	Transportation
98	Warehousing and support services for transportation	34	Warehousing and postal services
99	Postal and other delivery services	34	Warehousing and postal services
100	Hotel and similar accommodation services	35	Accommodation and food
101	Food services	35	Accommodation and food
102	Books, newspapers and magazines	36	Various services
103	Motion picture, music, radio and television services	36	Various services

conclusion

127 produtos		Classificação MIP-Biomas	
104	Telecommunications, pay TV and other related services	36	Various services
105	Development of systems and other information services	36	Various services
106	Financial intermediation, insurance and pension plans	36	Various services
107	Actual rent and real estate services	36	Various services
108	Imputed rent	36	Various services
109	Legal, accounting and consulting services	36	Various services
110	Research and development	36	Various services
111	Architectural and engineering services	36	Various services
112	Advertising and other technical services	36	Various services
113	Non-real estate rentals and management of intellectual property assets	36	Various services
114	Condominium and building services	36	Various services
115	Other administrative services	36	Various services
116	Surveillance, security and investigation services	36	Various services
117	Collective services of public administration	36	Various services
118	Welfare and social security services	36	Various services
119	Public education	36	Various services
120	Private education	36	Various services
121	Public Health	36	Various services
122	Private healthcare	36	Various services
123	Arts, culture, sport and recreation services	36	Various services
124	Employers' organisations, trade unions and other membership organisations	36	Various services
125	Maintenance of computers, telephones and household goods	36	Various services
126	Personal Services	36	Various services
127	Domestic services	36	Various services

Source: elaborated by the author.

APPENDIX B – Overview of the MIP-Biomas database

Table B.1 shows the breakdown of regional production[23] based on the origin of final demand, highlighting shares above 5%. This analysis allows us to identify how much of the total production of each region is generated to meet the intraregional final demand and how much is destined to other regions of the country (interregional) and to the rest of the world (Row).

The biomes-UF that have most of their production linked to their intraregional final demand are Amazônia-AM (R2) and Amazônia-RR (R8), with a percentage of 79% and 74%, respectively, which can be justified by the distance of these markets from the large centers. Among biomes-UF with lower participation in the product derived from their intraregional demands, that is, more linked to interregional requirements, are Mata Atlântica-GO (R33), Caatinga-MG (R13), Amazônia-MT (R5) and Caatinga-SE (R18), with respective participations of, 21%, 31%, 33% and 36%.

Regarding exports, one can observe the leadership of the regions Mata Atlântica-SP (R44) and Mata Atlântica-RJ (R39), representing, in order, 32% and 14% of the total exported product. These regions also stand out for their participation in the interregional trade of other biomes-UF.

Figure B.1 also shows the distribution of GDP among the biomes-UF, highlighting the higher percentages presented by the Southeast and South regions of the country in detriment of the North and Northeast, especially the biomes-UF located in the Mata Atlântica, such as Mata Atlântica-SP (27.19%), Mata Atlântica-RJ (11.01%), Mata Atlântica-MG (6.48%) and Mata Atlântica-PR (6.18%).

From Table B.2, we can explore the national production in agricultural activities (1 to 6 and 8), other primary agricultural and extractive activities industries (7, 9 and 10), manufactures (11-30), and services (31-36).

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[23] This measure is achieved by multiplying the inverse Leontief matrix (B) by the elements of internal demand aggregated by each region (except stock variation), and by exports vector.

Table B.1 – Breakdown of regional production based on origin of final demand – percentage values continue

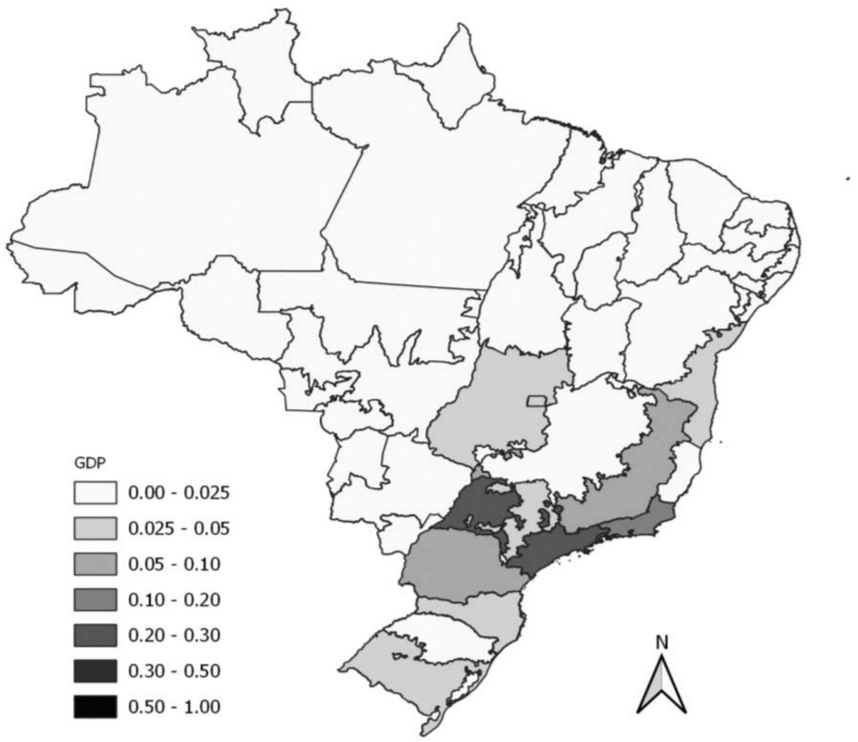
	Region	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17	R18	R19	R20	R21	R22	R23	R24
R1	Amazônia-AC	68.27	0.32	0.05	0.04	0.80	0.06	0.44	0.09	0.13	0.04	0.07	0.04	0.11	0.03	0.04	0.08	0.04	0.05	0.08	0.02	0.04	0.09	0.07	0.06
R2	Amazônia-AM	6.29	78.53	2.21	1.23	3.25	1.86	5.05	7.10	1.27	0.46	0.52	0.85	0.49	0.56	0.57	0.90	0.66	0.46	0.63	0.30	0.40	1.28	0.34	0.43
R3	Amazônia-AP	0.06	0.10	68.64	0.23	1.21	0.52	0.11	0.09	1.41	0.17	0.29	0.08	0.38	0.15	0.19	0.64	0.23	0.21	0.33	0.04	0.06	0.97	0.15	0.06
R4	Amazônia-MA	0.09	0.11	0.45	59.13	0.93	1.00	0.13	0.14	3.35	0.52	0.73	0.61	0.59	0.50	0.67	3.35	0.66	0.60	0.63	0.09	0.14	8.50	0.21	0.10
R5	Amazônia-MT	0.34	0.44	0.32	0.32	32.94	0.36	0.62	0.19	0.20	0.18	0.20	0.33	0.17	0.21	0.23	0.20	0.24	0.20	0.23	0.21	0.35	0.23	0.21	0.30
R6	Amazônia-PA	0.37	0.49	2.38	2.74	2.74	64.37	0.44	0.51	6.91	0.72	0.98	0.99	1.06	0.73	0.91	2.44	0.94	0.82	1.10	0.26	0.40	4.28	0.44	0.26
R7	Amazônia-RO	1.22	1.23	0.25	0.25	2.19	0.25	66.13	0.40	0.21	0.12	0.16	0.20	0.20	0.12	0.14	0.17	0.15	0.16	0.20	0.17	0.23	0.19	0.17	0.27
R8	Amazônia-RR	0.12	0.48	0.10	0.09	0.76	0.13	0.21	74.05	0.41	0.09	0.10	0.06	0.14	0.08	0.10	0.24	0.11	0.10	0.11	0.03	0.04	0.28	0.09	0.07
R9	Amazônia-TO	0.02	0.03	0.08	0.24	0.04	0.18	0.02	0.03	39.37	0.04	0.04	0.11	0.03	0.05	0.05	0.09	0.06	0.04	0.06	0.04	0.04	0.15	0.02	0.02
R10	Caatinga-AL	0.02	0.02	0.03	0.06	0.02	0.03	0.02	0.02	0.02	42.10	0.08	0.07	0.04	0.10	0.18	0.05	0.09	0.62	0.05	0.01	0.01	0.04	0.02	0.01
R11	Caatinga-BA	0.07	0.06	0.09	0.18	0.12	0.14	0.08	0.05	0.11	0.25	41.87	0.22	0.39	0.15	0.23	0.18	0.18	0.44	0.45	0.12	0.13	0.16	0.15	0.09
R12	Caatinga-CE	0.49	0.61	1.29	3.63	1.50	1.82	0.51	0.71	2.92	3.11	3.16	66.49	1.66	6.09	5.44	13.24	10.41	3.32	1.90	0.35	0.46	7.40	0.60	0.29
R13	Caatinga-MG	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	30.66	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.01	0.00
R14	Caatinga-PB	0.03	0.04	0.07	0.14	0.06	0.09	0.03	0.04	0.07	0.33	0.14	0.40	0.09	47.02	0.61	0.18	1.02	0.25	0.09	0.02	0.03	0.13	0.05	0.03
R15	Caatinga-PE	0.05	0.06	0.10	0.26	0.08	0.14	0.05	0.06	0.11	0.87	0.28	0.48	0.11	0.86	44.51	0.29	0.69	0.69	0.15	0.04	0.05	0.22	0.06	0.04
R16	Caatinga-PI	0.02	0.02	0.05	0.25	0.04	0.08	0.02	0.02	0.08	0.06	0.07	0.29	0.05	0.07	0.09	40.16	0.12	0.10	0.08	0.03	0.03	0.22	0.02	0.02
R17	Caatinga-RN	0.09	0.10	0.19	0.38	0.13	0.26	0.09	0.11	0.18	0.43	0.24	1.07	0.13	1.49	0.78	0.42	39.14	0.33	0.18	0.08	0.10	0.35	0.10	0.08
R18	Caatinga-SE	0.01	0.01	0.02	0.03	0.01	0.02	0.01	0.01	0.01	0.27	0.07	0.04	0.03	0.04	0.08	0.03	0.04	36.42	0.03	0.01	0.01	0.02	0.01	0.01
R19	Cerrado-BA	0.03	0.03	0.05	0.08	0.05	0.07	0.04	0.02	0.06	0.10	0.16	0.12	0.23	0.07	0.10	0.07	0.09	0.11	37.90	0.06	0.09	0.07	0.09	0.04
R20	Cerrado-DF	0.30	0.31	0.35	0.51	8.33	0.63	0.73	0.20	6.05	1.32	4.36	0.40	11.29	0.77	1.19	2.99	0.92	1.93	11.04	64.36	7.85	2.96	8.56	1.41
R21	Cerrado-GO	0.73	0.67	0.83	1.08	1.99	1.07	0.93	0.47	1.40	0.52	1.00	0.74	1.52	0.46	0.56	0.79	0.54	0.64	1.95	4.23	53.78	0.99	1.67	1.17
R22	Cerrado-MA	0.05	0.08	0.19	1.40	0.11	0.33	0.05	0.07	0.33	0.11	0.12	0.48	0.09	0.13	0.16	0.47	0.20	0.15	0.16	0.06	0.07	39.07	0.05	0.04
R23	Cerrado-MG	0.63	0.54	0.65	0.83	0.90	0.79	0.70	0.42	0.64	0.51	0.94	0.70	1.88	0.46	0.54	0.54	0.53	0.64	1.56	1.58	1.59	0.66	44.45	0.89
R24	Cerrado-MS	0.26	0.26	0.21	0.23	0.69	0.23	0.35	0.16	0.22	0.14	0.21	0.19	0.30	0.14	0.16	0.18	0.16	0.17	0.28	0.28	0.47	0.20	0.35	56.77
R25	Cerrado-MT	0.46	0.48	0.44	0.43	2.26	0.51	0.83	0.29	0.38	0.23	0.32	0.37	0.34	0.22	0.26	0.29	0.26	0.27	0.40	0.46	0.84	0.34	0.38	0.70
R26	Cerrado-PI	0.07	0.09	0.17	0.52	0.91	0.35	0.11	0.09	2.57	0.76	1.57	0.51	1.65	0.57	0.89	5.12	0.72	1.01	2.39	0.12	0.17	3.82	0.42	0.13
R27	Cerrado-PR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R28	Cerrado-SP	1.01	0.79	0.99	1.17	1.58	1.17	1.17	0.67	1.06	0.66	0.97	0.86	1.25	0.60	0.67	0.77	0.68	0.76	1.45	1.78	2.21	0.96	1.95	2.12
R29	Cerrado-TO	0.07	0.10	0.18	0.35	1.46	0.39	0.13	0.07	6.76	0.32	0.78	0.25	1.17	0.25	0.36	1.16	0.32	0.43	1.45	0.18	0.30	1.67	0.38	0.13
R30	Mata Atlântica-AL	0.18	0.19	0.29	0.53	0.31	0.35	0.18	0.19	0.32	7.12	1.04	0.63	0.54	1.49	2.54	0.72	1.22	3.88	0.55	0.11	0.14	0.55	0.20	0.10
R31	Mata Atlântica-BA	0.65	0.49	0.92	1.58	1.62	1.20	0.73	0.48	1.58	4.57	12.61	2.03	8.59	2.38	3.54	2.99	2.48	7.77	4.97	0.77	0.94	2.17	1.79	0.69
R32	Mata Atlântica-ES	0.18	0.13	0.19	0.26	0.33	0.22	0.20	0.13	0.21	0.33	0.57	0.30	0.71	0.26	0.30	0.28	0.28	0.44	0.48	0.29	0.29	0.27	0.57	0.21
R33	Mata Atlântica-GO	0.04	0.04	0.03	0.04	0.05	0.04	0.04	0.02	0.03	0.01	0.03	0.03	0.03	0.01	0.02	0.02	0.02	0.02	0.04	0.08	0.15	0.03	0.06	0.06
R34	Mata Atlântica-MG	1.06	0.80	1.19	1.40	2.35	1.36	1.16	0.78	1.57	1.45	2.83	1.36	5.47	1.14	1.37	1.48	1.27	1.78	3.12	1.79	1.90	1.52	5.39	1.42
R35	Mata Atlântica-MS	0.11	0.11	0.08	0.08	0.14	0.08	0.13	0.07	0.05	0.04	0.06	0.06	0.06	0.04	0.04	0.04	0.04	0.04	0.07	0.08	0.13	0.06	0.09	0.47
R36	Mata Atlântica-PB	0.06	0.08	0.12	0.24	0.28	0.16	0.07	0.07	0.35	2.17	0.79	0.61	0.49	5.87	3.33	1.05	5.65	1.60	0.37	0.05	0.06	0.61	0.16	0.06
R37	Mata Atlântica-PE	0.35	0.38	0.67	1.37	0.93	0.87	0.35	0.41	1.12	12.41	2.89	2.63	1.64	11.73	13.86	3.06	9.35	7.45	1.46	0.24	0.31	2.01	0.57	0.25
R38	Mata Atlântica-PR	1.43	1.13	1.27	1.49	2.34	1.51	1.65	1.00	1.30	0.85	1.18	1.11	1.41	0.77	0.85	0.99	0.89	0.96	1.59	1.52	2.02	1.25	1.72	3.60
R39	Mata Atlântica-RJ	3.51	2.28	3.60	4.20	6.28	4.18	3.92	2.53	4.12	3.34	5.56	3.59	8.62	2.97	3.51	3.70	3.34	3.94	6.11	4.75	5.46	4.00	9.04	5.15
R40	Mata Atlântica-RN	0.07	0.08	0.12	0.25	0.25	0.18	0.07	0.07	0.30	1.26	0.57	0.73	0.39	3.67	1.88	0.87	7.70	0.99	0.30	0.06	0.08	0.54	0.15	0.07
R41	Mata Atlântica-RS	0.84	0.69	0.73	0.77	0.98	0.81	0.85	0.62	0.61	0.44	0.55	0.61	0.55	0.41	0.44	0.49	0.47	0.47	0.70	0.58	0.80	0.62	0.66	1.21
R42	Mata Atlântica-SC	1.39	1.06	1.26	1.30	1.81	1.40	1.45	1.01	1.14	0.77	1.04	0.96	1.11	0.69	0.75	0.85	0.76	0.84	1.34	1.17	1.45	1.09	1.28	2.02
R43	Mata Atlântica-SE	0.14	0.12	0.21	0.39	0.24	0.30	0.16	0.13	0.25	4.10	0.98	0.50	0.46	0.73	1.26	0.51	0.66	11.11	0.45	0.14	0.17	0.40	0.21	0.14
R44	Mata Atlântica-SP	8.05	5.88	8.30	9.64	15.70	9.72	9.22	5.84	10.15	6.26	9.29	7.34	13.21	5.51	6.15	7.40	6.21	7.28	12.83	12.92	15.51	8.99	16.43	17.95
R45	Pampa-RS	0.73	0.52	0.62	0.65	1.21	0.70	0.78	0.52	0.65	0.44	0.56	0.53	0.65	0.39	0.44	0.51	0.45	0.47	0.70	0.50	0.67	0.62	0.65	1.02
R46	Pantanal-MS	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.05
R47	Pantanal-MT	0.02	0.02	0.01	0.01	0.05	0.01	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.02
	Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

