Faculté des sciences

Tropical deforestation embodied in agricultural and forestry imports

The case of Belgium

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Academic year 2020-2021
Master [120] in Geography: General

Abstract

Over the past two decades, more than 200 million hectares of forest across the tropics have disappeared. About 60% of deforestation have mainly been driven by agricultural expansion responding to a growing population, dietary changes and increasing biofuel demand. With international trade responsible for about one-third of agricultural expansion, the increasing geographic separation between production and consumption makes it difficult to assign responsibility for environmental and social impacts to consumers. As new legislation on a EU level is being discussed, other national measures should follow for tackling deforestation. The objectives of this thesis are therefore to quantify the environmental impacts embedded in Belgian agricultural and forestry imports and Belgian consumption, then to compare it with other EU countries. The next objective is to locate deforestation hotspots and main commodities imports with the highest impacts. The last step consists in analysing companies linked to some commodity-country combinations. The results indicate that Belgium has a high consumption of forest-risk commodities and the majority of its embedded deforestation area and CO_2 emissions are found in seven imported commodities that are mainly sourced from only a few countries, i.e. palm oil from Indonesia, Malaysia and Papua New Guinea; soybean from Brazil, Argentina and Paraguay; cocoa from Côte d'Ivoire, Papua New Guinea, Indonesia and Liberia; coffee from Honduras, Peru, Uganda and Indonesia; rapeseed from Australia; wood products from Brazil and Indonesia and beef and buffalo meat from Brazil and Argentina. About 60% of biodiversity loss embodied in Belgian imports are suffered in 10 tropical countries and more than 90% are due to coffee, cocoa, palm oil, bananas, rapeseed, coconuts and soy production. Moreover, at a subnational level, for Brazilian soy for example, the origin of deforestation embedded in Belgian imports is concentrated in 8 municipalities, mainly located in Mato Grosso. Finally, more than 92% of Belgian imports of Brazilian and Argentinian soy, Ghanaian cocoa and Brazilian beef and more than 65% for cocoa from Côte d'Ivoire were traded by only 10 companies (not the same companies for each commodity). Furthermore, zero-deforestation commitments are not covering the majority of soy imports, the achievement of them have been undermined by leakage and there are far from being met. Lastly, implementation of policies towards producers, supply-chain actors and consumers as well as actions taken by individuals, governments, civil society and private sector need to operate together for achieving zero-deforestation targets.

Acknowledgements

Before digging onto deforestation and the reason why I will never ever put Nutella on my toast again, I would like to thank all the people who have contributed to the realization of this thesis.

First of all, I would like to thank my supervisor Patrick Meyfroidt for having taken the time to find a subject that inspired me, for having given me the freedom to go towards what I wanted to deepen while guiding me all along, for his availability throughout the year until the end of the writing, for his listening and his support as well as his reflections and comments that allowed me to be more confident in what is about to be told in this thesis.

I would also like to thank all the people who participated in meetings, workshops and discussions in which I was able to take part and which proved to be very constructive.

Je voudrais également remercier K_mi pour toutes ces superbes journées passées à télétravailler ensemble, pour sa formation LaTeX sans qui ce mémoire ne paraîtrait pas aussi propre, pour ses relectures et son soutien, et pour avoir subvenu à mes besoins pendant les premiers mois #Windows3.

Merci à tous mes DBG préférées pour m'avoir accompagnée dans ces années d'études à rallonge et m'avoir montrée que la vie de jeune travailleuse, c'est bien mieux que ce que ça ne parait être. Un merci tout particulier à Delph Déèsse qui n'a jamais cessé de croire en moi.

Merci à mon groupe de runneuses ultra sportives, sans qui, le lac de LLN ne serait qu'un lointain souvenir du temps où l'on pouvait encore se poser boire des bières tranquillou.

Merci à ma famille pour l'interêt porté à mes *graphes remplis de belles couleurs*. Merci à mes parents de manière plus générale pour leur soutien dans mes choix, et la liberté qu'ils m'ont offert tout en en étant ne cessant jamais d'être la pour moi.

Merci aux CaillouxTD pour ces 5 années entre bottines de marche, bottes de pluies et London bridge.

Je voudrais terminer par remercier du fond du coeur le kot32 et plus particulièrement, Carla, Charles, Emile, Nico, Val, Vivi et Martin qui ont fait en sorte que cette dernière année à Louvain-la-Neuve, dans des conditions plutôt particulières, soit digne d'une année plus que mémorable. Merci à Nini pour toutes ces doses de caféines *fairtrade* partagées avec savoir-faire. Merci à Blanchon pour avoir fait en sorte que descendre les escaliers ne soient pas mes seules sorties de la journée #GuideLLN #SissySession #PermisB. Et enfin, un merci tout particulier à Mimi, pour son soutien continu, sans qui ce mémoire n'aurait peut-être jamais commencé, son aide si précieuse, ses idées, ses rerererelectures, et tant d'autres choses.

Glossary

AFOLU Agricultural, Forestry and Other Land Use. 4

apparent consumption is the "domestic disappearance/utilization defined as production plus imports minus exports, adjusted for changes in inventories." Note that "the concept distinguishes between intermediate consumption (seed, feed, processing) and final utilization (waste, food, industrial use) subject to data system boundaries. As highly processed products (e.g., cotton shirts, ethanol, furniture) are not tracked by the underlying FAO data system and recorded as industrial or other use, final consumption will differ from apparent consumption by the amount of traded highly processed products not recorded by this data system." (European Commission, 2013). 12–14

BASP Belgian Alliance for Sustainable Palm Oil. 41

BFA The mission of the Belgian Feed Association is to represent the interests of its members and to work towards the general social acceptance of sustainable feed production. BFA's 140 members (feed manufacturers) account for approximately 95% of the national production. Feed manufacturers use high-quality raw materials and recycle approximately 3.4 million tons of by-products from the food and biofuel industries each year, which would otherwise end up in landfills. Translated from BFA (2021). 41

biome is a large community of vegetation and wildlife adapted to a specific climate. The five major types of biomes are aquatic, grassland, forest, desert, and tundra (National Geographic definition). 4

CBA Consumption-based accounting. 11

commodities are "resources or basic agricultural and forestry products. These traded goods usually have not yet undergone much of processing" (European Commission, 2013). 1, 4, 6, 13, 35, 49

company code of conduct "is a document written up voluntarily by a company in which it sets out a set of principles that it commits itself to follow, or requires its employees to file. In some cases, codes of conduct reach suppliers, subcontractors, and third parties. It is a type of code of conduct." Wikipedia. 43

deforestation front is "place that [has] a significant concentration of deforestation hotspots and where large areas of remaining forests are under threat" (WWF). 3, 37

deforestation risk "deforestation (in hectares) and CO2 emissions (in tonnes) linked to commodities imported into the EU should be interpreted as indicators of exposure or "risk". This description of risk follows the terminology used in Trase where commodity deforestation risk describes the exposure of an actor (company or country) to the risk that the commodity it is sourcing is directly associated with recent deforestation in the region where it was produced." (Wedeux and Schulmeister-Oldenhove, 2021). 2, 12, 14, 36, 37

due diligence "According to the OECD Due Diligence Guidance for Responsible Business Conduct, supply chain due diligence is an ongoing, proactive and reactive process through which companies monitor and administer their purchases and sales with a view to ensuring that they do not contribute to conflict or related adverse impacts. According to a more comprehensive view, this also includes impacts on environment and climate, human rights (including labour rights) and health risks." (ETRMA, 2020). 9, 45

embedded deforestation synonym of *embodied deforestation*. 8, 16, 49

embodied deforestation "The deforestation embodied (as an externality) in a produced, traded, or consumed product, good, commodity or service.It is the deforestation associated with the production of a good, commodity or service.It excludes, per definition, deforestation that cannot be associated with consumable or tradable commodities, products, goods and services. Deforestation for which no clear cause can be identified or deforestation caused by natural hazards are thus excluded. [...] Embodied deforestation in soy meaning the deforestation that was necessary to convert a forest in cropland to cultivate soy." (European Commission, 2013). 1, 2, 9, 12–17, 36, 37, 48, 49

FAO Food and Agriculture Organisation. 3

FC Forest Code. 39, 40

FRA Forest Resources Assessment. 3

FRC Forest Risk Commodities. 1, 8, 9, 35, 42, 43, 69, 76

FSC Forest Stewardship Council. 36

indirect land use change is "essentially identical to land use spillover, so it is a land use change somewhere that happens because of some land use change somewhere else. Often used in the context of biofuels" (Meyfroidt *et al.*, 2020). 6

land sparing "consists of separating land for conservation from land for crops, with high-yield farming facilitating the protection of remaining natural habitats from agricultural expansion" (Phalan *et al.*, 2011). 43

leakage is "a land use spillover or iLUC that happens due to an environmental policy, and which reduces the effectiveness of that policy" (Meyfroidt *et al.*, 2020). 6, 7, 10, 45, 50

LULUC Land Use, Land-use Change. 5, 37

LULUCF Land Use, Land-use Change and Forestry. 37

MATOPIBA States of Maranhão, Tocantins, Piauí and Bahia. 39

MRIO Multi-Regional Input-Output. 11, 34, 47

New York Declaration on Forests "(NYDF) is a political declaration calling for global action to protect and restore forests. It offers a common, multi-stakeholder framework for forest action, consolidating various initiatives and objectives that drive forest protection, restoration, and sustainable use. Adopted in 2014, the NYDF is the major reference point for global forest action." It was signed by over 200 governments, companies, financial institutions and NGOs ($https://forestdeclaration.org/about$) . 1, 8, 49

PEFC Programme for the Endorsement of Forest Certification. 36

proximate causes "are human activities or immediate actions at the local level, such as agricultural expansion, that originate from intended land use and directly impact forest cover" (Geist and Lambin, 2002:143). 1, 5, 8

PTF Physical Trade Flow. 16, 34, 47

REDD Reducing Emissions from Deforestation and Forest Degradation. 44

RSPO Roundtable on Sustainable Palm Oil. 41

SDG Sustainable Development Goal. 5, 8, 12, 49

shifting agriculture "is a system of cultivation in which a plot of land is cleared and cultivated for a short period of time, then abandoned and allowed to revert to producing its normal vegetation while the cultivator moves on to another plot" (OECD-Glossary of Statistical terms $https://stats.oecd.org/glossary/detail.asp?ID = 2452$). 5, 46

SOC Soil Organic Carbon. 4

spillover "some effects happening somewhere due to some effect elsewhere" (Meyfroidt *et al.*, 2020). 6

telecoupled world is a world where socioeconomic and environmental interactions between coupled human and natural systems occur over distances (Liu *et al.*,2013). 1

third-party certification is a "certification provided by an external and independent organization which verifies that the compliance with the standards/specifications is being met (independent from the certified organization and from the organization that drew up the specifications. Within the context of the certifications, a set of "specifications" comprises a full range of economic, social and environmental criteria that must be fulfilled in order to receive certification). The third-party certification provides independent and impartial confirmation that a product fully meets a set of published specifications." (Euromonitor International Consulting, 2017). 41

TOC Theory of Change: the causal chain through which the policies address deforestation (Bager et al., 2021). 9

TRASE Transparency for Sustainable Economies. 13

underlying driving forces "are fundamental social processes, such as human population dynamics or agricultural policies, that underpin the proximate causes and either operate at the local level or have an indirect impact from the national or global level." (Geist and Lambin, 2020:143). 1, 5, 8

ZDC Zero Deforestation Commitment. 10, 17, 34, 40

Contents

Chapter 1
Introduction

If deforestation was a country, it would be the second emitter of anthropogenic greenhouse gas after fossil fuels (Pendrill *et al.*, 2019a; IPCC, 2019). Over the past two decades, more than 200 million hectares of forest have disappeared across the tropics (Hansen *et al.*, 2019 in Butler, 2019), roughly the size of Mexico. Enormous amounts of carbon were hence released into the atmosphere (Harris *et al.*, 2021). Yet, forest loss has not been distributed homogeneously across the globe. While some developed regions have seen their forest cover increase, tropical and subtropical regions have seen their forests being cut down at an alarming rate (Pendrill *et al.*, 2019a).

Deforestation affects and threatens both local and global population as it contributes to global warming (IPCC, 2019), loss of biodiversity (IPBES, 2019), disturbance of water cycle and soil carbon storage (Foley *et al.*, 2005; Folke *et al.*, 2019; IPCC, 2019), in addition to threatening the rights of local communities (Forest Peoples Programme, 2018). Tropical deforestation results from a combination of proximate causes and underlying driving forces happening both at local and regional level (Geist and Lambin, 2002). It is primarily induced by agriculture and forestry expansion accounting for approximately 60% of total forest loss (Pendrill *et al.*, 2019b), and particularly the expansion of a few commodities such as soy, palm oil, beef, cocoa, coffee and wood (Curtis *et al.*, 2018; Pendrill *et al.*, 2019b) called forest-risk commodities (FRCs). This cropland expansion is mainly driven by population growth, changes in dietary patterns and increasing biofuel demand (Meyfroidt and Lambin, 2011). International trade of commodities, by responding to this growing demand, accounts for about 29-39% of tropical deforestation driven by agricultural and forestry expansion (Pendrill *et al.*, 2019b).

In a globalized or telecoupled world (Liu *et al.*, 2013), the increasing geographical separation of production and consumption disconnects the consumers from the environmental and social impacts (Liu *et al.*, 2013). Unexpected consequences that can have great implications for sustainability are increasingly dependent on the influence of interactions occurring between distant places (Liu *et al.*, 2013). While it remains complex to draw the connections between environmental impacts and supply chains with growing number of actors, commitments taken by different entities have emerged throughout the years. For instance, the New York Declaration on Forests, the Amsterdam Declarations Partnership and zero deforestation company commitments (Gardner *et al.*, 2019) aim at reducing or achieving zero net deforestation. These voluntary commitments have shown themselves to be not as effective as declared (Lambin *et al.*, 2018; van der Ven *et al.*, 2018; Garrett *et al.*, 2019). In fact, some have proven to reduce deforestation in one location, while displacing the problem to others. Moreover, since commitments are voluntary, transparency and actual actions are currently lacking (Lambin *et al.*, 2018). This is why legal frameworks have emerged and new legislation is being discussed. To reduce imported embodied deforestation, the implementation of policies on all levels, namely producers, supply-chain actors and consumers, needs to be considered (Lambin *et al.*, 2018). On the production side along with supply-chain actors, zero-deforestation risk regulations could be enforced with a focus on certain commodities and geographic locations. On the consumer side, there is a need to reduce consumption of environmentally damaging commodities (Bager *et al.*, 2021). Therefore, the growing worldwide demand for commodities and the lack of investment in responsible production and consumption are increasing the risk of deforestation and also threatening other ecosystems (Jennings and Schweizer, 2019). With the complexity of international trade and the increasing spatial and temporal distance between producer and consumer, traceability and transparency are key to implementing efficient measures. Losing information along the line makes it difficult to understand the system and jeopardizes its improvement. In order to quantify environmental impacts and be able to establish regulations, different tools and approaches have been developed. Since different models and geographic scales of analysis provide different results, at what scale should the data be analyzed to furnish enough heterogeneity?

The European Union represents the second biggest importer of embodied deforestation (Pendrill *et al.*, 2019b) and Belgium has a particularly high impact as a small country. There are ongoing discussions on how Belgium could reduce its imported footprint. Clear numbers can help to make decisions and set priorities as well as target the efforts in order to prevent this deforestation. Therefore, the goal of this thesis is to quantify the environmental impacts of tropical deforestation associated with Belgian imports and to get a clear picture of the current operating actors, i.e. producer countries, supply-chain companies and consumers. The study is divided in two distinct parts: a literature review and a quantification of the environmental impacts attributed to Belgium. The literature review covers deforestation across the tropics, environmental and social impacts, direct and indirect drivers with a focus on agricultural and forestry expansion together with the role of international trade. Then, the current legal frameworks, the standards and commitments from a supply-chain standpoint will be reviewed. The last part of the literature review focuses on methods used to quantify the different environmental impacts. The second part of the thesis aims at putting numbers and names on these environmental impacts for commodities imported by Belgium. The objective is to answer the following questions: firstly, what are the environmental impacts embodied in Belgium's agricultural and forestry imports compared to other countries? Why is there a difference? What does it represent compared to Belgium's consumption? Secondly, what and from where are the environmental impacts embodied in Belgium's main commodity imports? Thirdly, for the commodities with higher embodied CO_2 emissions linked to deforestation and higher deforestation risk associated with Belgian imports, where does deforestation exactly happen, which companies are operating them and how?

Several hypotheses which will be tested in this piece of work were formulated on these research questions. Firstly, environmental impacts embodied in Belgium's agricultural and forestry imports are higher compared to the European average and Belgium has a high consumption. Secondly, a small number of commodities and producer countries accounts for the majority of the environmental impacts imported by Belgium. Finally, at the sub-national level, deforestation imported by Belgium is concentrated in a small number of municipalities/departments and only a handful of companies imports the majority of them.

Chapter 2
Literature review

2.1 Tropical deforestation

Deforestation trends significantly vary across the globe. It is increasing at an alarming rate in tropical and subtropical countries with high carbon stock and/or high biodiversity (Hansen *et al.*, 2013, Pendrill *et al.*, 2019a), while decreasing in many primarily developed countries where lands are less ecologically rich (Lambin, 2015). However, what is the overall balance of forest cover? Remote-sensing satellites have been monitoring the Earth since 1972. Nevertheless, estimates of annual deforestation do not match. According to FRA 2020, (FAO, 2020), deforestation is slowing down on a global scale, whereas from Hansen *et al.* (2013), it is increasing.

First of all, before digging on deforestation, defining this term seems necessary. Deforestation is a frequently used word, yet, there is currently no consensus on its definition (Fernàndez-Montes de Oca *et al.*, 2021). It becomes problematic when it is adopted in decision-making such as conservation policies (Lund, 2002), especially when contrasting definitions exist between different international and national reports (Fernàndez-Montes de Oca *et al.*, 2021). The most widely used definition for 'forest' is the one formulated by the FAO (Grainger, 2008) and is the first one to be used by all countries. A forest is defined by a "land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use" (FAO and UNEP, 2020). However, definition of *forest* is evolving depending on its objectives of use and management from timber management to Earth stewardship, to conversation and climate change (Chazdon *et al.*, 2016).

Since 2000, around 200 million of hectares of forest have been lost across the tropics (Hansen *et al.*, 2019 in Butler, 2019), while even more have been degraded (IPCC, 2019). In the last decade, the pace of deforestation has particularly rapidly accelerated in Sub-Saharan Africa and increased in Asia. In Latin and Central America, the rate at which deforestation occurs has slowed down, although deforestation in itself keeps increasing (IDH, 2020). Between 2004 and 2017, around 43 million hectares of forest were lost in deforestation fronts (Figure 2.1), which are "places that have a significant concentration of deforestation hotspots and where large areas of remaining forests are under threat" (Pacheco *et al.*, 2021).

2.1.1 Environmental and social impacts

Changes in land use due to the expansion of croplands, pastures, plantations and urban areas in the recent decades have been affecting the capacity of the earth to deliver important ecosystem services such as climate regulation, freshwater supply, air quality, carbon storage and biodiversity richness (Foley *et al.*, 2005).

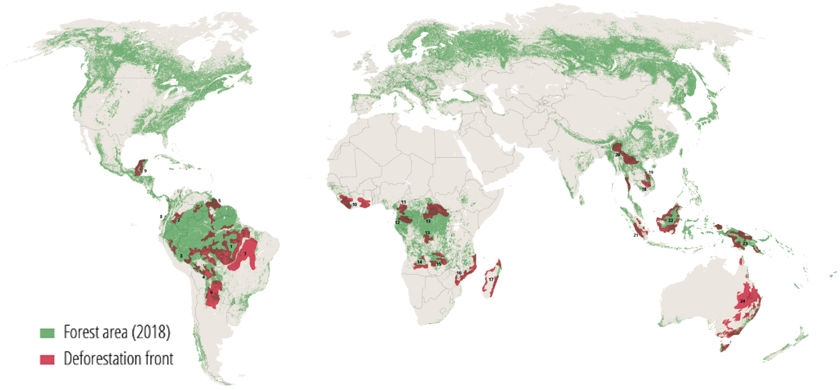


Figure 2.1: *Deforestation fronts. Modified from WWF (2021)*

Environmental and social impacts of deforestation can be observed at both local and global levels. At a local scale, deforestation followed by plantation is responsible of soil erosion, water pollution, forest degradation, use of chemicals, biodiversity loss and destruction of wild habitat, soil degradation due to high use of fertilizers, pesticides and fuels, etc. (Folke *et al.*, 2019). Local communities are directly affected. For example, international trade of commodities implying deforestation are responsible for 20% of the malaria risk in deforestation hot spots (Chaves *et al.*, 2020). Moreover, about 20% of fires on dried-out peat in Indonesia are associated with palm oil plantations. These fires which are particularly difficult to extinguish, release clouds of suffocating smoke into the atmosphere (Petrenko *et al.*, 2016), therefore exposing regional population to high smoke concentrations (Marlier *et al.*, 2015). Finally, removing forest cover threatens indigenous population's rights living in a symbiotic relationship with their environment (Forest Peoples Programme, 2020; Pacheco *et al.*, 2021).

On a global scale, the earth resilience is affected (IPBES, 2019). Tropical deforestation is one of the primary causes of global environmental changes (Geist and Lambin, 2002). As a matter of fact, since tropical forests are home of at least two-thirds of the world's biodiversity (Raven, 1988) and cover 10% of the earth (Bradshaw *et al.*, 2009), deforestation represents the first driver of territorial biodiversity loss (IPBES, 2019) putting biodiversity under high threat (Giam, 2017). Moreover, the loss of terrestrial biodiversity functions threatens human health and economic activities (Cardinale *et al.*, 2012; Hooper *et al.*, 2012; IPBES, 2019). Additionally, around one third of the global first-meter soil organic carbon (SOC) stock is contained in tropical soils (Köchy *et al.*, 2015). Hence, they represent major reservoirs of SOC, which are highly important components of the global carbon cycle (Köchy *et al.*, 2015). Exposure of deeper soil horizons and release of carbon are threatened by deforestation and land-use change such as agricultural expansion (Drake *et al.*, 2019). Converting one hectare of new land in the tropics releases nearly two times as much carbon than in temperate regions (West *et al.*, 2010). Tropical rainforest is the biome storing the highest quantity of carbon (Harris *et al.*, 2021). However, other biomes can store large amounts of it, such as grasslands (Bond and Parr, 2010) and savannahs in which trees can store high quantities of carbon in their roots (Grace *et al.*, 2006). These biomes are also considered as biodiversity hotspots (Bond and Parr, 2010; Soterroni *et al.*, 2019). Furthermore, deforestation is ranked at the second place regarding anthropogenic greenhouse gas emissions (Pendrill *et al.*, 2019b). The majority of AFOLU emissions happen in the tropics (Lamb *et al.*, 2021). Latin America and Southeast Asia are subject to the greatest increase, which is not stabilizing (Lamb *et al.*, 2021). Carbon losses from deforestation and degradation of organic soils, including peatlands, are the main components of these emissions from LULUC (Tubiello, 2019 in Crippa *et al.*, 2021). Since tropical countries are subject to higher levels of erosion because they cannot afford soil protection measures (Borrelli *et al.*, 2017), cropland expansion is expected to drive an overall increase in global soil erosion, especially in Sub-Saharan Africa, South America and Southeast Asia (Borrelli *et al.*, 2017).

Finally, tropical forests are essential for the accomplishment of SDGs (IDH, 2020). The achievement of all of them can be directly or indirectly supported by biodiversity (Blicharska *et al.*, 2019). However, they can also all be undermined by climate change (Fuso Nerini *et al.*, 2019).

2.1.2 Drivers

2.1.2.1 Agricultural and forestry expansion

Proximate causes of deforestation operate at a local level. They are associated with human activities or actions that directly impact forest cover by land use change such as agricultural expansion (Geist and Lambin, 2002). Underlying driving forces, on the other hand, occur either at local level or both national and global level. They are due to fundamental social processes that underlie the proximate causes, such as human population dynamics or agricultural policies (Geist and Lambin, 2002). Proximate drivers, namely agriculture (commercial and subsistence), mining, infrastructure and urban expansion are more easily linked to deforestation than underlying drivers (Hosonuma *et al.*, 2012). Interaction between the different causes is also responsible for deforestation (Geist and Lambin, 2002). Feedbacks can amplify deforestation in frontier regions such as in the Amazon lowlands and in southeast Asia with new roads and settlements alongside these frontiers (Geist and Lambin, 2002). Most of the links between cause and consequence are context dependent of a region, namely the historical and geographical background. Therefore, there is no universal direct link (Geist and Lambin, 2002).

Currently, agriculture and forestry expansion are the main drivers of deforestation across the tropics (Hosonuma *et al.*, 2012; Curtis *et al.*, 2018; Pendrill *et al.*, 2019b). It went from a small-scale farmer-led deforestation with the help of governments (state colonization programs) from the 1960s to the 1980s in the tropical forests of Latin America and Southeast Asia to a well-capitalized and large-scale ranchers, farmers and loggers deforestation from the 1980s in the lowland rainforests in Brazil and Indonesia (Rudel *et al.*, 2009). Deforestation has been driven since then by an increased globalized consumer demand, switching from a local to a more distant driver (Rudel *et al.*, 2009). Nowadays (Figure 2.2), 60% of tropical deforestation is caused by agricultural expansion (Pendrill *et al.*, 2019b). Yet, shifting agriculture and commodity-driven deforestation are primarily drivers not homogeneously distributed across the tropics (Curtis *et al.*, 2018). Most forest loss is caused by palm oil plantations in South-East Asia, especially in Indonesia and Malaysia, by raw crop agriculture (mainly soy) and cattle ranching in Central and South America (Curtis *et al.*, 2018; IDH, 2020) and by shifting agriculture in Sub-Saharan Africa (Curtis *et al.*, 2018; Seymour and

Harris, 2019). It might gain importance in the Congo Basin in the following years (IDH, 2020).

A few commodities such as soy, palm oil, beef and wood have the highest impacts (Curtis *et al.*, 2018; Pendrill *et al.*, 2019b). The most traded agricultural commodity worldwide is soy (Escobar *et al.*, 2020) and it is both directly and indirectly related to forest and other natural vegetation loss (Zalles *et al.*, 2019). In fact, since soy expands on pasture, which pushes cattle ranging -the direct cause- to deforest other areas (Smaling *et al.*, 2008; Boerema *et al.*, 2016; Pendrill *et al.*, 2019b), soy is considered as an indirect cause. However, in more recent years, soy production has also become a direct cause of deforestation (Smaling *et al.*, 2008).

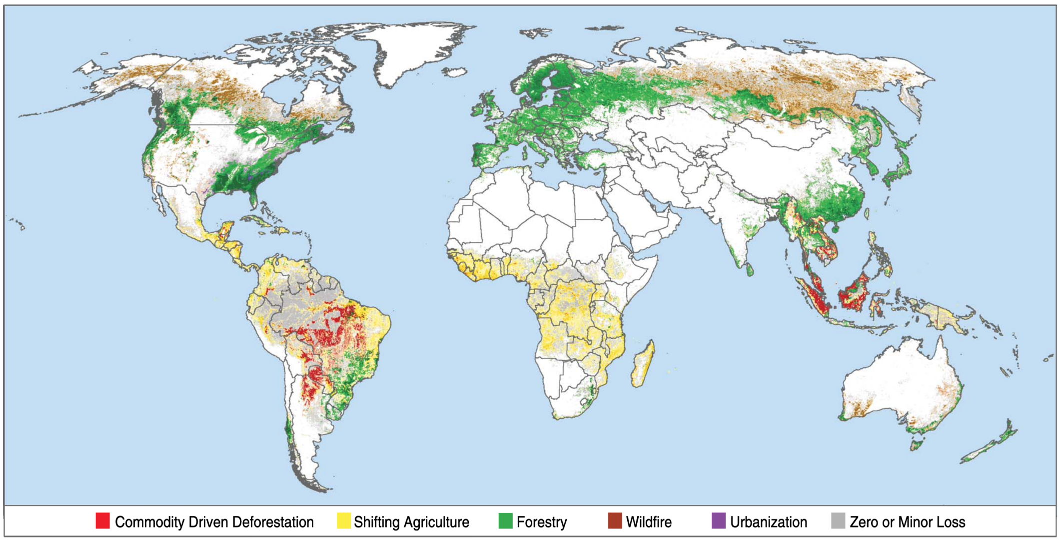


Figure 2.2: *Primary drivers of forest cover loss (2001-2015)* [1]. *From Curtis et al. (2018).*

2.1.2.2 Leakage and spillovers

When it comes to land use policies, unintended consequences can happen through leakage and indirect land use changes (i.e. land use spillovers) (Meyfroidt *et al.*, 2013) (see Appendix A.1 for more details). Human-nature interactions between distant places can cause unexpected outcomes impacting sustainability, called the spillover effects (Meyfroidt and Lambin, 2011; Liu *et al.*, 2013; Liu *et al.* 2018). Therefore, conservation efforts need to acknowledge potential spillover effects to other areas in order to be effective (Meyfroidt and Lambin, 2009: Lapola *et al.*, 2010; Meyfroidt and Lambin, 2011; Dou *et al.*, 2018). It can be illustrated with the Soy Moratorium and zero-deforestation beef agreement in the Amazon, which are supply-chain agreements that have been subject to spillover (Moffette and Gibbs, 2021) or undermined by leakage (Alix-Garcia and Gibbs, 2017). As a matter of fact, deforestation has significantly been reduced in the Amazon biome, but at the same time deforestation in the neighbouring biome, the Cerrado, has increased (Dou *et al.*, 2018). Since 1970, half of the natural vegetation in the Cerrado has disappeared for agricultural purposes and nowadays, around 7% of the biome - roughly the size of England - is dedicated to soy

[1] Note that the loss due to forestry in temperate regions is compensated by regrowth and is therefore not defined as 'deforestation' in the strict sense. By contrast, 27% of global forest loss can be referred as deforestation since permanent land use change occurs through commodity production (Curtis *et al.*, 2018).

production (Jennings and Schweizer, 2019). Same processes, i.e. spillover effects, have taken place with palm oil sustainability certification (Heilmayr *et al.*, 2020a). Previous studies have shown that forest transition countries, i.e. countries for which their forest cover is increasing, have experienced displaced land use outside their borders or illegal deforestation (Pendrill *et al.*, 2019a). For example, in Vietnam, after a logging ban was introduced, the country illegally offshored part of its deforestation (Meyfroidt and Lambin, 2009). Bhutan, following forest protection policies, has also started offshoring wood extraction mainly from India, although this was compliant with their internal legal framework. In India, the wood was extracted from sustainably managed forest plantations, rather than primary forests in Bhutan. So, in this case, sourcing from another country can also better serve biodiversity and carbon storage (Jadin *et al.*, 2016). In Costa Rica, intensification of bananas and pineapple production has allowed to protect forests. However, the need of wood for wooden pallets to export their production undermined the benefits of forest transition (Jadin *et al.*, 2016). Achieving global transition remains a more complex task than regional or national forest transition, since the net forest gains in post-forest transition countries are being offset by imported deforestation (Pendrill *et al.*, 2019a).

Overall effectiveness of deforestation regulations can be reduced by substitution effects between local and international consumer markets, and between different actors (le Polain de Waroux *et al.*, 2019). Therefore, to design better and more effective land-use regulations to avoid deforestation leakage (e.g. displacement of land use across countries in response to conservation policies) (Meyfroidt et Lambin, 2011), a clearer understanding of how regulations affects companies is necessary (le Polain de Waroux *et al.*, 2016). For instance, agricultural companies are now investing in the Gran Chaco region because they are attracted to invest in regions with less strict deforestation regulation and enforcement (le Polain de Waroux *et al.*, 2016). In addition, decreasing in agricultural expansion is not necessarily linked with leakage. For instance, from a study reviewing agricultural expansion and abandonment in Mato Grosso (Brazil), the decrease in agricultural expansion might be the consequence of the scarcity of remaining high quality agricultural land and not of deforestation governance (Spera *et al.*, 2014).

2.1.3 International trade

International trade has its positive and negative development and environmental impacts (Liu *et al.*, 2013). It can be linked to economic growth and poverty reduction for low- and middle-income countries (Dollar and Kraay, 2004). Moreover, considering that imports come mainly from higher yield areas, globalization has led to a more efficient use (Kastner *et al.*, 2014a; Sandström *et al.*, 2017) of land (Kastner *et al.*, 2014a), water (Dalin *et al.*, 2012) and other resources (Kastner *et al.*, 2014a; Sandström *et al.*, 2017). However, the disconnection between producer and consumer countries leads to a displacement of environmental and health impacts such as water, air pollution and biodiversity loss. These impacts are namely caused by high carbon emissions, agricultural land use and use of pesticides, insecticides and antimicrobial veterinary medicines (Foley *et al.*, 2011; Cederberg *et al.*, 2019). With increased income, the use of biomass increases, however due to international trade, it can be less clear (Mayer *et al.*, 2005; Erb *et al.*, 2009; Rudel *et al.*, 2009; Meyfroidt and Lambin, 2011).

Around 29-39% of the emissions related to deforestation driven by agricultural and forestry expansion in the tropics are caused by international trade (Pendrill *et al.*, 2019b) from which 87% is imported by countries wherein reforestation or decrease in deforestation is taking place, i.e. Europe and Asia with China, India and Russia (Pendrill *et al.*, 2019a). Following China, the European Union is the second importer of embedded deforestation (Pendrill *et al.*, 2019b). It is partly due to its limitation in producing most FRCs (forest-risk commodities) coupled with being a high consumer of these commodities and also a host of a great number of food and feed processing industries (IDH, 2020). Between 2000 and 2015, global trade of agricultural commodities has more than doubled (Escobar *et al.*, 2020). This is in part because of an increasing demand for FRCs such as soy, palm oil, cocoa, coffee, beef and timber. For instance, soybean meal produced from the residue left after oil extraction is used for animal feeding mainly in intensive breeding (Jennings and Schweizer, 2019). Soy expansion is therefore linked to the growing demand for meat consumption. These FRCs have in common a high elasticity of demand, which means that when the price falls, the demand increases sharply (Lambin, 2015). This is not the case for staple food such as rice and wheat. Moreover, the growth margin for the commodities with high elasticity of demand is tremendous. For example, a Belgian eats on average 9 kg of chocolate per year while a Chinese less than 50 gr (Lambin, 2015).

In addition to emissions, 30% of global endangered species - excluding invasive ones - are threatened by international trade (Lenzen *et al.*, 2012). Even if international trade allows for a more efficient use of resources, a trade-off between ecological impacts need to be considered since high biodiversity areas are being compromised (Sandström *et al.*, 2017).

2.2 Policies, measures and food patterns

Globalization makes it difficult to assign responsibility for imported deforestation. Progress has been made in sustainably producing some commodities such as palm oil, soy or cocoa (Lambin *et al.*, 2018). However, this only covers a small part of their total production and it is mainly based on voluntary commitments. Little effects come out of these commitments, which are not sufficient to reach carbon neutrality (Lambin *et al.*, 2018). Moreover, even if there are agreements on the table, most of them remain on paper and are not on the way to be met (Bager *et al.*, 2021) resulting in being far from the accomplishment of SDGs. Indeed, as global deforestation goals intentions were to eliminate commodity driven deforestation by 2020, for instance, the Consumer Goods Forum (CGF) failed to achieve zero net deforestation in key commodity sectors by 2020 and the New York Declaration on Forests (NYDF) failed to halve the rate of deforestation by 2020 making it even more difficult to stop it by 2030 (Thomson, 2020).

Case study-based evidence underlines that before implementing guidelines, understanding the complexity of proximate causes and underlying driving forces on a regional scale is necessary since no universal policy and measures can be applied to tropical deforestation around the globe (Geist and Lambin, 2002). Moreover, conservation actions need to consider possible spillover effects beforehand in order to be effective (Meyfroidt and Lambin, 2009:

Lapola *et al.*, 2010; Meyfroidt and Lambin, 2011; Dou *et al.*, 2018). Furthermore, taking into account all farmers is important. Indeed, the decrease in deforestation coupled with the increase in production in the Amazon show that the sector is able to adapt to new measures. However, the gaps between medium- and- large-scale producers and smallholders-farmers is widening since the latter do not have enough resources for complying with the environmental legislation (Laurent *et al.*, 2017). Understanding the complexity of the system could be done with the help of a telecoupling framework, which "identifies systems, flows, causes, effects, as well as agents, which provides a more comprehensive evaluation of the spillover effect" (Dou *et al.*, 2018: 1717).

2.2.1 Legal frameworks

The legal frameworks discussed in this section focus on importer and/or consumer countries. There is a whole other set of legal frameworks that concerns producing countries such as land zoning and anti-deforestation policies (Nolte *et al.*, 2017a;b) that is only indirectly addressed here.