conclusion

	Region	R25	R26	R27	R28	R29	R30	R31	R32	R33	R34	R35	R36	R37	R38	R39	R40	R41	R42	R43	R44	R45	R46	R47	Row
R1	Amazônia-AC	0.17	0.04	0.09	0.05	0.03	0.03	0.04	0.03	0.10	0.03	0.16	0.03	0.03	0.05	0.02	0.03	0.11	0.05	0.04	0.04	0.04	0.28	0.66	0.03
R2	Amazônia-AM	1.16	0.78	0.32	0.21	0.71	0.42	0.39	0.27	0.47	0.22	0.57	0.48	0.54	0.25	0.20	0.58	0.38	0.25	0.43	0.28	0.24	0.96	2.25	0.59
R3	Amazônia-AP	0.21	0.07	0.15	0.08	0.08	0.04	0.05	0.05	0.19	0.03	0.21	0.03	0.04	0.06	0.03	0.04	0.17	0.07	0.07	0.05	0.05	0.29	0.73	0.14
R4	Amazônia-MA	0.23	0.57	0.19	0.11	0.37	0.21	0.17	0.10	0.26	0.07	0.24	0.20	0.24	0.09	0.06	0.24	0.20	0.10	0.28	0.09	0.07	0.32	0.55	0.54
R5	Amazônia-MT	0.78	0.36	0.19	0.20	0.28	0.27	0.30	0.21	0.24	0.22	0.20	0.29	0.32	0.22	0.16	0.33	0.18	0.18	0.30	0.24	0.18	0.24	0.69	0.91
R6	Amazônia-PA	0.72	1.16	0.40	0.24	1.01	0.50	0.42	0.22	0.58	0.20	0.52	0.52	0.62	0.23	0.14	0.63	0.43	0.24	0.59	0.22	0.18	0.71	1.53	3.11
R7	Amazônia-RO	0.73	0.24	0.20	0.12	0.17	0.16	0.19	0.11	0.28	0.12	0.31	0.15	0.18	0.14	0.08	0.18	0.18	0.12	0.20	0.15	0.12	0.60	1.94	0.34
R8	Amazônia-RR	0.16	0.06	0.11	0.05	0.04	0.04	0.03	0.03	0.11	0.03	0.19	0.04	0.04	0.05	0.02	0.04	0.14	0.06	0.05	0.05	0.04	0.24	0.65	0.03
R9	Amazônia-TO	0.03	0.22	0.02	0.01	0.27	0.05	0.05	0.02	0.03	0.02	0.01	0.06	0.07	0.01	0.01	0.07	0.01	0.01	0.06	0.02	0.01	0.01	0.02	0.05
R10	Caatinga-AL	0.02	0.07	0.01	0.01	0.03	0.61	0.11	0.02	0.01	0.02	0.01	0.12	0.25	0.01	0.01	0.11	0.01	0.01	0.76	0.01	0.01	0.01	0.02	0.01
R11	Caatinga-BA	0.12	0.30	0.08	0.08	0.15	0.30	0.72	0.15	0.11	0.13	0.08	0.20	0.25	0.07	0.09	0.20	0.07	0.06	0.51	0.09	0.06	0.09	0.12	0.25
R12	Caatinga-CE	0.61	2.93	0.37	0.25	1.17	1.74	1.37	0.51	0.50	0.37	0.44	2.16	2.33	0.23	0.27	3.29	0.38	0.25	1.89	0.27	0.19	0.63	0.96	0.56
R13	Caatinga-MG	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R14	Caatinga-PB	0.04	0.13	0.03	0.02	0.06	0.39	0.13	0.04	0.03	0.03	0.03	0.83	0.68	0.02	0.02	0.80	0.02	0.01	0.26	0.02	0.01	0.03	0.05	0.05
R15	Caatinga-PE	0.06	0.28	0.03	0.02	0.11	1.08	0.29	0.06	0.04	0.05	0.03	0.85	1.31	0.02	0.04	0.73	0.03	0.02	0.85	0.03	0.02	0.05	0.06	0.09
R16	Caatinga-PI	0.03	0.32	0.02	0.01	0.06	0.10	0.07	0.02	0.02	0.02	0.02	0.10	0.10	0.01	0.01	0.11	0.01	0.01	0.12	0.01	0.01	0.02	0.03	0.03
R17	Caatinga-RN	0.11	0.35	0.07	0.06	0.16	0.57	0.24	0.10	0.08	0.09	0.07	1.53	1.03	0.07	0.08	2.52	0.07	0.07	0.40	0.08	0.07	0.08	0.10	0.22
R18	Caatinga-SE	0.01	0.04	0.01	0.01	0.02	0.17	0.08	0.02	0.01	0.01	0.01	0.05	0.09	0.00	0.01	0.05	0.00	0.00	0.88	0.01	0.00	0.01	0.01	0.01
R19	Cerrado-BA	0.05	0.20	0.04	0.05	0.10	0.14	0.22	0.08	0.06	0.08	0.03	0.13	0.15	0.03	0.04	0.12	0.02	0.03	0.16	0.05	0.02	0.04	0.04	0.44
R20	Cerrado-DF	3.37	0.63	3.95	2.85	0.99	0.31	0.70	1.21	18.33	0.98	4.18	0.19	0.28	1.32	0.70	0.24	2.58	1.27	0.69	1.43	0.61	5.64	10.67	0.56
R21	Cerrado-GO	2.12	1.24	1.09	1.12	1.60	0.58	1.00	0.83	4.42	0.97	1.08	0.53	0.65	0.80	0.65	0.60	0.75	0.68	0.75	1.17	0.59	1.42	2.46	2.05
R22	Cerrado-MA	0.07	0.60	0.04	0.03	0.21	0.17	0.14	0.05	0.06	0.04	0.04	0.18	0.19	0.03	0.03	0.20	0.03	0.03	0.18	0.04	0.03	0.05	0.07	0.48
R23	Cerrado-MG	1.09	1.11	0.87	1.04	0.97	0.67	1.44	1.48	1.51	2.05	0.70	0.58	0.71	0.75	1.14	0.64	0.59	0.65	0.86	1.22	0.58	0.82	0.93	2.88
R24	Cerrado-MS	0.68	0.26	0.60	0.47	0.22	0.17	0.27	0.24	0.68	0.30	2.06	0.16	0.19	0.65	0.25	0.19	0.52	0.45	0.21	0.58	0.39	2.49	1.05	1.09
R25	Cerrado-MT	54.78	0.48	0.35	0.34	0.43	0.32	0.41	0.29	0.69	0.33	0.50	0.30	0.36	0.35	0.23	0.35	0.29	0.27	0.38	0.41	0.25	0.69	3.48	2.52
R26	Cerrado-PI	0.28	59.82	0.28	0.16	0.38	0.22	0.29	0.15	0.38	0.10	0.33	0.18	0.23	0.11	0.07	0.20	0.23	0.11	0.38	0.13	0.08	0.41	0.68	0.16
R27	Cerrado-PR	0.00	0.00	17.54	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.02
R28	Cerrado-SP	1.82	1.25	3.48	44.82	1.35	0.74	1.25	1.34	3.23	1.84	1.84	0.65	0.81	2.05	1.62	0.73	1.24	1.45	0.91	4.83	1.12	1.88	1.68	4.70
R29	Cerrado-TO	0.34	0.44	0.29	0.18	65.20	0.15	0.20	0.13	0.56	0.11	0.35	0.13	0.16	0.13	0.08	0.15	0.27	0.14	0.22	0.13	0.09	0.47	0.89	0.29
R30	Mata Atlântica-AL	0.21	0.52	0.11	0.08	0.28	58.29	0.89	0.23	0.12	0.16	0.11	1.02	2.63	0.08	0.11	0.92	0.10	0.08	3.30	0.09	0.08	0.16	0.25	0.30
R31	Mata Atlântica-BA	1.00	2.17	0.90	0.69	1.25	2.82	61.85	1.86	1.16	1.08	0.93	1.88	2.53	0.62	0.90	1.91	0.81	0.63	5.55	0.72	0.54	1.12	1.46	3.02
R32	Mata Atlântica-ES	0.26	0.35	0.30	0.23	0.25	0.34	0.88	56.76	0.36	0.95	0.24	0.26	0.33	0.19	0.86	0.30	0.22	0.19	0.50	0.28	0.16	0.25	0.32	3.19
R33	Mata Atlântica-GO	0.08	0.04	0.04	0.06	0.04	0.02	0.04	0.04	20.79	0.05	0.04	0.02	0.02	0.04	0.04	0.02	0.03	0.04	0.02	0.06	0.04	0.05	0.06	0.12
R34	Mata Atlântica-MG	1.76	1.70	2.70	2.16	1.51	1.28	2.85	5.74	2.87	60.15	1.94	1.02	1.38	1.39	4.59	1.16	1.63	1.37	1.75	2.36	0.98	2.06	2.45	6.63
R35	Mata Atlântica-MS	0.19	0.08	0.18	0.14	0.08	0.05	0.09	0.09	0.11	0.11	39.05	0.05	0.06	0.39	0.09	0.06	0.20	0.20	0.06	0.20	0.20	0.35	0.18	0.29
R36	Mata Atlântica-PB	0.10	0.21	0.11	0.06	0.11	0.94	0.29	0.11	0.11	0.07	0.12	57.95	2.80	0.05	0.06	4.22	0.10	0.06	0.77	0.06	0.05	0.15	0.22	0.08
R37	Mata Atlântica-PE	0.48	1.30	0.36	0.23	0.64	10.76	1.70	0.51	0.38	0.34	0.40	12.21	62.12	0.20	0.25	8.19	0.32	0.21	5.46	0.26	0.19	0.50	0.74	0.57
R38	Mata Atlântica-PR	2.34	1.50	6.64	2.59	1.51	0.96	1.43	1.33	2.66	1.61	7.33	0.84	1.07	57.70	1.53	0.97	4.08	4.29	1.15	3.96	2.65	3.49	2.53	7.09
R39	Mata Atlântica-RJ	5.36	4.73	9.21	6.43	4.31	3.45	5.83	12.23	6.90	10.76	6.40	3.22	3.72	5.35	69.81	3.38	6.06	5.53	4.32	7.08	4.47	6.03	6.49	13.50
R40	Mata Atlântica-RN	0.11	0.23	0.11	0.07	0.11	0.61	0.24	0.11	0.11	0.08	0.12	3.19	1.35	0.07	0.07	56.87	0.10	0.07	0.55	0.08	0.06	0.14	0.20	0.10
R41	Mata Atlântica-RS	1.02	0.71	1.35	0.77	0.71	0.51	0.69	0.68	0.80	0.74	1.52	0.45	0.59	1.95	0.74	0.53	42.35	4.04	0.58	1.27	6.64	1.19	0.95	2.95
R42	Mata Atlântica-SC	1.76	1.26	3.50	1.46	1.33	0.84	1.25	1.19	1.66	1.32	2.82	0.69	0.90	3.65	1.35	0.79	7.39	59.01	0.98	2.48	5.09	2.07	1.79	4.20
R43	Mata Atlântica-SE	0.20	0.47	0.15	0.13	0.24	2.25	0.85	0.21	0.16	0.17	0.15	0.79	1.21	0.12	0.15	0.70	0.13	0.12	54.20	0.14	0.12	0.16	0.22	0.32
R44	Mata Atlântica-SP	14.34	10.10	41.96	31.59	10.81	6.25	9.92	10.54	27.95	13.36	22.62	5.32	6.91	18.86	12.83	6.14	14.14	13.78	7.79	68.25	9.00	20.17	17.01	31.62
R45	Pampa-RS	0.93	0.63	1.55	0.70	0.63	0.45	0.58	0.58	0.83	0.58	1.93	0.40	0.51	1.55	0.58	0.46	13.42	3.75	0.51	1.01	64.64	1.37	1.20	3.77
R46	Pantanal-MS	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.01	42.22	0.02	0.09
R47	Pantanal-MT	0.08	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	31.59	0.02
	Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Source: elaborated by the author based on MIP-Biomas.