Regarding European policies, they lack an explicit and proven theory of change (TOC) (see Appendix A.2 for more details)(Bager *et al.*, 2021). Although some legislation exists concerning the reduction of imported illegal harvested wood such as the EUTR (EU Timber Regulation), the FLEGT (Forest Law Enforcement and Governance and Trade) and some voluntary partnership agreements, currently, there is no legislation addressing deforestation caused by imports of FRCs (Pirlot *et al.*, 2018; Bager *et al.*, 2021). However, there is an ongoing process at the European Commission that began in 2008 and from which conclusions were drawn in July 2019 (European Commission, 2019). The objective is to develop and review existing policies in order to find ways to avoid imported deforestation (Bager *et al.*, 2021) that will be based on demand-side regulatory and non-regulatory measures (i.e. collaboration with the producer countries, commitments along the supply-chain/companies and also consumer awareness). The reduction embodied deforestation currently represents a 'policy window'[2] (Kingdon, 1984). Among European countries, France (Ministère de la Transition Écologique et Solidaire, 2018) and Germany (Bundesministerium für Ernährung und Landwirtschaft, 2020) have adopted policies to tackle imported tropical deforestation. However, they cannot act alone and need the support of the EU. In the course of 2021, the EU impacts assessment should be published and followed by eventual adoption of a legislation in the coming years (Bager *et al.*, 2021). As mentioned before, Bager *et al.* (2021) study reveals that politically feasible policies suffer from weak TOC which undermines either feasibility or impact. However, mandatory due diligence could be a politically feasible solution with clear impacts on the ground.

2.2.2 Supply chain approaches

In supply chain approaches, there is the supply side, i.e. companies offering deforestation-free products, and the demand side, i.e. consumers willing to buy these products.

[2]A subject gets on the agenda when a problem deems to require attention (problem stream), there is an available solution to the problem (policy stream) and motivation and opportunity to turn it into policy (political stream).

On the supply side, over the years, more and more companies have committed to zero-deforestation along their supply-chain (Donofrio *et al.*, 2017). The potential of action in the supply chain is important because there is a high level of concentration of transnational corporations within sectors (Folke *et al.*, 2019). For example, around 90% of palm oil trade in 2015 was traded by 5 companies, i.e. Wilmar International (43%), Musim Mas (18%), GAR (14%), IOI (11%) and Cargill (4%) (Kusumaningtyas and van Gelder, 2017) and about 60% of the world cocoa processed and traded was controlled by 3 companies in 2013, i.e. Barry Callebaut, Cargill and ADM. Supply chain initiatives (e.g. zero-deforestation commitments, commodity standards, etc.) have allowed to decrease new deforestation (Gibbs *et al.*, 2015; Gibbs *et al.*, 2016). Some companies that measured the outcomes of their forest-focuses supply chain policies (certifications, codes of conduct, and market exclusion mechanisms) had positive livelihood outcomes as well as conversation benefits. However, the former were more common (Garrett *et al.*, 2021). Nonetheless, there are limited results of ZDCs (Lambin *et al.*, 2018; van der Ven *et al.*, 2018; Garrett *et al.*, 2019). They have been undermined by leakage in the same country or across countries, by lack of transparency and traceability allowing greenwashing [3], by selective adoption since there are based on voluntary commitments and by smallholder marginalization as unintended social consequences (Lambin *et al.*, 2018). Public-private policies are needed to increase the efficiency of these commitments (Lambin *et al.*, 2018). For instance, the Soy Moratorium, which is the first agreement in tropical forest signed by major agrobusiness traders (Cargill, ADM and Bunge, which control more than 60% of finance, production, and trading of soybean in Brazil) and aims at halting purchasing soybean grown on lands deforested after July 2006 (Dou *et al.*, 2018) has decreased deforestation in one part, but deforestation has been moving somewhere else (Gibbs *et al.*, 2015; Gibbs *et al.*, 2016).

On the demand side, increasing the environmentally sustainable consumer's eating patterns is a pressing goal since food consumption is associated with high environmental impacts (Ivanova *et al.*, 2015; Springmann *et al.*, 2016). Higher footprints are generated by wealthier countries (Ivanova *et al.*, 2015). Out of a household impact, globally, 48% to 70% of the emissions are due to food consumption, and higher incomes are associated with higher consumption of meat, dairy and processed food (Ivanova *et al.*, 2015). More and more consumers are concerned about how food is produced. These consumers primarily care for physical properties of their food. Social, ethical, and environmental impacts are gaining more attention (Van Loo *et al.*, 2014). However, there is an attitude-behavior gap, namely the fact that even if consumers are concerned by environmental impacts, they do not necessarily do something about it. A significant gap remains between concerns and actual purchase of sustainable products (Horne *et al.*, 2009; Vermeir *et al.*, 2020).

2.2.3 Private-public policies

Supporting legal reforms and enforcement, reforming land tenure without triggering more deforestation, reaching marginal forest users, broadening the scope of interventions, incentivizing producers to participate in supply-chain initiatives, improving traceability and

[3] When poor environmental performance happens at the same time as positive communication about environmental performance (Delmas and Burbano, 2011)

transparency and stepping up demand-side measures are major knowledge and implementation gaps to complement the private and public sectors to tackle deforestation (Lambin *et al.*, 2018). Depending on the type of information chosen for transparency as well as how, to whom and for what purposes, transparency can be both empowering or disempowering (Gardner *et al.*, 2019). For instance, transparency cannot be taken as a substitute for effective environmental and social governance or when too much data are available, it can paralyse action. As an example of private-public partnership, deforestation associated with soy production has reduced partly thanks to the Amazon Soy Moratorium (Heilmayr *et al.*, 2020c). The success of this Moratorium in the Amazon biome was dependent on deforestation monitoring and public property registries showing the importance of complementary measures (Heilmayr *et al.*, 2020c).

2.3 Methodologies for quantifying the environmental impacts embedded in traded agricultural and forestry products

2.3.1 Product flows

With increasing length of international supply chains, attributing environmental impacts to the consumption in a relevant way poses methodological challenges (Kastner *et al.*, 2011). Various methodological approaches exist for estimating environmental impacts embodied in flows (Bruckner *et al.*, 2015; Matuštík and Kočí, 2021). Consumption-based accounting (CBA) approaches allocate environmental impacts to the consumption entity and not the production place (Davis *et al.*, 2014) as it is the case for production-based accounting (Bhan *et al.*, 2021). On one side, bilateral trade analysis, such as physical trade accounting (Kastner *et al.*, 2011) will estimate the impacts based on commodity, country of production and country of consumption, i.e. the country where products are physically consumed as food or for industrial processes. On the other side, multi-regional input-ouput (MRIO) models attribute consumption to the final consumer. Complex matrices of global supply-chains allow to trace monetary fluxes between different sectors, contrary to physical fluxes, commodities and countries are aggregated (Kastner *et al.*, 2011). Further information on physical and monetary flows is provided in Section 3.1.

It is important to understand what these different approaches can be used for (Hubacek and Feng, 2016). When datasets are produced, varying one's understanding of the system, decisions about space and time are made (Davis *et al.*, 2014). Depending on the spatial resolution chosen, there is a trade-off between the analyses of proximate causes or underlying drivers (Geist and Lambin, 2002). For example, physical trade models usually analyze spatially aggregated data since unraveling the links along supply chain is challenging due to considerable lack of transparency. However, they allow to cover all countries and all commodities. With new developments, subnational data can be available for some commodities (Trase, 2021) and it is more likely to help improving enforcement of existing policies by locating where exactly deforestation happens (Skidmore *et al.*, 2021). National and then subnational datasets can be used in a complementary way. Coarser-grained scale will attribute connections between producer and consumer, setting priorities and then it can be useful to resort to finer scale information where it is most needed (Gardner *et al.*, 2019).

2.3.2 Environmental impacts

Environmental impacts - also called environmental extension of matrix flows - of imported deforestation embodied in commodities via international trade can be measured through indicators such as carbon emissions, land area, water and nitrogen, biomass flows, land use, biodiversity loss or virtual water (Meyfroidt *et al.*, 2013). Different metrics need to be considered to enable a trade-off between environmental impacts due to the complexity of international trade (Sandström *et al.*, 2017). Some of them will be briefly presented in the following paragraphs. Note that theses impacts can be estimated by different modelling approaches and provide different results (Kastner *et al.*, 2014b).

Deforestation risk/area: Land footprint accounting based on a consumer's perspective gives information on the supply's sources and outlines the use of commodities up to final demand or apparent consumption - depending on the approach used (Bruckner *et al.*, 2015). Deforestation risk/area refers to the surface deforested or where native vegetation is cleared for agricultural products (Mammadova *et al.*, 2020).

Deforestation CO_2 emissions: Carbon emissions associated with agricultural products are estimated by quantifying changes in carbon stocks due to forest loss and subsequent land use (Pendrill *et al.*, 2019b). It is important to mention that ranking of countries based on carbon footprint is not the same as area/quantity ranking. For example, China is the largest importer of Brazilian soy in terms of quantity, while the European Union is the first importer of embodied deforestation linked to Brazilian soy imports (Escobar *et al.*, 2020).

Loss of biodiversity: To project species extinctions on a global scale, SAR (species-area relationship) models are often used. However, they lack knowledge of taxon affinity, and filling that gap in near future is unlikely since plot-scale field monitoring is expensive. Embodied biodiversity loss cannot be approximated by land area because it is not reflecting the reality since some commodities such as palm oil, rubber, sugarcane and coffee have the highest impact (23%) while they requisition only a small global area (10%) (Chaudhary and Kastner, 2016).

Water: The water footprint of an agricultural product depends on its production conditions, i.e. water use efficiency, place and time of production (da Silva *et al.*, 2016). Then, virtual water trade between producer and consumer countries can be calculated.

2.4 The case of Belgium

European Countries have an historic responsibility over deforestation (Humphreys, 2008). In recent years, even if the EU has become the second importer of embodied deforestation after China, its impact is still consequent (Pendrill *et al.*, 2019a;b). As well as many European countries, Belgium faces challenges to achieve Sustainable Development Goal (SDG) targets (such as responsible consumption and production (No.12), climate action (No.13) and life on land (No.15))(IEEP, 2019). Nevertheless, these statements sometimes lack operational metrics to genuinely assess improvements or impediments towards the achievement of SDGs.

Chapter 3
Methodology

The first part of this thesis answers the following questions: Where does Belgium stand compared to other European countries and international trade in general? What do environmental impacts embedded in Belgium traded agricultural and forestry products represent compared to Belgium's consumption? What are the differences between estimated deforestation based on physical fluxes and the one estimated via the final consumption? This is achieved through an exploratory analysis of available aggregated data linking deforestation embodied in agricultural commodities between consumer and producer countries. The second part responds to the question about the nature of the environmental impacts embodied in Belgium's main commodity imports, by focusing on key commodities with embodied deforestation and their main producer countries. The goal is to spot the main commodities and hotspots of environmental impacts linked to deforestation embodied in Belgian imports. The third part aims at answering the question 'for the commodities with higher deforestation footprint associated with Belgium imports, where does deforestation happen exactly and which and how companies are operating them?' by concentrating on a few commodities and countries only, where information is available, using data based on a subnational level and by analyzing the supply-chain actors and their commitments to zero-deforestation.

It is important to specify that arbitrary choices were made with respect to the selection of datasets based on research questions formulated (see SECTION 5.3.3) and also with respect to the range of data presented in the results. Data processing was done with *R* and mapping with *R* and *QGIS*.

3.1 Data

Four different datasets are considered in this study. Concerning physical trade fluxes at a national level, for deforestation land- and carbon footprint and biodiversity loss respectively, Pendrill *et al.* (2020) and Chaudhary and Kastner (2016) datasets were used. Environmental indicators and supply chain information at subnational level were provided by TRASE (2021). Finally, data obtained using a MRIO model were extracted from Pendrill *et al.* (2019b). They attributed environmental indicators, i.e. deforestation CO_2 emissions and deforestation area based on the environmentally-extended MRIO model EXIOBASE 3. Depending on the type of data used, the Netherlands and Luxembourg were also taken into account to assess in a better way the environmental impacts embedded in Belgian imports. Indeed, in some datasets, agricultural and forestry products first arriving in the Netherlands and then re-exported in Belgium are not well captured.

3.1.1 Physical trade fluxes

Physical trade fluxes allow to link the deforestation footprint from production to apparent consumption of each crop product. For example, if cocoa beans are exported from Côte d'Ivoire to Belgium and then Belgian chocolate to Sweden, the impacts will be attributed to

Sweden. However, when food is highly processed such as frozen pizza, the track is lost. In brief, the tracking of physical trade fluxes stops where they are physically consumed as food or in industrial processes (Pendrill *et al.*, 2019a;b). One exception stands for crop products used as animal feed as they are tracked indirectly through traded animal products (Pendrill *et al.*, 2019b).

3.1.1.1 Deforestation emissions and deforestation risk/area - national level

The dataset used is extracted from Pendrill *et al.* (2020), which is an update of the results of Pendrill *et al.* (2019a;b). It uses the same methodology although there are some small changes (see Pendrill *et al.*, 2020 for more details). It compiles the imports of embodied deforestation (in ha/year) and associated emissions from losses in aboveground, belowground and soil carbon including peat drainage (in tCO_2/year) for agricultural and forestry products from 2005 to 2017 produced in the tropics and subtropics. Year, importing country and country of production are detailed for each commodity. Pendrill *et al.* (2020) use a land-balance model that includes cropland, pastures and forest plantations as well as indirectly other land uses to quantify embodied deforestation across 135 countries at national level (except for Brazil and Indonesia for which the model is implemented on a micro-region and province level respectively). Observed forest loss[1] to agricultural and forestry commodities is therefore attributed with the land-balance model. There are two main premises of the this model. Firstly, it considers that where cropland expansion happens, it first expands into pastures (if gross pasture area loss is detected) and then into forests (if gross forest loss is detected). Secondly, when pasture areas and forest plantation areas expand, it is because they replace forests. Then, with a crop attribution model, each crop or group of crops is linked to forest loss due to cropland expansion. After this step, deforestation footprint is calculated for each commodity with a 5-year amortization. Finally, with a physical bilateral trade model, i.e. the one developed by Kastner *et al.* (2011b), embodied deforestation to countries of apparent consumption is attributed. Deforestation attribution risk combines direct and indirect drivers and reflects national average. Therefore, embodied deforestation should be interpreted as a measure of deforestation risk (Pendrill *et al.*, 2020b).

3.1.1.2 Biodiversity loss - national level

Chaudhary and Kastner dataset is extracted from their 2016 article. Based on a countryside SAR (species area relationship) model, species loss (i.e. species, namely mammals, birds, amphibians and reptiles committed to extinction) is estimated as a result of agricultural land use. Then, by combining the estimations with high spatial resolution global maps of crop yields, species lost per ton for 170 crops in 184 countries are obtained. By applying Kastner *et al.* (2011) approach, they associated the apparent consumption to the bilateral trade linkages for the year 2011. Finally, embodied regional species loss is provided for each crop from exporting to importing country.

[1] forest loss is defined as "complete removal of tree cover exceeding 5 m height and 25% canopy cover (in year 2000), and ideally not within tree plantations". (Pendrill et al., 2019b)

3.1.1.3 Physical trade fluxes - subnational level

Trase data goals are to increase transparency across agricultural commodity supply-chains in tropical areas in order to unveil the links between environmental and social risks and lead to a more sustainable commodity production. Trase data provide subnational level information about production, actors along the supply chain (importers, exporters and logistic hubs) and some social as well as environmental indicators such as deforestation emissions (5-year annual deforestation risk) and deforestation risk (5-year annual risk). Their approach is a Spatially Explicit Information on Production to Consumption Systems (SEI-PCS) adapted for each country-commodity combination depending on data availability and methodological improvements (Trase, 2018). As physical flows, they do not account for re-exports (once it has been processed) and final consumption. Their focus is rather on entry points. The data can be downloaded from Trase website.

3.1.2 Monetary fluxes

EXIOBASE 3 dataset (environmentally-extended MRIO model) is the one used by Pendrill *et al.* (2019b) for estimating deforestation risk (Stadler *et al.*, 2018; Wood *et al.*, 2015). MRIO models track monetary fluxes while physical trade models track physical quantities. The *end-user* is not the same. In physical trade models, the *end-user* is the one that physically consumed the product (as food or in industrial processes), and in this MRIO model, the *end-user* represents the final consumption, along with food processing, manufacturing and services (Pendrill *et al.*, 2019b). It thus allows to further follow indirect monetary trade flows (Pendrill *et al.*, 2019b).

3.1.2.1 Deforestation emissions and deforestation area

EXIOBASE 3 dataset has been processed with environmental indicators. The first steps are the same as for Section 3.1.1.1. Only, for the last step, the emissions embodied in consumption are calculated through an economic environmentally-entended multi-regional input-output model developed by Stadler *et al.* (2018) and Wood *et al.* (2015) instead of a physical trade model. Embodied impacts in final consumption are attributed across all sectors of the economy. However, the dataset provides more coarser regional and commodity resolutions. The data extracted from Pendrill *et al.* (2019b) compile exports and imports of embodied deforestation area (in ha/yr) and associated net emissions from losses in above-ground, below-ground and soil (incl. peat drainage) carbon (in tCO_2/yr), by country of production, country/region of consumption, year and commodity group for the 2010-2014 time period. Products are divided into 10 groups: cattle meat, forestry products and eight crop groups including pant-based fibers (Pendrill *et al.*, 2019b).

3.2 Extracting data of Belgian agricultural imports and consumption

Two types of data are used for this part: physical trade (Pendrill *et al.*, 2020) and MRIO model (Pendrill *et al.*, 2019a). The first part of this analysis consists in 2 steps.

Firstly, a quantification of the impacts embodied in trade with PTF data (Pendrill *et al.*, 2020) for Belgium, Benelux, the European Union and international trade and a comparison between them are carried out. Secondly, the objective is to grasp the quantity of embedded deforestation found in Belgian final consumption by looking and comparing main imported commodities with embodied deforestation obtained by an MRIO model (Pendrill *et al.*, 2019a) and by a physical trade one (Pendrill *et al.*, 2020).

To begin with, data extracted from the physical trade model are subsetted for Belgium, Benelux, EU28 (the UK are included) and international trade (all flows that do no have the same consumer and producer country). Deforestation emissions including peat drainage and deforestation risk are compared between 2005-2017. For 2017 only, both indicators per capita are mapped[2] for the EU27. Population data come from Eurostat. Then, for plotting the evolution between 2005-2017 of the different commodities, a top 7 commodities are highlighted, i.e. palm oil, soybeans, rapeseed, beef and buffalo meat, cocoa beans, wood products and coffee, while the others are aggregated. These key commodities are the ones in which most deforestation area was embodied in Benelux's and Belgian imports. The top 7 for deforestation emissions is slightly different, as rubber (natural) for Benelux and coconuts for Belgium replace wood products. Note that for convenience, the top 7 commodities of deforestation area is the one used for all results. Then, data extracted from the MRIO model are subsetted for Belgium and Benelux. Commodities are already divided into 10 categories. Both indicators, deforestation emissions and deforestation area are plotted for the available years (2010-2014). In order to compare both MRIO and trade model results, the sum of deforestation emissions and area are plotted for each year between 2010-2014.

3.3 Extracting data of environmental impacts of the main imported commodities per country of origin

To provide an overview of the origin of Belgian and Benelux's imports with embodied deforestation, physical trade data are used (Pendrill *et al.*, 2020). First, to assess the share of Belgium's imported deforestation coming from the different tropical countries, a world map is created[3]. The same maps are done for the share of Benelux's imported deforestation. Second, to display the main countries from which Benelux and Belgium have imported the highest amount of deforestation area, a bar plot of the top 18 countries is made, filled with the share of the different main commodities. By its side, the percentage share of the top 7 commodities can be found. The same graphs are made for the top 17 countries for deforestation emissions both for Benelux and Belgium. Note that the countries are not the same and are ordered according to their value. Third, to visualize the share of the main commodities responsible for the most embodied deforestation area and emissions for Belgium and Benelux, donut plots are generated. Fourth, for each of the top 7 commodities, donut plots are produced to identify the main exporter countries to Belgium and the Benelux, i.e. the top countries amount for at least 98% of deforestation emissions imported by Belgium of the commodity in question, except for coffee and wood products for which it is at least 95%.

[2] Jenks method was adopted for the classification used in all maps produced in this thesis.

[3] Note that proportional symbol maps should have been produced for SECTION 4.2.1 instead of choropleth maps. However, for a question of clarity, choropleth maps is chosen.

To assess the proportion of biodiversity loss of Belgium's and Benelux's imported products coming from producer countries, maps [4] are produced with data extracted from regional biodiversity loss (Chaudhary and Kastner, 2016) [5]. To keep tropical countries only, the data are then merged with Pendrill *et al.* (2020) dataset. To visualize the main commodities (i.e. sum amounts for more than 90% of embodied biodiversity) and the main exporting countries (i.e. sum amount for more than 60% of embodied biodiversity) from which imported embodied biodiversity loss originates, donut charts are made both for Belgium and Benelux.

3.4 Extracting data of environmental impacts of the main imported commodities at subnational level, main companies involved and zero-deforestation commitments

Physical trade and MRIO model (Pendrill *et al.*, 2019a;b) provide an overview of the main countries and commodities imported by countries around the world for which embodied deforestation emissions and area are attributed in trade. However, they do not include details on the regions of origin of the imports. In order to determine where the impacts of commercial activities of Belgium and the Netherlands are happening, the following part uses Trase (2021) data. Only some commodities and exporting countries are selected, as not all of the available ones have extensive data to work with. When available, the following information can be found in each dataset (Appendix B.1), i.e. importing company, year, subnational entity of production, country of consumption, equivalent quantities, deforestation emissions and deforestation risk associated with those imports. Imports concerning Belgium and the Netherlands are subsetted if possible and then separated. Note that part of the imported fluxes does not have known biomes/state/municipalities and therefore deforestation indicators cannot be attributed on a subnational level (see Appendix B.2).

For better visualization of subnational data, maps [6] of the different indicators were done for Brazilian soy (on a municipality level), cocoa from Côte d'Ivoire (on a department level) and Indonesian palm oil (on a kabupaten level). Some additional graphs are made for Brazilian soy only. For companies exporting or importing, depending on availability, Brazilian soy (importers), Brazilian beef (importers), Paraguayan soy (exporters), Argentinian soy (exporters), Ivorian cocoa (exporters) and Ghanaian cocoa (importers) to visualize the top 10 companies in terms of quantity for each commodity both for Belgium and the Netherlands, tables are made. Finally, in order to analyze the quantity and the share of soy imports relying on ZDCs across Brazilian, Paraguayan (only for Netherlands) and Argentinian biomes imported by Belgium and the Netherlands, bar plots are created.

[4] Same note as Footnote 3 for section 4.2.2.

[5] From Chaudhary and Kastner (2016): Table 5 and Table 6 found in their supplementary data

[6] Same note as Footnote 3 for Section 4.3.1, 4.3.2 and 4.3.3.

Chapter 4
Results

4.1 Belgian agricultural imports and consumption

4.1.1 Impacts embodied in trade for Belgium, Benelux and the EU

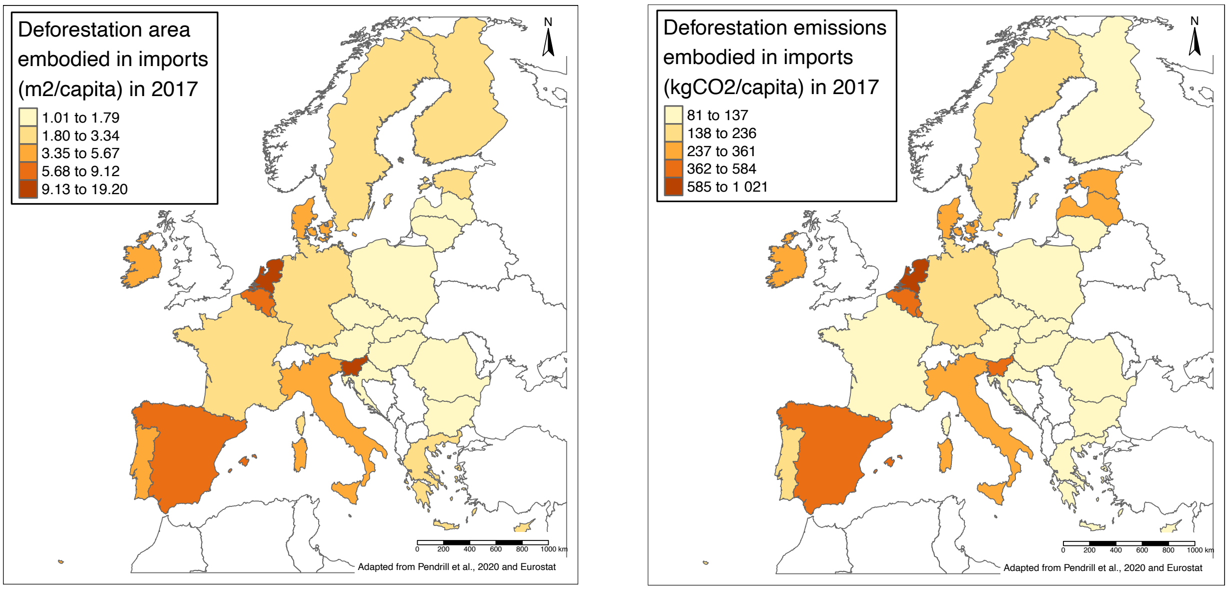
Based on net physical flows, between 2005 and 2017, deforestation area embodied in Belgian imports represent 14 770 ha/year (192 022 ha in total), in Benelux's imports 44 708 ha/year (581 208 ha in total), in European imports (EU28) 269 086 ha/year (3 498 124 ha in total), in international trade[1] 1 298 690 ha/year (16 882 968 ha in total) and in the total tropical production 5 057 803 ha/year, roughly the size of Spain every year (65 751 443 ha in total). European share of deforestation area has been decreasing from 30.5% to 15.7% between 2005 and 2017 (APPENDIX A.3*b*). The average deforestation area embedded in Belgian commodity imports compared to European (EU28) ones is 5.5% and it has been quite the same between 2005 and 2017 (APPENDIX A.4*b*).

Deforestation emissions embodied in Belgian imports account for 7.3 $MtCO_2$/year (95.3 $MtCO_2$ in total), Benelux's imports for 24.3 $MtCO_2$/year (315.3 $MtCO_2$ in total), European imports (EU28) for 139 $MtCO_2$ (1 807.5 $MtCO_2$ in total), international trade for 685.3 $MtCO_2$/year (8 908.8 $MtCO_2$ in total) and tropical production for 2 549.7 $MtCO_2$/year (3 3145.9 $MtCO_2$ in total). As well as for deforestation area, the share of EU28 emissions embodied in imports of international trade has been decreasing between 2005 and 2017. In 2005, it shared 29.3% of the emissions and in 2017, 16.7% (APPENDIX A.3*a*). The average emissions embedded in Belgian commodity imports compared to European (EU27) ones is 5.3% and it has been more or less stable throughout the years (APPENDIX A.4*a*).

In 2017, deforestation area per capita embodied in imports (FIGURE 4.1*a*), also based on physical trade flows per capita, was the highest for Slovenia (19.2 m^2/capita), then the Netherlands (17.1 m^2/capita), Belgium (9.1 m^2/capita) and Spain (8.1 m2/capita). Luxembourg was at 6th place (4.9 m^2/capita). EU(27) mean was 4.2 m^2/capita. CO_2 emissions from deforestation per capita embodied in European imports (FIGURE 4.1*b*) were high in Benelux, the highest being in the Netherlands (1021 $kgCO_2$/capita), followed by Luxembourg (584 $kgCO_2$/capita) and Belgium (532 $kgCO_2$/capita). EU(27) mean was 239.3 $kgCO_2$/capita. Note this is not exactly representative of per capita consumption as the data are based on net physical flows and does not account for re-exports after being highly processed.

Palm oil is the commodity for which deforestation-related emissions are the highest (more than half) for Belgian and Benelux's imports (APPENDIX A.5*b,d*) both for total imports over the period from 2005 to 2017 and for almost each year (physical trade model). For Belgium, in 2017, 56.2% of embedded deforestation emissions are caused by palm oil. It is followed by

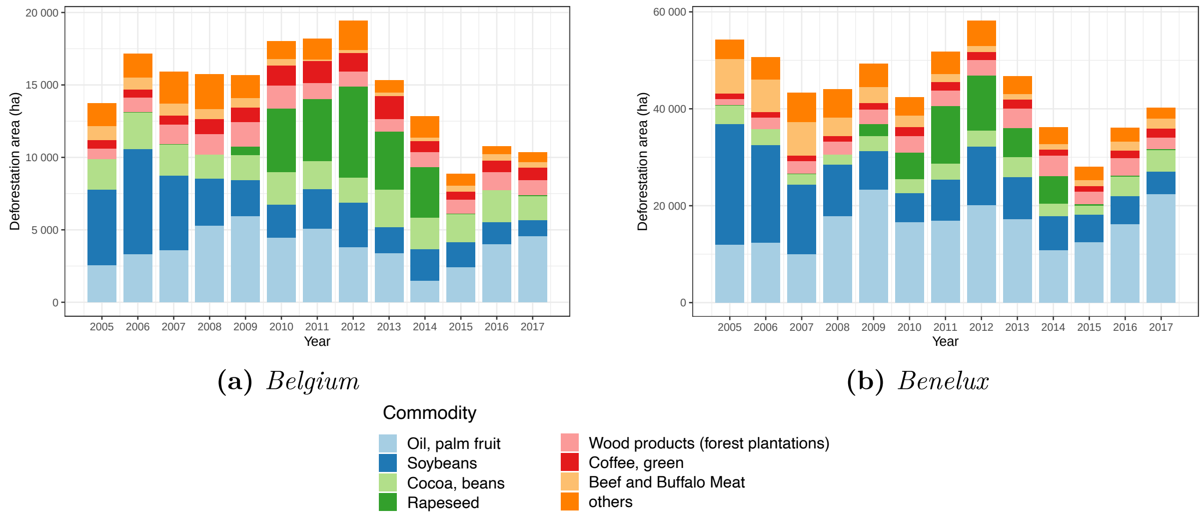
[1] when the consumer country is different from the producer country



(a) **(b)**

Figure 4.1: *Deforestation area (a) and deforestation CO_2 emissions including peat drainage (b) embodied in imported in 2017 in the EU(27). Data from Pendrill et al. (2020).*

soybeans, for which the impacts of CO_2 emissions have been decreasing over the years. Over the 2005-2017 period, palm oil caused 41.7% of the total embodied deforestation emissions imported by Belgium, followed by soybeans (15.5%), cocoa beans (12.1%), rapeseed (7.6%) and coffee (6.4%), beef and buffalo meat (3.4%), coconuts (2.4%), wood products (1.9%) and the other 112 commodities (11.4%) (Appendix A.6*b*). For embedded deforestation area (Figure 4.2*a*), impact shares of commodities follow a different order than embedded emissions (Appendix A.6*a*) and palm oil (41.7%) had a smaller share than for deforestation emissions (26%). This difference between GHG emissions and area can, in part, be explained



(a) *Belgium* **(b)** *Benelux*

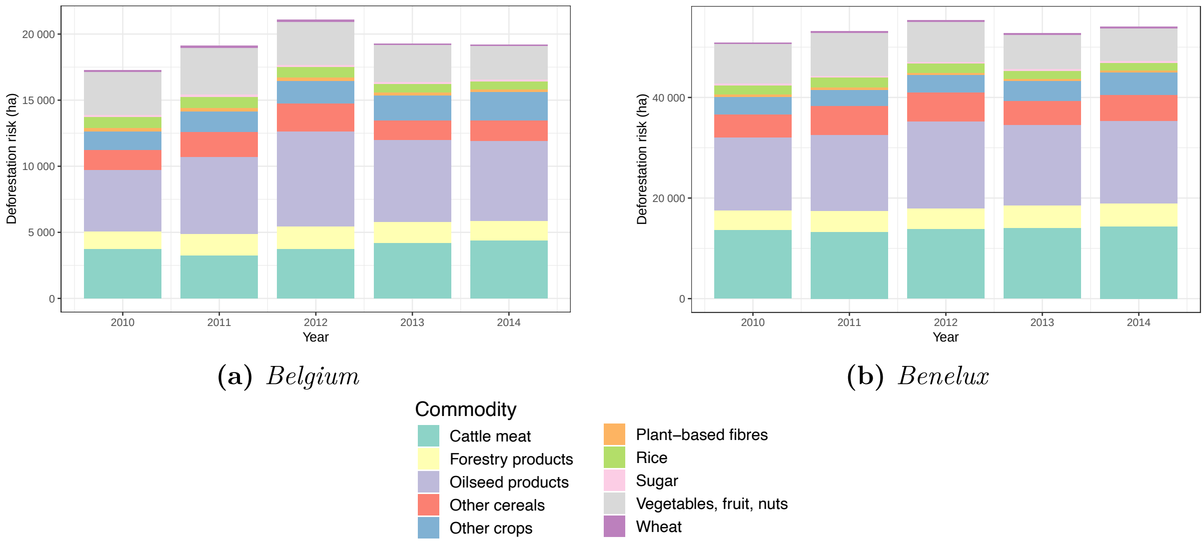
Figure 4.2: *Main imported commodities from 2005 to 2017. Deforestation area embodied in Belgian (a) and Benelux's (b) agricultural and forestry commodity imports. Data from Pendrill et al. (2020).*

by peatland emissions in South-East Asia which are mainly caused by palm oil production.

Following palm oil, soybeans represent 20.6% of embedded CO_2 emissions, cocoa bean 14%, rapeseed 12.1%, wood products 7.7%, coffee 6.5%, beef and buffalo meat 3.5% and the other 112 commodities (9.6%). Both for deforestation emissions (APPENDIX A.6*d*) and deforestation area (APPENDIX A.6*c*) embedded in Benelux's commodity imports, palm oil and beef and buffalo meat have a higher percentage. Cocoa, coffee and rapeseed imports account for less than for Belgium and the other main commodities share more or less the same. The evolution throughout the years for deforestation area can be seen in FIGURE 4.2*b* and in APPENDIX A.5*c* for deforestation emissions. Finally, particularly high embodied deforestation impacts were embedded in rapeseed imported from Australia between 2010 and 2014.

4.1.2 Belgian consumption: physical versus financial fluxes

Oilseed products are the main impacted commodities in terms of embodied deforestation area (FIGURE 4.3) and emissions (APPENDIX A.7) linked to Belgian (~31%) and Benelux's (~29.7%) final consumption (MRIO model). They are followed by cattle meat (~20% for Belgium and ~26% for Benelux) and then vegetable fruits and nuts (~15% for Belgium and ~13% for Benelux). Embodied impacts from oilseed products mainly come from Indonesia and the rest of Asia and Pacific, cattle meat from Brazil, vegetable fruits and nuts from Africa.

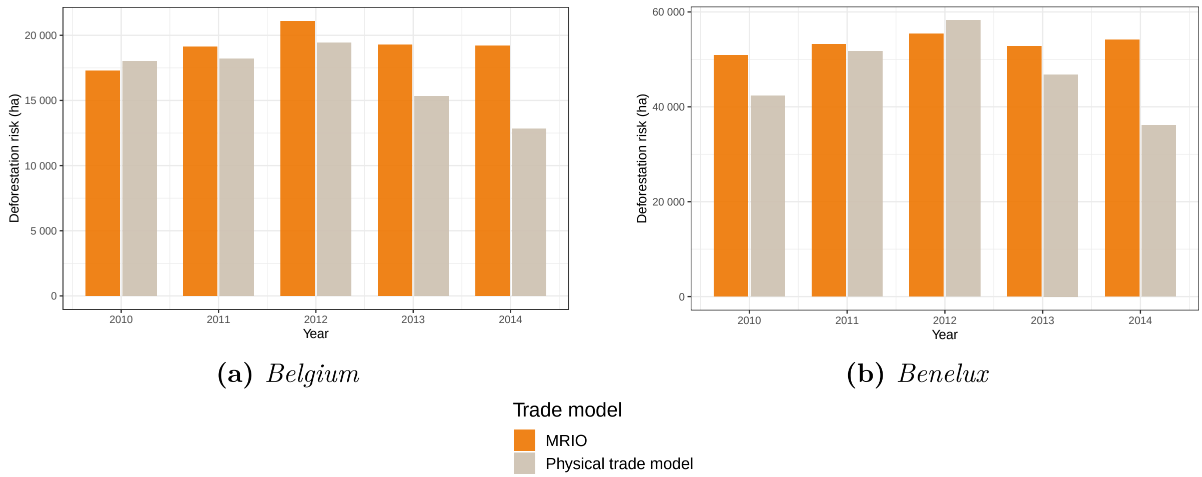


(a) *Belgium* **(b)** *Benelux*

Figure 4.3: *Deforestation area embodied in Belgian (a) and Benelux's (b) imports (2005-2017). MRIO model (EXIOBASE 3). Data from Pendrill et al. (2019).*

For the 2010-2014 period, by comparing both results described above (FIGURE 4.2*a* and FIGURE 4.3*a*), Belgium's deforestation area footprint embedded in final consumption (MRIO model) is higher than in physical trade (FIGURE 4.4*a*). Belgian consumption is indeed high and supply-chains are probably at higher risk. In addition, since the country also re-export goods, hidden footprint is more important than visible footprint. For deforestation emissions, the difference is less significant (APPENDIX A.8*a*). Benelux follows the same tendency for deforestation area as Belgium (FIGURE 4.4*b*). For carbon footprint, actual consumption is lower that what enters the region. Part of the difference could be explained by the re-exports

(Appendix A.8*b*). This signifies that the Netherlands re-exports great quantity of imported deforestation.