Figure B.1 – Distribution of GDP – percentage values



Source: elaborated by the author in QGIS 3.28.

Most of the value of national agricultural production analyzed (activities 1 to 6 and 8), in 2015, is concentrated in the Mata Atlântica and Cerrado biomes as shown in Table B.2, where the shares higher than 5% in each activity are highlighted. It is worth mentioning: sugarcane in São Paulo, accounting for more than 50% of the value of national production, with 26.07% in the Cerrado-SP and 25.94% in the Mata Atlântica-SP; soybeans in Mato Grosso, specifically 15.45% in the Cerrado-MT and 11.85% in the Amazônia-MT; coffee in Minas Gerais, with a percentage higher than 60%, being 40.06% in the Mata Atlântica-MG and 24.34% in Cerrado-MG; other products from permanent crops in São Paulo, being 16.50% in Cerrado_SP and 14.50% in the Mata Atlântica-MG and logging and forestry in Minas Gerais, being 12.89% in Cerrado-MG and 9.73% in Mata Atlântica-MG.

Mata Atlântica_RJ accounts for 35.63% of the other primary agricultural and extractive activities industries, a region characterized by oil exploration. The Mata Atlântica_RJ region also ranks second in terms of the concentration of manufacturing activities and services, second only to the Mata Atlântica_SP.

Table B.2 – Exploring national production – percentage values

Regions/Activities		Sugarcane (1)	Soybeans (2)	Other temporary crop products and services (3)	Coffee beans (4)	Other products from permanent crops (5)	Bovine and other live animals, animal products, hunting and services (6)	Logging and forestry (8)	Other primary agricultural and extractive activities (7,9,10)	Manufactures (11-30)	Services (31-36)
R1	Amazônia-AC	0.01	0.00	0.32	0.03	0.18	0.61	0.36	0.04	0.05	0.31
R2	Amazônia-AM	0.09	0.00	0.73	0.00	1.01	0.18	0.20	1.26	1.28	1.19
R3	Amazônia-AP	0.00	0.01	0.11	0.00	0.13	0.06	0.73	0.18	0.02	0.38
R4	Amazônia-MA	0.00	0.19	0.38	0.00	0.15	0.66	3.65	0.44	0.20	1.06
R5	Amazônia-MT	1.91	11.85	4.79	0.17	0.23	5.75	1.84	0.20	0.38	0.24
R6	Amazônia-PA	0.02	1.14	2.54	0.00	7.30	5.39	4.61	5.78	0.82	2.25
R7	Amazônia-RO	0.03	0.70	0.57	1.20	0.29	2.48	0.35	0.23	0.39	0.73
R8	Amazônia-RR	0.00	0.09	0.17	0.00	0.28	0.07	0.11	0.02	0.02	0.26
R9	Amazônia-TO	0.00	0.03	0.07	0.00	0.05	0.85	0.40	0.03	0.07	0.06
R10	Caatinga-AL	0.03	0.00	0.18	0.00	0.02	0.07	0.00	0.05	0.07	0.11
R11	Caatinga-BA	0.49	0.00	1.16	0.61	5.93	0.62	0.19	1.43	0.17	0.50
R12	Caatinga-CE	0.06	0.00	0.72	0.00	2.62	0.35	0.14	1.67	1.57	2.48
R13	Caatinga-MG	0.00	0.00	0.05	0.00	0.28	0.05	0.00	0.00	0.00	0.01
R14	Caatinga-PB	0.11	0.00	0.25	0.00	0.30	0.10	0.00	0.16	0.17	0.36
R15	Caatinga-PE	0.04	0.00	0.35	0.00	4.65	0.13	0.01	0.35	0.24	0.43
R16	Caatinga-PI	0.02	0.00	0.39	0.00	0.32	0.05	0.17	0.14	0.05	0.18
R17	Caatinga-RN	0.08	0.00	0.65	0.00	0.86	0.14	0.01	2.21	0.38	0.30
R18	Caatinga-SE	0.00	0.00	0.26	0.00	0.12	0.15	0.00	0.03	0.05	0.06
R19	Cerrado-BA	0.06	4.95	3.41	1.11	0.71	0.53	0.36	0.06	0.07	0.13
R20	Cerrado-DF	0.01	0.24	0.27	0.04	0.06	0.23	0.02	0.17	0.30	5.84
R21	Cerrado-GO	8.46	9.76	8.29	0.32	1.22	10.49	1.11	2.33	2.48	2.68
R22	Cerrado-MA	0.47	1.63	1.47	0.00	0.25	0.51	1.39	0.12	0.19	0.31
R23	Cerrado-MG	10.26	4.22	6.81	24.34	6.76	9.76	12.89	3.84	2.75	1.81
R24	Cerrado-MS	4.92	4.77	3.03	0.00	0.22	7.92	8.16	0.30	0.82	1.02
R25	Cerrado-MT	0.63	15.45	11.63	0.00	0.15	5.61	0.85	0.75	0.91	1.22
R26	Cerrado-PI	0.23	1.92	1.08	0.00	0.12	0.07	0.14	0.08	0.14	0.68
R27	Cerrado-PR	0.00	0.04	0.03	0.00	0.00	0.01	0.63	0.01	0.01	0.00
R28	Cerrado-SP	26.07	1.35	2.40	4.71	16.50	4.38	6.19	1.43	6.68	2.84
R29	Cerrado-TO	0.45	1.85	1.38	0.00	0.12	1.85	0.71	0.20	0.15	0.54
R30	Mata Atlântica-AL	2.52	0.00	0.20	0.00	0.43	0.24	0.03	0.38	0.62	0.70
R31	Mata Atlântica-BA	0.45	0.00	0.47	3.03	5.76	2.79	7.53	4.74	3.04	3.58
R32	Mata Atlântica-ES	0.38	0.00	0.28	18.17	3.92	1.32	3.48	5.39	1.10	1.75
R33	Mata Atlântica-GO	2.29	0.17	0.13	0.00	0.01	0.45	0.01	0.01	0.15	0.02
R34	Mata Atlântica-MG	2.03	0.55	2.69	40.06	2.58	7.91	9.73	11.44	5.42	6.55
R35	Mata Atlântica-MS	2.66	2.85	1.86	0.01	0.03	2.07	0.08	0.11	0.32	0.18
R36	Mata Atlântica-PB	0.86	0.00	0.10	0.00	0.33	0.08	0.03	0.17	0.31	0.75
R37	Mata Atlântica-PE	2.24	0.00	0.16	0.00	0.68	0.42	0.17	0.49	1.70	2.58
R38	Mata Atlântica-PR	4.45	15.27	12.91	1.78	3.60	5.04	10.84	2.25	7.45	5.93
R39	Mata Atlântica-RJ	0.58	0.00	0.28	0.39	0.70	2.50	0.41	35.63	12.39	11.33
R40	Mata Atlântica-RN	0.22	0.00	0.10	0.00	0.17	0.04	0.00	1.49	0.19	0.75
R41	Mata Atlântica-RS	0.36	9.97	8.09	0.00	9.19	0.65	0.71	0.94	4.15	1.58
R42	Mata Atlântica-SC	0.14	1.94	5.82	0.00	5.61	0.96	6.21	3.19	5.82	3.87
R43	Mata Atlântica-SE	0.28	0.00	0.13	0.00	0.77	0.32	0.02	2.32	0.54	0.64
R44	Mata Atlântica-SP	25.94	1.40	3.32	4.01	14.50	10.47	8.92	6.77	32.99	27.67
R45	Pampa-RS	0.11	7.56	9.86	0.00	0.83	3.98	6.08	0.85	3.35	4.13
R46	Pantanal-MS	0.00	0.00	0.02	0.00	0.00	0.78	0.11	0.26	0.02	0.01
R47	Pantanal-MT	0.03	0.10	0.10	0.00	0.03	0.92	0.38	0.06	0.01	0.01

Source: elaborated by the author based on MIP-Biomas.

APPENDIX C – Agricultural land and agriculture-caused deforestation embodied in intranational trade by activities

Table C.1 – Percentage values by 36 activities

	Activities	land use	deforestation
1	Sugarcane	0.20	0.02
2	Soybeans	0.01	0.00
3	Other temporary crop products and services	3.11	3.18
4	Coffee beans	0.02	0.05
5	Other products from permanent crops	0.60	0.98
6	Bovine and other live animals, animal products, hunting and services	20.52	25.68
7	Pigs, poultry and eggs	0.25	0.28
8	Logging and forestry	1.16	0.68
9	Fishing and aquaculture	0.12	0.09
10	Extractive activities	0.01	0.00
11	Meat of bovine animals and other meat products	26.17	28.12
12	Pork and poultry	8.10	7.55
13	Industrialized fish	1.28	1.62
14	Milk and dairy products	14.65	15.99
15	Other food products	6.87	3.67
16	Beverages	0.35	0.16
17	Tobacco products	0.22	0.20
18	Manufacture of textiles, clothing and accessories	0.29	0.28
19	Manufacture of footwear and leather goods	0.74	0.85
20	Wood products, excluding furniture	0.04	0.02
21	Cellulose, paper and paper products manufacturing	0.11	0.06
22	Various industries	0.11	0.06
23	Petroleum refining and coking plants	0.60	0.12
24	Manufacture of biofuels	1.98	0.33
25	Chemical products	0.35	0.21
26	Fertilizers, pesticides and disinfectants	0.00	0.00
27	Mineral products, steel, metallurgy and related	0.04	0.02
28	Machinery and equipment	0.23	0.11
29	Manufacture of transport vehicles, including parts	0.17	0.09
30	Furniture	0.11	0.06
31	Energy, gas, water, sewage, waste management and other utilities	0.10	0.06
32	Trade	1.87	0.84
33	Transportation	0.22	0.07
34	Warehousing and postal services	0.02	0.01
35	Accommodation and food	4.66	4.39
36	Various services	4.75	4.15

Source: elaborated by the author based on the results.

APPENDIX D – Agricultural land and agriculture-caused deforestation embodied in intranational trade by activity in each region

Table D.1 – Percentage values by activities in each region

continue

Region	Activities	land use	deforestation	Region	land use	deforestation	Region	land use	deforestation
R1	1	0.00	0.00	R2	0.02	0.00	R3	0.00	0.00
	2	0.00	0.00		0.00	0.00		0.00	0.00
	3	0.17	0.13		0.31	0.28		5.83	3.14
	4	0.00	0.00		0.00	0.00		0.00	0.00
	5	0.04	0.03		0.16	0.11		0.14	0.09
	6	34.41	35.04		46.27	57.32		30.97	51.15
	7	0.02	0.02		0.29	0.24		0.03	0.03
	8	0.03	0.02		0.01	0.01		0.00	0.00
	9	0.03	0.02		0.04	0.02		0.02	0.01
	10	0.00	0.00		0.02	0.01		0.03	0.01
	11	43.73	44.81		19.00	17.86		7.15	7.03
	12	5.19	5.31		0.39	0.37		0.20	0.20
	13	4.22	4.32		3.81	3.58		6.63	6.52
	14	4.07	4.16		11.28	10.57		20.71	20.26
	15	0.82	0.39		0.43	0.20		0.00	0.00
	16	0.14	0.06		0.79	0.26		0.46	0.11
	17	0.00	0.00		0.01	0.00		0.00	0.00
	18	0.01	0.00		0.03	0.01		0.01	0.00
	19	0.08	0.09		0.03	0.02		0.00	0.00
	20	0.00	0.00		0.01	0.00		0.04	0.01
	21	0.00	0.00		0.06	0.01		0.00	0.00
	22	0.01	0.00		0.16	0.06		0.02	0.00
	23	0.00	0.00		0.68	0.07		0.00	0.00
	24	0.42	0.08		0.00	0.00		0.00	0.00
	25	0.01	0.00		0.21	0.10		0.02	0.01
	26	0.00	0.00		0.00	0.00		0.00	0.00
	27	0.00	0.00		0.03	0.01		0.00	0.00
	28	0.00	0.00		0.90	0.34		0.00	0.00
	29	0.00	0.00		0.52	0.19		0.02	0.00
	30	0.01	0.00		0.02	0.01		0.02	0.00
	31	0.08	0.05		0.09	0.04		0.29	0.07
	32	0.85	0.40		1.39	0.53		3.05	0.85
	33	0.06	0.02		0.24	0.05		0.22	0.03
	34	0.01	0.01		0.03	0.01		0.03	0.01
	35	1.71	1.64		5.41	3.29		5.45	2.30
	36	3.88	3.37		7.38	4.42		18.63	8.17

continue

Region	Activities	land use	deforestation	Region	land use	deforestation	Region	land use	deforestation
R4	1	0.00	0.00	R5	0.04	0.00	R6	0.00	0.00
	2	0.00	0.00		0.07	0.00		0.00	0.00
	3	0.78	1.69		4.25	1.24		0.83	0.96
	4	0.00	0.00		0.00	0.00		0.00	0.00
	5	0.02	0.02		0.01	0.01		1.10	0.15
	6	54.95	58.30		36.19	38.50		37.55	40.75
	7	0.24	0.23		0.03	0.03		0.15	0.14
	8	0.81	0.15		0.07	0.02		0.35	0.05
	9	0.02	0.01		0.00	0.00		0.04	0.02
	10	0.01	0.00		0.00	0.00		0.00	0.00
	11	26.92	27.01		51.98	53.97		45.86	46.39
	12	0.02	0.02		0.71	0.74		0.85	0.86
	13	0.00	0.00		0.00	0.00		0.00	0.00
	14	4.41	4.42		4.08	4.22		5.67	5.72
	15	0.67	0.40		0.00	0.00		1.38	0.70
	16	0.44	0.20		0.00	0.00		0.15	0.06
	17	0.01	0.01		0.00	0.00		0.02	0.01
	18	0.01	0.01		0.00	0.00		0.01	0.01
	19	0.00	0.00		0.08	0.08		0.00	0.00
	20	0.00	0.00		0.03	0.01		0.01	0.00
	21	0.00	0.00		0.00	0.00		0.01	0.00
	22	0.01	0.01		0.00	0.00		0.01	0.00
	23	0.09	0.02		0.00	0.00		0.02	0.00
	24	0.00	0.00		1.25	0.27		0.30	0.05
	25	0.00	0.00		0.00	0.00		0.00	0.00
	26	0.00	0.00		0.00	0.00		0.00	0.00
	27	0.01	0.00		0.00	0.00		0.00	0.00
	28	0.01	0.00		0.00	0.00		0.01	0.01
	29	0.00	0.00		0.00	0.00		0.01	0.00
	30	0.02	0.01		0.00	0.00		0.01	0.01
	31	0.10	0.05		0.00	0.00		0.04	0.02
	32	1.30	0.65		0.28	0.12		0.77	0.33
	33	0.25	0.07		0.01	0.00		0.08	0.02
	34	0.02	0.01		0.00	0.00		0.01	0.00
	35	3.16	2.52		0.45	0.42		1.83	1.55
	36	5.70	4.18		0.43	0.35		2.91	2.16

continue

Region	Activities	land use	deforestation	Region	land use	deforestation	Region	land use	deforestation
R7	1	0.00	0.00	R8	0.00	0.00	R9	0.00	0.00
	2	0.00	0.00		0.00	0.00		0.00	0.00
	3	1.07	1.21		0.54	0.95		0.26	0.34
	4	0.01	0.00		0.00	0.00		0.00	0.00
	5	0.02	0.01		0.14	0.11		0.01	0.01
	6	20.60	18.93		25.18	28.98		30.33	26.88
	7	0.01	0.01		0.05	0.04		0.01	0.01
	8	0.01	0.00		0.10	0.01		0.04	0.03
	9	0.05	0.03		0.03	0.02		0.00	0.00
	10	0.00	0.00		0.00	0.00		0.00	0.00
	11	59.13	61.04		57.80	56.73		62.07	65.57
	12	1.28	1.32		0.00	0.00		0.83	0.88
	13	0.79	0.82		0.00	0.00		0.00	0.00
	14	12.46	12.84		5.39	5.29		4.55	4.80
	15	0.65	0.38		0.59	0.35		0.38	0.22
	16	0.10	0.05		0.05	0.02		0.00	0.00
	17	0.00	0.00		0.00	0.00		0.00	0.00
	18	0.01	0.01		0.00	0.00		0.01	0.01
	19	0.16	0.17		0.00	0.00		0.02	0.02
	20	0.02	0.01		0.01	0.00		0.00	0.00
	21	0.00	0.00		0.00	0.00		0.00	0.00
	22	0.01	0.00		0.00	0.00		0.00	0.00
	23	0.00	0.00		0.00	0.00		0.00	0.00
	24	0.09	0.02		0.36	0.08		0.00	0.00
	25	0.01	0.00		0.00	0.00		0.00	0.00
	26	0.00	0.00		0.00	0.00		0.00	0.00
	27	0.01	0.00		0.00	0.00		0.01	0.00
	28	0.01	0.00		0.00	0.00		0.00	0.00
	29	0.01	0.01		0.00	0.00		0.00	0.00
	30	0.01	0.01		0.00	0.00		0.00	0.00
	31	0.04	0.03		0.11	0.06		0.01	0.00
	32	0.60	0.32		0.72	0.39		0.30	0.16
	33	0.04	0.02		0.03	0.01		0.03	0.01
	34	0.00	0.00		0.01	0.00		0.00	0.00
	35	1.07	1.09		2.32	1.94		0.56	0.56
	36	1.76	1.63		6.54	5.01		0.57	0.49

continue

Region	Activities	land use	deforestation	Region	land use	deforestation	Region	land use	deforestation
R10	1	0.02	0.00	R11	0.02	0.00	R12	0.00	0.00
	2	0.00	0.00		0.00	0.00		0.00	0.00
	3	0.18	0.12		0.96	0.30		1.70	1.02
	4	0.00	0.00		0.01	0.01		0.00	0.00
	5	0.01	0.01		1.42	0.75		7.74	11.58
	6	36.72	40.33		63.75	67.02		4.46	13.96
	7	0.55	0.54		0.10	0.09		0.97	0.90
	8	0.00	0.00		0.15	0.04		0.00	0.00
	9	0.00	0.00		0.04	0.02		0.58	0.33
	10	0.00	0.00		0.01	0.00		0.01	0.00
	11	6.59	6.84		15.94	16.00		14.80	15.27
	12	1.31	1.36		0.38	0.38		2.08	2.14
	13	0.88	0.91		4.06	4.08		5.77	5.96
	14	38.96	40.35		6.61	6.63		23.13	23.78
	15	8.86	5.20		1.66	1.12		11.79	6.82
	16	0.21	0.09		0.00	0.00		0.82	0.37
	17	0.73	0.50		0.00	0.00		0.15	0.10
	18	0.06	0.04		0.00	0.00		0.84	0.52
	19	0.00	0.00		1.46	1.21		6.62	5.12
	20	0.00	0.00		0.00	0.00		0.01	0.00
	21	0.00	0.00		0.00	0.00		0.03	0.01
	22	0.03	0.02		0.00	0.00		0.05	0.02
	23	0.00	0.00		0.00	0.00		0.35	0.06
	24	0.00	0.00		0.13	0.03		0.32	0.06
	25	0.00	0.00		0.03	0.02		0.21	0.11
	26	0.00	0.00		0.00	0.00		0.00	0.00
	27	0.00	0.00		0.00	0.00		0.05	0.02
	28	0.00	0.00		0.00	0.00		0.11	0.05
	29	0.00	0.00		0.00	0.00		0.04	0.02
	30	0.01	0.00		0.01	0.00		0.08	0.03
	31	0.03	0.02		0.03	0.01		0.10	0.05
	32	1.02	0.53		0.59	0.32		2.08	0.92
	33	0.01	0.00		0.02	0.01		0.19	0.05
	34	0.00	0.00		0.00	0.00		0.03	0.01
	35	1.49	1.28		0.83	0.65		6.70	4.99
	36	2.31	1.85		1.75	1.29		8.21	5.73

continue

Region	Activities	land use	deforestation	Region	land use	deforestation	Region	land use	deforestation
R13	1	0.01	0.00	R14	0.02	0.01	R15	0.01	0.00
	2	0.00	0.00		0.00	0.00		0.00	0.00
	3	1.42	0.85		0.12	0.09		0.67	0.27
	4	0.03	0.30		0.00	0.00		0.00	0.00
	5	2.57	2.70		0.07	0.05		2.87	1.19
	6	80.99	82.34		36.32	42.76		40.63	44.25
	7	0.00	0.00		0.64	0.58		1.28	1.25
	8	0.05	0.07		0.00	0.00		0.00	0.00
	9	0.00	0.00		0.01	0.00		0.08	0.06
	10	0.00	0.00		0.00	0.00		0.00	0.00
	11	0.00	0.00		1.10	1.06		2.02	2.10
	12	0.00	0.00		17.35	16.75		14.71	15.32
	13	0.00	0.00		0.06	0.06		0.00	0.00
	14	12.65	12.14		32.35	31.19		26.73	27.79
	15	0.55	0.61		2.29	1.28		3.53	2.21
	16	0.03	0.02		0.07	0.03		0.18	0.09
	17	0.00	0.00		0.00	0.00		0.00	0.00
	18	0.24	0.11		0.08	0.05		0.29	0.19
	19	0.00	0.00		3.56	2.37		0.21	0.18
	20	0.00	0.00		0.00	0.00		0.00	0.00
	21	0.00	0.00		0.01	0.00		0.01	0.00
	22	0.01	0.00		0.02	0.01		0.02	0.01
	23	0.00	0.00		0.00	0.00		0.00	0.00
	24	0.00	0.00		0.03	0.00		0.01	0.00
	25	0.00	0.00		0.03	0.01		0.02	0.01
	26	0.00	0.00		0.00	0.00		0.00	0.00
	27	0.01	0.00		0.02	0.01		0.02	0.01
	28	0.00	0.00		0.01	0.00		0.05	0.02
	29	0.00	0.00		0.00	0.00		0.00	0.00
	30	0.00	0.00		0.02	0.01		0.03	0.01
	31	0.00	0.00		0.06	0.02		0.04	0.02
	32	0.36	0.17		0.91	0.43		1.22	0.67
	33	0.01	0.00		0.03	0.01		0.05	0.02
	34	0.00	0.00		0.01	0.00		0.01	0.00
	35	0.19	0.12		1.52	1.03		2.37	1.98
	36	0.89	0.57		3.28	2.18		2.93	2.33