(a) *Belgium* **(b)** *Benelux*

Figure 4.4: *Deforestation area embodied in Belgian (a) and Benelux's (b) imports (2005-2017). Comparison between MRIO and physical trade model. Data from Pendrill et al. (2019-2020).*

4.2 Environmental impacts of the main imported commodities per country of origin

4.2.1 Deforestation emissions and deforestation risk

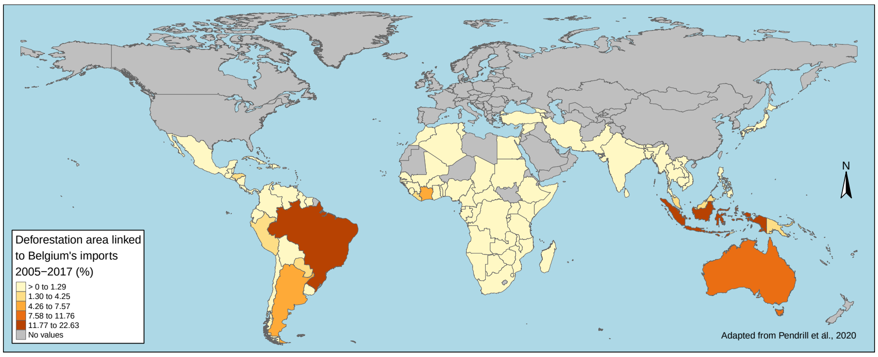
Out of 192 022 ha embedded in Belgian imports between 2005-2017 (Figure 4.5*a*), almost half of the embedded deforestation area comes from Indonesia and Brazil, with, respectively, 22.6% and 22.4%, followed by Australia (11.8%), Argentina (7.6%), Côte d'Ivoire (6.3%), Papua New Guinea (4.3%), Paraguay (4.2%), Honduras (3.2%), Malaysia (2.9%) and Peru (2.2%). Belgium imported embodied deforestation area from 98 countries and the 10 cited above represents 87.9% of the total deforestation risk.

Regarding, deforestation CO_2 emissions including peat drainage embodied in Belgian imports between 2005 and 2017, out of 95 Mtons (Figure 4.5*b*), half comes from Indonesia and Brazil, as it is the case for deforestation area. However, the share is different, i.e. 35.6% for Indonesia and 16.7% for Brazil. The following 8 countries do not follow the same order as for deforestation area. Papua New Guinea accounts for 10.2% of the embedded deforestation emissions, Malaysia for 8%, Australia for 7.5%, Argentina for 3.7%, Côte d'Ivoire for 2.8%, Honduras for 2.3%, Paraguay for 2.2% and Peru for 2%. 91% of the deforestation emissions are gathered in 10 countries. The difference of proportion between both indicators, particularly for Indonesia, Malaysia and Papua New Guinea is due to the great presence of peatland in these countries that emits larger amount of CO_2 emissions.

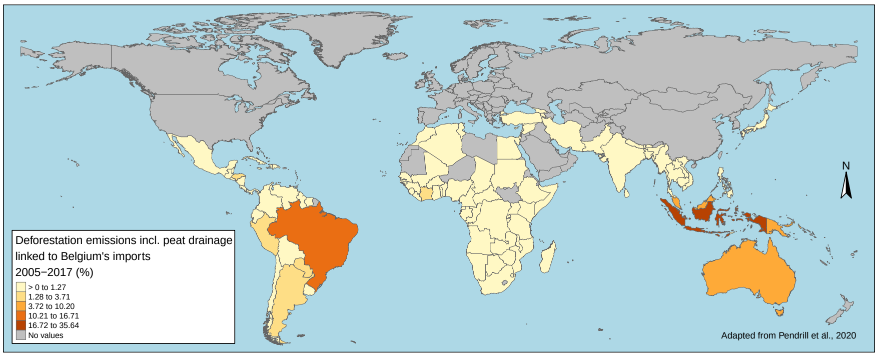
Benelux's tendency (Appendix A.9) is more or less the same as Belgium, meaning that they import from the same countries. Moreover, impacts per producer country are of the same order of magnitude as for Belgium.

4.2.1.1 Main commodities and main producers

Figures 4.6*a,b* and Figures 4.6*c,d* present an overview of the main exporting countries with the highest yearly carbon footprint and deforestation area embedded in Belgian imports as well as the share of main commodities per exporting country.



(a) *Deforestation area*



(b) *Deforestation emissions*

Figure 4.5: *Share of deforestation area (a) and deforestation CO_2 emissions including peat drainage (b) embodied in Belgian imports (100%) 2005-2017. Data from Pendrill et al. (2020).*

Embodied emissions from Indonesia and Malaysia mainly come from palm oil (90% and 88% respectively). From Brazil, it is mainly soy (57%), followed by wood products (24%) and beef and buffalo meat (14%). Almost all emissions (99%) imported from Australia are due to rapeseed. 83% of embedded emissions from Côte d'Ivoire are caused by cacao. Embodied emissions from Papua New Guinea mainly come from palm oil (53%) and cocoa (34%). From Paraguay, it is mainly soy (82%). From Honduras, it is mainly coffee (81%) followed by palm oil (19%). From Peru, it is coffee (51%) and cocoa (29%). From Liberia, it is almost only cocoa (99%). From Ghana, it is cocoa (86%) and wood products (12%). From Chile, it is almost only wood products (99%). For Cameroon, Uganda, Ecuador, Tanzania and Congo, and embodied area, the details can be found in Figure 4.6. For Benelux (Appendix A.10), the top 18 countries for embodied deforestation emissions and top 17 for deforestation area do not follow the same order as for Belgium. This is explained in large part by Dutch imports. Moreover, Bolivia and Uruguay are added on the top list of countries.

The following paragraphs focus on each of the top 7 commodities. The results presented here are for Belgium. The corresponding results for Benelux can be found in the Appendices A.11 - A.17.

Oil, palm fruit: The total amount of embodied deforestation emissions imported by Belgium (2005-2017) is 39.8 $MtCO_2$ (~3$MtCO_2$/year) and deforestation risk accounts for 49 993 ha (~3 945 ha/year). Palm oil imports comes from 31 producer countries and mainly from South-East Asia. 69.7% of the deforestation emissions including peat drainage come from Indonesia, 17.1% from Malaysia, 11.8% from Papua New Guinea, 0.9% from Honduras, and all the 27 remaining countries have a share of less than 0.1%/country (FIGURE 4.7*b*). The share of deforestation risk embodied in palm oil imports is higher for Indonesia than the deforestation emissions (78.2%). It represents 9.8% for Malaysia, 8.6% for Papua New Guinea and 2.3% for Honduras (FIGURE 4.7*a*). Presence of peatland seems to be higher for Malaysia and Papua New Guinea. Benelux's imports account for ~12.7 $MtCO_2$/year of deforestation emissions and ~16 036 ha/year of deforestation area. The share per country follows the same tendency as for Belgium (APPENDIX A.11).

Soy: Deforestation emissions embodied in Belgian soy imports between 2005-2017 account for 14.7 $MtCO_2$ (~1.1 $MtCO_2$/year) and deforestation risk represents 39 567 ha (~ 3043 ha/year). Soybeans were imported from 24 producer countries between 2005-2017 and the majority came from South America. 74.2% of the deforestation emissions including peat drainage come from Brazil, 13.3% from Argentina, 11.3% from Paraguay, and from all the 21 remaining countries 1.12% (FIGURE 4.8*b*). The share of deforestation risk embodied in palm oil imports is lower for Brazil than the deforestation emissions (62.2%). 20.1% for Argentina, 16.8% for Paraguay and 0.9% for the other 21 countries (FIGURE 4.8*a*). Benelux's annual embodied deforestation emissions account for ~3.9 $MtCO_2$ and deforestation area for ~10 436 ha. The share of impacts per country follows the same tendency as for Belgium for both indicators (APPENDIX A.12*c,d*).

Cocoa: Embodied CO_2 emissions from cocoa amount to 11.5 $MtCO_2$ between 2005-2017 (~0.9 $MtCO_2$/year) and deforestation risk to 26 823 ha (~2 063 ha/year) in Belgian imports. The origin of the majority of the imported embodied deforestation is more diversified. Indeed, 14 countries account for more than 98% of total imported deforestation (29 countries for the remaining 2%) (FIGURE 4.9). The difference between carbon footprint and area footprint is more pronounced for cocoa than for soy or palm oil. 19.5% of the embodied CO_2 emissions are imported from Côte d'Ivoire and it represents 37% of deforestation area. For Papua New Guinea, it is the opposite, deforestation emissions amount for more than deforestation area, with 31.9% and 10.4% respectively. Liberia, Ghana, Congo, Cameroon, Togo, Sierra Leone, Guinea and DRC follow the same tendency as Côte d'Ivoire, i.e. their share of embodied deforestation area exceeds their deforestation emissions one, whereas for Indonesia, Peru, Ecuador and Uganda, it is the opposite. For Benelux, annual deforestation emissions are ~1.3 $MtCO_2$/year and deforestation area ~3 192 ha/year. Benelux follows Belgium in terms of percentage of main countries (APPENDIX A.13*c,d*).

Coffee: For the 2005-2017 period, 6 $MtCO_2$ (~0.5 $MtCO_2$/year) and 12 551 ha (965 ha/year) were embodied in coffee imported by Belgium. As it is the case for cocoa, embodied impacts of coffee also originate from a larger number of countries across the entire tropics. Around 95% of embodied deforestation are gathered in 12 countries and the 5% left in 37 countries (FIGURE 4.10). The highest impacts are imported from Honduras (39.8% for embodied deforestation area and 28.7% for embodied deforestation emissions), followed by

Peru (about 17% for both indicators), Uganda (7.2% and 15.4%), Indonesia (2.4% and 11.2%), Papua New Guinea, Côte d'Ivoire, Viet Nam, Brazil, Laos, Congo, Cameroon and Tanzania. Benelux imported ∼0.7 $MtCO_2$/year and ∼1 426 ha/year embodied deforestation, and has the same tendency as Belgium in terms of country share (Appendix A.14).

Rapeseed: 7.2 tCO_2 (∼0.56 $MtCO_2$/year) and 23 239 ha (∼1 787 ha/year) were embodied in rapeseed mainly imported from Australia (more than 96% for both indicators) by Belgium between 2005 and 2017 (Appendix A.15*a,b*). For Benelux, embodied deforestation amounted to ∼1 $MtCO_2$/year and ∼3 374 ha/year. Australia has a smaller share and Argentina a bigger one than for Belgium (Appendix A.15*c,d*).

Wood products (forestry plantations): Deforestation emissions embodied in Belgian soy imports between 2005-2017 account for 1.8 $MtCO_2$ (∼0.14 $MtCO_2$/year) and deforestation risk represents 14 800 ha (∼ 1 138 ha/year). Wood products are imported from 68 countries across the tropics and the highest impacts come from South America, followed by South-East Asia and then Sub-Saharan Africa. Around half of the embodied deforestation in wood products are sourced from Brazil (66.3% for embodied deforestation area and 46% for embodied deforestation emissions). Embodied deforestation from Chile is also higher for deforestation area. On the opposite, Indonesia, Malaysia, Côte d'Ivoire, Cameroon, Ghana, South Africa, Madagascar and Peru have their deforestation emissions impact higher than deforestation area (Figure 4.11). Benelux imported ∼0.37 $MtCO_2$/year and ∼2 918 ha/year. In terms of tendency share, Benelux imported less from Brazil and almost the double from Chile than Belgium (Appendix A.16*c,d*).

Beef and buffalo meat: 3.3 tCO_2 (∼0.25 $MtCO_2$/year) and 6 667 ha (∼512 ha/year) embodied deforestation were imported by Belgium between 2005 and 2017. Benelux's imports amounted to more than 6 times Belgian imports with ∼1.5 $MtCO_2$/year and ∼3 194 ha/year. More than 95% of embodied deforestation come from South America, particularly Brazil (between 85% and 96%) and Argentina (between 3% and 10%) (Appendix A.17).

4.2.2 Biodiversity loss

Of the total regional loss embodied in Belgian and Benelux's imports in 2011, 83% (9.7 out of 11.6 regional species lost) and 86% (23 out of 26.6 regional species lost) happened in tropical regions (Appendix A.18). Coffee, cocoa, palm oil, bananas, rapeseed, coconuts and soybeans are the commodities that induce most biodiversity loss (Figure 4.12*a*). More than 60% of the loss are incurred in 10 tropical countries (Figure 4.12b). 12.4% of total regional species loss come from commodity imports from Indonesia and the majority is due to Indonesian palm oil (9.2%). From Ecuador (8.1%) regional species loss is mainly due to cocoa beans (6.4%), for Cameroon (8.10%), it is cocoa beans (6.6%), from Australia (5.71%), it is rapeseed (5.73%), from Malaysia (4.8%), it is palm oil (5%), from Colombia (4.3%), it is coffee (2.1%).

Embodied biodiversity loss in coffee imports (28.2%) mainly comes from Viet Nam, Brazil, Honduras, Peru, Mexico, Indonesia, Colombia, India and Guatemala. In cocoa imports (25.6%), it is mainly from Ecuador, Cameroon, Nigeria, Dominican Republic, Ghana and

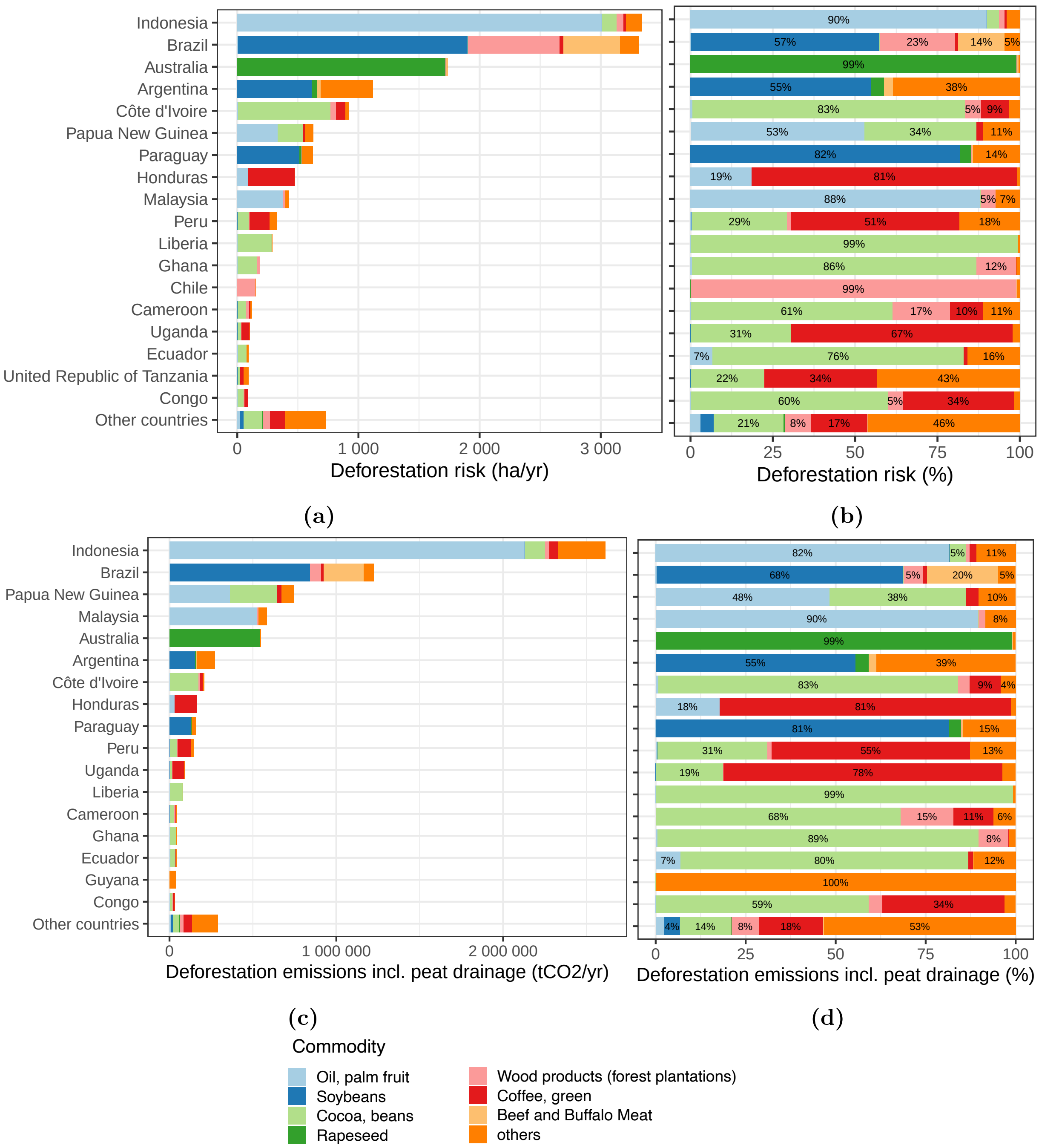
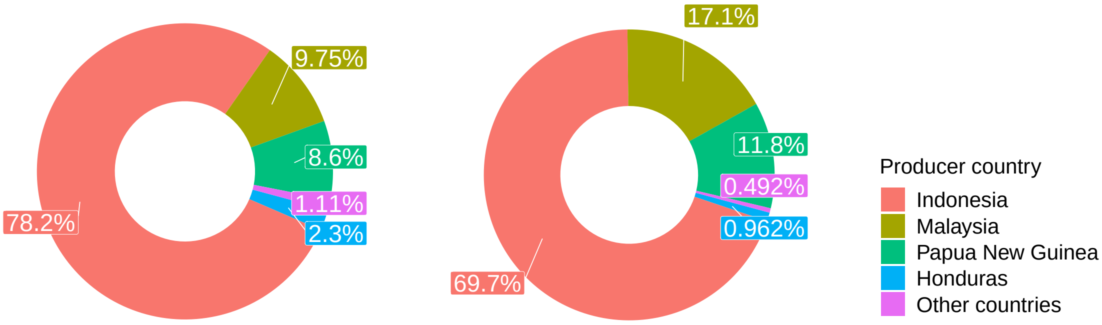
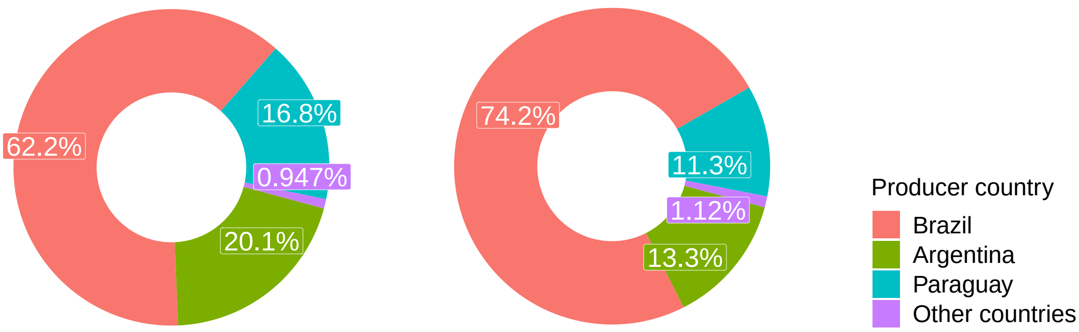


Figure 4.6: *Main producer countries. Deforestation area (a and b) and deforestation CO_2 emissions including peat drainage (c and d) embodied in Belgian commodity and forestry imports (2005-2017). Data from Pendrill et al. (2020).*



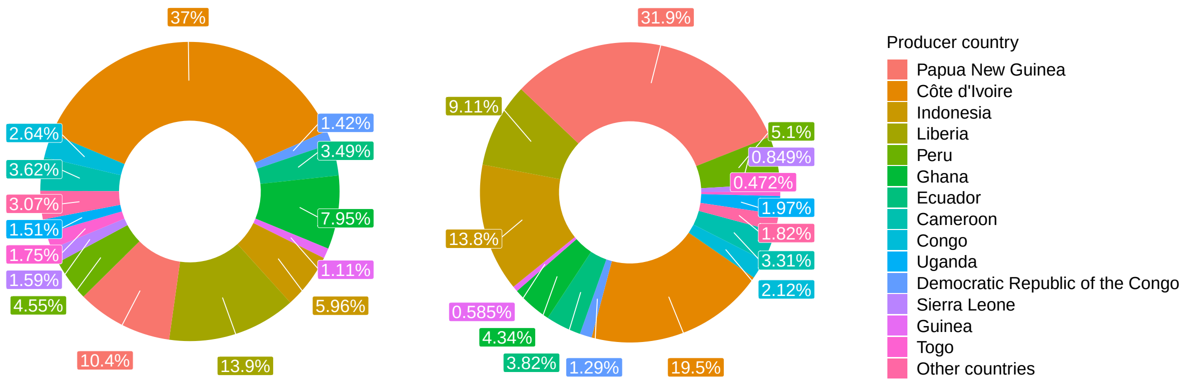
(a) *Deforestation area* **(b)** *Deforestation emissions*

Figure 4.7: *Main producer countries of* ***palm oil*** *imported by Belgium. Embodied deforestation area (a) and deforestation CO_2 emissions including peat drainage (b) in Belgian palm oil imports (2005-2017). Data from Pendrill et al. (2020).*



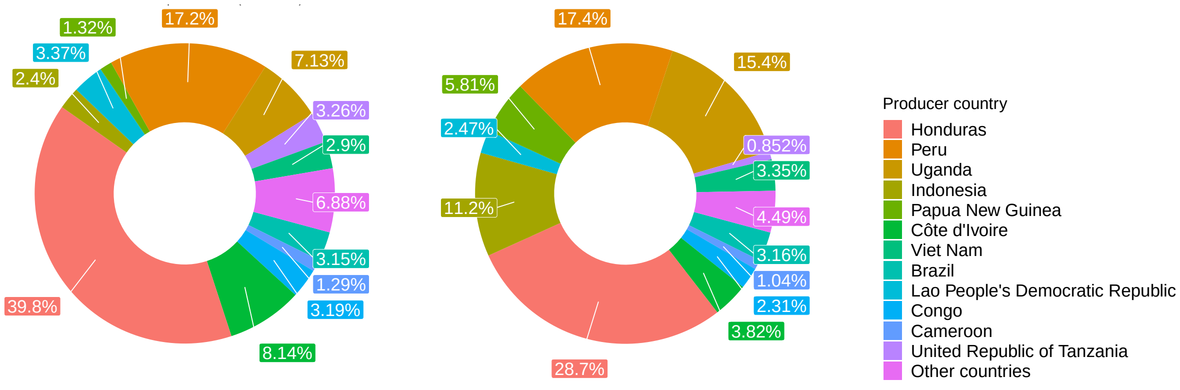
(a) *Deforestation area* **(b)** *Deforestation emissions*

Figure 4.8: *Main producer countries of* ***soy*** *imported by Belgium. Embodied deforestation area (a) and deforestation CO_2 emissions including peat drainage (b) in Belgian soy imports (2005-2017). Data from Pendrill et al. (2020).*



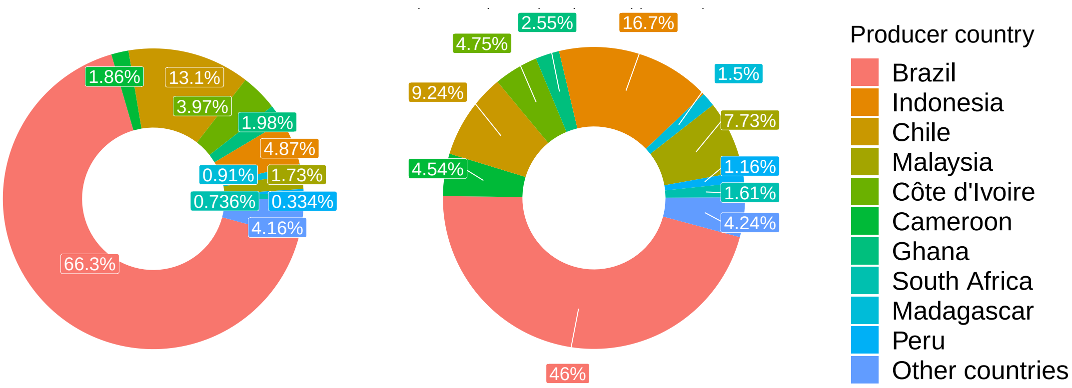
(a) *Deforestation area* **(b)** *Deforestation emissions*

Figure 4.9: *Main producer countries of* ***cocoa*** *imported by Belgium. Embodied deforestation area (a) and deforestation CO_2 emissions including peat drainage (b) in Belgian cocoa imports (2005-2017). Data from Pendrill et al. (2020).*



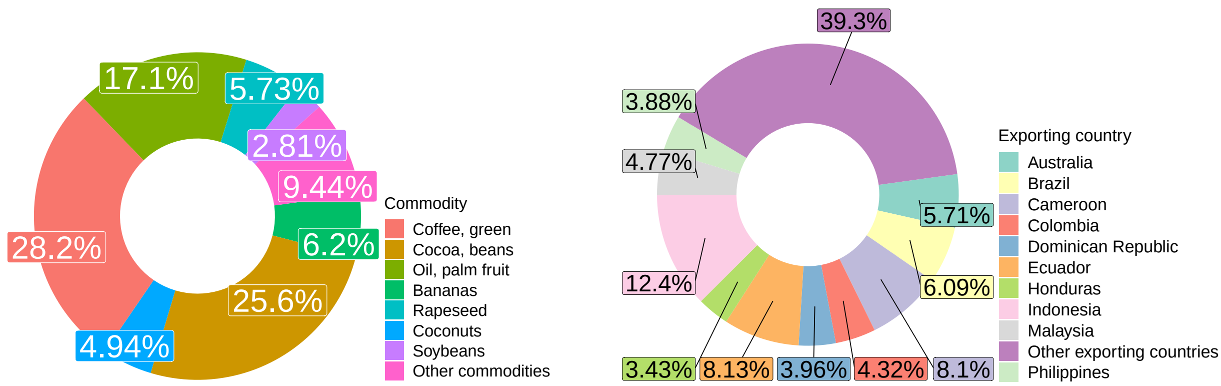
(a) *Deforestation area* **(b)** *Deforestation emissons*

Figure 4.10: *Main producer countries of* ***coffee*** *imported by Belgium. Embodied deforestation area (a) and deforestation* CO_2 *emissions including peat drainage (b) in Belgian coffee imports (2005-2017). Data from Pendrill et al. (2020).*



(a) *Deforestation area* **(b)** *Deforestation emissions*

Figure 4.11: *Main producer countries of* ***wood products (forestry plantations)*** *imported by Belgium. Embodied deforestation area (a) and deforestation* CO_2 *emissions including peat drainage (b) in Belgian wood products imports (2005-2017). Data from Pendrill et al. (2020).*



(a) *(b)*

Figure 4.12: *Share of biodiversity loss embodied in Belgian imports per commodity (a) and producer country (b) in 2011. Data from Chaudhary and Kastner (2016).*

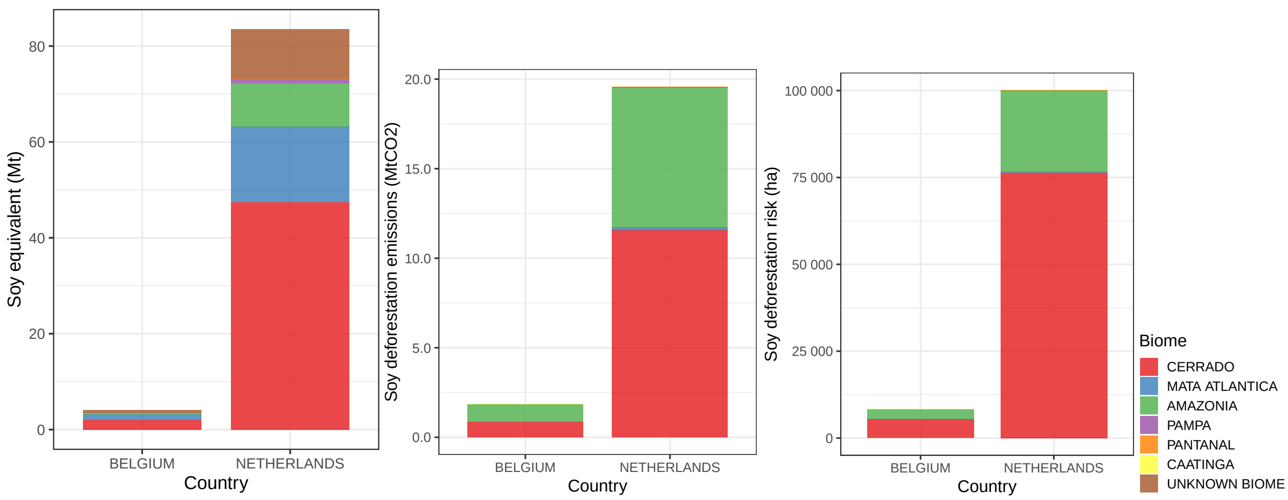
Côte d'Ivoire. In palm oil imports (17.1%), it is mainly from Indonesia, Malaysia and Papua New Guinea. In bananas imports (6.2%), it is mainly from Colombia and Ecuador. In rapeseed imports (5.7%), it is mainly from Australia. In coconuts imports (4.9%), it is mainly from Philippines and in soybean imports (2.8%), it is mainly from Brazil. The remaining 9.4% include, among others, commodities such as rice (2.4%), tea (2.4%), pineapples (0.8%) and castor oil seed (0.7%).

For Benelux (Appendix A.19*a*), the main embodied biodiversity loss is found in cocoa (27.3%), followed by palm oil (22.3%), coffee (14.5%), coconuts (7.9%), rubber (5.11%), rapeseed (4.3%), bananas (2.6%), soybeans (2.5%), tea (2.6%) and rice (1.3%). In terms of percentage, more biodiversity loss is suffered in Indonesia, Philippines, Cameroon and Malaysia than for Belgian imports (Appendix A.19*b*).

4.3 Environmental impacts of the main imported commodities at subnational level, main companies involved and zero-deforestation commitments

4.3.1 Mapping of brazilian soy on subnational level

Brazilian soy imported from Belgium and the Netherlands over the period of 2004-2018 amounts to more than 87.5 Mt. It represents 7.7% of the total soy produced in Brazil over the same period. Soy mainly came from the Cerrado, Mata Atlantica and the Amazon biome (Figure 4.13*a*). By looking at embodied deforestation emissions (Figure 4.13*b,c*), it appears that the highest impacts are sourced from the Cerrado (>50% for deforestation emissions and >75% for deforestation risk) and the Amazon biome both for Belgian and Dutch imports. By analyzing on a state level, Mato Grosso state (>60%) is from where the



(a) Quantity *(b) Deforestation emissions* *(c) Deforestation risk*

Figure 4.13: *Brazilian soy (a) imported by Belgium and the Netherlands per Brazilian* ***biome*** *(2004-2018). Deforestation risk (b) and deforestation emissions (c) (5 year annual risk). Data from Trase (2021).*

most embodied deforestation footprint is imported by Belgium and the Netherlands, followed by Goias, Bahia, Tocantins and Minas Gerais (Appendix A.20). On municipality-level, 22.7% of the CO_2 emissions embodied in Brazilian soy imported by Belgium (Figure 4.14*a*) was produced in Querência, 11.9% in Balsas, 9.3% in Gaúcha do Norte, 7,5% in Jaborandi, 7.3% in Nova Ubiratã, 7.2% in Nova Mutum, 6.9% in Sinop and 2.3% in Sorriso. All of these municipalities are part of Mato Grosso state except for Balsas and Jaborandi, which belongs to Maranhão and Bahia state respectively. CO_2 emissions embodied in Dutch imports (Figure 4.14*b*) came from Querência (14.9%), Nova Ubiratã (8.1%), Nova Mutum (4.4%), São Felix do Araguaia (4.2%), Sorriso (4.1%), Gaúcha do Norte (3%) and Tossa Fragosso (2.7%). Except from Tasso Fragoso that belongs to the state of Maranhão, the municipalities cited above are located in the state of Mato Grosso. For deforestation area, the concentration of municipalities is quite the same (Appendix A.21). The maps in Appendix A.22 allow to state that only a small number of municipalities where the share of imports to not exceed 3.8% of total imports can cause up to 22.5% of embodied deforestation. It is important to note that municipalities of about 40% of imported soy by both Belgium and the Netherlands remain unknown.

4.3.2 Mapping of cocoa from Côte d'Ivoire on subnational level

In 2019, cocoa imported by Belgium (179.4 Mtons) from Côte d'Ivoire mainly came from the South of the country (Figure 4.15). 4.8% of the cocoa came from Duékoué department, 4.6% from San-Pedro department, 3.25% from Daloa department, 3.2% from Aboisso department, 2.8% from Soubré department and 2.5% from Gagnoa department. The Netherlands imported 545.7 Mtons of cocoa. As for Belgium, highest quantities were sourced from Duékoué department (3.6%), San-Pedro department (3.59%) and Daloa department (2.8%) and also from Divo (2.7%) and Sassandra (2.3%) departments (Appendix A.23). However, departments of 53% of imported cocoa beans by both Belgium and the Netherlands (94.9 Mtons for Belgium and 291.7 Mtons for the Netherlands) remain unknown.

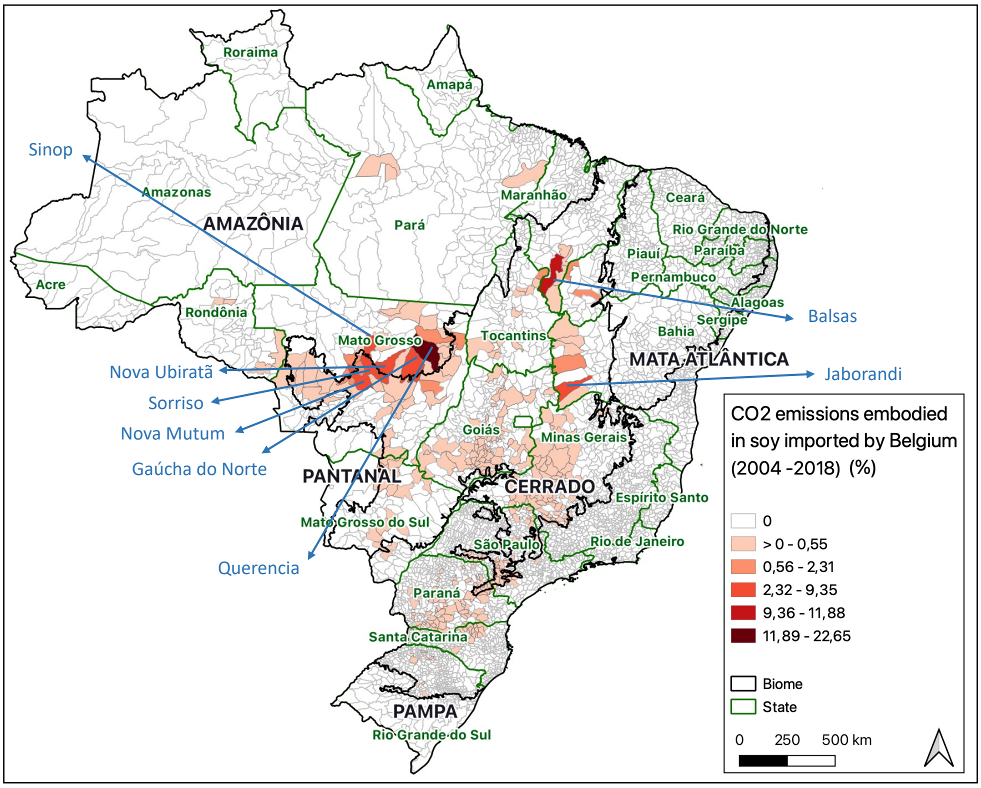
4.3.3 Mapping of Indonesian palm oil on subnational level

In 2015, 1.2 Mtons of Indonesian palm oil were exported from 171 kabupaten to the Netherlands. These exports were associated with 8 027 ha of embodied deforestation risk (with 2.7% of unknown kabupaten). Imports mainly came from Sumatra, Borneo (Kalimantan) and Sulawesi (Appendix A.24). While the majority was exported from Sumatra, the highest embodied deforestation is found in both Sumatra and Borneo (Appendix A.25).