continue

Region	Activities	land use	deforestation	Region	land use	deforestation	Region	land use	deforestation
R16	1	0.09	0.14	R17	0.01	0.00	R18	0.00	0.00
	2	0.00	0.00		0.00	0.00		0.00	0.00
	3	18.70	8.95		9.22	13.44		1.90	0.35
	4	0.00	0.00		0.00	0.00		0.00	0.00
	5	2.18	3.08		3.40	2.07		0.08	0.06
	6	0.00	0.00		31.83	34.50		52.20	56.28
	7	0.57	0.67		0.28	0.27		0.19	0.18
	8	0.48	0.07		0.00	0.00		0.00	0.00
	9	1.19	0.88		1.02	0.66		0.00	0.00
	10	0.01	0.01		0.04	0.02		0.00	0.00
	11	7.74	9.82		17.14	17.43		2.30	2.39
	12	1.17	1.48		0.54	0.55		0.78	0.81
	13	0.00	0.00		1.40	1.43		0.00	0.00
	14	41.60	52.64		18.86	19.14		28.54	29.61
	15	6.18	4.43		5.78	3.95		4.20	2.27
	16	0.22	0.15		0.20	0.10		0.00	0.00
	17	0.00	0.00		0.25	0.29		1.16	0.69
	18	0.09	0.07		0.39	0.38		0.11	0.07
	19	0.43	0.48		0.16	0.13		5.13	4.75
	20	0.01	0.00		0.01	0.00		0.00	0.00
	21	0.00	0.00		0.01	0.00		0.00	0.00
	22	0.02	0.01		0.02	0.01		0.04	0.02
	23	0.02	0.00		1.82	0.31		0.00	0.00
	24	0.00	0.00		0.62	0.12		0.00	0.00
	25	0.31	0.24		0.05	0.03		0.00	0.00
	26	0.00	0.00		0.00	0.00		0.00	0.00
	27	0.06	0.03		0.02	0.01		0.01	0.00
	28	0.01	0.00		0.02	0.01		0.00	0.00
	29	0.00	0.00		0.00	0.00		0.00	0.00
	30	0.02	0.01		0.02	0.01		0.05	0.02
	31	0.16	0.10		0.05	0.03		0.04	0.02
	32	3.60	1.96		1.09	0.59		0.49	0.23
	33	0.10	0.04		0.08	0.02		0.05	0.02
	34	0.04	0.03		0.01	0.01		0.00	0.00
	35	5.21	5.47		2.39	1.97		0.78	0.68
	36	9.78	9.24		3.26	2.52		1.93	1.53

continue

Region	Activities	land use	deforestation	Region	land use	deforestation	Region	land use	deforestation
R19	1	0.00	0.00	R20	0.00	0.00	R21	0.16	0.02
	2	0.09	0.00		0.02	0.00		0.05	0.00
	3	31.56	2.70		0.56	0.55		2.55	1.20
	4	0.23	1.09		0.00	0.34		0.01	0.23
	5	1.19	12.02		0.01	0.01		0.03	0.02
	6	37.28	51.25		3.63	2.58		27.37	21.18
	7	0.20	0.20		0.38	0.41		0.15	0.17
	8	0.08	0.10		0.07	0.08		0.35	0.55
	9	0.01	0.00		0.03	0.02		0.02	0.02
	10	0.00	0.00		0.00	0.00		0.01	0.00
	11	14.81	17.21		13.74	15.61		24.63	30.28
	12	9.40	10.90		9.19	10.42		15.96	19.60
	13	0.14	0.16		0.70	0.79		0.19	0.24
	14	1.78	2.06		2.71	3.07		13.06	16.01
	15	0.00	0.00		3.84	2.13		4.17	2.85
	16	0.00	0.00		0.72	0.36		0.22	0.12
	17	0.00	0.00		0.02	0.02		0.04	0.04
	18	0.02	0.01		0.03	0.02		0.13	0.12
	19	0.00	0.00		0.04	0.06		0.00	0.00
	20	0.00	0.00		0.03	0.02		0.01	0.01
	21	0.00	0.00		0.02	0.02		0.06	0.06
	22	0.01	0.00		0.05	0.04		0.03	0.03
	23	0.01	0.00		0.00	0.00		0.00	0.00
	24	0.00	0.00		0.00	0.00		4.87	1.16
	25	0.00	0.00		0.38	0.32		0.22	0.20
	26	0.00	0.00		0.00	0.00		0.00	0.00
	27	0.01	0.00		0.03	0.03		0.01	0.01
	28	0.00	0.00		0.05	0.03		0.03	0.02
	29	0.00	0.00		0.01	0.01		0.03	0.02
	30	0.00	0.00		0.06	0.04		0.05	0.04
	31	0.02	0.01		0.48	0.34		0.06	0.05
	32	0.56	0.24		4.60	2.13		0.96	0.52
	33	0.04	0.01		0.64	0.26		0.09	0.04
	34	0.00	0.00		0.20	0.15		0.01	0.01
	35	1.21	1.06		13.66	16.20		2.30	2.85
	36	1.33	0.97		44.12	43.96		2.20	2.34

continue

Region	Activities	land use	deforestation	Region	land use	deforestation	Region	land use	deforestation
R22	1	0.06	0.04	R23	0.28	0.02	R24	0.16	0.02
	2	0.00	0.00		0.02	0.00		0.03	0.00
	3	4.48	2.08		3.33	0.83		1.10	1.47
	4	0.00	0.00		0.23	0.44		0.00	0.00
	5	0.04	0.03		0.28	0.21		0.01	0.01
	6	38.84	43.16		30.61	29.85		37.17	24.66
	7	0.10	0.10		0.56	0.60		0.05	0.06
	8	0.62	0.08		5.07	4.35		3.16	1.58
	9	0.03	0.02		0.02	0.02		0.07	0.06
	10	0.00	0.00		0.01	0.00		0.00	0.00
	11	38.08	41.20		15.49	18.69		41.32	55.20
	12	1.79	1.94		3.13	3.77		4.84	6.46
	13	0.08	0.08		0.14	0.17		0.16	0.21
	14	4.14	4.47		25.64	30.80		2.24	2.98
	15	1.83	1.09		5.31	2.83		2.01	1.55
	16	0.16	0.08		0.17	0.08		0.05	0.03
	17	0.00	0.00		0.48	0.40		0.02	0.04
	18	0.01	0.01		0.14	0.12		0.04	0.07
	19	0.30	0.30		1.14	1.48		0.00	0.00
	20	0.00	0.00		0.03	0.03		0.01	0.01
	21	0.00	0.00		0.02	0.02		0.00	0.00
	22	0.01	0.00		0.02	0.02		0.02	0.02
	23	0.02	0.00		0.01	0.00		0.00	0.00
	24	4.11	1.22		2.88	0.58		4.05	1.16
	25	0.08	0.06		0.07	0.06		0.02	0.02
	26	0.00	0.00		0.00	0.00		0.00	0.00
	27	0.02	0.01		0.01	0.01		0.01	0.01
	28	0.00	0.00		0.05	0.04		0.02	0.02
	29	0.01	0.01		0.04	0.03		0.00	0.00
	30	0.02	0.01		0.06	0.05		0.01	0.01
	31	0.05	0.03		0.02	0.02		0.03	0.03
	32	1.14	0.55		0.96	0.48		0.58	0.40
	33	0.04	0.01		0.11	0.04		0.06	0.04
	34	0.01	0.00		0.01	0.01		0.01	0.01
	35	1.63	1.52		2.07	2.37		1.14	1.73
	36	2.31	1.90		1.57	1.56		1.62	2.15

continue

Region	Activities	land use	deforestation	Region	land use	deforestation	Region	land use	deforestation
R25	1	0.02	0.01	R26	0.07	0.13	R27	0.00	0.00
	2	0.05	0.00		0.14	0.01		0.09	0.02
	3	2.40	2.29		35.80	45.70		4.60	14.02
	4	0.00	0.00		0.00	0.00		0.00	0.00
	5	0.01	0.00		0.06	0.05		0.03	0.03
	6	17.97	18.09		2.70	10.07		16.47	31.81
	7	0.11	0.10		0.46	0.40		0.00	0.00
	8	0.20	0.02		0.12	0.02		71.26	46.73
	9	0.05	0.03		0.01	0.01		0.00	0.00
	10	0.00	0.00		0.00	0.00		0.01	0.01
	11	50.67	52.83		3.22	3.14		0.00	0.00
	12	19.71	20.51		11.31	11.01		0.00	0.00
	13	0.13	0.14		0.02	0.02		0.00	0.00
	14	1.56	1.62		6.78	6.59		2.11	3.16
	15	0.00	0.00		8.04	4.80		0.00	0.00
	16	0.23	0.10		1.04	0.52		0.00	0.00
	17	0.02	0.02		0.49	0.51		0.00	0.00
	18	0.04	0.03		0.31	0.27		0.08	0.12
	19	0.08	0.08		0.31	0.22		0.00	0.00
	20	0.01	0.00		0.01	0.00		0.95	0.67
	21	0.00	0.00		0.01	0.00		2.13	1.50
	22	0.03	0.01		0.05	0.02		0.00	0.00
	23	0.00	0.00		0.05	0.01		0.00	0.00
	24	2.00	0.41		4.57	1.45		0.00	0.00
	25	0.01	0.01		0.06	0.03		0.08	0.06
	26	0.00	0.00		0.00	0.00		0.00	0.00
	27	0.01	0.01		0.03	0.01		0.00	0.00
	28	0.01	0.01		0.02	0.01		0.00	0.00
	29	0.00	0.00		0.05	0.02		0.00	0.00
	30	0.03	0.01		0.09	0.03		0.02	0.01
	31	0.04	0.02		0.39	0.17		0.00	0.00
	32	0.88	0.37		3.28	1.35		0.44	0.25
	33	0.12	0.04		0.24	0.06		0.15	0.06
	34	0.01	0.01		0.05	0.02		0.00	0.00
	35	1.77	1.72		7.64	5.34		0.82	0.84
	36	1.84	1.51		12.58	8.00		0.74	0.71

continue

Region	Activities	land use	deforestation	Region	land use	deforestation	Region	land use	deforestation
R28	1	1.94	0.32	R29	0.01	0.00	R30	0.69	0.06
	2	0.00	0.00		0.00	0.00		0.00	0.00
	3	0.91	1.47		4.36	2.81		0.07	0.08
	4	0.07	0.36		0.00	0.00		0.00	0.00
	5	3.74	5.77		0.01	0.01		0.07	0.07
	6	4.96	4.60		41.62	40.12		16.37	14.19
	7	0.39	0.48		0.06	0.06		0.21	0.30
	8	1.57	0.78		0.06	0.03		0.00	0.00
	9	0.02	0.02		0.06	0.04		0.04	0.04
	10	0.00	0.00		0.00	0.00		0.01	0.01
	11	26.06	34.73		34.55	38.25		6.27	9.44
	12	3.85	5.12		9.93	10.98		0.90	1.35
	13	1.05	1.40		0.47	0.52		0.34	0.51
	14	8.79	11.67		2.03	2.25		10.69	16.06
	15	23.54	15.72		0.32	0.20		45.54	36.77
	16	0.26	0.15		0.01	0.00		0.35	0.23
	17	0.18	0.32		0.01	0.01		0.12	0.14
	18	0.47	0.70		0.01	0.00		0.02	0.03
	19	1.32	1.96		0.12	0.14		0.04	0.06
	20	0.06	0.05		0.00	0.00		0.00	0.00
	21	0.24	0.22		0.00	0.00		0.01	0.00
	22	0.16	0.15		0.00	0.00		0.04	0.03
	23	0.93	0.28		0.00	0.00		0.00	0.00
	24	8.19	1.77		1.80	0.48		3.05	0.78
	25	0.28	0.26		0.01	0.01		0.36	0.38
	26	0.00	0.00		0.00	0.00		0.00	0.00
	27	0.05	0.05		0.01	0.00		0.01	0.01
	28	0.53	0.41		0.00	0.00		0.00	0.00
	29	0.33	0.29		0.00	0.00		0.00	0.00
	30	0.17	0.16		0.01	0.00		0.01	0.01
	31	0.07	0.06		0.04	0.02		0.10	0.09
	32	2.20	1.31		0.51	0.26		1.31	0.98
	33	0.21	0.10		0.03	0.01		0.11	0.06
	34	0.02	0.01		0.01	0.00		0.02	0.02
	35	4.52	5.97		1.07	1.14		7.03	10.27
	36	2.91	3.35		2.89	2.64		6.20	8.02

continue

Region	Activities	land use	deforestation	Region	land use	deforestation	Region	land use	deforestation
R31	1	0.00	0.00	R32	0.00	0.00	R33	0.85	0.09
	2	0.00	0.00		0.00	0.00		0.00	0.00
	3	0.10	0.07		1.08	3.60		3.22	1.71
	4	0.03	0.07		0.08	0.05		0.00	0.00
	5	0.26	0.20		0.29	0.28		0.00	0.00
	6	28.68	27.75		23.06	14.45		21.12	12.88
	7	0.19	0.21		0.27	0.31		0.03	0.04
	8	2.62	1.36		2.04	3.61		0.08	0.24
	9	0.13	0.09		0.07	0.10		0.03	0.04
	10	0.02	0.01		0.00	0.00		0.00	0.00
	11	21.86	25.70		29.26	32.56		6.20	9.30
	12	5.55	6.51		9.56	10.63		13.23	19.81
	13	0.40	0.47		1.10	1.22		0.34	0.51
	14	16.55	19.39		14.92	16.61		27.86	41.73
	15	3.48	1.92		4.87	3.33		7.29	6.04
	16	0.49	0.24		0.16	0.10		0.00	0.00
	17	0.19	0.12		0.09	0.13		0.00	0.00
	18	0.12	0.08		0.21	0.28		0.01	0.02
	19	1.27	1.35		0.28	0.38		0.02	0.03
	20	0.02	0.01		0.04	0.05		0.00	0.00
	21	0.00	0.00		0.00	0.00		0.00	0.00
	22	0.11	0.06		0.08	0.08		0.00	0.00
	23	1.07	0.22		0.06	0.02		0.00	0.00
	24	0.10	0.02		0.68	0.18		18.75	6.12
	25	0.42	0.29		0.08	0.07		0.00	0.00
	26	0.00	0.00		0.00	0.00		0.00	0.00
	27	0.02	0.01		0.01	0.01		0.01	0.01
	28	0.07	0.04		0.09	0.07		0.00	0.00
	29	0.08	0.04		0.05	0.04		0.00	0.00
	30	0.06	0.03		0.10	0.10		0.00	0.00
	31	0.13	0.08		0.09	0.07		0.01	0.02
	32	1.97	0.94		2.06	1.23		0.18	0.14
	33	0.26	0.08		0.34	0.16		0.01	0.01
	34	0.03	0.02		0.03	0.03		0.00	0.00
	35	7.46	7.28		4.55	5.52		0.33	0.59
	36	6.26	5.35		4.38	4.74		0.42	0.65

continue

Region	Activities	land use	deforestation	Region	land use	deforestation	Region	land use	deforestation
R34	1	0.07	0.00	R35	0.45	0.03	R36	0.33	0.02
	2	0.00	0.00		0.09	0.02		0.00	0.00
	3	2.38	1.85		4.40	3.84		0.07	0.08
	4	0.00	0.00		0.00	0.00		0.00	0.00
	5	0.05	0.04		0.00	0.00		0.12	0.12
	6	22.72	19.21		21.99	8.81		9.92	17.89
	7	0.21	0.22		0.08	0.12		0.52	0.66
	8	1.46	2.36		0.18	0.61		0.01	0.00
	9	0.03	0.03		0.03	0.05		0.16	0.13
	10	0.00	0.00		0.00	0.00		0.01	0.00
	11	24.78	27.78		28.66	39.09		11.26	15.76
	12	7.61	8.52		21.41	29.18		1.16	1.62
	13	0.05	0.05		1.28	1.75		3.36	4.71
	14	23.59	26.37		1.60	2.19		7.51	10.49
	15	4.98	2.66		9.01	7.92		19.11	14.08
	16	0.15	0.07		0.00	0.00		0.94	0.54
	17	0.12	0.11		0.00	0.00		0.25	0.30
	18	0.27	0.25		0.05	0.10		0.56	0.59
	19	0.31	0.39		0.16	0.29		2.93	3.49
	20	0.01	0.02		0.01	0.01		0.01	0.00
	21	0.02	0.02		0.00	0.00		0.03	0.02
	22	0.07	0.07		0.01	0.02		0.10	0.07
	23	0.18	0.05		0.00	0.00		0.11	0.03
	24	0.21	0.04		7.90	2.29		16.47	3.38
	25	0.11	0.08		0.01	0.01		0.04	0.03
	26	0.00	0.00		0.00	0.00		0.00	0.00
	27	0.05	0.04		0.01	0.01		0.05	0.03
	28	0.14	0.09		0.01	0.01		0.02	0.02
	29	0.20	0.14		0.00	0.00		0.00	0.00
	30	0.13	0.10		0.01	0.02		0.06	0.03
	31	0.11	0.08		0.01	0.01		0.22	0.16
	32	1.57	0.80		0.60	0.49		2.56	1.68
	33	0.21	0.09		0.04	0.03		0.21	0.08
	34	0.02	0.01		0.00	0.00		0.04	0.03
	35	3.95	4.38		0.93	1.52		8.99	10.36
	36	4.21	4.07		1.05	1.59		12.90	13.60

continue

Region	Activities	land use	deforestation	Region	land use	deforestation	Region	land use	deforestation
R37	1	0.14	0.01	R38	0.26	0.02	R39	0.00	0.00
	2	0.00	0.00		0.02	0.00		0.00	0.00
	3	0.03	0.01		4.14	15.36		1.05	0.34
	4	0.00	0.00		0.00	0.01		0.00	0.00
	5	0.04	0.03		0.07	0.06		0.02	0.02
	6	5.72	4.59		5.24	2.03		12.66	7.78
	7	0.30	0.33		0.33	0.33		0.05	0.06
	8	0.01	0.01		2.46	1.87		0.04	0.14
	9	0.04	0.03		0.05	0.04		0.28	0.35
	10	0.00	0.00		0.00	0.00		0.09	0.06
	11	23.74	28.52		19.09	19.16		19.65	25.36
	12	4.97	5.96		30.07	30.14		3.56	4.59
	13	2.04	2.45		1.09	1.10		2.90	3.74
	14	27.15	32.53		13.15	13.19		11.35	14.61
	15	16.17	10.16		7.61	4.50		4.35	2.25
	16	0.74	0.37		0.26	0.12		0.81	0.41
	17	0.17	0.17		0.32	0.56		0.09	0.10
	18	0.11	0.10		0.37	0.52		0.22	0.24
	19	0.26	0.28		0.00	0.00		0.27	0.40
	20	0.00	0.00		0.09	0.06		0.01	0.02
	21	0.08	0.04		0.22	0.16		0.10	0.12
	22	0.06	0.04		0.12	0.09		0.22	0.23
	23	0.00	0.00		0.47	0.11		9.91	3.06
	24	2.72	0.48		2.34	0.39		0.00	0.00
	25	0.38	0.27		0.19	0.13		0.75	0.69
	26	0.00	0.00		0.00	0.00		0.00	0.00
	27	0.04	0.02		0.05	0.03		0.06	0.05
	28	0.06	0.03		0.30	0.18		0.16	0.12
	29	0.21	0.13		0.21	0.14		0.21	0.17
	30	0.05	0.02		0.28	0.20		0.09	0.08
	31	0.13	0.08		0.12	0.08		0.25	0.20
	32	1.78	1.00		2.34	1.16		3.77	2.06
	33	0.22	0.08		0.24	0.09		0.77	0.36
	34	0.03	0.02		0.02	0.02		0.04	0.03
	35	6.50	6.58		4.45	4.56		14.52	19.04
	36	6.10	5.65		4.01	3.60		11.77	13.30

continue

Region	Activities	land use	deforestation	Region	land use	deforestation	Region	land use	deforestation
R40	1	0.10	0.00	R41	0.00	0.00	R42	0.00	0.00
	2	0.00	0.00		0.07	0.01		0.00	0.00
	3	1.30	0.47		8.32	16.43		8.07	15.09
	4	0.00	0.00		0.00	0.00		0.00	0.00
	5	0.06	0.05		0.17	0.11		0.15	0.12
	6	3.20	5.19		0.95	0.39		2.38	2.41
	7	0.31	0.34		0.21	0.18		0.38	0.36
	8	0.00	0.00		0.91	0.14		3.35	2.75
	9	1.34	0.93		0.02	0.01		0.92	0.66
	10	0.05	0.03		0.00	0.00		0.01	0.00
	11	10.69	12.85		22.65	22.40		22.14	22.29
	12	3.10	3.73		33.00	32.56		12.19	12.26
	13	9.92	11.93		0.14	0.14		10.12	10.20
	14	27.16	32.57		15.39	15.12		14.09	14.15
	15	7.26	4.77		5.25	2.61		8.02	4.50
	16	0.56	0.29		0.42	0.18		0.24	0.11
	17	0.25	0.27		0.00	0.00		0.52	0.75
	18	0.75	0.70		0.18	0.18		2.04	2.44
	19	0.02	0.02		4.76	4.74		0.43	0.44
	20	0.01	0.00		0.09	0.04		0.22	0.15
	21	0.01	0.01		0.11	0.05		0.40	0.27
	22	0.05	0.03		0.18	0.09		0.29	0.19
	23	0.00	0.00		0.00	0.00		0.01	0.00
	24	5.99	1.09		0.65	0.10		0.00	0.00
	25	0.07	0.05		0.07	0.04		0.14	0.09
	26	0.00	0.00		0.00	0.00		0.00	0.00
	27	0.01	0.01		0.06	0.03		0.11	0.06
	28	0.03	0.01		0.34	0.17		0.58	0.31
	29	0.01	0.00		0.25	0.14		0.17	0.10
	30	0.05	0.02		0.53	0.29		0.29	0.18
	31	0.23	0.14		0.05	0.03		0.12	0.07
	32	2.92	1.64		1.16	0.48		2.38	1.09
	33	0.17	0.06		0.13	0.04		0.25	0.08
	34	0.03	0.02		0.01	0.00		0.02	0.01
	35	13.68	13.23		2.34	2.10		5.95	5.58
	36	10.67	9.55		1.58	1.20		4.00	3.26

continue

Region	Activities	land use	deforestation	Region	land use	deforestation	Region	land use	deforestation
R43	1	0.04	0.00	R44	0.50	0.04	R45	0.00	0.00
	2	0.00	0.00		0.00	0.00		0.00	0.00
	3	0.13	0.11		0.11	0.36		29.96	13.66
	4	0.00	0.00		0.00	0.00		0.00	0.00
	5	0.23	0.22		0.39	0.79		0.05	0.04
	6	33.57	30.67		4.92	2.38		0.49	0.54
	7	0.67	0.86		0.15	0.18		0.10	0.12
	8	0.02	0.01		0.58	0.51		2.43	0.41
	9	0.11	0.10		0.09	0.08		0.09	0.06
	10	0.07	0.05		0.00	0.00		0.01	0.00
	11	6.47	8.90		23.85	29.06		28.38	45.36
	12	2.34	3.22		2.47	3.00		0.00	0.00
	13	0.12	0.16		0.47	0.58		1.28	2.05
	14	16.64	22.83		22.37	27.18		3.79	5.99
	15	10.69	7.53		13.77	8.64		7.32	4.67
	16	0.49	0.29		0.75	0.39		0.70	0.40
	17	0.08	0.07		0.29	0.47		2.72	2.90
	18	0.31	0.29		0.54	0.75		0.18	0.20
	19	0.11	0.15		0.40	0.54		0.96	1.49
	20	0.03	0.02		0.05	0.04		0.09	0.05
	21	0.04	0.02		0.36	0.31		0.11	0.08
	22	0.04	0.03		0.34	0.29		0.16	0.12
	23	2.26	0.62		0.42	0.11		0.98	0.31
	24	5.41	1.28		2.94	0.61		0.00	0.00
	25	0.05	0.04		1.62	1.36		0.21	0.19
	26	0.02	0.01		0.00	0.00		0.00	0.00
	27	0.05	0.04		0.10	0.08		0.07	0.05
	28	0.05	0.04		0.76	0.53		0.50	0.37
	29	0.09	0.07		0.60	0.47		0.31	0.25
	30	0.06	0.04		0.16	0.14		0.12	0.09
	31	0.21	0.17		0.14	0.11		0.20	0.16
	32	2.38	1.52		4.02	2.22		3.71	2.14
	33	0.19	0.08		0.47	0.21		0.46	0.22
	34	0.03	0.03		0.05	0.04		0.05	0.04
	35	8.13	10.44		8.77	10.61		6.74	9.23
	36	8.89	10.09		7.53	7.90		7.82	8.77