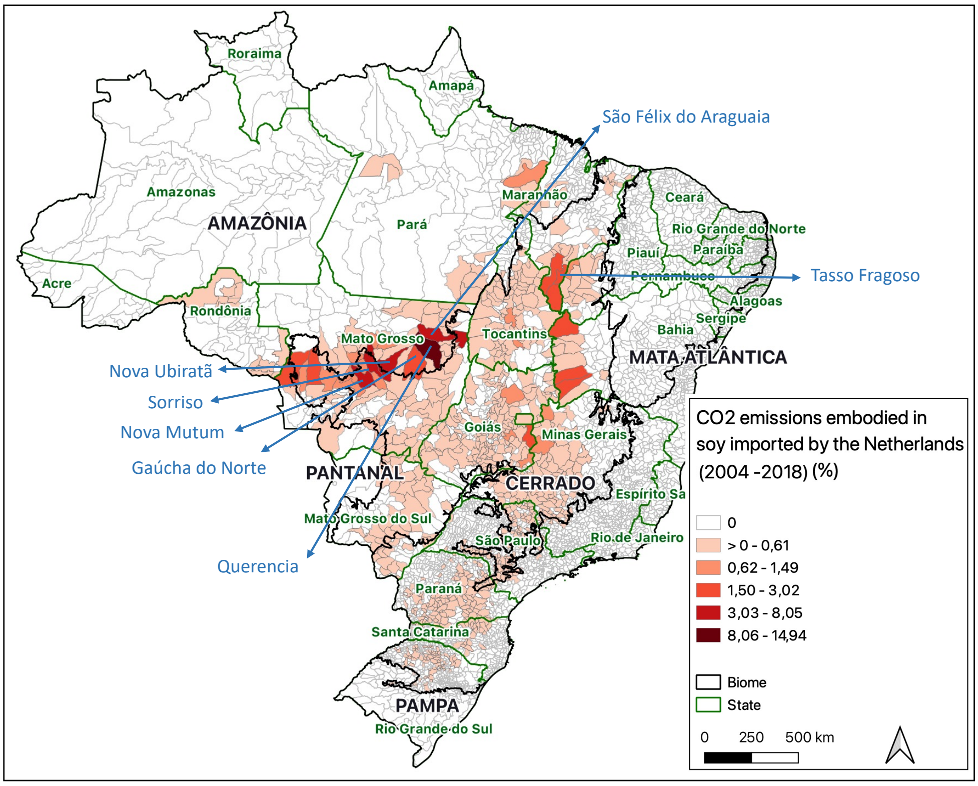
4.3.4 Importing companies and commitments

4.3.4.1 Main importing companies for some commodities

This section focuses on main companies that imported Brazilian soy and beef, Argentinian soy, cocoa from Côte d'Ivoire and Ghana to Belgium (Table 4.1) and to the Netherlands (Appendix B.3). Paraguayan soy and Indonesian palm oil are added for the Netherlands according to the available data. Some companies import/export several commodities such as Cargill (in yellow), Bunge (in salmon), Cofco (in green) and Barry Callebaut (in blue). Concerning Belgian imports between 2004-2018 (Table 4.1), in terms of quantity, Cargill



(a) *Belgian soy imports*



(b) *Dutch soy imports*

Figure 4.14: *Share of CO_2 emissions (5 year annual risk) embodied in Brazilian soy imported by Belgium (a) and the Netherlands (b) (2004-2018). Data from Trase (2021), IBGE for municipality boundaries and MapBiomas for biome boundaries.*

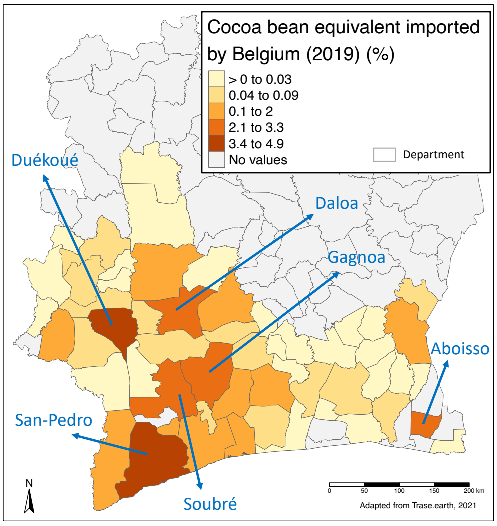


Figure 4.15: *Share of cocoa imported by Belgium from Côte d'Ivoire in 2019. Data from Trase (2021) and GADM for department boundaries.*

has imported 61.6% of the Brazilian soy, Bunge 7.9%, Amaggi 6.9% and Agrograin 5.4%. The top 10 companies accounted for more than 95% of total imports while the remaining share was divided into 33 importing companies. For the period of 2015-2017, 74.8% of the Brazilian beef was imported by JBS Toledo, 8% by Weston Importers, 7.5% by Van Aerde and 5% by JBS Global UK. For Argentinian soy between 2016-2018, 80% were exported by COFCO (27.2%), Cargill (15.6%), Vicentin (13%), Viluco S.A (12.4%) and Bunge (10.9%). In 2019, 58 companies exported around 179.4 Mtons of cocoa to Belgium. 50% of cocoa from Côte d'Ivoire in 2019 were exported by Barry Callebaut (21.9%), Ecookim (8.4%), Sucden (6.2%), Ecom (4.8%), Scat (4.7%) and Touton (4.4%). Barry Callebaut (38.3%), Sucden (12%), Cargill (8.9%), Touton (8.83%), Olam (7.4%) and Ecom (5.7%) imported more than 80% of cocoa from Ghana between 2018-2019.

For the Netherlands (Appendix B.3), for the same years as for Belgium for each commodity, around half of Brazilian soy was imported by Agrograin (17.0%), Cargill (13.8%), Amaggi (12.8%) and Bunge (8.7%). Almost 50% of Brazilian beef was imported by Weston Importers (17.8%), Feburo Global Meat (12.5%), Meat Import Zandbergen Brothers (8.4%) and JBS Global UK (8.3%). 95% of the Paraguayan soy was exported by ADM (50%), Cargill (19.7%), Compagnia Paraguaya de Granos (17.5%) and COFCO (7.7%) between 2014-2018. For Argentinian soy, 90% was exported by Glencore (42.2%), Vicentin (19.5%), Perez Company Family Group (10.4%), Aceitera General Deheza SA. (10.2%) and Fibro SRL. (8.1%) In 2015, 76% of Indonesia palm oil was imported by Golden Agri International (49.5%), Inter-Continental Oils and Fats (17%) and AAA Oils and Fats (9.8%). In 2019, 56 companies exported around 545.8 Mtons of cocoa to the Netherlands. Almost half of cocoa from Côte d'Ivoire was exported by Cargill (27.31%) and Olam (19.7%). 80% of Ghanaian cocoa was imported by Cargill (32.1%), Olam (23.6%), Ecom (12.4%), Touton (7.5%) and Sucden (4.2%).

Companies importing highest quantities are have a different share in terms of imports of embodied deforestation impacts. For instance, (Appendix B.4), as Cargill imported 61.6% of Brazilian soy to Belgium, it represents 70% of embodied deforestation risk associated with those. Ten companies are responsible for approximately 99.5% of deforestation emissions embedded in Brazilian soybeans imported by Belgium.

Table 4.1: *Top 10 companies importing commodities to Belgium. Data from Trase (2021).*

Brazilian soy (2004-2018)		Argentinian soy (2016-2018)		Côte d'Ivoire cocoa (2019)		Ghanaian cocoa (2018-2019)		Brazilian beef (2015-2017)	
Importer group	Import share (%)	Exporter group	Import share (%)	Exporter group	Import share (%)	Importer group	Import share (%)	Importer group	Import share (%)
CARGILL	61,62	COFCO	27,15	BARRY CALLEBAUT	21,85	BARRY CALLEBAUT	38,29	JBS TOLEDO	74,78
BUNGE	7,91	CARGILL	15,64	ECOOKIM	8,36	SUCDEN	12,06	WESTON IMPORTERS	8,00
AMAGGI	6,87	VICENTIN	13,03	SUCDEN	6,24	CARGILL	8,93	VAN AERDE	7,52
AGROGRAIN	5,42	VILUCO S.A.	12,38	ECOM	4,81	TOUTON	8,83	TOLEDO INTERNATIONAL	0,65
COFCO	4,65	BUNGE	10,87	SCAT	4,67	OLAM	7,38	MITERA BVBA	0,65
INTERGRAIN SA	3,94	GLENCORE	7,70	TOUTON	4,44	ECOM	5,70	MEAT IMPORT ZANDBERGEN BROTHERS	0,60
LOUIS DREYFUS	1,77	YPF	3,70	IVOIRE COMMODITIES SOURCING	4,13	COCOANECT BV	4,88	UNKNOWN	0,13
CEFETRA BV	1,37	UNKNOWN	3,08	COEX-CI	3,99	PETROFORCE TRADING AND SHIPPING	2,27	PNM PAN NORDIC MEAT	0,08
NETHGRAIN	0,93	LOUIS DREYFUS	2,38	OLAM	3,64	ARASCO FOOD BV	1,99	MAGMA FOODS	0,05
GLENCORE	0,75	AMAGGI	2,23	CARGILL	3,57	ITOCHU	1,99	VE	0,01
Total =	**95,22**	**Total =**	**98,16**	**Total =**	**65,70**	**Total =**	**92,32**	**Total =**	**92,48**

4.3.4.2 Zero-deforestation commitments for Brazilian, Paraguayan and Argentinian soy

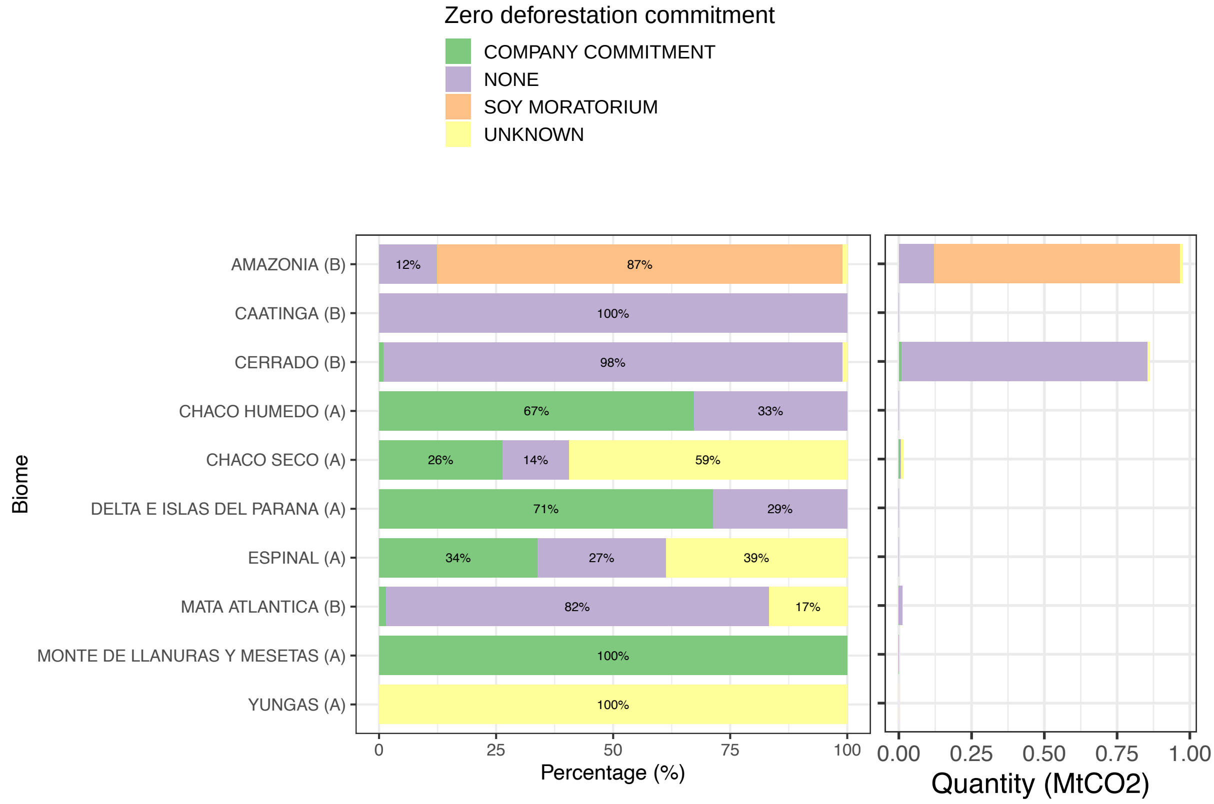
85% of the soy imported from the Amazon biome by Belgium was under the Soy Moratorium and the remaining 15% had no zero-deforestation commitment (Appendix A.27). In the Cerrado, less than 2% of total deforestation CO_2 emissions embedded in imports was under company commitment (Figure 4.16*a*). Some biomes where soy is produced, such as el Chaco Humedo or el Delta e Islas del Parana in Argentina were under a higher percentage of company commitment but Belgium did not import high quantities from them.

Cargill, the largest supplier of soy in Belgium, is part of the Soy Moratorium and 10% of its soy came from the Amazon biome. However, the company imported 45.7% of its soy from the Cerrado, from which only 1.4% was under the company commitment (knowing that Cargill imports represented almost 60% of the soy imported from the Cerrado). 12% of the soy imported by Bunge, the second largest supplier of soy in Belgium, was under commitment in the Cerrado whereas 53% of its imports remains without commitments. For the Netherlands, see Appendix A.28**b** and Appendix A.27**b**.

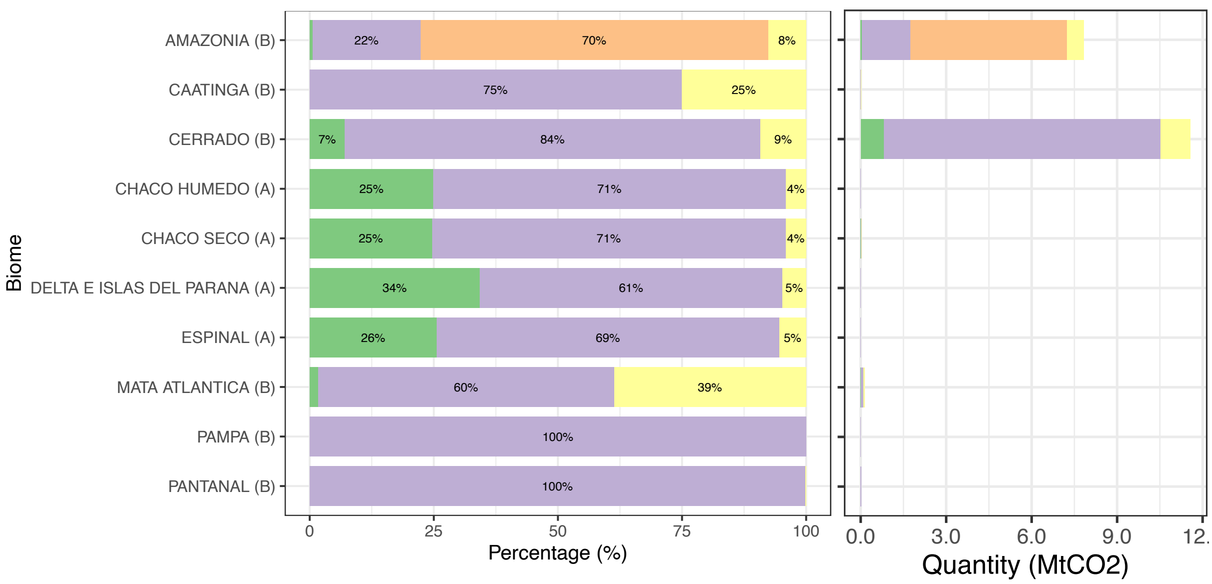
4.4 Summary of the results

1) Based on physical trade accounting, Belgium has a high embodied deforestation footprint in its agricultural and forestry imports across tropical countries. Embedded deforestation area and deforestation emissions per capita were more than the double of the European mean between 2005 and 2017. Belgian imported deforestation footprint accounted for about 5.5% of total EU28 (see Section 4.1.1).

2) More than 40% of embodied deforestation emissions are due to palm oil imports for Belgium and Benelux (2005-2017) (see Section 4.1.1). All together, palm oil, soybeans, cocoa beans, rapeseed, wood products, coffee and beef and buffalo meat encompass ~90% of embedded deforestation (area and CO_2 emissions) in Belgian and Benelux's agricultural and forestry imports.



(a) Belgium



(b) The Netherlands

Figure 4.16: *Zero deforestation commitments for soy imports (deforestation CO_2 emissions 5-year annual risk) from Brazil (B) (2004-2018) and Argentina (A) (2016-2018) by Belgium (a) and the Netherlands (b). Data from Trase (2021).*

3) According to consumption-based accounting (MRIO), most imported embedded deforestation (∼67.5% for Belgium and ∼69.8% for Benelux) are found in oilseed products followed by cattle meat, vegetable fruits and nuts (see SECTION 4.1.2). The difference between final consumption (MRIO) and apparent consumption (PTFs) could be explained by Belgium and Benelux's high consumption, high risk supply chains and processed industries that re-export products (see SECTION 4.1.2).

4) Based on PTF accounting, imports from Indonesia and Brazil are responsible for more than 50% of embedded deforestation (see SECTION 4.2.1). Since peatland are largely found in South-East Asia, share in deforestation intensity (CO_2 emissions) are higher for countries such as Indonesia, Papua New Guinea and Malaysia than for 'gross' deforestation (deforestation area).

5) Most of the embodied deforestation emissions (>95%) in main commodities imported by Belgium and Benelux come from only a few tropical countries, i.e. palm oil from Indonesia, Malaysia and Papua New Guinea; soybeans from Brazil, Argentina and Paraguay; rapeseed from Australia; and finally beef and buffalo meat from Brazil and Argentina. More than 70% of embodied deforestation emissions in imported cocoa come from Papua New Guina, Côte d'Ivoire, Indonesia and Liberia, in imported coffee from Honduras, Peru, Uganda and Indonesia and in imported wood products from Brazil, Indonesia and Chile (see SECTION 4.2.1.1).

6) Most of the biodiversity loss occurring in producing tropical countries (>90%) attributed to Belgian and Benelux's imports are linked, in the following order, to coffee, cocoa, palm oil, bananas, rapeseed, coconuts and soybeans (see SECTION 4.2.2). 60% of this biodiversity loss happen in Australia, Brazil, Cameroon, Colombia, Dominican Republic, Ecuador, Honduras, Indonesia, Malaysia and Philippines.

7) Embodied environmental impacts (deforestation risk and emissions) in Brazilian soy imported by Belgium and the Netherlands are highly concentrated in the Cerrado (>50% for deforestation emissions and >75% for deforestation risk) and the Amazon Biome, particularly in the Mato Grosso state (>60% for deforestation emissions) which straddles both biomes (see SECTION 4.3.1). More than 75% of CO_2 emissions embodied in Belgian imports of Brazilian soy are concentrated in only 8 municipalities.

8) Highest embodied deforestation risk from Indonesian palm oil imported by the Netherlands in 2015 came from Sumatra and Borneo (see SECTION 4.3.3).

9) More than 92% of Belgian imports of Brazilian and Argentinian soy, Ghanaian cocoa and Brazilian beef were operated by 10 companies (not the same companies for each commodity) and more than 65% for cocoa from Côte d'Ivoire (see SECTION 4.3.4.1). Only 10 companies encompass 99.5% of deforestation emissions and area embedded in Belgian soy imports from Brazil.

10) ZDCs across Brazil and Argentina cover the majority of embodied deforestation in the Amazon biome through the Soy Moratorium. However, those commitments account for less than 3% and 8% respectively for Belgian and Dutch soy imports from the Cerrado (see SECTION 4.3.4.2).

Chapter 5
Discussion

5.1 Interpretation of the results

5.1.1 Belgian agricultural imports and consumption

As seen in Figure 4.1*b*, in 2017, the Netherlands, Luxembourg and Belgium stand at the first, second and third place respectively in term of deforestation carbon footprint for food consumption per capita. From a worldwide perspective - based on the same data (physical trade) - on average, between 2010-2014, Brazil had the first place, followed by Indonesia, the Netherlands, Luxembourg and Belgium (Appendix A.29). Indonesia and Brazil consume domestically high quantities of what they produce (Pendrill *et al.*, 2019b) and hence, have a high deforestation impact. For the MRIO model, with the same data as used in Figure 4.3, first place goes to Brazil, second to Luxembourg, third to Taiwan, fourth to the Netherlands and fifth to Belgium (Appendix A.29).

By comparing both physical trade with MRIO model (Figure 4.3) and Benelux's countries with other countries (Appendix A.29), the different results could be explained by Benelux's high consumption, by being part of a transit economy and by sourcing commodities from high risk areas.

Consumption of FRCs is important in Belgium. In this paragraph, some numbers concerning Belgian consumption of main FRCs will be briefly presented. Firstly, Belgian indirect consumption of soy (through animal feed)[1] is particularly high. The Belgian average diet shows a significant over consumption of animal-based products (Riera *et al.*, 2019). Indeed, Belgian consumption of meat (121-114gr/day/capita versus 57gr/day/capita recommended) and cheese per capita is higher than recommended (De Ridder *et al.*, 2016) and the percentage of vegetarians is low (<1.5%) compared to other European countries (Mulle *et al.* 2017). Following a study about Belgian consumer's valuation of sustainability labels on meat, it emerges that consumers are less willing to pay for carbon footprint labels than animal welfare (Van Loo *et al.*, 2014). Secondly, more than one-third of daily energy intake consists of ultra-processed food such as frozen meals, hot dogs, fast food, packaged cookies and cakes and the percentage is higher among children (Vandevijvere *et al.*, 2019). Along with meat, diary products and cocoa, palm oil is present in many of these processed foods (Ritchie and Roser, 2021). On average, between 2000 and 2003, palm oil consumption in food was around 5kg per capita. Belgium is in third place on a global scale (the Netherlands being at the first place followed by Luxembourg). Considering all sectors, the increase of palm oil in Belgian consumption (2010-2012) seems to be related to an increase in the use of palm oil as feed for manufacture of coke and refined petroleum products (for biodiesel) (Shigetomi *et al.*, 2020). Thirdly, Belgium has an important cocoa and coffee culture. Belgian consumers

[1] Through animal feed, soybean meal is indirectly used in bovine meat (1.6kg soybean meal/kg animal protein), pork (3.3kg soybean meal/kg animal protein), broiler meat (2.3kg soybean meal/kg animal protein), eggs (4.9kg soybean meal/kg animal protein) and milk (1.5kg soybean meal/kg animal protein) (Riera *et al.*, 2019).

eat approximately 6.4kg of chocolate - while EU mean is 5kg - (Syndicat du chocolat, 2019) and on average, drink 2.1 cups of coffee a day (Euromonitor International Consulting, 2017). In 2016, certified coffee (e.g. Fairtrade, UTZ or Rainforest Alliance) accounted for about 20% of the Belgian consumption (12% being private label and 8% branded coffee) which is below its neighbouring countries such as the Netherlands (45% in total with 28% branded) or Germany (18% in total with 13% branded) and Scandinavian markets (Sweden: 64% in total with 60%). Since certification costs are high, without added value beyond sustainability (e.g. higher quality or ethical production), Belgian consumers will have difficulties in paying the additional costs (Euromonitor International Consulting, 2017). Finally, Belgium and the Netherlands are great consumers of tropical sawnwood. Verified sustainable tropical timbers (under FSC and PEFC) represent 27.5% of Belgian imports and 67.5% of Dutch imports (IDH, 2020).

Benelux countries are part of open economies, meaning that they process and re-export products. In addition, major world transportation hubs such as Antwerp in Belgium and Rotterdam in the Netherlands are key entry and exit points for the European market[2] (Duprez and Dresse, 2013). For example, the port of Antwerp is the second-largest cocoa beans port in Europe, making the country a key trade hub for the cocoa bean trade (CBI, 2020). Additionally, the port of Antwerp is the 5th largest for palm oil imports (Jenning and Schweizer, 2019) and the port of Rotterdam is the first importer of palm oil[3] (Brunswijck *et al.*, 2018). Belgium as well as the Netherlands import great quantities of physical fluxes that are then reexported to other European countries. Therefore, in physical trade accounting, these other European countries that import from Belgium and the Netherlands do not necessarily import from deforestation risk areas anymore. These results highlight a significant potential for improvement for embodied deforestation entering Benelux if measures are implemented.

Belgium and the Netherlands are hosting large manufacturing industries. For example, globally, Belgium is the second largest chocolate exporter after Germany (CBI, 2020). It mainly reexports to Germany, France and the Netherlands. The Netherlands, as the first cocoa processor, supplies high quantity of cocoa-derived products to Belgium, i.e. grinding cocoa. Belgium hosts large manufacturer such as Godiva, Leonidas, Neuhaus and Mondelez which is the largest manufacturer of the country that owns Côte d'Or and Milka. Moreover, Barry Callebaut, which is the largest producer of industrial chocolate, houses its largest production site in Wieze (Belgium). Cargill and Puratos also produce industrial chocolate in Belgium and, with growing demand, these companies have invested in increasing their production capacity (CBI, 2020). In addition, the EU is the main exporter of animal productions (21% of total exports in 2018) (Chatellier, 2021). Since domestic Belgian supply is higher than domestic demand specially for pork, followed by bovine meat, poultry meat and dairy products, the country exports the rest mainly to other EU countries, and particularly neighbouring countries such as the Netherlands, Germany and France. Around 60% of total GHG emissions produced by Belgian livestock sector is related to national consumption, whereas the 40% remaining are for export (Riera *et al.*, 2019).

[2]Note that the Rotterdam-Antwerp Effect can induce errors in the way trade is attributed to the actual final consumer due to transshipments and complex custom procedures (Lemmers and Wong, 2019).

[3]Note that between 2005 and 2015, the EU has doubled its palm oil imports (Brunswijck *et al.*, 2018).

Finally, supply-chain with higher deforestation risk could be part of the explanation between the difference of both model's estimations. Indeed, the supply comes mainly from deforestation frontiers and, in general, effective commitments are lacking. These points will be detailed in SECTION 5.1.2.2 and SECTION 5.1.3.

5.1.2 Tropical deforestation embodied in trade

5.1.2.1 Deforestation emissions vs deforestation area

Depending on the indicator used, namely deforestation emissions and deforestation area (FIGURE 4.5), the share of impacts is quite different. Deforestation area refers to the surface area, while the deforestation CO_2 emissions refer to the intensity of deforestation. Indeed, in South-East Asia, in Indonesia and in Malaysia particularly (Page *et al.*, 2011), tropical rainforests with peatland enclose much more CO_2 than savannah/dry forest that can be found in the Brazilian Cerrado for which the carbon stock is lower. It is important to underline that Indonesia holds about two-thirds of tropical peatland carbon (Page *et al.*, 2011). Because of palm oil plantation, drainage of peatland converts net carbon sink (peat accumulation) into net carbon source (peat degradation) (Page *et al.*, 2011). Peat drainage occurring in South-East Asia encompasses the equivalent of 2% of global fossil fuel CO_2 emissions (Petrenko *et al.*, 2016). In fact, a third of global anthropogenic GHG emissions are owed to food systems, from which around 30% come from LULUCF (Crippa *et al.*, 2021). Carbon losses from deforestation and degradation of organic soils, including peatlands, are the main components of these emissions from LULUC (Crippa *et al.*, 2021).

5.1.2.2 Deforestation fronts

As seen in SECTION 4.2, most embodied deforestation imported by Belgium and Benelux originates from Brazil and Indonesia. However, main commodities are also sourced from places where new frontiers for deforestation are opening, particularly in West Africa (Côte d'Ivoire, Ghana, DR Congo and Cameroon), Southern Africa (Tanzania and Madagascar) and South America (Colombia and Peru) (IDH, 2020). These deforestation fronts (FIGURE 2.1) represent areas at great risk in the future, as nearly half of their forests have been fragmented and are therefore more susceptible to further deforestation (Pacheco *et al.*, 2021). An example can be found in SECTION 5.1.3.1.

5.1.2.3 Biodiversity loss

Key commodities and producer countries vary across indicators, and some commodities with lower deforestation and carbon footprint such as coffee and cocoa have more important biodiversity impacts than the ones having higher deforestation footprints (see SECTION 4.2.1.1 and SECTION 4.2.2). Note that results from Chaudhary and Kastner (2016) focuses on habitat loss and concentrates on endemic species. The results are particularly interesting in terms of habitat niches.

In general, biodiversity impacts are higher for industrialized countries with high per capita GDP (Lenzen *et al.*, 2012; Chaudary and Kastner, 2016). Around 53% of threatened terrestrial species are negatively impacted by agricultural activities (Tanentzap *et al.*, 2015). Key commodities responsible for highest regional biodiversity loss are mainly high-quality food (including luxury products with a large biodiversity and water stress impact) such as cocoa, coffee, palm oil, fruits, cashew, nuts, and rubber and not staple food, e.g. wheat and rice (Oberle *et al.*, 2019).

Deforestation-associated commodities (timber, wood products, tobacco, cocoa, coffee and cotton) and biodiversity loss can also be linked to disease. For example, international trade is driving around 20% of the malaria-risk in deforestation hotspots (Chaves *et al.*, 2020). Belgium and the Netherlands import cocoa mainly from Africa and reexport it mostly to European countries (Chaves *et al.*, 2020). Mainly due to this commodity traded, per capita, these two countries potentially cause the world's highest malaria footprint (31,25 risk cases per 1000 inhabitants).

5.1.2.4 Crops for food or energy

As biofuel has been and still is a hot discussed topic, before taking about it, it is important to note that only imports of agricultural products are found in Pendrill *et al.*, 2020 and Trase datasets (see Sections 3.1.1.1 and 3.1.1.3) and not direct imports of biofuels. Unexpected impacts have arisen from the will of producing more biofuel (Liu *et al.*, 2015) particularly with palm oil, soy and rapeseed. By analyzing systems integration, with the objective to reduce CO_2 emissions associated with energy on one side, it causes cascading and spillover effects of biofuel production on land conversion and CO_2 emissions on the other side (Liu *et al.*, 2015). Moreover, increasing demand for bioenergy reflects on food price and threatens food security in some part of the world (Liu *et al.*, 2015). According to an analysis carried out by Transport and Environment (2016), cars and trucks, heat and electricity burned respectively 45% and 15% of palm oil imported in Europe from 2010 to 2014 and over this period there was an increase of 34% in EU biodiesel, and a particularly high increase for palm oil use (+606%). The use of virgin vegetable oils (first-generation biofuels) being around 80% worse than fossil diesel, the average climate footprint has not been improved (Transport and Environment, 2016). In recent years, crops dedicated to bioenergy has been increasing and the tendency is expected to continue (IEA, 2020). As a response to negative environmental impacts, the Belgian Minister of Environment and Climat, Zakia Khattabi, has announced that Belgium, following Denmark, France and the Netherlands will ban the use palm oil by 2022 and soy by 2023 for biodiesel production (Khattabi, 2021). This is likely to be effective in reducing deforestation associated with crop production if the percentage of total biodiesel is reduced. If not, some European oil would be used, such as rapeseed. Then it might imply that imports of palm oil for the agro-industry will rise since rapeseed will no longer go to the agro-industry but rather biocarburant (Brunswijck *et al.*, 2018).

5.1.3 Environmental impacts of the main imported commodities at subnational level, main companies involved and zero deforestation commitments

5.1.3.1 Brazilian soy - subnational level

Figure 4.13 shows that highest deforestation impacts have been happening in the Amazon and the Cerrado. According to the latest data, between 2019 and 2020, no Brazilian biomes (see Appendix A.30 to visualize the different Brazilian biomes) has been spared by deforestation. However, 69% of deforestation took place in forest formation areas and the remaining 31% in savannahs and grasslands making 92.1% of deforestation happening in the Amazon and Cerrado biome (MapBiomasProject, 2020). 98.9% of deforested areas were illegal deforestation (MapBiomasProject, 2020). Agricultural expansion in Brazil between 2000 and 2014 has mainly taken place in repurposed pasture lands (79%), while around 20% was due to the conversion of natural vegetation (Zalles *et al.*, 2020). The Cerrado, a global biodiversity hotspot composed of grasslands, shrublands and woodlands (Mittermeier *et al.*, 1999; Klink and Machado, 2005; Bond and Parr, 2010), has experienced conversion 2.5 times of what the Amazon forests have between 2000 and 2014 (Zalles *et al.*, 2020). 74% of new cropland areas occurred in previously intact Cerrado vegetation (Spera *et al.*, 2016). The Cerrado, which is the largest savannah biome in South America, covers over around 26% of Brazil (Lambin *et al.*, 2013). Until 1970, it was unaltered (Bustamante and Ferreira, 2010 in Lambin *et al.*, 2013), and since then, it became the most coveted biome for agri-business expansion (Jepson *et al.*, 2010; Soares-Filho *et al.*, 2014). Less strict environmental regulations, more attractive prices and a more crop-friendly topography are attracting investors (Dou *et al.*, 2018; Moffette and Gibbs, 2021). Currently, the soy sector is the leading cause of conversion of natural vegetation in the Cerrado (Rausch *et al.*, 2019). It has become the new agricultural frontier of soy, and especially in the region of Matopiba (Noojipady *et al.*, 2017; Lima *et al.*, 2019).

On a subnational division, as seen in section 4.3.1, currently, the State of Mato Grosso and MATOPIBA region (states of MAranhão, TOcantins, PIauí, BAhia) geographically concentrate deforestation. Theses states, in addition to Mato Grosso do Sul and Pará, have doubled their cropland extent between 2000 and 2014 (Zalles *et al.*, 2019). MATOPIBA's agricultural expansion is mainly happening by clearing native vegetation rather than previously cleared pasture areas (Spera *et al.*, 2016). Balsas, located in MATOPIBA is the second largest deforestation alert of 2020 (MapBiomasProject, 2020) and from where Belgium and the Netherlands imported great quantities of soy between 2004 and 2018 (see Appendix A.22). Mato Grosso state regroups 3 biomes: 57% is covered by the rainforests of the Amazon, 37% by the Cerrado savannahs, grasslands and forest, and 6% by the Pantanal which is the world's largest tropical wetland area (Vasconcelos *et al.*, 2020). In addition to being concentrated in certain municipalities, deforestation is also highly concentrated on large properties[4] (Vasconcelos *et al.*, 2020). 51% of soy farms violated the FC (Rausch *et al.*, 2019). Only 2% of farms in Mato Grosso (∼400 farms) accounted for 80% of total illegal deforestation linked

[4] Large property have more than 825 ha by Brazilian standards

to soy production between 2012-2017[5](Trase, 2020). According to estimations, around 20% of exported Brazilian soy from Mato Grosso to the EU in 2018 was soy produced on farms that resorted to illegal deforestation (Vasconcelos *et al.*, 2020). Moreover, over 50% of illegal deforestation in Mato Grosso (2012-2017) was concentrated in 15 municipalities, Paranatinga and Nova Ubiratã accounting for 10% and 5% respectively (APPENDIX A.31)(Vasconcelos *et al.*, 2020). By visually comparing APPENDIX A.31 with FIGURE 4.14, high percentage share of deforestation emissions imported by Belgium and the Netherlands are sourced in these municipalities. Illegal deforestation implies that environmental impacts of deforestation are not managed (Vasconcelos *et al.*, 2020). In addition, negative social impacts such as increased land conflicts, violence and crimes against environmental defenders and violation of local communities' rights are not insignificant (Vasconcelos *et al.*, 2020).

5.1.3.2 Cocoa from Côte d'Ivoire - subnational level

Cocoa (FIGURE 4.15) is mainly imported from the South of Côte d'Ivoire which is coherent with climatically most suitable cocoa regions that are only located in the South of the country (Abu *et al.*, 2021). By comparing FIGURE 4.15 with a map of estimated areas of cocoa plantation within protected areas (APPENDIX A.32), it suggests that Belgian and Dutch cocoa imports could originate, at least in part, from these protected areas. In total, 70% of protected areas in Côte d'Ivoire and Ghana are housing cocoa plantations, which represent 20% of the cocoa plantation area (Abu *et al.*, 2021).

5.1.3.3 Main companies involved and zero-deforestation commitments

Nowadays, around 12% of companies in agricultural supply chains have taken a zero- or zero-net deforestation commitment for all their sourced commodities (Schatz and Jenkins, 2020).

Soy: FIGURE 4.16 and APPENDICES A.27 & A.28 show that ZDCs associated with soy production in Brazil, Argentina and Paraguay is far from covering all Belgian and Dutch imports. The Soy Moratorium has decreased deforestation in the Amazon (Dou *et al.*, 2018). However, only areas of land where soy is produced is monitored by the Soy Moratorium, and hence does not cover the entire farm. Because of this, many of the farms are breaking the FC (Azevedo *et al.*, 2015; Gibbs *et al.*, 2015). As a result, Brazilian soy exported under zero-deforestation label from the Amazon, has been compromised. Global markets have been importing soy produced by farms deforesting the Amazon illegally, not for soy but for other purposes (Vasconcelos *et al.*, 2020). Therefore, the Soy Moratorium needs to broader its scope to farm level if it wants to be effective (Vasconcelos *et al.*, 2020). Even with these gaps, soy-related deforestation has decreased in the Amazon (Gibbs *et al.*, 2015). Unfortunately, this happened while leading to spillover in the Cerrado. The expansion in the Cerrado is mainly due to the expansion of soy production and pasture (Soares-Filho *et al.*, 2014; Gibbs *et al.*, 2015, Lima *et al.*, 2019). Illegal clearing of natural vegetation in the Cerrado within Mato Grosso accounted for 98.5% between 2012-2017 (Vasconcelos *et al.*, 2020). 26% (235 kha of this illegal deforestation happened on soy farms, from which 62 kha (25% of 235 kha)

[5]Illegal soy production linked to deforestation represent 27% of all illegal deforestation happening in Mato Grosso

were for soy cultivation (Vasconcelos *et al.*, 2020). This corresponds to almost the double of illegal deforestation on soy farms in the Amazon (Vasconcelos *et al.*, 2020).