conclusion

Region	Activities	land use	deforestation	Region	land use	deforestation
R46	1	0.00	0.00	R47	0.03	0.00
	2	0.00	0.00		0.00	0.00
	3	0.09	0.03		1.75	1.17
	4	0.00	0.00		0.00	0.00
	5	0.00	0.00		0.03	0.02
	6	60.90	58.12		74.84	75.02
	7	0.00	0.00		0.00	0.00
	8	0.09	0.21		0.83	0.08
	9	0.06	0.05		0.04	0.02
	10	0.01	0.01		0.01	0.01
	11	34.34	37.12		11.05	12.12
	12	0.00	0.00		0.65	0.71
	13	0.00	0.00		0.24	0.27
	14	0.91	0.99		5.43	5.93
	15	0.00	0.00		0.31	0.17
	16	0.00	0.00		0.06	0.03
	17	0.00	0.00		0.00	0.00
	18	0.00	0.00		0.00	0.00
	19	0.00	0.00		0.32	0.37
	20	0.00	0.00		0.00	0.00
	21	0.00	0.00		0.00	0.00
	22	0.00	0.00		0.00	0.00
	23	0.00	0.00		0.00	0.00
	24	0.00	0.00		0.12	0.03
	25	0.00	0.00		0.00	0.00
	26	0.00	0.00		0.00	0.00
	27	0.01	0.01		0.01	0.00
	28	0.00	0.00		0.00	0.00
	29	0.00	0.00		0.00	0.00
	30	0.00	0.00		0.00	0.00
	31	0.03	0.02		0.01	0.01
	32	0.61	0.33		0.58	0.30
	33	0.10	0.04		0.04	0.02
	34	0.01	0.01		0.00	0.00
	35	1.37	1.57		2.66	2.82
	36	1.45	1.49		0.96	0.89

Source: elaborated by the author based on the results.

APPENDIX E – Export structure by activities and countries/regions

Table E.1 – Percentage values of Brazilian exports by activities to each country/region – percentage values

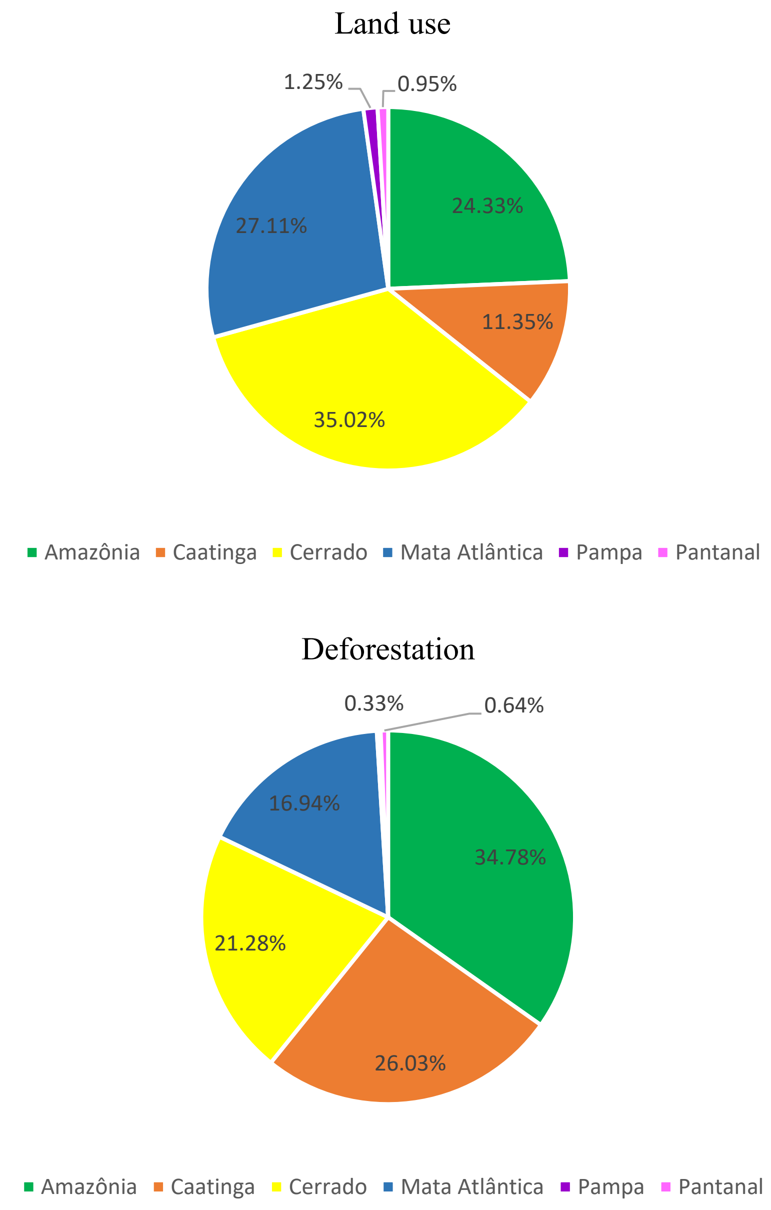
	Activities	EU	US	China	Row
1	Sugarcane	0.00	0.00	0.00	0.00
2	Soybeans	7.07	0.00	44.94	3.31
3	Other temporary crop products and services	2.08	0.47	0.56	7.17
4	Coffee beans	9.65	4.98	0.04	1.68
5	Other products from permanent crops	3.95	1.74	0.83	1.22
6	Bovine and other live animals, animal products, hunting and services	0.21	0.57	0.05	0.34
7	Pigs, poultry and eggs	0.00	0.00	0.00	0.14
8	Logging and forestry	0.16	0.05	0.06	0.20
9	Fishing and aquaculture	0.03	0.32	0.00	0.03
10	Extractive activities	15.11	9.90	31.62	12.01
11	Meat of bovine animals and other meat products	4.66	1.21	1.32	5.36
12	Pork and poultry	0.57	0.01	1.76	7.06
13	Industrialized fish	0.06	0.11	0.02	0.06
14	Milk and dairy products	0.00	0.03	0.00	0.36
15	Other food products	17.63	3.85	2.98	12.70
16	Beverages	0.13	1.91	0.16	0.49
17	Tobacco products	0.02	0.01	0.00	0.08
18	Manufacture of textiles, clothing and accessories	0.26	0.59	0.12	0.81
19	Manufacture of footwear and leather goods	2.87	1.90	1.78	1.58
20	Wood products, excluding furniture	1.42	3.57	0.15	0.86
21	Cellulose, paper and paper products manufacturing	7.74	5.15	5.67	2.38
22	Various industries	0.62	1.89	0.08	2.07
23	Petroleum refining and coking plants	1.20	1.03	0.01	1.37
24	Manufacture of biofuels	0.04	0.02	0.00	0.11
25	Chemical products	6.33	6.38	1.42	8.41
26	Fertilizers, pesticides and disinfectants	0.05	0.07	0.00	0.57
27	Mineral products, steel, metallurgy and related	9.12	21.33	3.82	9.95
28	Machinery and equipment	6.78	18.88	2.02	13.52
29	Manufacture of transport vehicles, including parts	2.04	13.27	0.57	5.73
30	Furniture	0.16	0.49	0.01	0.31
31	Energy, gas, water, sewage, waste management and other utilities	0.02	0.06	0.00	0.07
32	Trade	0.00	0.00	0.00	0.00
33	Transportation	0.00	0.00	0.00	0.00
34	Warehousing and postal services	0.00	0.00	0.00	0.00
35	Accommodation and food	0.00	0.00	0.00	0.00
36	Various services	0.02	0.23	0.00	0.06

Source: elaborated by the author based on ComexStat (2023).

APPENDIX F – Sensitivity analysis of the results – land use (2015-2017) and deforestation (2012-2017)

Appendix F.1 – Intranational trade

Figure F.1.1 – Agriculture land use embodied in trade by biome



Source: elaborated by the author based on the results.

Table F1.1 – Embodied agricultural land in trade between Brazilian biomes – percentage values

		receptor					
		Amazônia	Caatinga	Cerrado	Mata Atlântica	Pampa	Pantanal
consumer	Amazônia	54.03	1.58	3.16	1.31	0.60	6.29
	Caatinga	4.44	61.79	2.53	2.32	0.62	1.30
	Cerrado	12.43	5.29	49.30	10.41	5.74	23.31
	Mata Atlântica	27.69	30.81	43.53	83.96	30.53	43.61
	Pampa	1.34	0.51	1.40	1.98	62.50	2.25
	Pantanal	0.07	0.01	0.07	0.03	0.02	23.24
	Total	100.00	100.00	100.00	100.00	100.00	100.00

Source: elaborated by the author based on the results.

Table F.1.2 – Embodied agricultural deforestation in trade between Brazilian biomes – percentage values

		receptor					
		Amazônia	Caatinga	Cerrado	Mata Atlântica	Pampa	Pantanal
consumer	Amazônia	58.70	1.59	3.80	1.09	0.55	6.93
	Caatinga	4.74	63.09	3.37	2.95	0.60	1.34
	Cerrado	10.89	4.96	54.55	7.78	5.82	24.18
	Mata Atlântica	24.41	29.85	36.98	86.70	30.19	42.62
	Pampa	1.20	0.49	1.24	1.46	62.83	2.21
	Pantanal	0.06	0.01	0.06	0.02	0.02	22.72
	Total	100.00	100.00	100.00	100.00	100.00	100.00

Source: elaborated by the author based on the results.

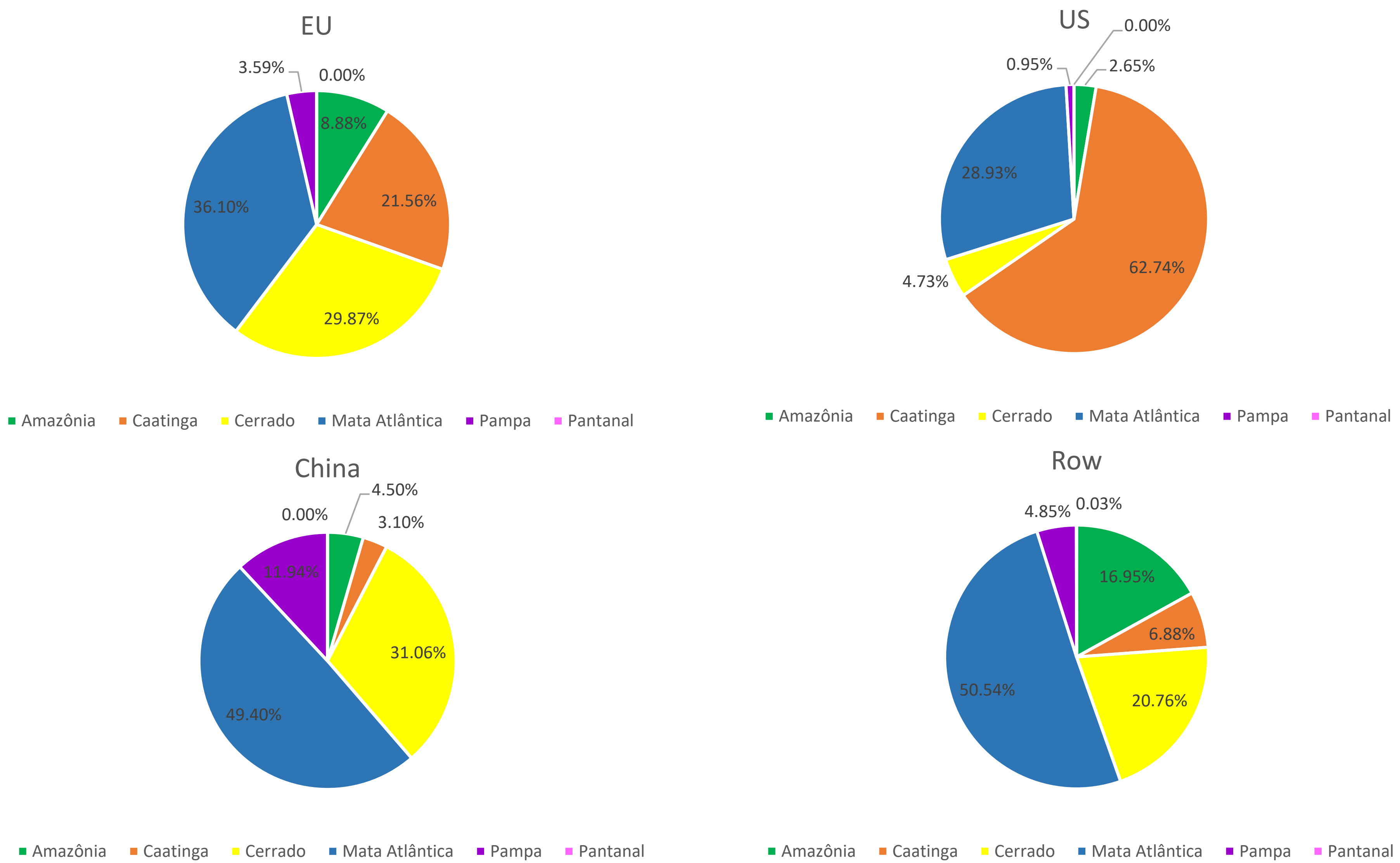
Table F.1.3 – Agricultural land and agriculture-caused deforestation embodied in intranational trade by activities – percentage values