46% of processed soy in Belgium was certified in 2014/2015 (Kroes and Kuipper, 2015). According the BFA (Belgian Feed Association), 100% of the soy dedicated to animal feed will be certified by 2030 (BFA, 2021). Note that high quantity of soy are also produced in the US and Canada (IDH, 2020). As shown in Section 4.3.4.1, Cargill has a high soy-deforestation risk for Belgian and Dutch imports and this is also the case on a global scale (zu Ermgassen *et al.*, 2020a). The company has moved its deforestation reduction targets to 2030 since they have not been met in 2020.

Palm oil: In 2017, around 20% of palm oil produced globally was under RSPO certification. Between 2001 and 2015, in Indonesia, certified palm oil was linked to reduced deforestation (Carlson *et al.*, 2017) and particularly to reduced illegal deforestation (Heilmayr *et al.*, 2020a). However, in peatlands and active fire areas, certification did not have a significant impact (Carlson *et al.*, 2017). The majority of plantations, when they received the certification had already little amount of forest left, meaning that deforestation and forest fire had already happened before certification (Carlson *et al.*, 2017). Therefore, supply chain interventions should be directed towards high-risk locations, rather than places where standard can easily be met (Carlson *et al.*, 2017). The RSPO (Roundtable on Sustainable Palm Oil) formed in 2004 in order to tackle socio-envtironmental issues linked to the oil palm industry (Santika *et al.*, 2020), has certified around 4.38 Mha of palm oil plantations in 2021 (around 20% of the total area) (RSPO, 2021a). However, after 15 years of the creation of RSPO, social and environmental outcomes in local communities remain uncertain (Santika *et al.*, 2020).

In Belgium, the BASP, created in 2012, aims at making the Belgian market of palm oil sustainable (Brunswijck *et al.*, 2018). Companies such as Aigrement, Ferrero, Lotus Bakeries, Puratos and Unilever are signatory members of the BASP (BASP, 2021). However, this commitments are only targeting the agro-industry (99% of total palm oil used by members are certified (IDH, 2020)) and not the transportation sector or other non-food sectors (Brunswijck *et al.*, 2018). Moreover, only SIPEF as a major company linked to the production of palm oil is a member of BASP, whereas SIAT, SOCFIN and FERONIA are not (Brunswijck *et al.*, 2018). Even if Belgian company imports of palm oil do not compete with Asian companies such as Wilmar, and Sime Darby, there are well implanted in Africa, which is considered to be the future El Dorado of palm oil production (Brunswijck *et al.*, 2018). Finally, there is currently no third-party certification to verify the respect of these commitments (Brunswijck *et al.*, 2018).

Cocoa : Currently, certification projects have little effect (cocoa côte d'Ivoire and Ghana) (Wessel and Quist-Wessel, 2015). In Belgium, *Beyond chocolate*, a partnership for a more sustainable Belgian chocolate industry has been signed by more than 100 companies, civil society organizations, the Belgian government, large retailers, NGO's and universities. The Belgian industry is one of the most important importers of cocoa beans and relies on more or less 140 000 – 190 000 cocoa farming families annually. Beyond chocolate, goals are to provide better income and working conditions, to eliminate child labor [6], to adapt for present and future climate change, to stop deforestation and to maintain biodiversity. By 2030, Belgian chocolate should be entirely sustainable, cocoa producers should earn a living income well above the poverty line and cocoa production will no longer lead to deforestation (IDH *et al.*, 2020). Barry Callebaut, Cargill and Olam are among the signatories. However, questions remain in terms of certifications since all companies do not have the same standards.

5.2 Perspectives for reducing Belgium's imported deforestation footprint

To reduce Belgium's imported deforestation footprint, a solution could be the substitution of FRCs. However, substitution is not a synonym of positive environmental effects. For example, palm oil could be replaced by other oils such as coconut oils or other vegetable oils (rapeseed, sunflower or soy). However, it is the oleaginous fruit with the highest yields, more than 2 and 10 times l/ha for palm oil than for coconut oil and soybean respectively[7] (Parsons *et al.*, 2020). If substitutes were to be produced in the same quantity, it would require more area than palm oil (Parsons *et al.*, 2020). From an environmental perspective, there is no optimal palm oil replacement possible and in the short to medium term, the realistic solution seems to ensure sustainability in palm oil production (Parsons *et al.*, 2020). As palm oil, cocoa, coffee and other FRCs cannot really be produced in temperate regions and, as substitution is not always a solution (Parsons *et al.*, 2020), increasing production of deforestation-free FRCs seems more adequate in the current context (Bager *et al.*, 2021). Moreover, if Belgium or Europe were to withdraw from these markets, supply-chain leakage (Meyfroidt *et al.*, 2018) could occur. This process happens when producers keep producing the same commodities but no longer provide the same buyer or when they switch to producing other high environmental impact commodities (Rausch and Gibbs, 2016; Lambin *et al.*, 2018).

With the increasing worldwide demand owing to global population growth, change in dietary habits and energy production, how can the pressure on the environment be reduced? There is a need of up-scaling successful solutions (Lambin *et al.*, 2020). As many studies have shown (see Lambin *et al.*, 2020 for the references), it only works if there is a coalition between multiple stakeholders, namely the public sector, the private sector and civil society. They need to work hand in hand. How can scaling-up happen? Legislation has a role to play both in producer and consumer countries. In producer countries, consumer countries can support legislation. In consuming countries, governments need to increase demand for eco-certified commodities with public policies that endorse private sustainable standards (Lambin *et al.*, 2020). Indeed, private companies need to integrate voluntary sustainability standards in internal code of conduction and sourcing practices. Today, most policies are applied to the most progressive actors and therefore, there is a market differentiation that leaves people behind. The transformation needs to be system-wide. In fact, a well designed hybrid private-public governance that provides great complementary, substitution and poor

[6]Currently, 1.5 million children are working in cocoa production in Côte d'Ivoire and Ghana (Fountain and Hütz-Adams, 2020).

[7](556 l/ha for soybean, 2 689 l/ha for coconut oil and 5 950 l/ha for palm oil)

antagonistic interactions is required (Lambin *et al.*, 2014). Actions and solutions might need to happen on different levels at the same time (Lambin *et al.*, 2018; Bager *et al.*, 2021), i.e. increasing production and demand of deforestation-free FRCs while reducing demand for FRCs (Bager *et al.*, 2021). Some solutions will now be described.

In some places where most damaging impacts on biodiversity happen, crop yields are below normal range because of, in part, lack of technology (Mueller *et al.*, 2012, Pradhan *et al.*, 2015 in Chaudhary and Kastner, 2016). **Sustainable intensification** might be part of the solution (Garnett *et al.*, 2013; Godfray *et al.*, 2014). However, attention needs to be paid as it could lead to land sparing in a first time (Phalan *et al.*, 2016) and rebound effects in a second (Meyfroidt *et al.*, 2018) (see Appendix A.33 for more details). In fact, increasing productivity on the most fertile land would spare some at the same time as increasing growth without deforesting new areas and threatening biodiversity, i.e. land sparing) (Meyfroidt et al., 2018). However, with new technology, costs are lowered and therefore drive increased consumption - 'Jevons paradox', which in turn can reduced the land spared initially and provide a rebound effect (Meyfroidt et al., 2018). This phenomenon has been happening during the last decades in soy production mostly in South America and in palm oil production in Indonesia and Malaysia. According to Garrett *et al.* (2018), cropland and pasture intensification go hand to hand with forest conservation restrictions and a larger supply chain development (Garrett *et al.*, 2018). Nevertheless, this is more the case for regions where less forest area is remaining (Carlson *et al.*, 2017; Garrett *et al.*, 2018). Measures should accompany intensification to ensure limited potential for area expansion and therefore prevent rebound effects to happen (Rudel *et al.*, 2009), particularly for products with high elastic demand such as palm oil, soy, cocoa and coffee (Lambin, 2015). Another perspective for reducing Belgium's imported deforestation footprint is the **cash for carbon**. Producer countries could implement payments for ecosystem services (Jayachandran *et al.*, 2017). It would be a final compensation for forest owners who agreed to preserve their forest and lead to sequestration of carbon and preservation of biodiversity. This represents a simple and cheap solution. In 2018, cash for carbon accounted for less than 0.1% of value of international trade (Lambin, 2020). The **eco-certification** consists on giving access to niche market and could be another solution (Rueda and Lambin, 2013). Farm eco-certified have increased their forest tree cover (Rueda and Lambin, 2013). It is a simple solution and currently represents 2-22% of market shares (Lambin, 2020). Companies could also play a role by implementing **company code of conduct**. Significant improvement in legal practices and better soil- and water management practices in South Africa even if in some cases it can only result in window dressing (Thorlakson *et al.*, 2018). Moreover, by expanding the Soy Moratorium to the Cerrado biome, a study showed that 3.6 Mha of native vegetation would be protected from direct conversion to soybean production by 2050 (Soterroni *et al.*, 2019). Currently, there are around 300 multinational companies active in agri-business sector out of 80 00 companies that are 'progressive' (Lambin *et al.*, 2020). Few companies have combined these solutions and implemented them in their policies. They have been able to reverse the tendency over the years, from deforestation to reforestation as it was the case for Vietnam (Meyfroidt and Lambin, 2009), Costa Rica and Buthan (Jadin *et al.*, 2016). However, they have been subject to leakage (Lambin, 2020).

From a consumer-side, reduction of consumption and increase demand for FRCs could be part of the solution as well. Globally, more than one-third of the calories produced are being used for animal feeding and around 9% for industrial uses, including biofuel (Cassidy *et al.*, 2013). To ensure global food security in the coming years, crops dedicated to animal feed and biofuels could switch to human consumption, increasing food availability up to 70% (Cassidy *et al.*, 2013). In the UK (de Ruiter *et al.*, 2017) and Denmark (Osei-Owusu *et al.*, 2019), the total land footprint has decreased owing to a lower ruminant livestock products consumption (between the period of 1986-2011 for the UK and 2000-2013 for Denmark) which led to a decrease in grassland footprint. Various studies showed that reducing domestic ruminant product consumption along with local self-sufficiency policies directed to food and feed supply is a way of reducing the ecological footprint in exporting countries (de Ruiter *et al.*, 2017; Osei-Owusu *et al.*, 2019). Therefore, dietary changes from meat towards more plant-based diets is part of the solution (D'Odorico *et al.*, 2014) especially knowing that feeding animals with crops and then eating them is not efficient in providing calories to humans (Cassidy *et al.*, 2013). Finally, sustainability labels are currently not playing a major role in consumer's food choices (Grunert *et al.*, 2014). Depending of the future general consumer concerns about sustainability, the labels could have a great part to play (Grunert *et al.*, 2014).

5.2.1 Definition of ***deforestation***

As seen in SECTION 5.1.3.1, a broader definition of *deforestation* encompassing conversion of natural vegetation such as grasslands and savannahs seems more appropriate (zu Ermgassen *et al.*, 2020b) for protecting the Cerrado. This biome houses the richest flora among the world's savannahs and is associated with high levels of endemism (Mendonça *et al.*, 1998; Mittermeier *et al.*, 1998; Klink and Machado, 2005). Moreover, it shelters an important fauna. Fauna and flora are threatened to extinction due to agricultural expansion and forestry. In fact, out of the 40 Mha that are not protected in the Cerrado, half of it is suitable for agricultural production (Lambin *et al.*, 2013) and due to currently little legal protection, clearing is expected to increase in the following years (Rausch *et al.*, 2019).

An inadequate definition of *forest* can lead to leakage (Lima *et al.*, 2019) or, as most definitions, consider forest plantations and primary forest as equal (Sasaki and Putz, 2009; Fernàndez-Montes de Oca *et al.*, 2021). For REDD for example, although primary forests and forest plantations have quite different ecological values, they are equal in terms of financial value (Fernàndez-Montes de Oca *et al.*, 2021). Depending on what is being protected, an understanding of the framework might be necessary for defining the variable at stake before implementing governance policies (Lima *et al.*, 2019; Heilmayr *et al.*, 2020b). Whether protection policies are aiming at preserving 'rainforest' or 'native vegetation' will imply different measures (Chazdon *et al.*, 2016; Lima *et al.*, 2019). This is also the case with other variables such as carbon stocks and biodiversity (Lima *et al.*, 2019).

5.2.2 Improving governance, private-public partnerships, due diligence

Currently, a policy window is emerging (Kingdon, 1984). In fact, enough information is known about trade to start acting, there are solutions that are already successfully implemented in pilot projects and there is an ongoing discussion at the European Commission for a legislation about reducing EU's footprint on global deforestation as part of the *Green Deal* (European Commission, 2019). This new legislation the current EU Commissioner for Environment, Ocean and Fisheries - declared, will address deforestation and forest restoration on a range of commodities by covering both bulk commodities and derived products and will go beyond illegal deforestation as well as improving due diligence (Sinkevičius, 2021) and will spot high-risk countries in a first time. This can be done by adopting a *middle-ground* approach to supply chain mapping because mapping at the individual level can be too costly to be implemented, and decisions taken at this level can result in leakage (Godar *et al.*, 2016). Enhancing of spatial resolution and identification of key actors are required (Godar *et al.*, 2016). Moreover, there is a need of mandatory requirements for business and finance to provide transparency, traceability (to avoid greenwashing) and due diligence as government regulatory quality plays a key role in the effectiveness of company-led sustainability approaches (Lambin *et al.*, 2018). Today, the EU has a chance to be part of the solution and ensures that products placed on the European market are deforestation-free (Sinkevičius, 2021). No EU legislation will be able to repair mistakes of the past but they need to make sure that we are not contributing to the problem anymore (Schally, 2021). New legislation will only prove to be effective if it is implemented correctly. Furthermore, complementary measures are essential whether it is by supporting producer countries for protection and restoration of natural vegetation and sustainable agriculture or on the consumer side. In Belgium, *Beyond Food*, a federal strategy intending to contribute to a transition of the agri-food sector towards sustainable foot import chains is being developed by the FPS Public Health. Through the empowerment and cooperation of relevant actors in Belgium, the goal is to contribute to SDG12, Sustainable Food and Nutrition (CIDD, 2021). Finally, it is important to keep in mind that there might be trade-offs between political feasibility and potential policy impact (Bager *et al.*,2021).

5.3 Methodological aspect: limits and strengths of the study

Some limitations, data gaps, errors and strengths of physical trade fluxes and monetary fluxes are discussed in SECTION 5.3.1 and SECTION 5.3.2 respectively and complemented by the SECTION 5.3.3.

5.3.1 Physical trade fluxes

Pendrill *et al.* (2020): In their approach, they include cropland, pastures and plantations as the main drivers of deforestation (Geist and Lambin, 2002; Hosonuma *et al.*, 2012), while other drivers are excluded. The two main premises, on which the land-balance model is based represent well the data. Indeed, the main sources of new agricultural land across the tropics are forests and other native vegetation such as woodlands and scrublands (Pendrill *et* *al.*, 2019a). Mining, urban expansion and infrastructure are not covered in the land-balance model. However, they do not represent main direct causes of deforestation but rather indirect ones by colonizing new areas and expanding land-use into forests (Pendrill *et al.*, 2019a). Moreover, small-scale and subsistence farming might not be well represented as deforestation drivers because there are not accounted for in official agricultural statistics of many countries (Pendrill *et al.*, 2019a).

Over the 2005-2017 time period, there has been a reversal of the trend between attributed and unattributed forest loss (APPENDIX A.34). The unattributed forest loss has more than tripled (from 2.39 to 7.67 Mha), whereas the attributed forest loss has stayed quite constant (around 5 Mha/year), and even a little bit decreased. According to Pendrill *et al.* (2019b;2020), the unattributed forest loss might be coming from primarily logging, shifting agriculture not represented in the national statistics, natural forest loss, as forest fires for example, and expansion of other land uses such as urbanization and mining. Some reasons are not always corresponding to deforestation, which is supported by Curtis *et al.* (2018). However, clear reasons are missing. Moreover, FAOSTAT data are given by each country and since they have different ways of inventorying, it might be a source of errors.

Trase (2021): Currently, Trase data cover only some commodities and countries. Trase allows to trace data linking supply-chain actors to production places. Indeed, acquiring information can turned to be complicated as it is often confidential and private. Only some specific companies and actors deliver information and for this reason, it is limited in scope for now (Gardner *et al.*, 2019). Moreover, part of the information such as biome (see FIGURE 4.13*a*) and municipality is still unknown for the datasets used (see APPENDIX B.2).

Chaudhary and Kastner (2016): Chaudhary and Kastner approach was based on one year (i.e. 2011). Therefore, the data constitutes a snapshot at some point in time. Biodiversity loss is calculated on relatively coarse land use classification (in contrast to Pendrill *et al.* (2019b;2020)). It covers endemic scopes. However, where other approaches will rely on more refined data and will give more precise results, this one is able to provide a global overview.

Countryside SAR model accounts for habitat heterogeneity. It is not only about impacts due to agriculture land use but also crop production that causes biodiversity damages through, for example, fertilizer run-off, pollution from machinery use, grazing of livestock, etc. As a consequence, the results, in this case, underestimated biodiversity impacts traded (Chaudhary and Kastner, 2016). Moreover, changes in compositions and community structure caused by lands use are not taken into account. Lastly, the invertebrates, fungi and bacteria, which amount up to 80% of global terrestrial species are not included in these data due to the lack of data availability (Chaudhary and Kastner, 2016).

5.3.2 Monetary fluxes

Pendrill *et al.* (2019b): EXIOBASE 3 provides details about agricultural and food manufacturing sector, about the most important countries (Brazil and Indonesia) and annual estimates between 2010-2014. Other MRIO models lack theses advantages since some are only available for a few years or do not account for the agricultural sector resolution (Pendrill *et al.*, 2019b).

5.3.3 Different approaches - different results

Physical trade flows focus on direct trade using international trade statistics (FAOSTAT for both Pendrill *et al.* (2020) and Chaudhary and Kastner (2016)). Trade flows are weighted by land requirements per unit of agricultural product based on land use parameters for agricultural products in the respective countries, to derive embodied land in trade (Hubacek and Feng 2016). One advantage of Pendrill *et al.* (2020) dataset is exhaustiveness. It allows to cover all commodities and producing countries of tropical deforestation on a national level whilst Trase data only covers some commodities and some countries though it includes many more details such as subnational data and supply chain companies.

MRIO model tracks commodities to the final consumption as well as describing the final sector of activity. However, it is not always easy to distinguish as PTF both for commodities and producer countries since commodities are aggregated as well as producer countries (Bruckner *et al.*, 2015). The attribution of land use can turn out to be problematic as commodities are aggregated (Bruckner *et al.*, 2015). Firstly, crops such as spice and fodder crops are found in the same commodity group even if they do not have the same mass-value-ratios (Bruckner *et al.*, 2015). Secondly, it is based on the hypothesis, for soy for example, that 1$ from the animal sector has the same impact of 1$ from the car industry (leather) although value-to-land ratios vary between different uses (Bruckner *et al.*, 2015). Thirdly, traceability can sometimes be lost. For instance, from Brazil to Belgium, the commodity traded between both countries is assumed to be soy. From Indonesia to Belgium, it is palm oil but from the Netherlands to Belgium, it is not possible to know. Therefore, it is not producing-country based but rather region of production-based.

PTF models do not account for reexports once it has been transformed as it is the case for highly processed food as opposed to MRIO model. Moreover, Pendrill *et al.* (2020) focus on land-intensive sectors, so mainly food and other agricultural products but lacks details on industrial and service sectors as it is the case for MRIO model.

PTF accounting provides regular updates and long time series, whereas MRIO analysis has a large time-lag (Bruckner *et al.*, 2015).

Instead of seeing these different approaches as imperfect, they should be seen as complementary. Indeed, they provide results that allow to answer questions from different point of views and to understand a little bit more the complexity behind international trade. Combining Pendrill *et al.* data with Trase allows, in the first place, to spot deforestation hotspots and main commodities linked to deforestation, and, in a second place, with Trase data, to identify subnational knowledge and main actors along the supply chain for which data is available. Emphasizing on whether direct or underlying drivers may require the use of different methods. For instance, deforestation in Brazil is mainly happening through land clearing for pasture or cattle ranching then pasture/cattle ranching to soybean expansion. By analyzing remote sensing data, conversion of natural vegetation to pasture/cattle ranging will be attributed to direct drivers of deforestation, and eventually beef production. With a land-balance approach as Pendrill *et al.* (2020), by analysing land uses that increase their footprint, it will rather attribute deforestation to soybean expansion because pasture/cattle ranching area remains quite constant over time as opposed to soybean production (in this case, focus is on net land use changes). Trase method produces spatially-explicit maps and, therefore, aims attention at direct drivers and allows to make companies directly accountable. By using a 5-year time lag, it takes into account in some way the underlying causes. Physical trade and MRIO model also complement themselves. The Pendrill *et al.* (2020) physical trade model is more relevant for policies aiming at upstream actors (trading companies, investors, governments etc. that are in search of reduction of deforestation through direct supply-chain interventions), while the MRIO model will provide relevant information for downstream actors on underlying distant drivers of embodied deforestation emissions (Pendrill *et al.*, 2019b).

Chaudhary and Kastner (2016) approach provides some insights, but comparing results from different approaches are always more contrasted than carbon emissions. The interesting aspect about it is that it reveals that biodiversity is multidimensional, and other indicators should be taken into account into assessing the impacts' scope of deforestation on biodiversity.

Some methodological suggestions that might be interesting to explore for further analysis are briefly presented in this last paragraph. Hybrid accounting methods combining MRIO analysis with physical accounting can provide the advantages of both approaches as well as overcoming some of their limitations and weaknesses (Bruckner *et al.*, 2015). Embodied deforestation in non-food land-based products such as textiles, biofuels, paper and wood, leather and other biomaterials could be analyzed (Bruckner *et al.*, 2015). For example, Escobar *et al.* (2020) used a hybrid approach for the quantification carbon emissions embodied in agricultural exports by combining LCA (Life Cycle Assessment) and physical trade accounting allowing to capture their whole distribution of carbon footprints. Also, the development of database such as Trase could provide greater transparency and traecability of physical fluxes. Finally, concerning biodiversity, approaches that cover a larger temporal perspective would be interesting since it is limited for now (see Bjelle *et al.*, 2021). Moreover, coupled approaches such as combining biodiversity and carbon storage can identify areas of potential co-benefits for conservation policy and action (Soto-Navarro *et al.*, 2020).

Chapter 6
Conclusion

Tropical deforestation is a global issue. Disappearance and degradation of tropical forests and other natural vegetation have an impact on both local and global scale (Geist and Lambin, 2002). Today, agriculture expansion is the main driver of native vegetation clearance (Pendrill et al., 2019b). Distant environmental and socio-economic interactions have existed for a long time (Liu *et al.*, 2013). However, interdepencies and connection between distant actors and land-uses is rather recent (Lambin *et al.*, 2014). In our globalized world, these spatial interactions are increasing and have rendered the assessing of impacts and responsibility even more complex (Meyfroidt and Lambin, 2011). Ambitious global deforestation goals such as the Amsterdam Declarations Partnership, the New York Declaration on Forests and other zero-deforestation company commitments were to eliminate deforestation from the production of agricultural commodities by 2020 (Thomson, 2020). Now in 2021, these goals have not been met yet. Making room for an ever-growing demand for commodities such as palm oil, soy and cocoa is continuously done at the expense of biodiversity, carbon storage, climate change, water-cycle, local communities' rights, etc. (IPCC, 2019).

The EU is the second importer of embedded deforestation (Pendrill *et al.*, 2019b) and Belgium is one of the countries with the highest per capita impact in the world. The spatial disconnections between drivers, impacts, producers and consumers reduce the ability of local actors both from production and consumption side to take concrete actions (Meyfroidt and Lambin, 2011). As new legislation is being discussed at the moment, it seems necessary to quantify embedded deforestation, to locate where deforestation is taking place and how. Several metrics can assess the impacts of deforestation, although depending on the approach used, the results are different and show different parts of the reality.

In this thesis, the first step was to test whether Belgium has higher embodied deforestation impacts in its agricultural and forestry imports compared to European average and if Belgian consumption is indeed high. Based on physical trade accounting, Belgian embodied deforestation footprint in its agricultural and forestry imports per capita is more than the double of the European average. This brings Belgium at the 5th place on a global scale. By comparing physical (Pendrill *et al.*, 2020) and monetary fluxes (MRIO), deforestation embedded in final consumption (MRIO) is higher than in physical trade. Although Belgium plays a key role as a transit country with the port of Antwerp and its large manufacturing industries, its consumption cannot be undermined. Indeed, there is an over-consumption of animal-based products, high consumption of cocoa, coffee and ultra-processed food. The difficulty in achieving SDGs could partly be explained by Belgium's high consumption, by its key position as en entry point for commodities in Europe, by its processing industries and also by Belgium's supply-chain linked to higher deforestation risk.

The second step was to assess if a small number of commodities and producer countries account for the majority of the environmental impacts imported by Belgium. By using physical fluxes, the majority of embodied deforestation (CO_2 emissions and area) is concentrated in only a few commodities (~90%), i.e. palm oil, soybean, cocoa, coffee, rapeseed, wood products and beef and buffalo meat. The highest impacts of these major commodities come from a few tropical countries and in particular from deforestation fronts. Palm oil is mainly sourced from Indonesia, Malaysia and Papua New Guinea; soybean from Brazil, Argentina and Paraguay; cocoa from Côte d'Ivoire, Papua New Guinea, Indonesia and Liberia; coffee from Honduras, Peru, Uganda and Indonesia; rapeseed from Australia; wood products from Brazil and Indonesia and beef and buffalo meat from Brazil and Argentina. Difference in share between both indicators for palm oil for example, i.e. deforestation CO_2 emissions (42%) and deforestation area (26%), is mainly due to peatland found in South-East Asian tropical rainforest that enclose more CO2 than savannahs that can be found in Brazil (Page *et al.*, 2011). With growing demand for biofuel, high imports of palm oil and rapeseed question the future use of crops. Concerning biodiversity loss, more than 60% of the loss attributed to Belgian imports are suffered in 10 tropical countries and more than 90% are associated with coffee, cocoa, palm oil, bananas, rapeseed, coconuts and soy production. This difference between biodiversity loss footprint and land- and carbon footprint shows that key commodities and countries vary across indicators. Some commodities that have a lower deforestation or carbon footprint can have important biodiversity impacts, at least with the approach used in this thesis that focuses on small habitats. This part allowed to locate deforestation risk *hotspots* and to identify most damaging commodities at the national level.

The last hypothesis that was tested, namely at a subnational level and for some country-commodity combinations only, is if deforestation was concentrated in a small number of municipalities and a small number of importer companies were linked with the majority of deforestation impacts embedded in imports. Indeed, more than 50% of CO_2 emissions embodied in Brazilian soy imported by Belgium come from the Cerrado (the largest savannah biome in South America) and more than 75% from 8 municipalities, where the majority of them are located in Mato Grosso. This raises the question of how *deforestation* should be defined to protect and encompass the conversion of natural vegetation (zu Ermgassen *et al.*, 2020b). If only forests are protected, then other biomes become new target for agricultural expansion. Therefore, in order to avoid leakage, the scope of interventions must be broadens (Lambin *et al.*, 2020). Moreover, illegal deforestation is still an important issue as Belgium is sourcing soy from municipalities that have experienced the highest illegal deforestation rate. The last result shows that more than 92% of Belgian imports of Brazilian and Argentinian soy, Ghanaian cocoa and Brazilian beef were operated by 10 companies (not the same companies for each commodity) and more than 65% for cocoa from Côte d'Ivoire. For instance, only 10 companies encompass 99.5% of deforestation emissions and area embedded in Belgian soy imports from Brazil. Zero-deforestation commitments across Brazil cover the majority of embodied deforestation in the Amazon biome through the Soy Moratorium. However, those commitments account for less than 3% for Belgian soy imports from the Cerrado. As stated previously, the goals of zero deforestation have not been met yet. Lack of transparency and actual actions are lacking (Lambin *et al.*, 2018). This suggests that effective efforts could target particular commodity flows keeping in mind that leakage could take place if policies are not thought well enough. Lastly, implementation of policies towards producers, supply-chain actors and consumers as well as actions taken by individuals, governments, civil society and private sector need to operate together for tackling deforestation (Bager *et al.*, 2021) and biodiversity loss (Lenzen *et al.*, 2012; Chaudhary and Kastner, 2016).

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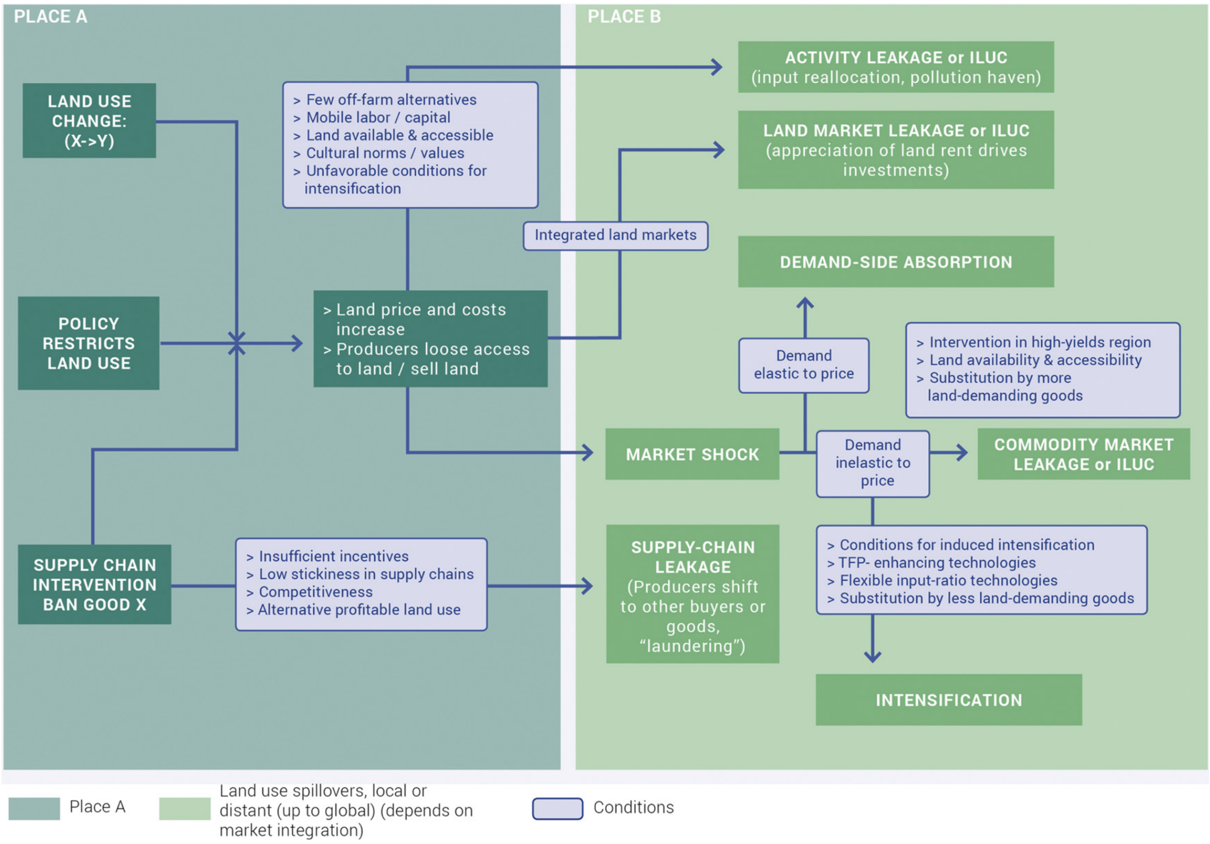

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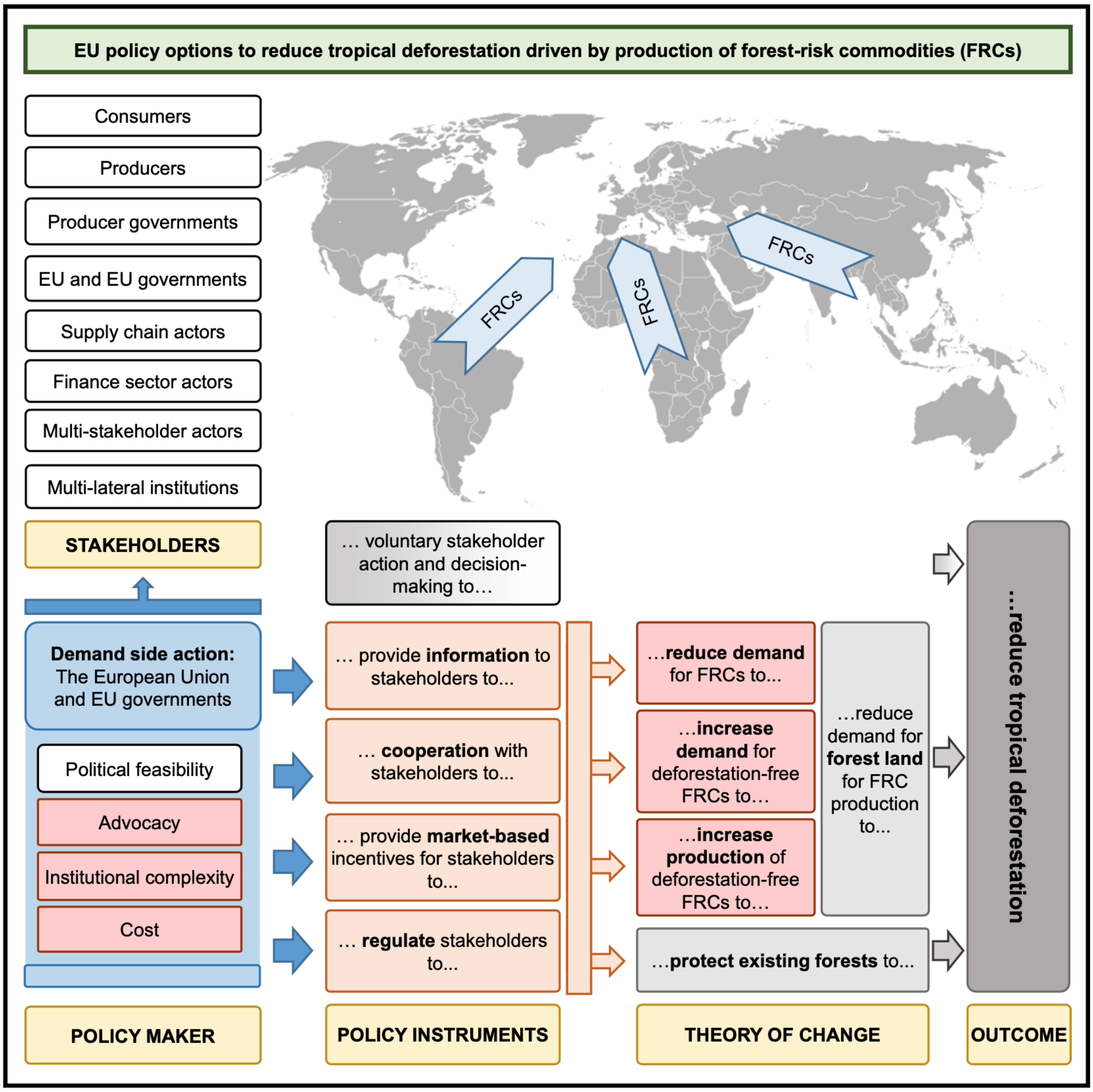

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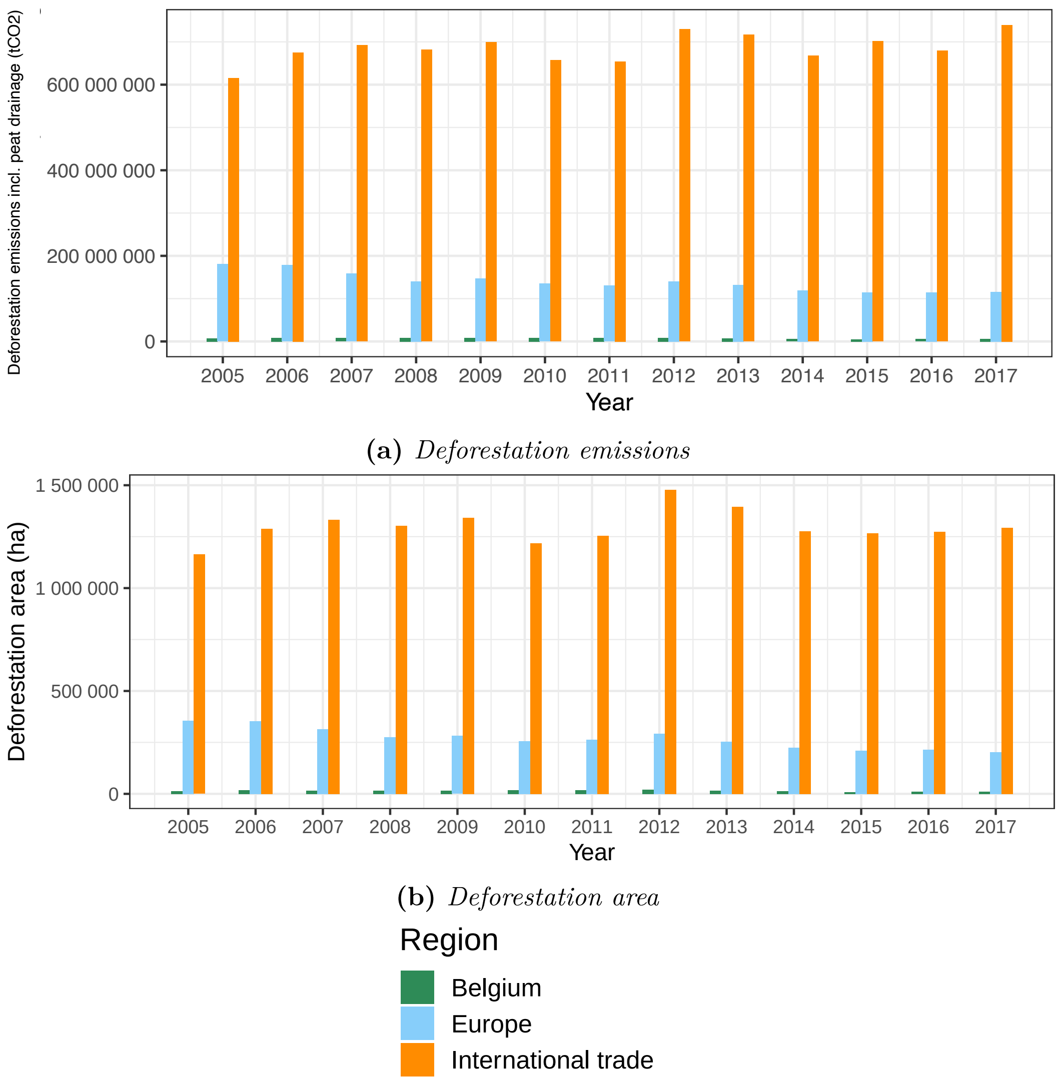

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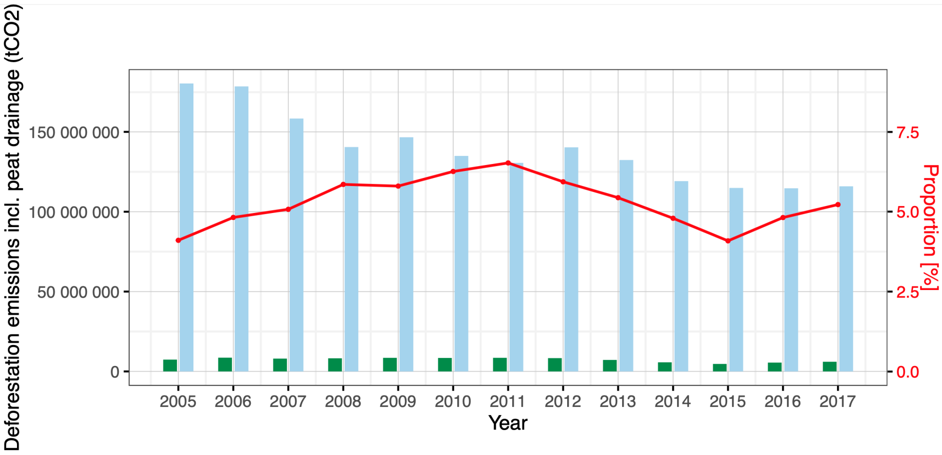
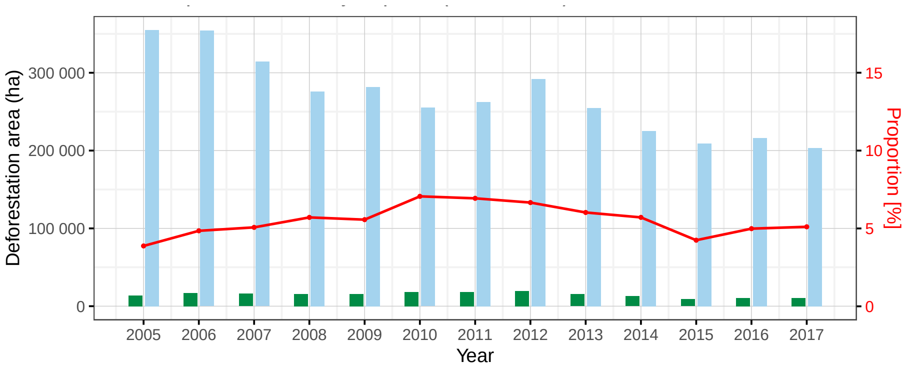


(a) *Deforestation CO_2 emissions*



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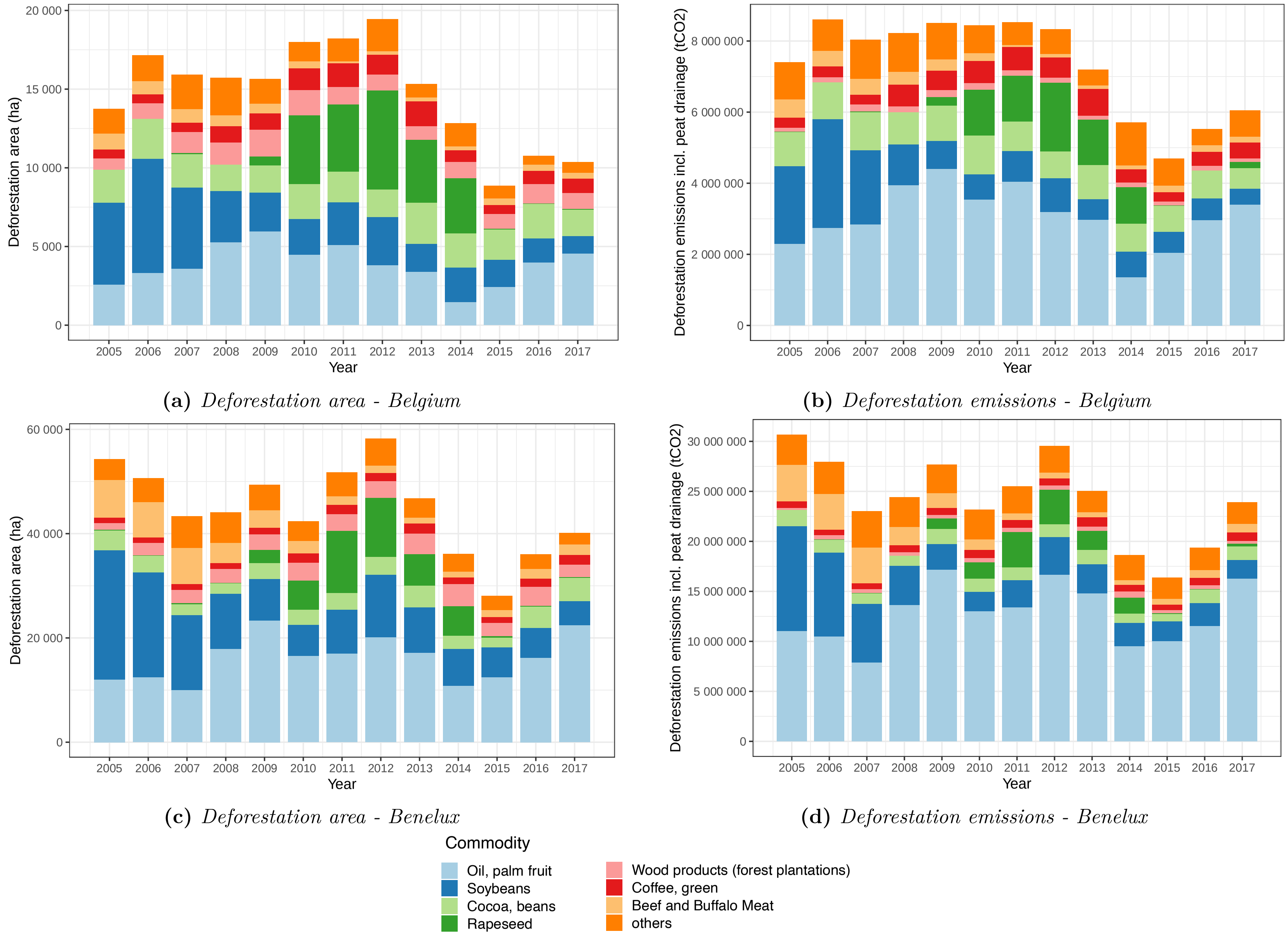

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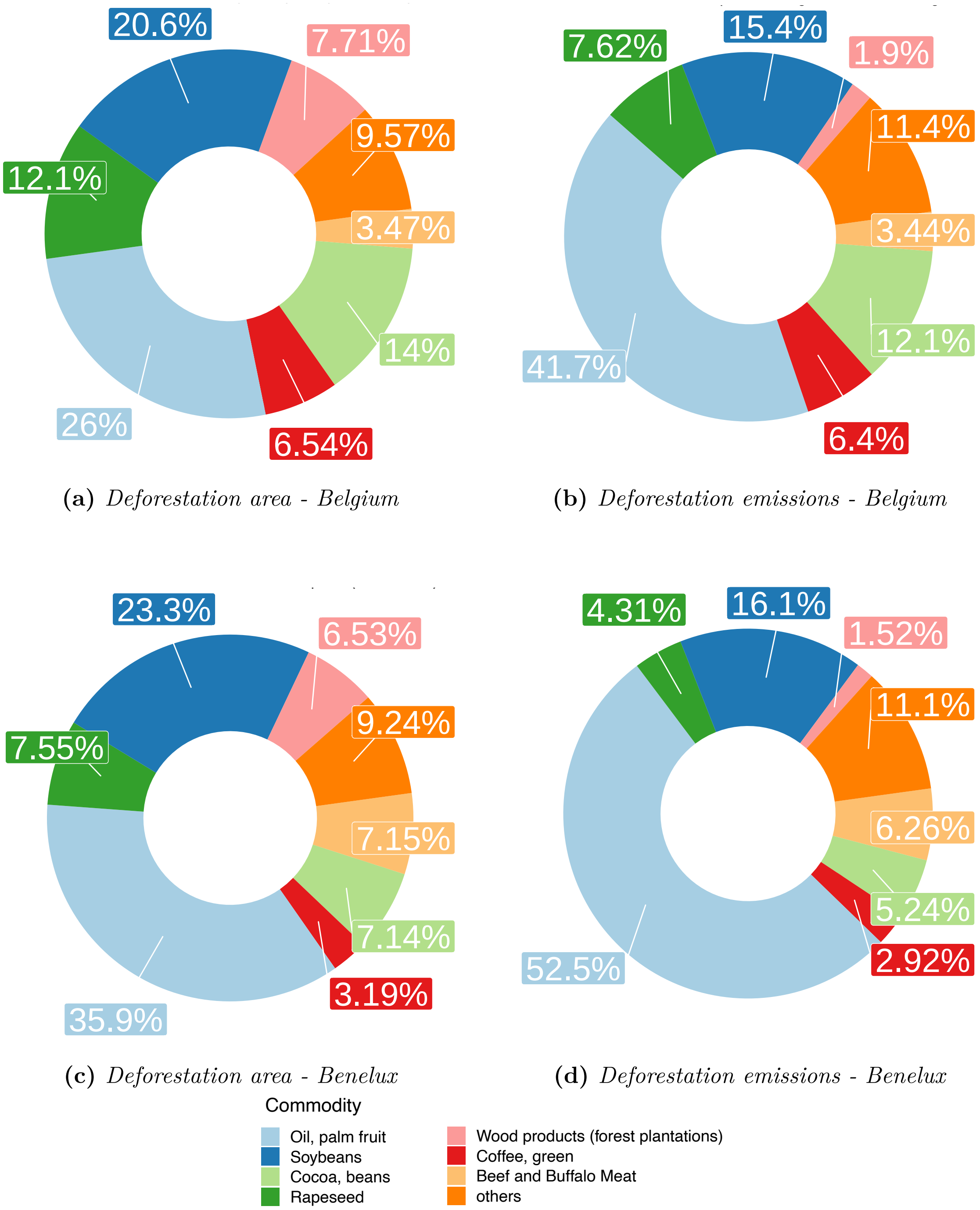

(a) *Deforestation area - Belgium*

(b) *Deforestation emissions - Belgium*

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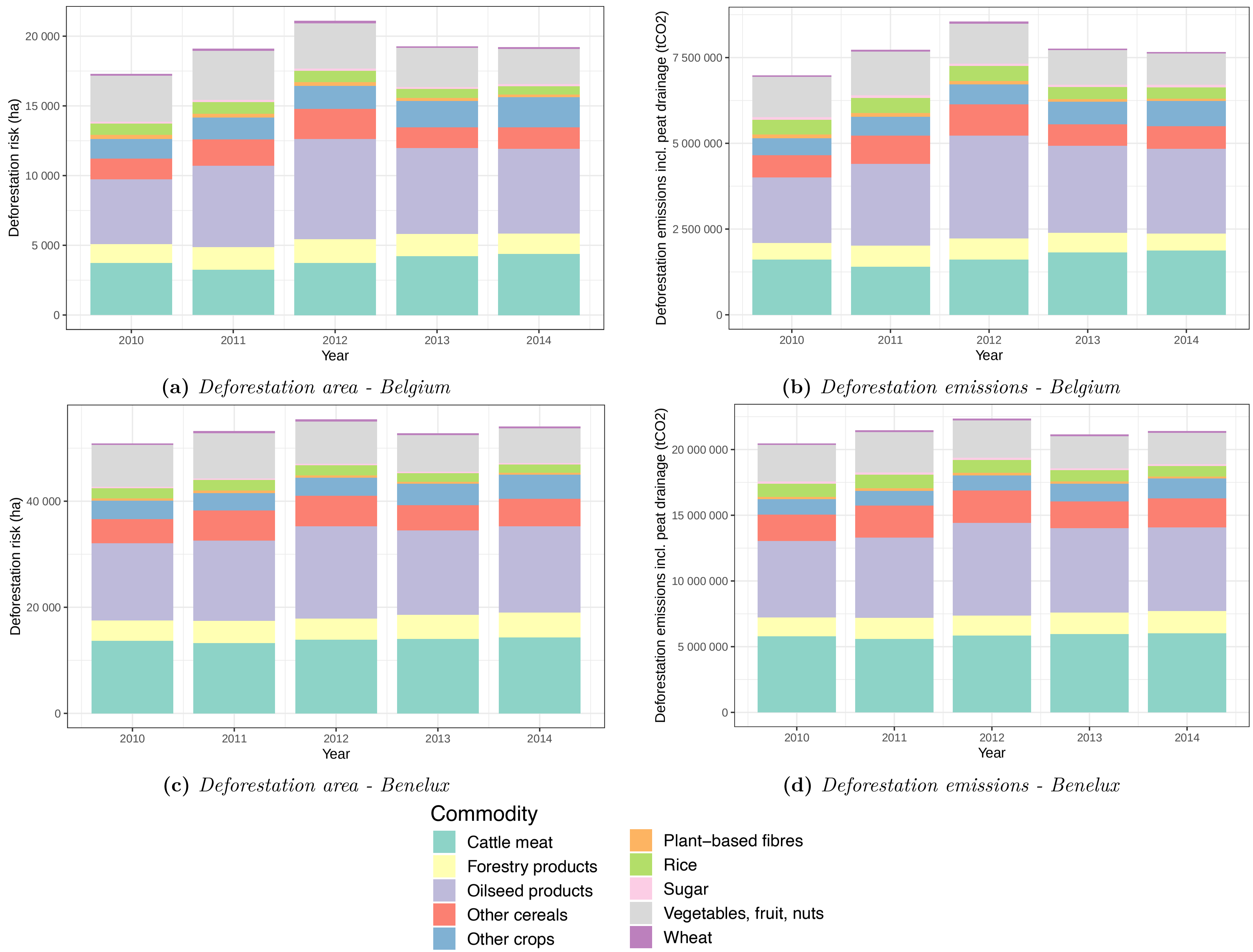

(a) *Deforestation area - Belgium*

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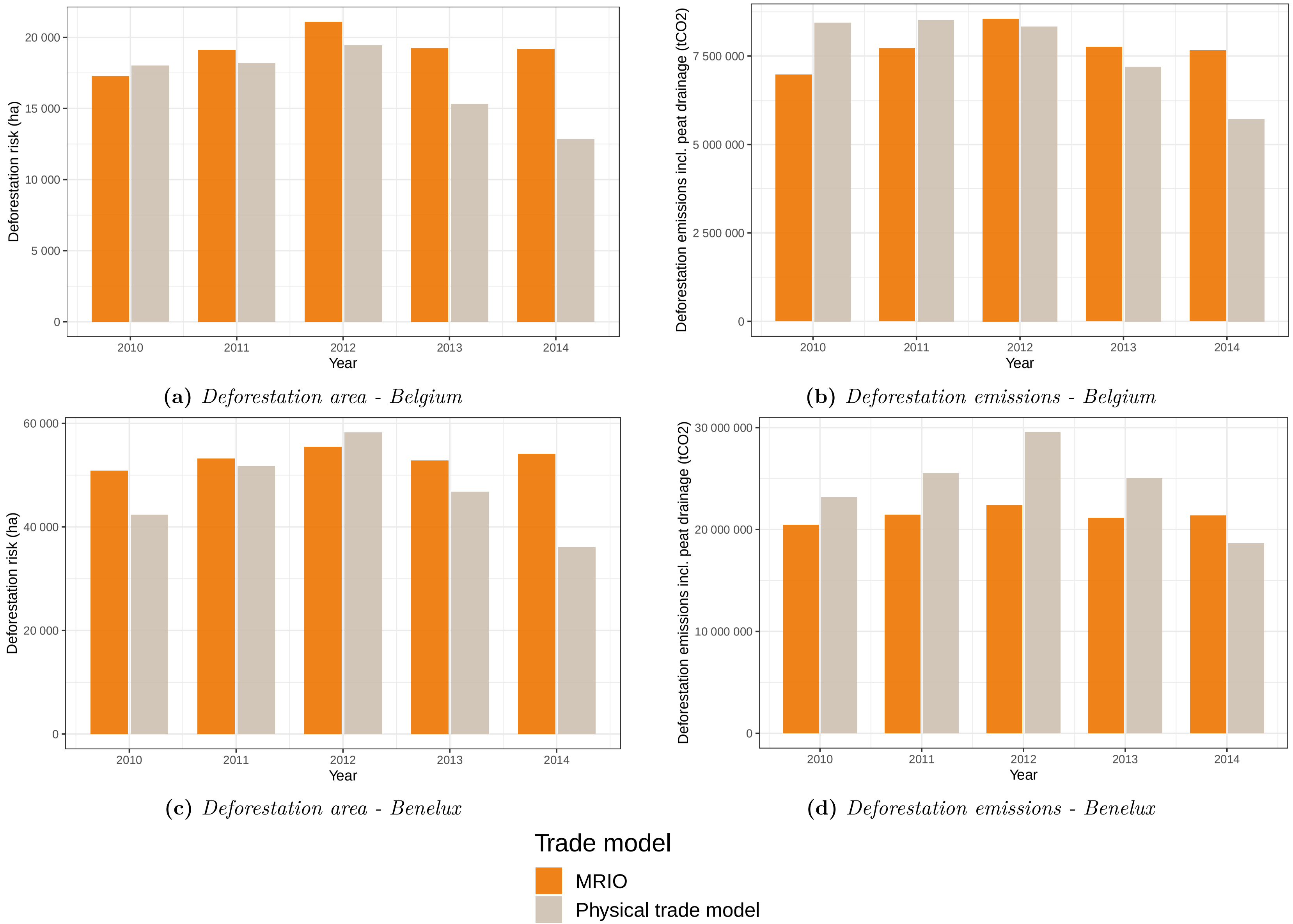

(a) *Deforestation area - Belgium*

(b) *Deforestation emissions - Belgium*

(c) *Deforestation area - Benelux*

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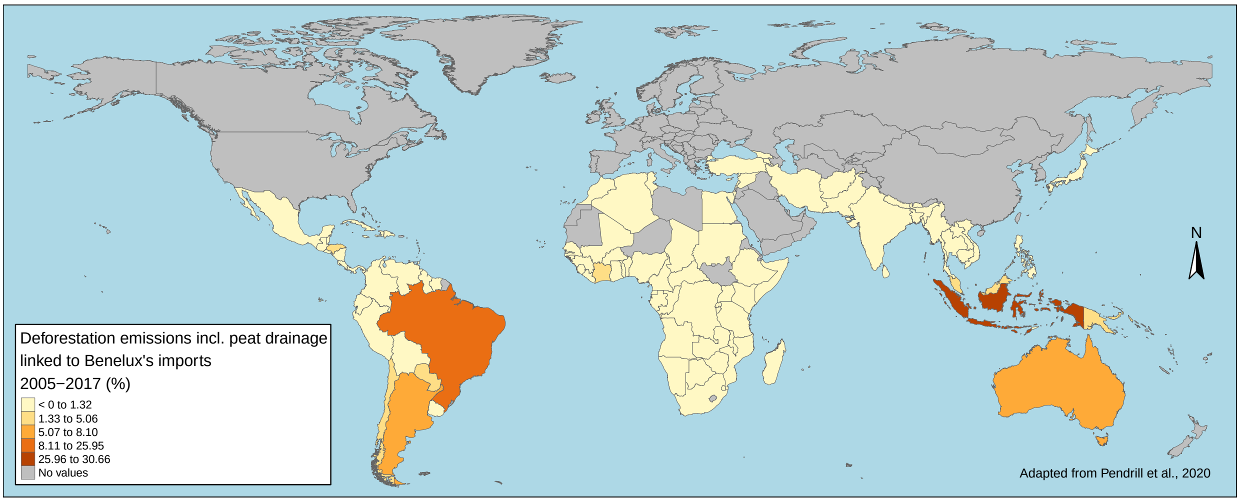
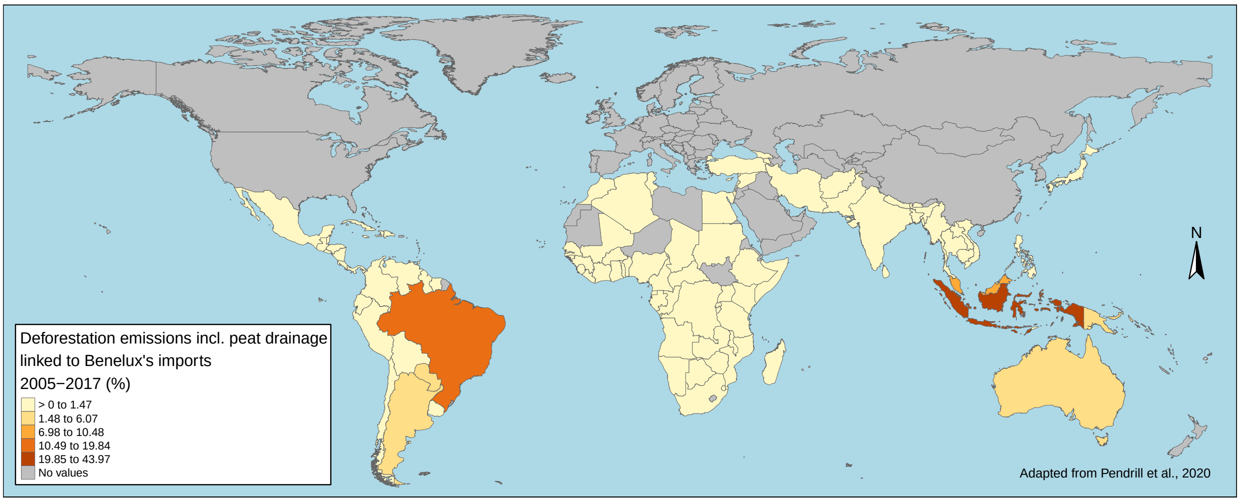


(a) *Deforestation emissions*



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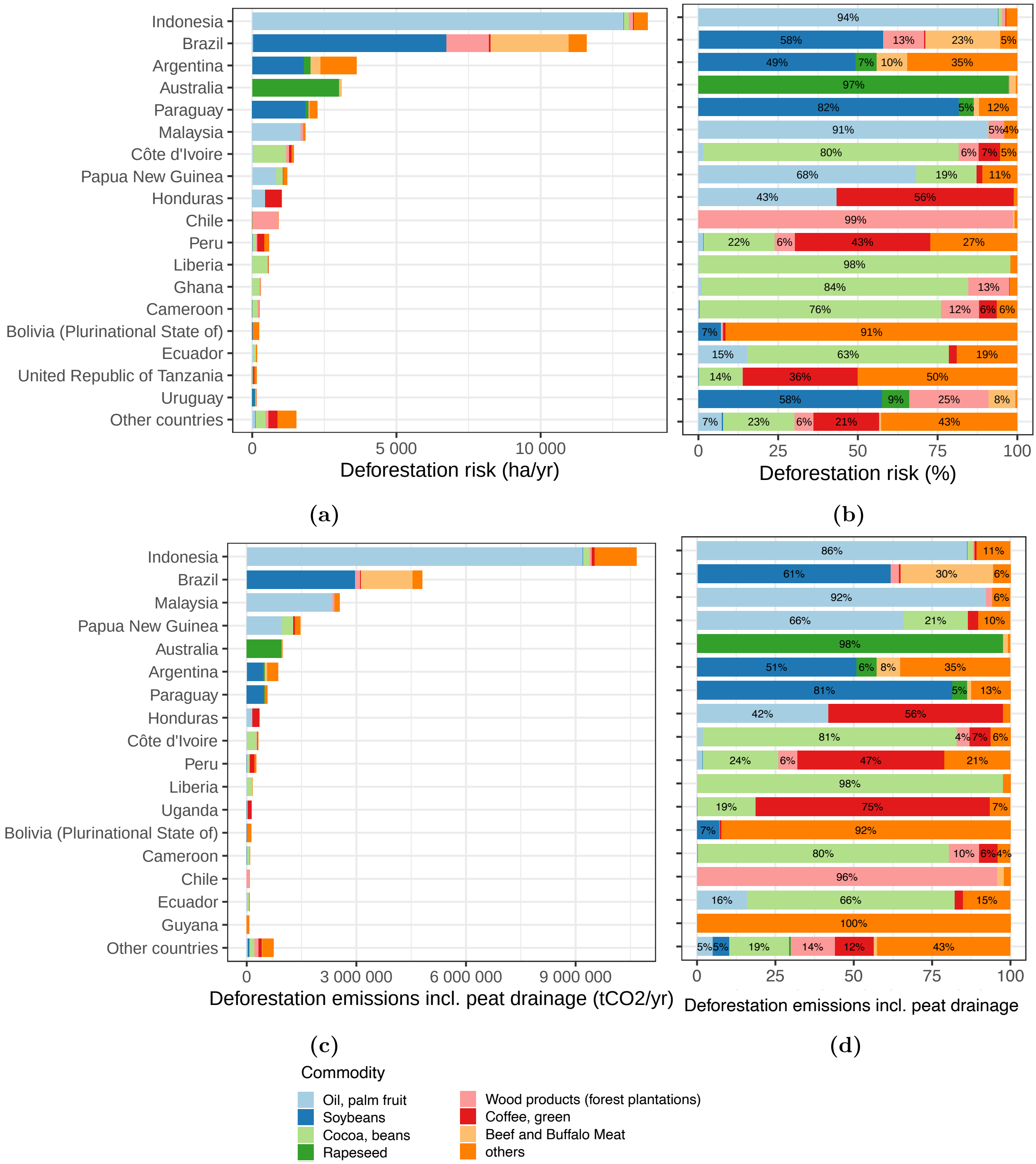

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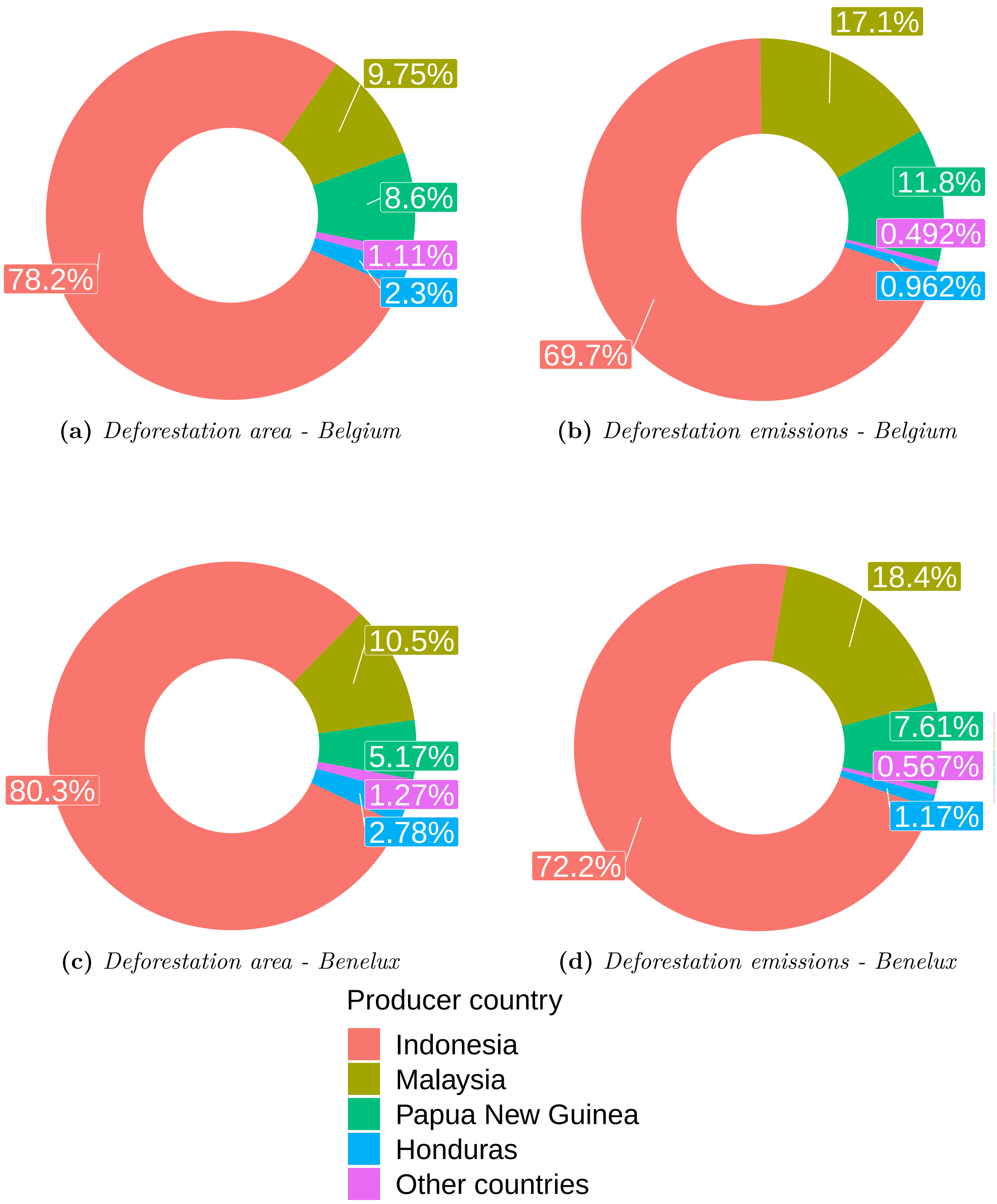

(a) *Deforestation area - Belgium*

(b) *Deforestation emissions - Belgium*

(c) *Deforestation area - Benelux*

(d) *Deforestation emissions - Benelux*

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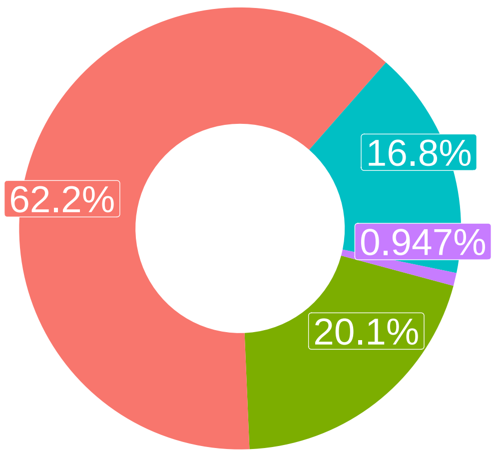
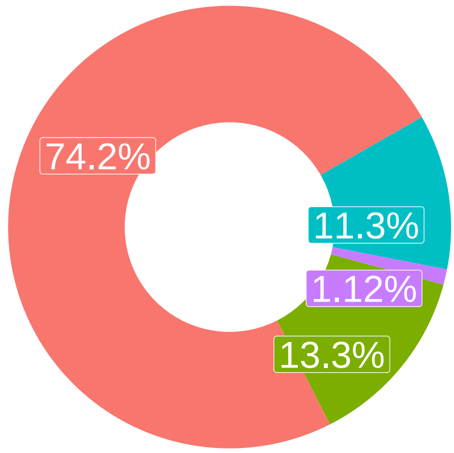
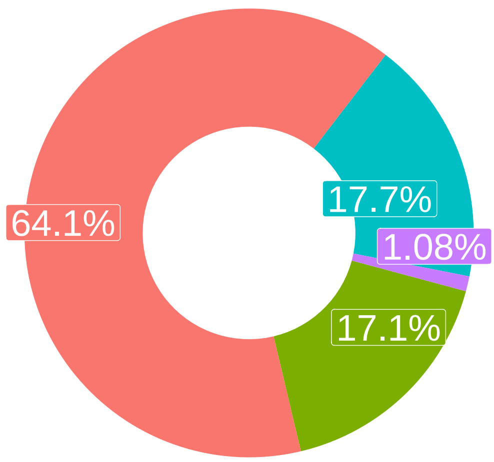


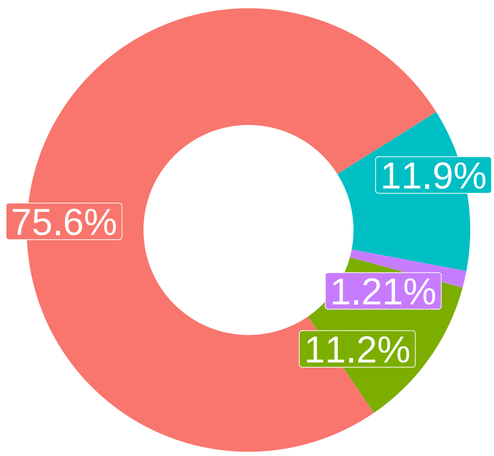
(a) *Deforestation area - Belgium*



(b) *Deforestation emissions - Belgium*



(c) *Deforestation area - Benelux*



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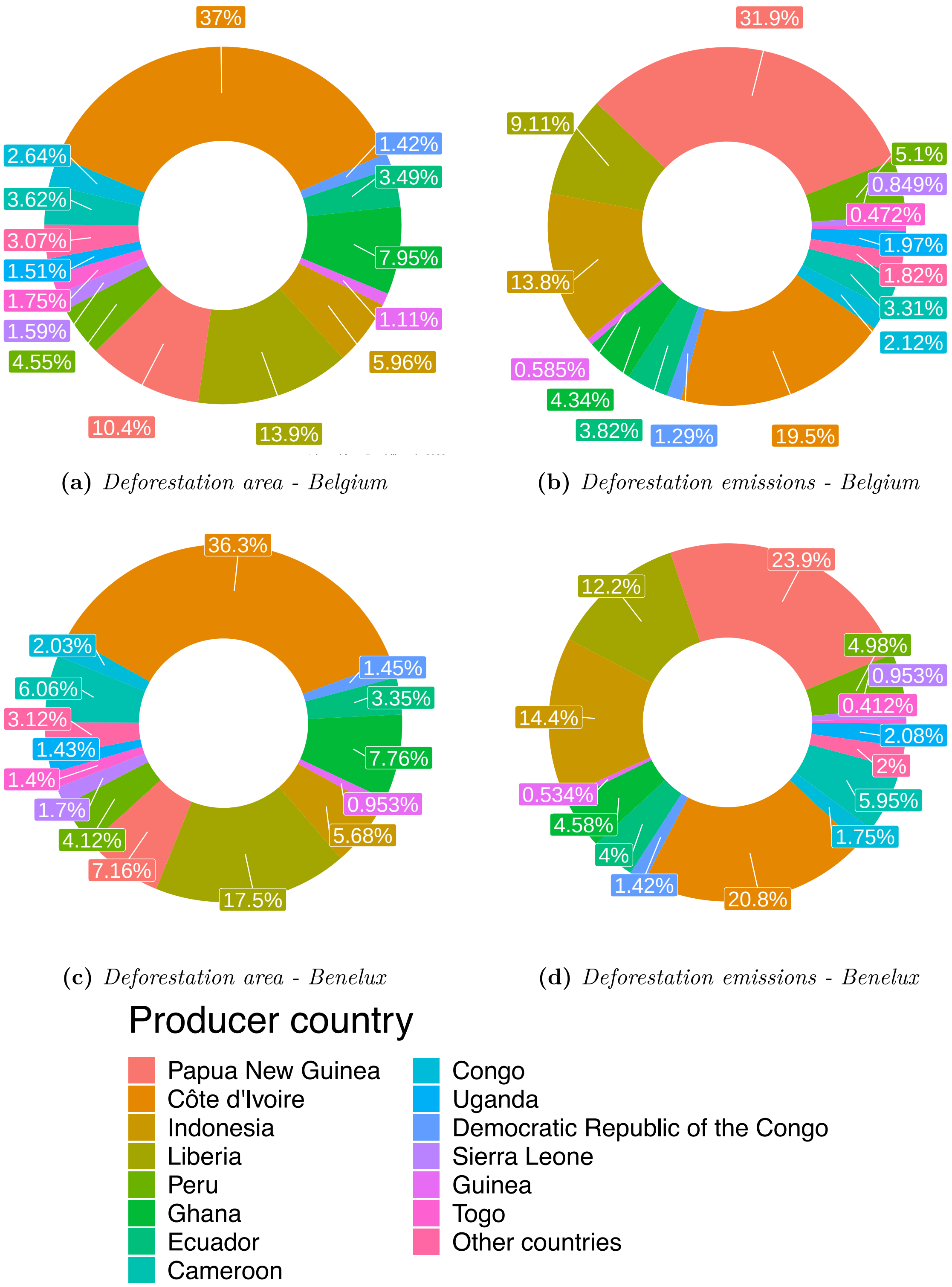