	Activities	land use	deforestation
1	Sugarcane	0.21	0.02
2	Soybeans	0.02	0.00
3	Other temporary crop products and services	2.73	3.07
4	Coffee beans	0.02	0.05
5	Other products from permanent crops	0.61	0.65
6	Bovine and other live animals, animal products, hunting and services	20.46	26.07
7	Pigs, poultry and eggs	0.24	0.28
8	Logging and forestry	1.20	0.72
9	Fishing and aquaculture	0.12	0.10
10	Extractive activities	0.01	0.00
11	Meat of bovine animals and other meat products	26.12	27.78
12	Pork and poultry	8.02	7.53
13	Industrialized fish	1.27	1.65
14	Milk and dairy products	14.54	16.30
15	Other food products	7.13	3.67
16	Beverages	0.37	0.17
17	Tobacco products	0.19	0.19
18	Manufacture of textiles, clothing and accessories	0.27	0.26
19	Manufacture of footwear and leather goods	0.74	0.85
20	Wood products, excluding furniture	0.04	0.02
21	Cellulose, paper and paper products manufacturing	0.11	0.06
22	Various industries	0.12	0.07
23	Petroleum refining and coking plants	0.63	0.12
24	Manufacture of biofuels	2.07	0.36
25	Chemical products	0.36	0.20
26	Fertilizers, pesticides and disinfectants	0.00	0.00
27	Mineral products, steel, metallurgy and related	0.04	0.02
28	Machinery and equipment	0.24	0.11
29	Manufacture of transport vehicles, including parts	0.18	0.09
30	Furniture	0.11	0.06
31	Energy, gas, water, sewage, waste management and other utilities	0.10	0.06
32	Trade	2.00	0.86
33	Transportation	0.23	0.07
34	Warehousing and postal services	0.02	0.01
35	Accommodation and food	4.66	4.35
36	Various services	4.82	4.16

Source: elaborated by the author based on the results.

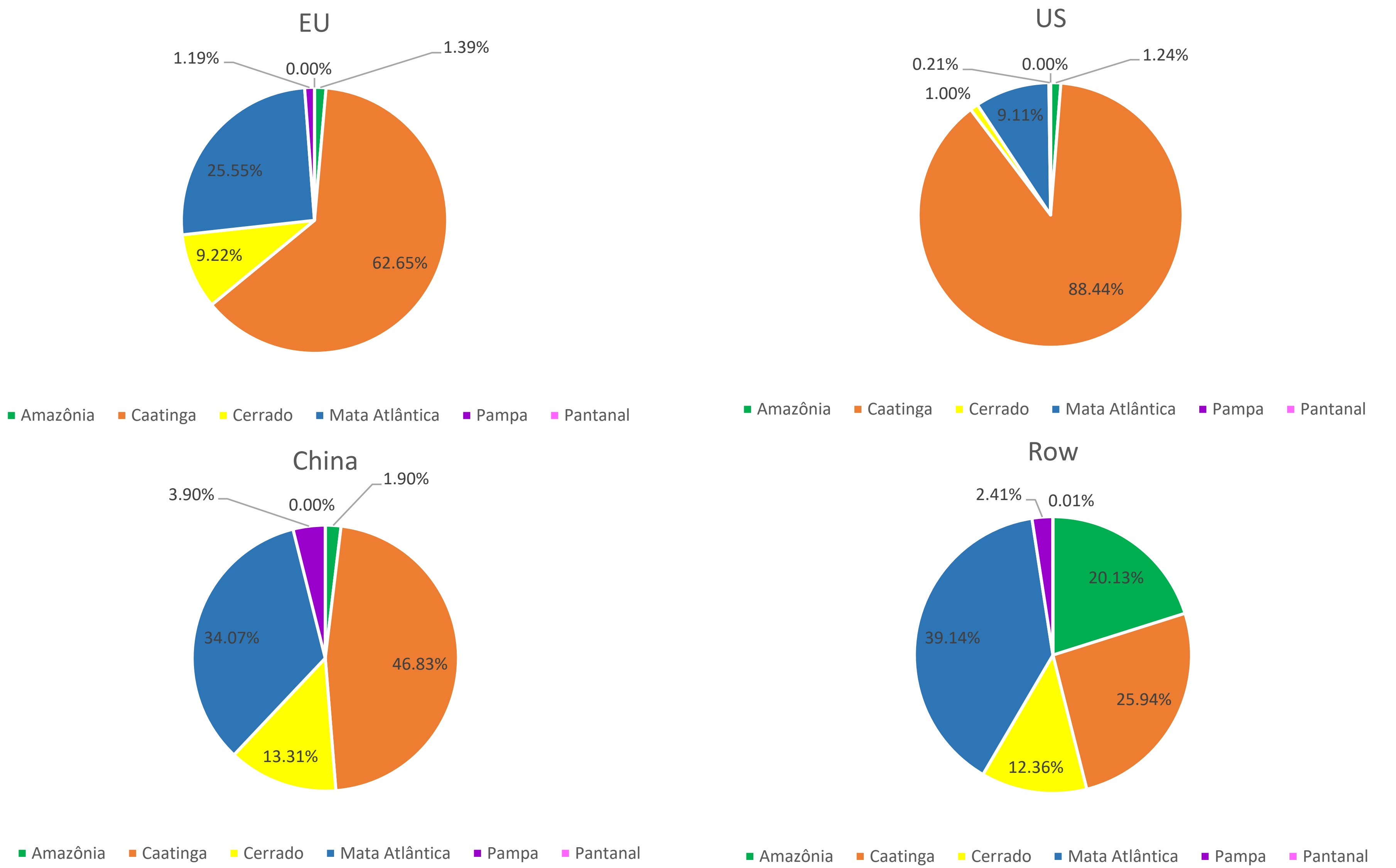
Appendix F.2 – International trade

Figure F.2.1- Distribution of trade with agricultural land content by biome and country/region



Source: elaborated by the author based on the results.

Figure F.2.2- Distribution of trade with agriculture-caused deforestation content by biome and country/region



Source: elaborated by the author based on the results.

Table F.2.1 – Distribution of trade with agricultural land content by country/region and activity – percentage values

	Activities	EU	US	China	Row
1	Sugarcane	0.00	0.00	0.00	0.00
2	Soybeans	21.72	0.02	84.83	8.81
3	Other temporary crop products and services	4.22	1.03	0.36	6.09
4	Coffee beans	7.39	5.14	0.02	0.92
5	Other products from permanent crops	0.33	0.54	0.02	0.09
6	Bovine and other live animals, animal products, hunting and services	18.71	63.94	3.06	12.88
7	Pigs, poultry and eggs	0.00	0.00	0.00	0.08
8	Logging and forestry	1.42	0.45	0.26	1.29
9	Fishing and aquaculture	0.01	0.13	0.00	0.01
10	Extractive activities	0.37	0.34	0.41	0.23
11	Meat of bovine animals and other meat products	22.52	8.02	3.44	24.87
12	Pork and poultry	2.78	0.04	4.72	27.60
13	Industrialized fish	0.45	3.14	0.22	0.69
14	Milk and dairy products	0.01	0.11	0.00	0.85
15	Other food products	14.15	4.79	1.32	8.31
16	Beverages	0.02	0.48	0.01	0.07
17	Tobacco products	0.35	0.14	0.01	1.20
18	Manufacture of textiles, clothing and accessories	0.02	0.08	0.01	0.06
19	Manufacture of footwear and leather goods	1.48	1.41	0.48	0.62
20	Wood products, excluding furniture	0.52	2.41	0.03	0.31
21	Cellulose, paper and paper products manufacturing	1.33	1.27	0.56	0.39
22	Various industries	0.06	0.26	0.00	0.16
23	Petroleum refining and coking plants	0.39	0.49	0.00	0.36
24	Manufacture of biofuels	0.48	0.34	0.02	0.92
25	Chemical products	0.52	0.82	0.07	0.61
26	Fertilizers, pesticides and disinfectants	0.00	0.01	0.00	0.03
27	Mineral products, steel, metallurgy and related	0.40	1.38	0.09	0.36
28	Machinery and equipment	0.11	0.44	0.02	0.18
29	Manufacture of transport vehicles, including parts	0.11	1.02	0.02	0.24
30	Furniture	0.01	0.06	0.00	0.02
31	Energy, gas, water, sewage, waste management and other utilities	0.00	0.00	0.00	0.00
32	Trade	0.00	0.00	0.00	0.22
33	Transportation	0.00	0.00	0.00	0.14
34	Warehousing and postal services	0.00	0.00	0.00	0.03
35	Accommodation and food	0.00	0.00	0.00	1.13
36	Various services	0.11	1.72	0.01	0.22

Source: elaborated by the author based on the results.

Table F.2.2 – Distribution of trade with agriculture-caused deforestation content by country/region and activity – percentage values

	Activities	EU	US	China	Row
1	Sugarcane	0.00	0.00	0.00	0.00
2	Soybeans	1.16	0.00	27.21	0.81
3	Other temporary crop products and services	3.11	0.42	1.21	8.24
4	Coffee beans	11.56	3.61	0.10	1.69
5	Other products from permanent crops	0.19	0.17	0.04	0.07
6	Bovine and other live animals, animal products, hunting and services	60.54	87.87	46.61	35.39
7	Pigs, poultry and eggs	0.00	0.00	0.00	0.06
8	Logging and forestry	0.25	0.05	0.22	0.22
9	Fishing and aquaculture	0.00	0.04	0.00	0.01
10	Extractive activities	0.15	0.05	0.57	0.11
11	Meat of bovine animals and other meat products	13.60	2.24	8.19	22.03
12	Pork and poultry	1.62	0.01	10.56	21.50
13	Industrialized fish	0.30	1.86	0.98	0.99
14	Milk and dairy products	0.01	0.03	0.00	0.64
15	Other food products	4.58	0.92	1.52	3.62
16	Beverages	0.01	0.06	0.01	0.02
17	Tobacco products	0.28	0.08	0.04	1.27
18	Manufacture of textiles, clothing and accessories	0.02	0.03	0.02	0.06
19	Manufacture of footwear and leather goods	1.18	0.54	1.38	0.63
20	Wood products, excluding furniture	0.21	0.48	0.05	0.17
21	Cellulose, paper and paper products manufacturing	0.57	0.30	0.92	0.21
22	Various industries	0.02	0.05	0.01	0.08
23	Petroleum refining and coking plants	0.06	0.04	0.00	0.08
24	Manufacture of biofuels	0.05	0.02	0.01	0.14
25	Chemical products	0.23	0.19	0.13	0.44
26	Fertilizers, pesticides and disinfectants	0.00	0.00	0.00	0.01
27	Mineral products, steel, metallurgy and related	0.16	0.27	0.16	0.19
28	Machinery and equipment	0.04	0.07	0.03	0.08
29	Manufacture of transport vehicles, including parts	0.04	0.18	0.02	0.12
30	Furniture	0.00	0.01	0.00	0.01
31	Energy, gas, water, sewage, waste management and other utilities	0.00	0.00	0.00	0.00
32	Trade	0.00	0.00	0.00	0.07
33	Transportation	0.00	0.00	0.00	0.04
34	Warehousing and postal services	0.00	0.00	0.00	0.02
35	Accommodation and food	0.00	0.00	0.00	0.85
36	Various services	0.05	0.41	0.02	0.14

Source: elaborated by the author based on the results.