(a) *Deforestation area - Belgium* **(b)** *Deforestation emissions - Belgium*

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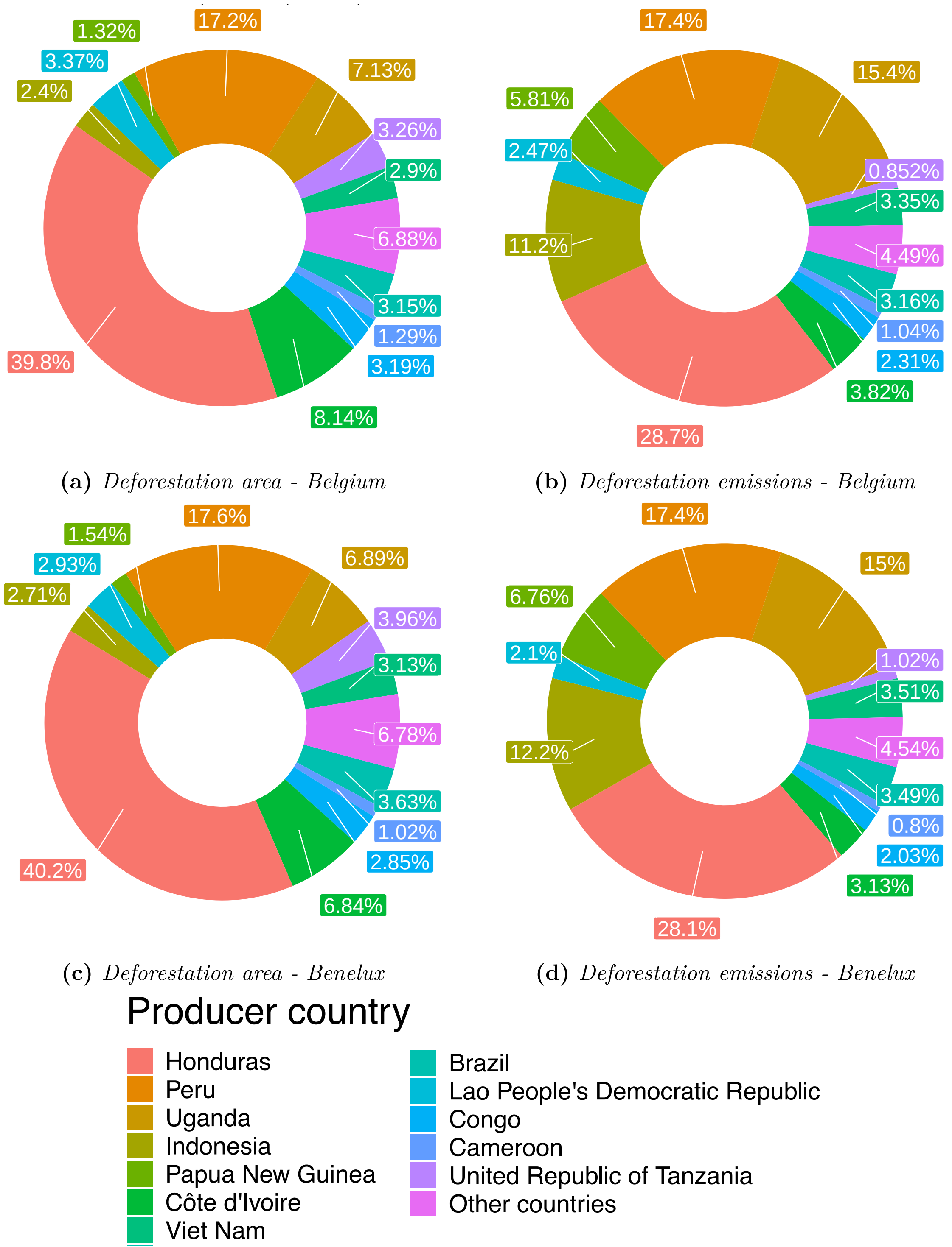

(a) *Deforestation area - Belgium*

(b) *Deforestation emissions - Belgium*

(c) *Deforestation area - Benelux*

(d) *Deforestation emissions - Benelux*

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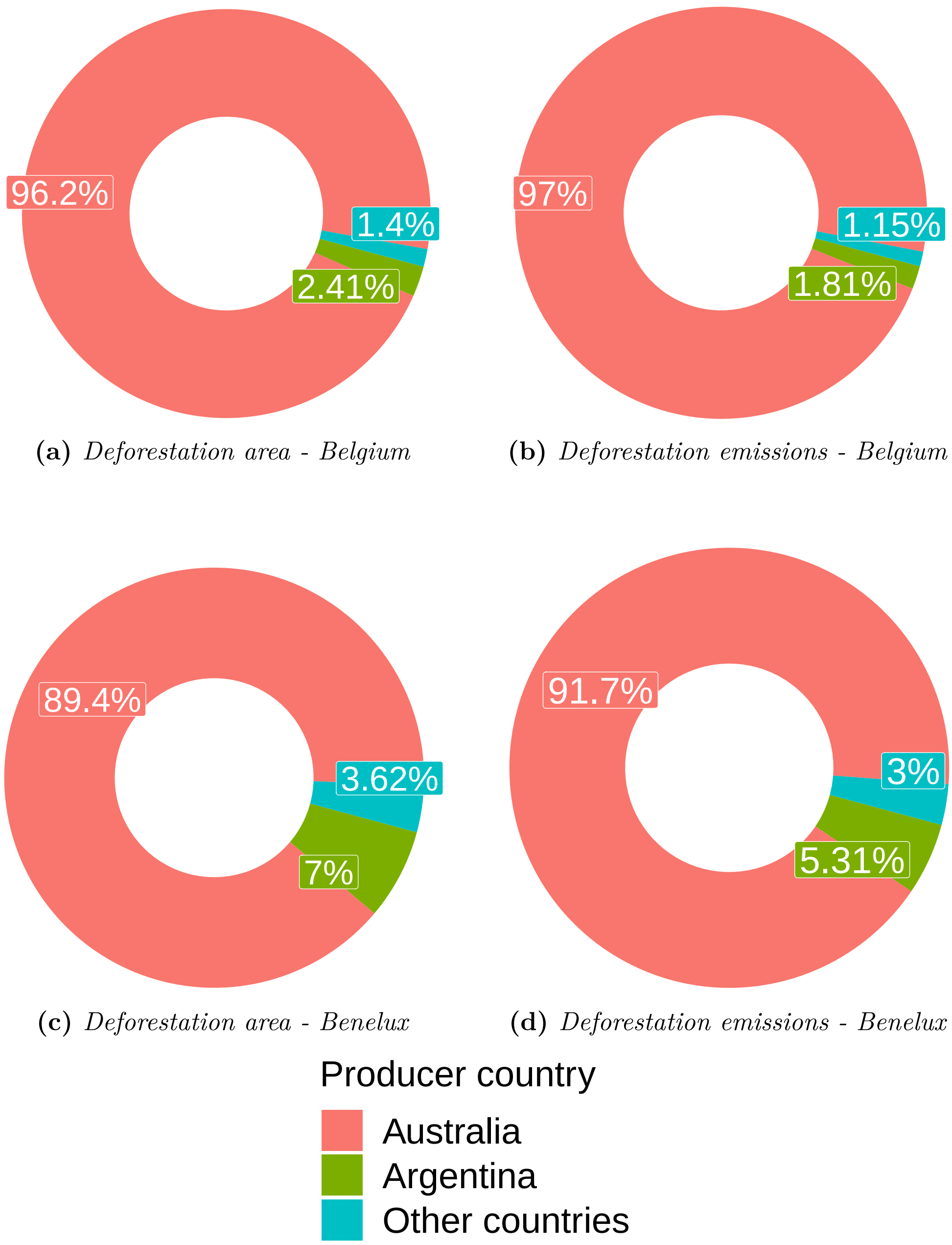

(a) *Deforestation area - Belgium* **(b)** *Deforestation emissions - Belgium*

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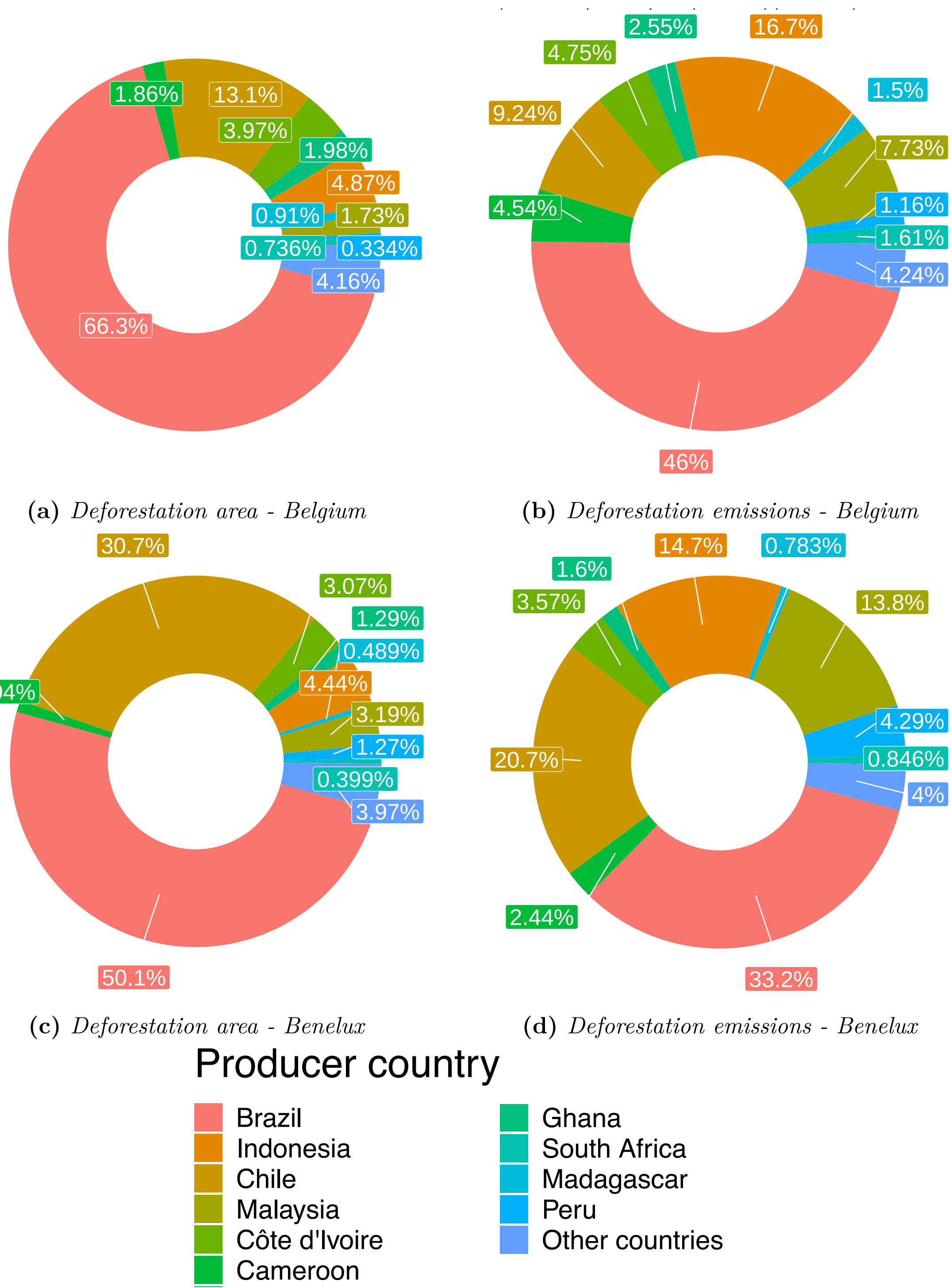

(a) *Deforestation area - Belgium* **(b)** *Deforestation emissions - Belgium*

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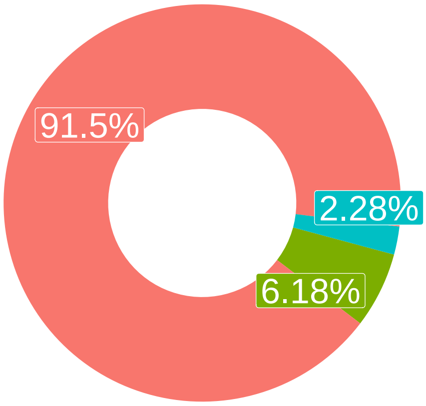
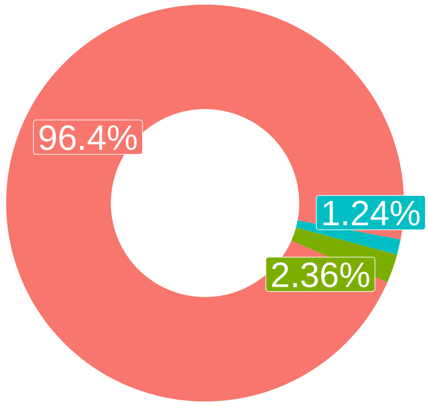
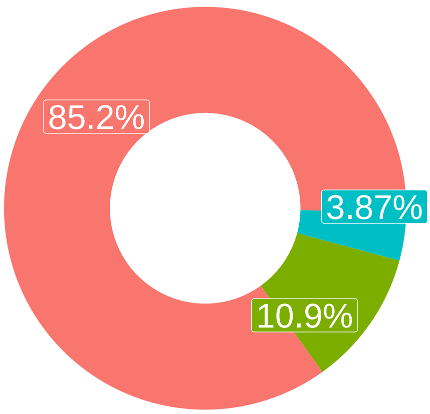


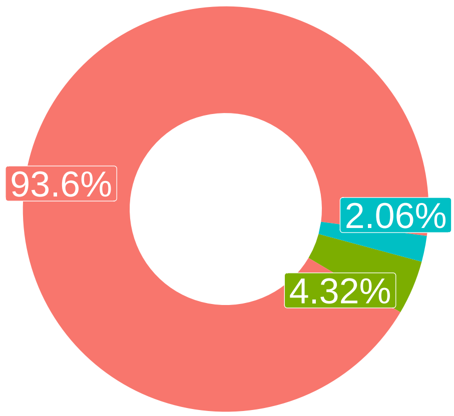
(a) *Deforestation area - Belgium*



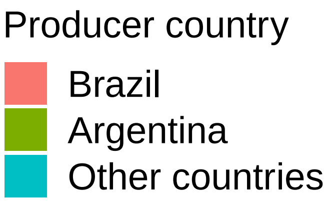
(b) *Deforestation emissions - Belgium*



(c) *Deforestation area - Benelux*



(d) *Deforestation emissions - Benelux*



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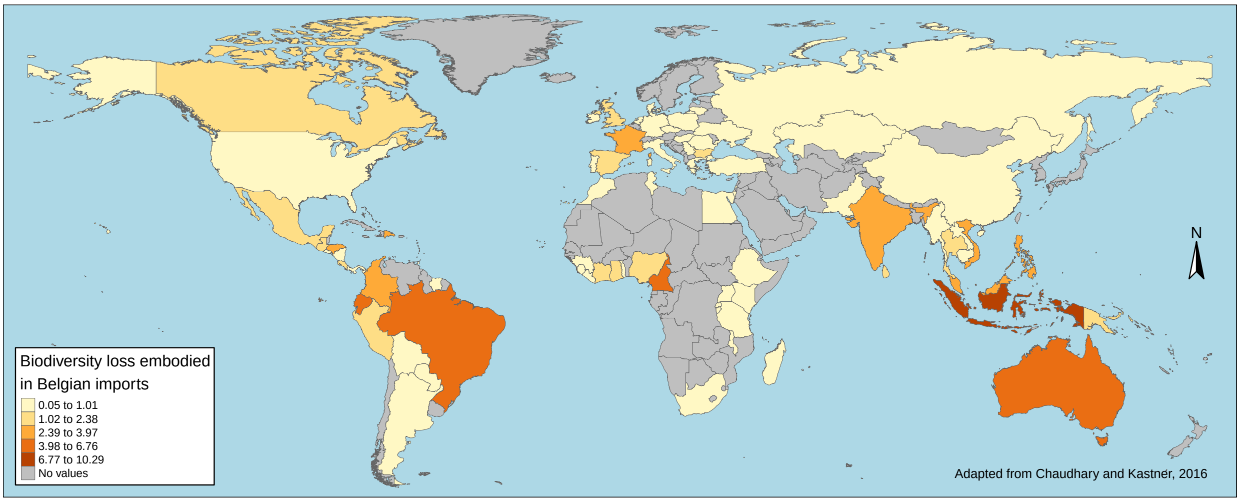
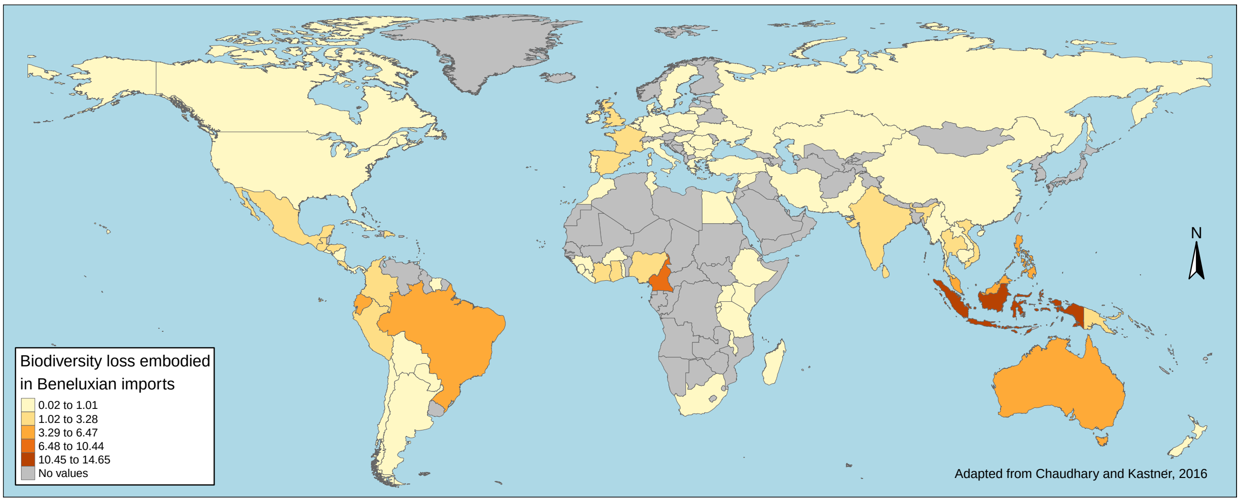


(a) *Belgium*



(b) *Benelux*

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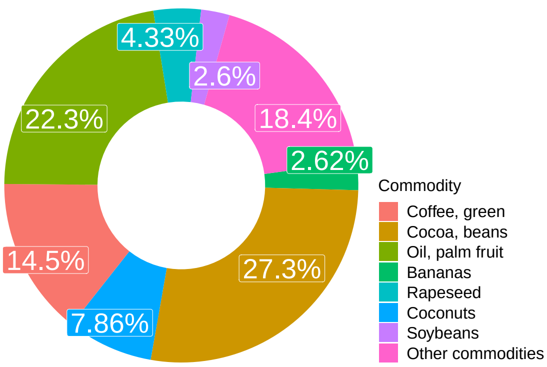
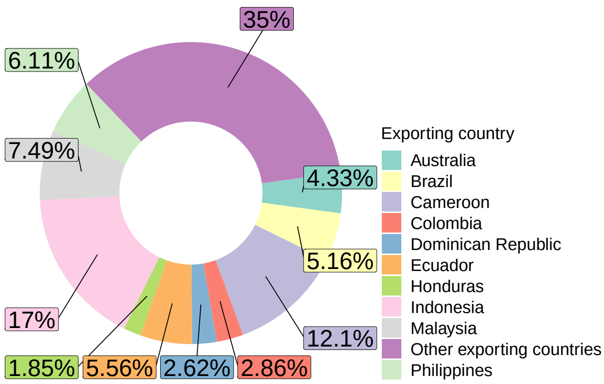


(a)



(b)

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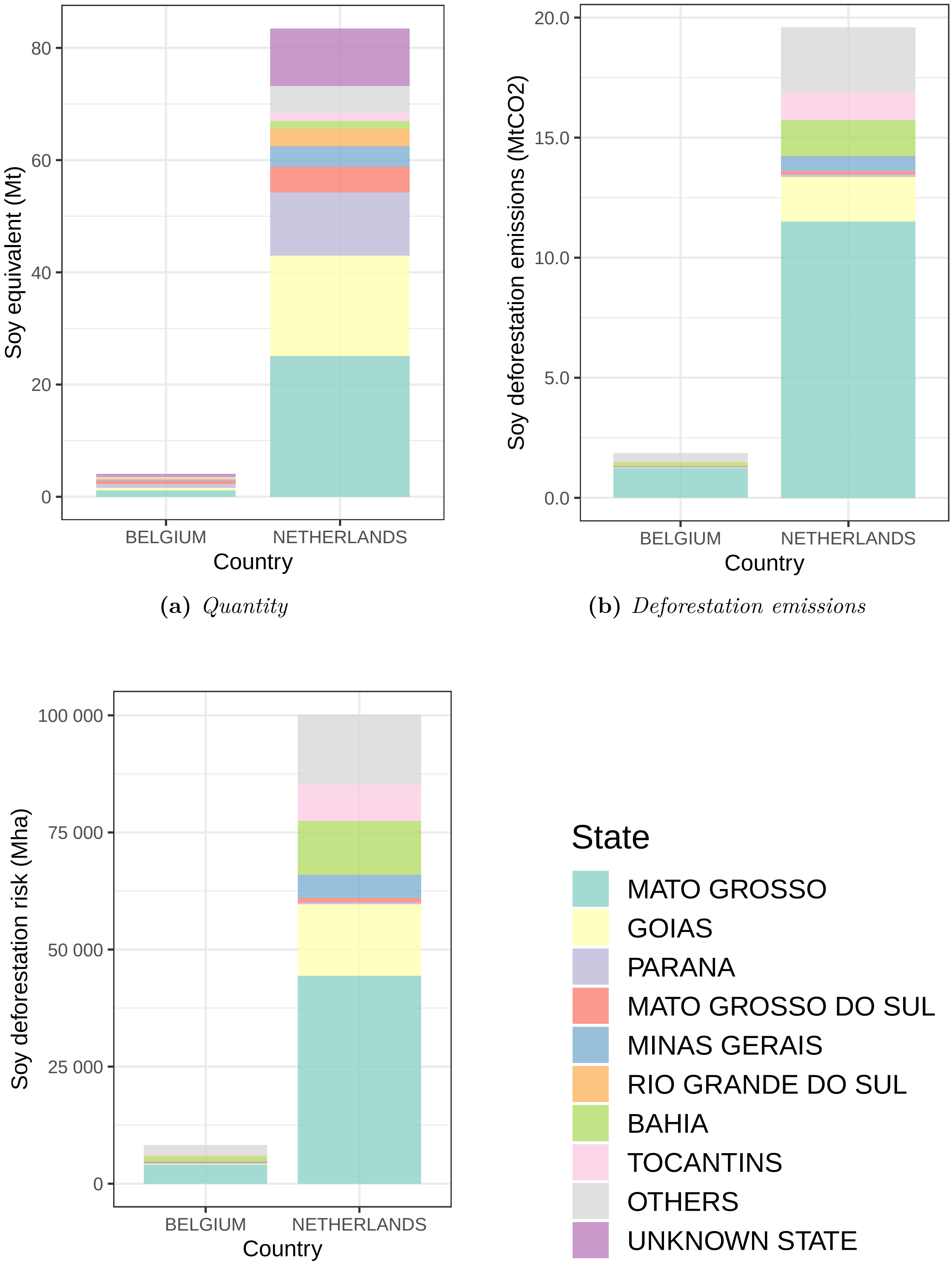

(a) *Quantity*

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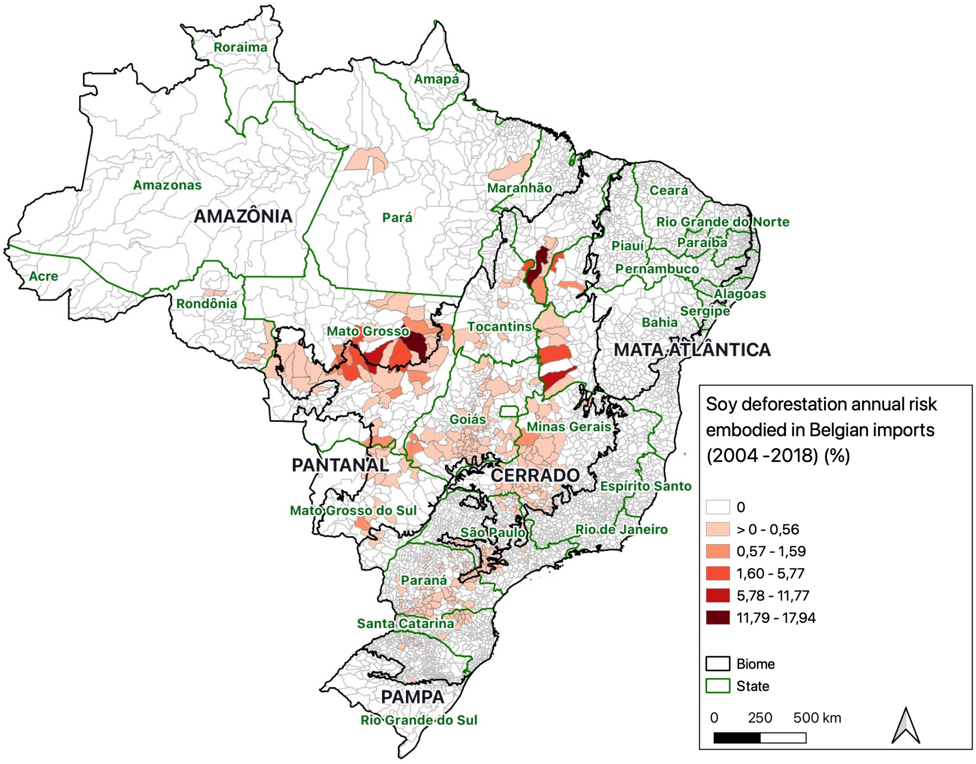
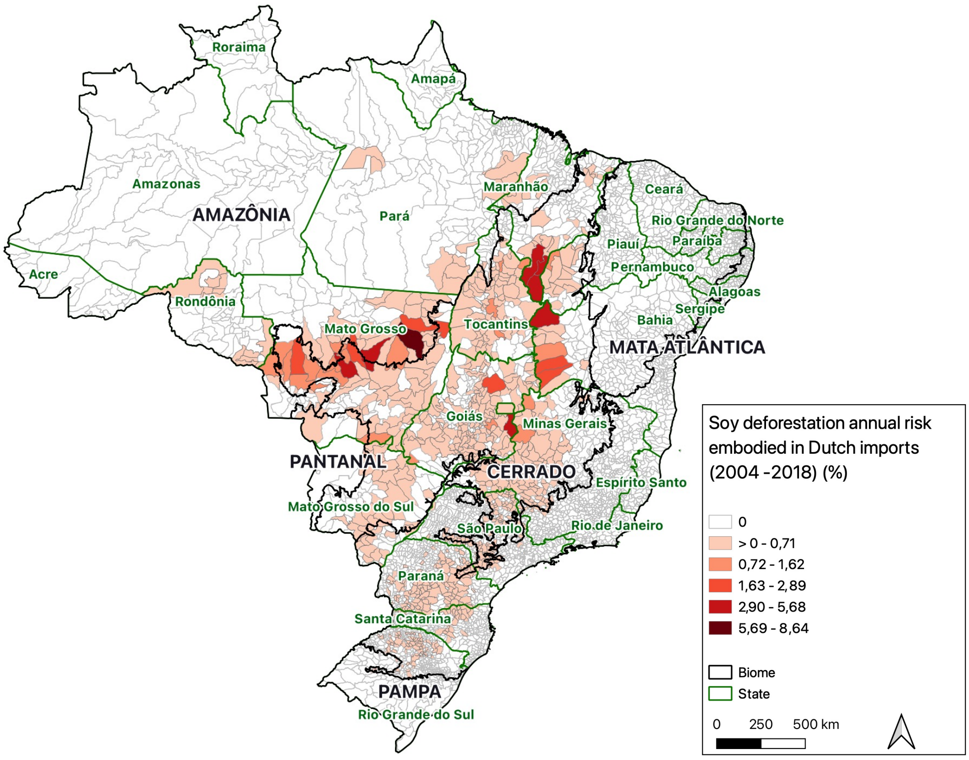
(c) *Deforestation risk*

Figure A.20: *Brazilian soy (a) imported by Belgium and the Netherlands per Brazilian* ***state*** *(2004-2018). Deforestation risk (b) and deforestation emissions (c) (5 year annual risk). Data from Trase (2021).*

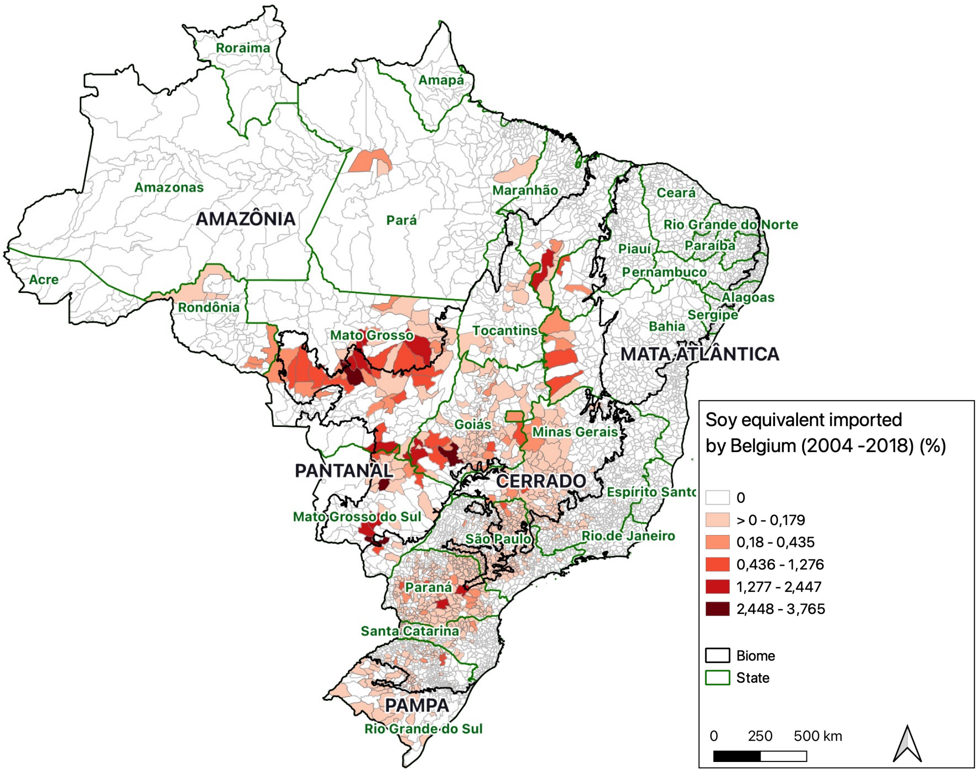


(a) *Belgian soy imports*

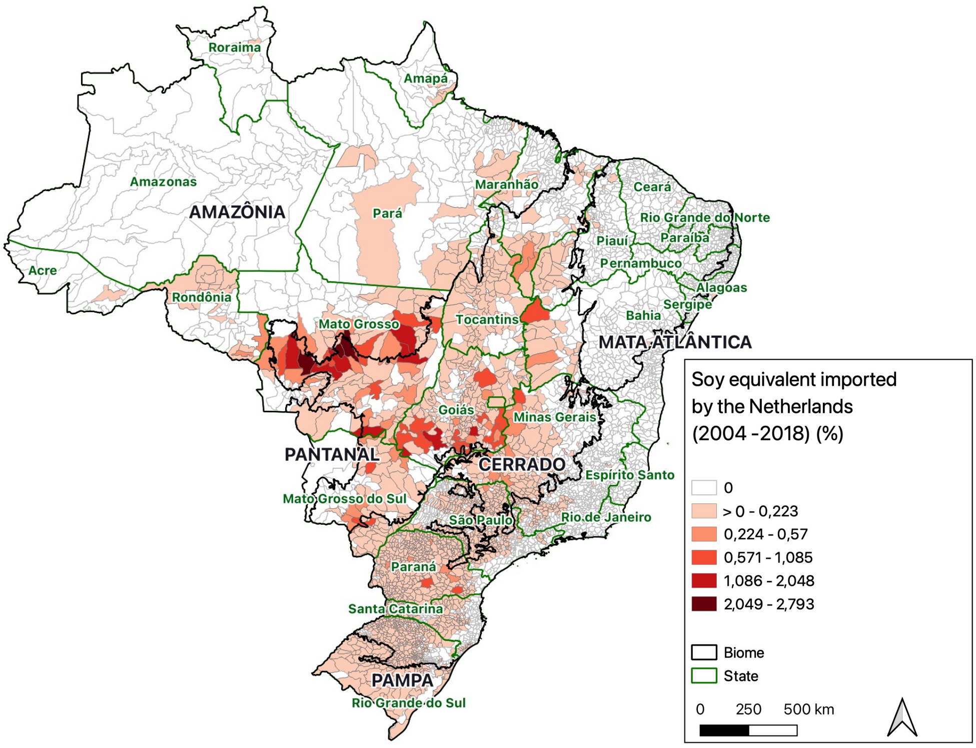


(b) *Dutch soy imports*

Figure A.21: *Share of deforestation risk (5 year annual risk) embodied in Brazilian soy imported by Belgium (a) and the Netherlands (b) (2004-2018). Data from Trase (2021), IBGE for municipality boundaries and MapBiomas for biome boundaries.*



(a) *Belgian soy imports*



(b) *Dutch soy imports*

Figure A.22: *Share Brazilian soy imported by Belgium (a) and the Netherlands (b) (2004-2018). Data from Trase (2021), IBGE for municipality boundaries and MapBiomas for biome boundaries.*

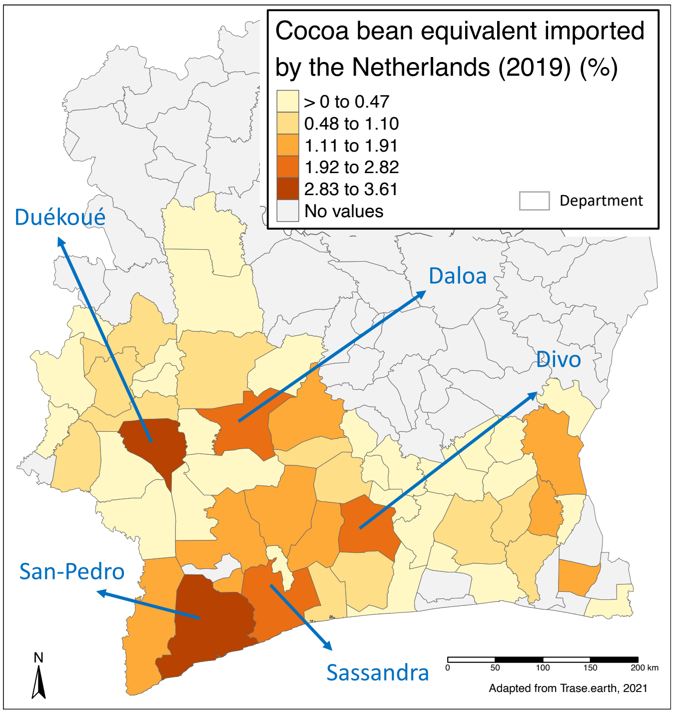


Figure A.23: *Share of soy imported by the Netherlands from Côte d'Ivoire in 2019. Data from Trase (2021) and GADM for department boundaries.*

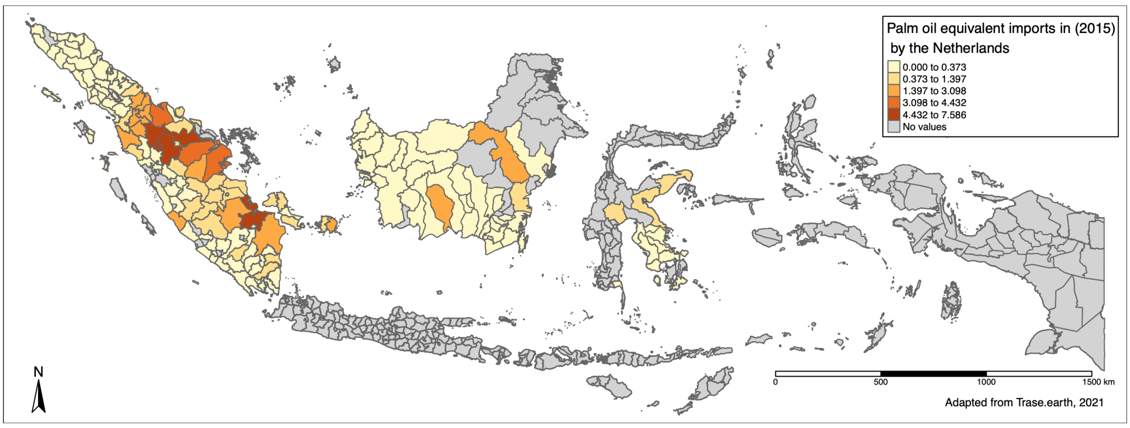


Figure A.24: *Share of palm oil imported by the Netherlands from Indonesia in 2015. Data from Trase (2021) and GADM for kabupaten boundaries*

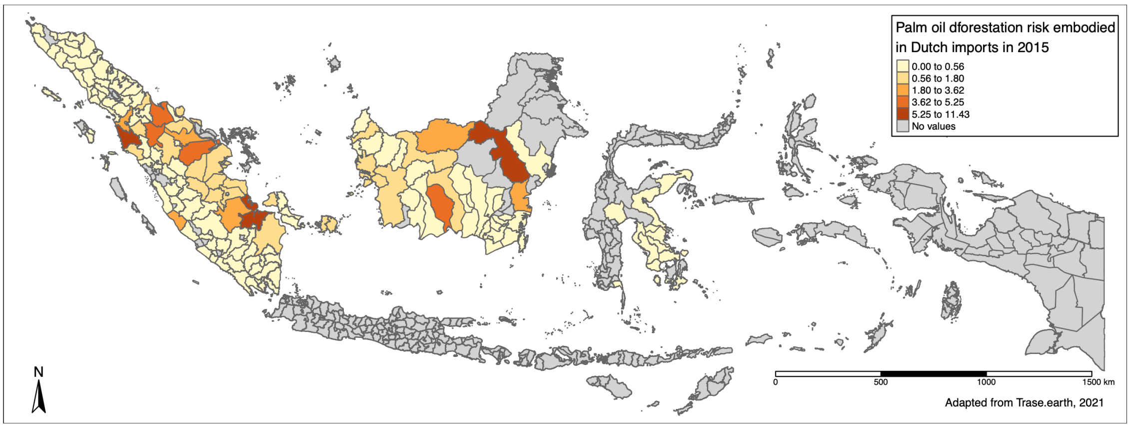
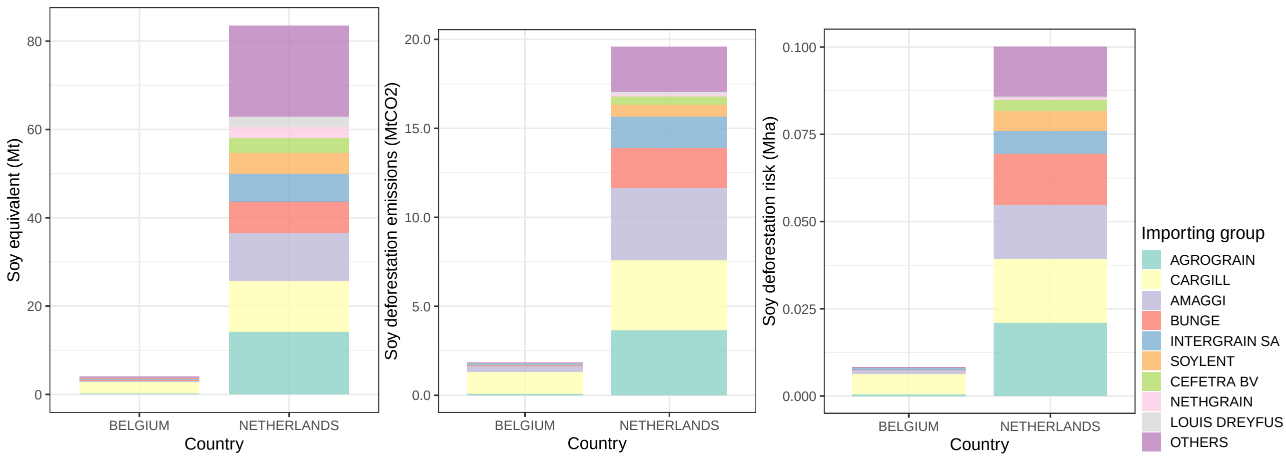
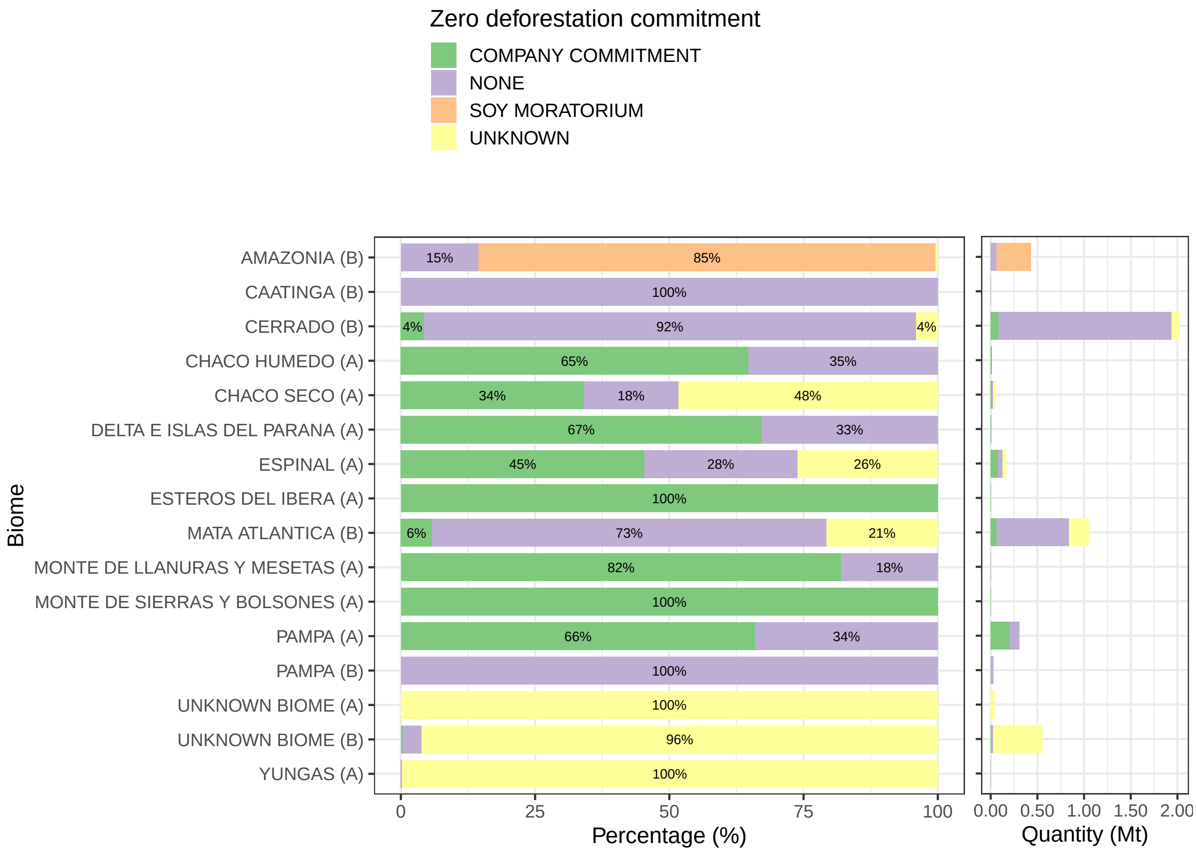


Figure A.25: *Share of embodied deforestation risk in palm oil imported by the Netherlands from Indonesia in 2015. Data from Trase (2021) and GADM for kabupaten boundaries.*

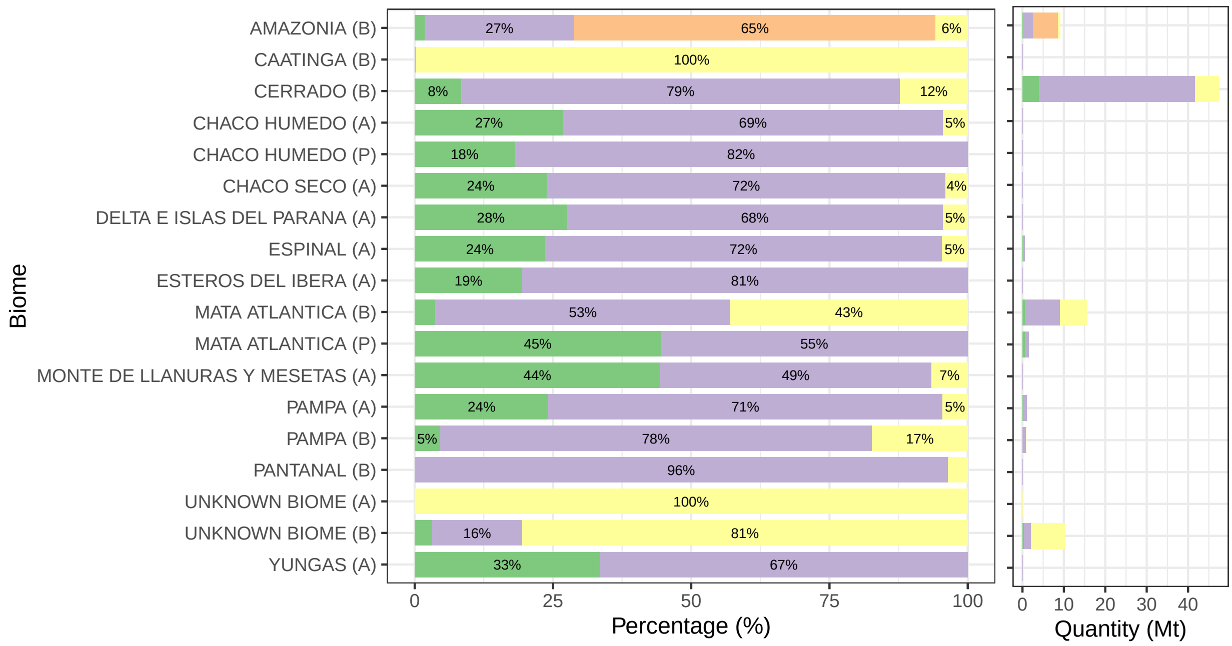


(a) *Quantity* **(b)** *Deforestation emissions* **(c)** *Deforestation risk*

Figure A.26: *Brazilian soy (a) imported by Belgium and the Netherlands per **importing group** (2004-2018). Deforestation risk (b) and deforestation emissions (c) (5 year annual risk). Data from Trase (2021).*

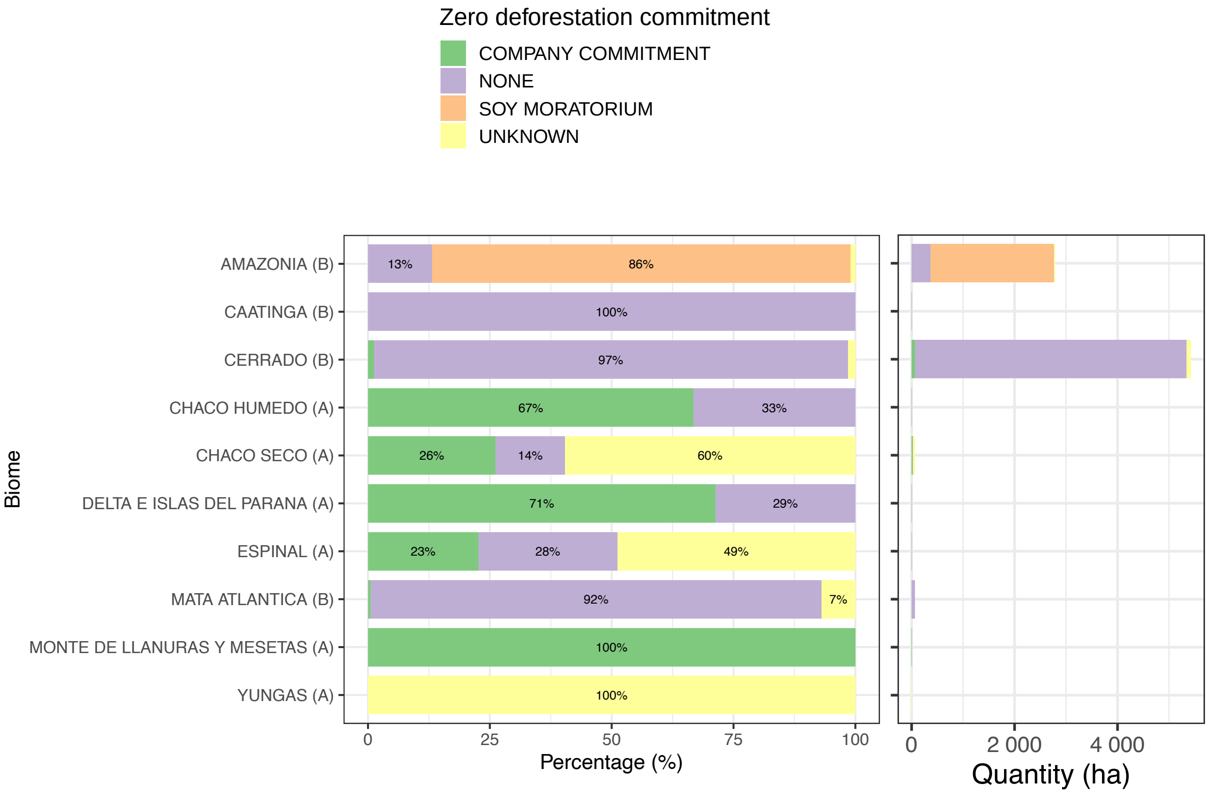


(a) Belgium

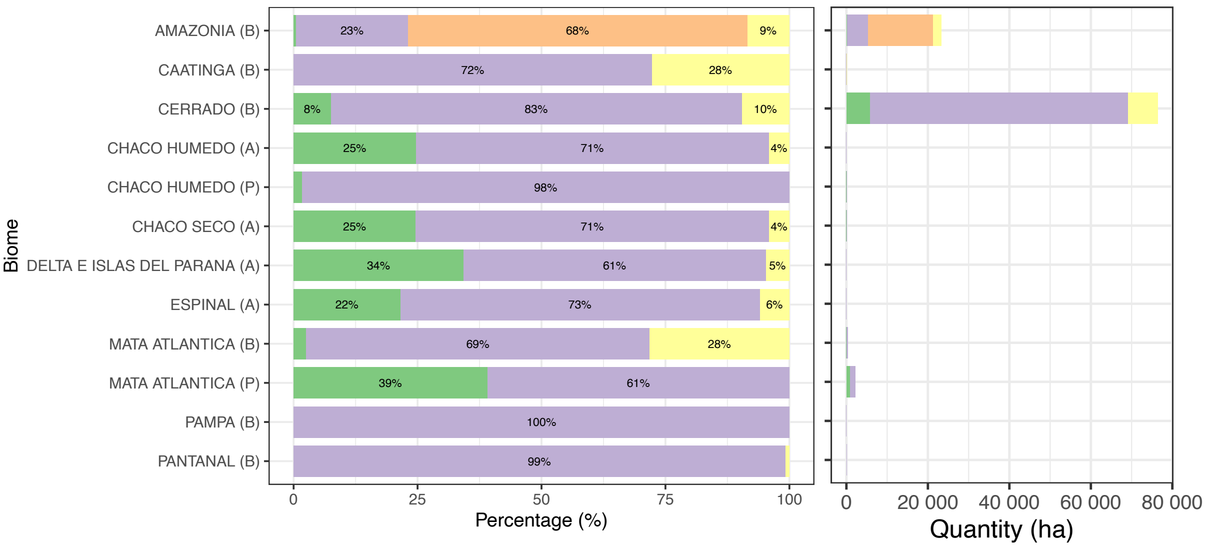


(b) The Netherlands

Figure A.27: *Zero deforestation commitments for soy imports from Brazil (B) (2004-2018), Argentina (A) (2016-2018) and Paraguay (P) (2014-2018). Data from Trase (2021).*



(a) Belgium



(b) The Netherlands

Figure A.28: *Zero deforestation commitments for soy imports (deforestation 5-year annual risk) from Brazil (B) (2004-2018), Argentina (A) (2016-2018) and Paraguay (P) (2014-2018). Data from Trase (2021).*

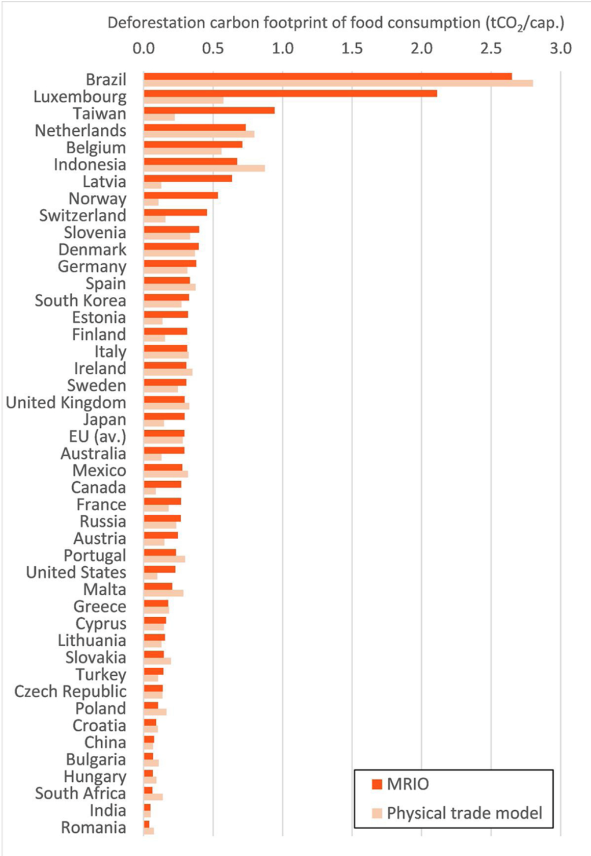


Figure A.29: *The average (2010-2014) deforestation carbon footprint for food consumption across countries. From Pendrill et al. (2019b)*

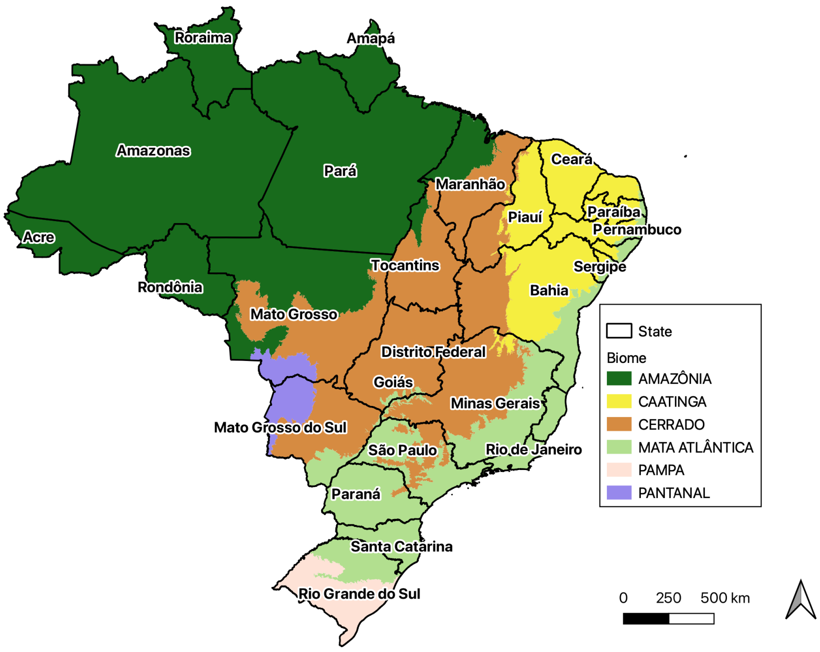


Figure A.30: *Brazilian biomes. Data from IBGE2020 (States) and IBGE2008 (Biome).*

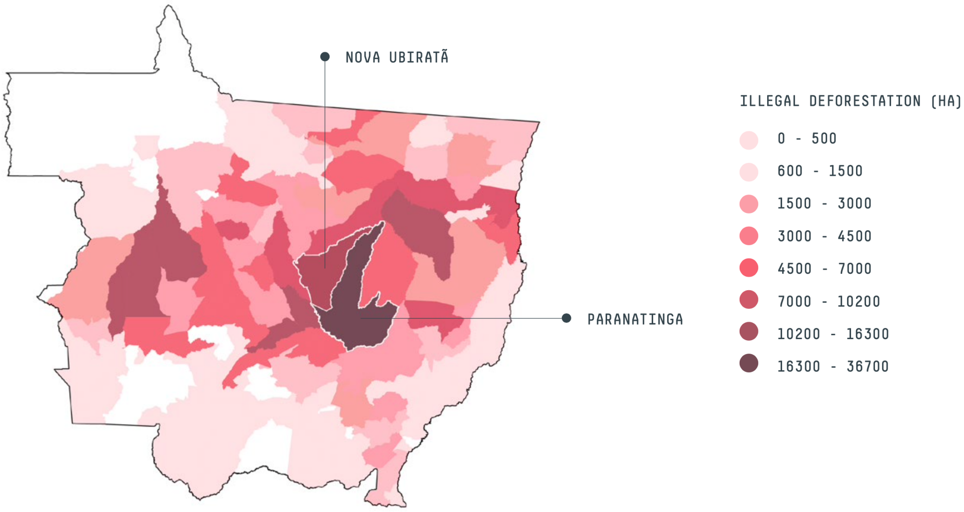


Figure A.31: *Illegal deforestation (ha) on soy farms per municipality in Mato Grosso (2012-2017). Source: Vasconcelos et al., 2020*

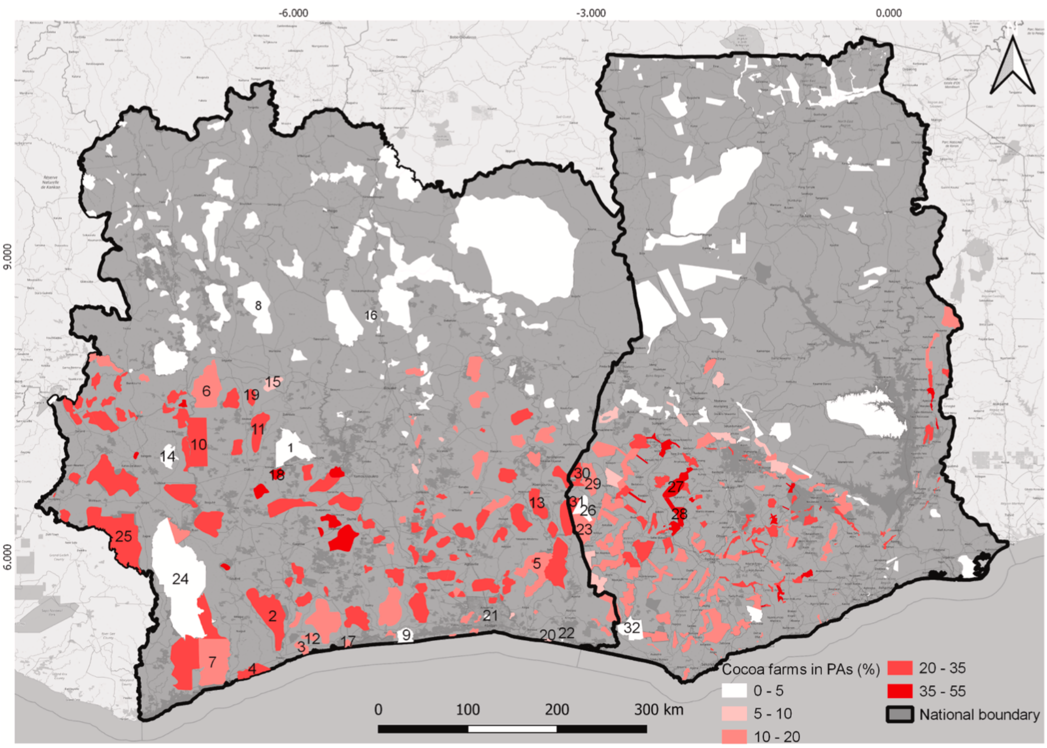


Figure A.32: *Estimated area of cocoa plantations (%) within protected areas. From Abu et al. (2021)*

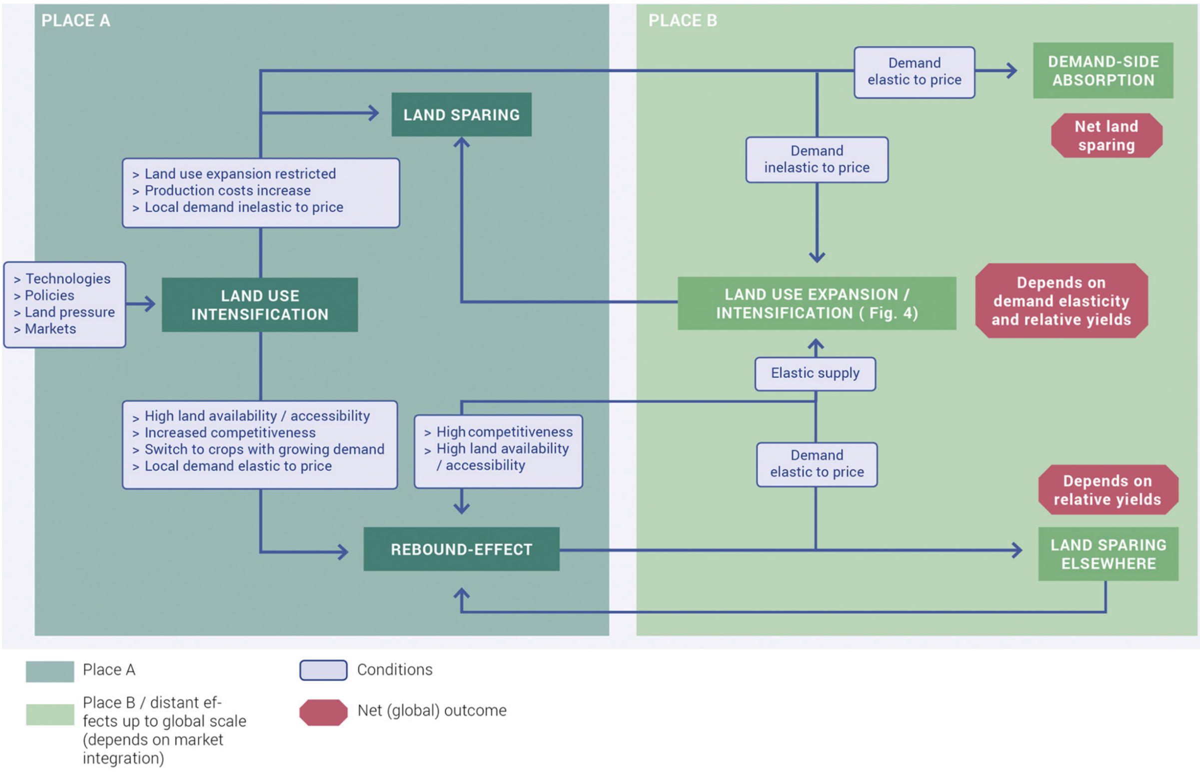


Figure A.33: *Theory of land sparing and rebound effect with intensification. From Meyfroidt et al. (2018)*

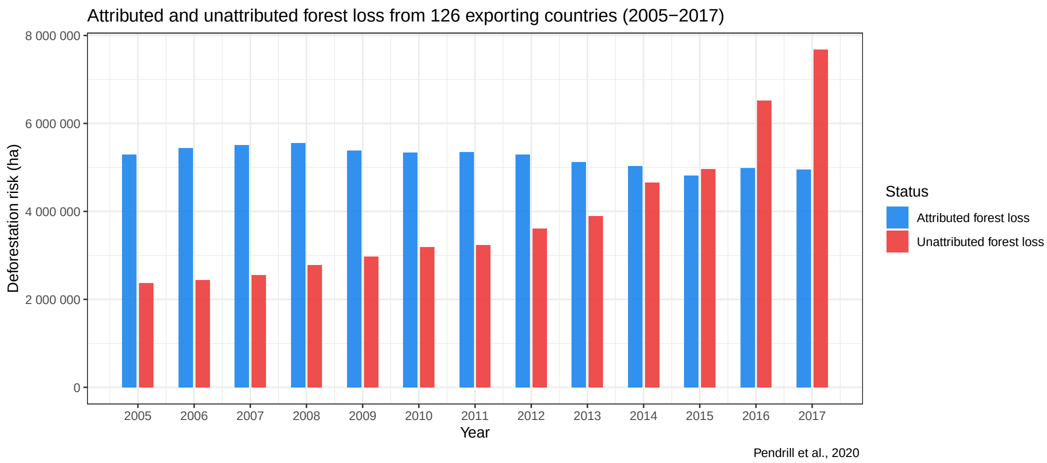


Figure A.34: *Attributed and unattributed forest loss from 126 exporting countries (2005-2017) from the Pendrill et al. (2020) dataset*

Chapter B
Appendix - Tables

Table B.1: *Datasets extracted from Trase.earth (2021).*

Commodity	Country	Years	Notes
Soy	Argentina	2016 – 2018	Exporting companies only
Soy	Brazil	2004 – 2018	
Soy	Paraguay	2014 – 2018	Netherlands only, no record for Belgium Exporting companies only No deforestation emissions 5-year annual risk data
Beef	Brazil	2015 – 2017	
Palm oil	Indonesia	2015	Netherlands only, no record for Belgium Only deforestation risk (but not 5-year annual risk) No zero deforestation commitment data
Cocoa	Côte d'Ivoire	2019	No zero deforestation commitment data Only quantity equivalent available Preliminary results for subnational data
Cocoa	Ghana	2018 – 2019	No zero deforestation commitment data Only quantity equivalent available

Table B.2: *Share of unknown municipalities (for Brazilian soy) departments (for cocoa from Côte d'Ivoire) and kabupaten (for Indonesian palm oil) extracted from Trase (2021).*

Commodity	Country	Year	Variable	Unknown municipality/department/kabupaten
Soy	Brazil	2004-2018	Equivalent soy volume (t) Deforestation risk (5-year annual risk) Deforestation CO2 emissions (5-year annual risk)	13.5% for Belgian imports 12.3% for Dutch imports 41.2% for Belgian imports 39.4% for Dutch imports 40.8% for Belgian imports 39.42% for Dutch imports
Cocoa	Côte d'Ivoire	2019	Equivalent bean volume (t)	52.8% for Belgian imports 53.5% for Dutch imports
Palm oil	Indonesia	2015	Equivalent palm oil volume (t)	2.74% kapubaten for Dutch imports

Table B.3: *Top 10 companies importing commodities to the Netherlands. Data from Trase (2021).*

(a)

Brazilian soy (2004-2018)		Paraguayan soy (2014 - 2018)		Argentinian soy (2016-2018)		Côte d'Ivoire cocoa (2019)		Ghanaian cocoa (2018-2019)		Brazilian beef (2015-2017)		Indonesian palm oil (2015)	
Importer group	**Import share (%)**	**Exporter group**	**Import share (%)**	**Exporter group**	**Import share (%)**	**Exporter group**	**Import share (%)**	**Importer group**	**Import share (%)**	**Importer group**	**Import share (%)**	**Importer group**	**Import share (%)**
AGROGRAIN	17,02	ADM	49,98	GLENCORE	42,20	CARGILL	27,31	CARGILL	32,14	WESTON IMPORTERS	17,83	GOLDEN AGRI INTERNATIONAL	49,46
CARGILL	13,82	CARGILL	19,68	VICENTIN	19,54	OLAM	19,69	OLAM	23,63	FEBURO GLOBAL MEAT	12,48	INTER-CONTINENTAL OILS & FATS	16,96
AMAGGI	12,83	COMPANIA PARAGUAYA DE GRANOS	17,54	PEREZ COMPANC FAMILY GROUP	10,43	AFRICA SOURCING	5,83	ECOM	12,35	MEAT IMPORT ZANDBERGEN BROTHERS	8,41	AAA OILS & FATS	9,80
BUNGE	8,69	COFCO	7,66	ACEITERA GENERAL DEHEZA SA.	10,18	S3C	4,55	TOUTON	7,53	JBS GLOBAL UK	8,30	YIHAI KERRY	8,35
INTERGRAIN SA	7,38	BUNGE	2,28	FIBRO SRL.	8,11	ECOM	4,01	SUCDEN	4,20	MONACO FOODS	6,01	ASTRA - KLK	6,32
SOYLENT	5,82	AGROFERTIL	1,16	COFCO	3,54	BARRY CALLEBAUT	3,43	ASCOT AMSTERDAM	2,27	INTERVLEES	5,68	FIRST RESOURCES	4,05
CEFETRA BV	4,04	FRANCISCO VIERCI Y CIA	0,80	MOLINOS RIO DE LA PLATA SA.	2,93	IVOIRE COMMODITIES SOURCING	3,21	WALTER MATTER SA	2,05	JBS TOLEDO	4,89	SIPEF N V	3,26
NETHGRAIN	3,00	VICENTIN	0,59	RENOVA	1,27	CAP	2,16	BD ASSOCIATES	1,74	GOUDSMIT MEAT TRADING	3,42	SIME DARBY	1,24
CARAMURU ADMINISTRACAO E PARTICIPACOES LTDA	2,74	CHS	0,32	YPF	0,91	SCAT	2,16	BARRY CALLEBAUT	1,61	GVFI EUROPE	3,25	WILMAR	0,33
LOUIS DREYFUS	2,71			BUNGE	0,46	ECOOKIM	1,94	FACTA INTERNATIONAL BV	1,51	PRINCES FOODS	2,55	LOYALINE LIMITED	0,13
Total =	**78,05**	**Total =**	**100**	**Total =**	**99,57**	**Total =**	**74,28**	**Total =**	**89,03**	**Total =**	**72,83**	**Total =**	**99,89**

Table B.4: *Brazilian soy imported by Belgium (top 10 companies). Data from Trase.earth, 2021*

Quantity

Brazilian soy	
Importer group	Import share (%)
CARGILL	61,62
BUNGE	7,91
AMAGGI	6,87
AGROGRAIN	5,42
COFCO	4,65
INTERGRAIN SA	3,94
LOUIS DREYFUS	1,77
CEFETRA BV	1,37
NETHGRAIN	0,93
GLENCORE	0,75
Total =	95,22

Deforestation emissions

Brazilian soy	
Importer group	Import share (%)
CARGILL	66,26
AMAGGI	17,31
INTERGRAIN SA	7,09
AGROGRAIN	4,93
BUNGE	2,36
AGRILEX LIMITED	0,59
GRANEX S.A.	0,34
CEFETRA BV	0,23
GLENCORE	0,20
LOUIS DREYFUS	0,18
Total =	99,51

Deforestation risk

Brazilian soy	
Importer group	Import share (%)
CARGILL	70,01
AMAGGI	14,09
AGROGRAIN	5,38
INTERGRAIN SA	5,24
BUNGE	2,55
GRANEX S.A.	0,51
GLENCORE	0,43
AGRILEX LIMITED	0,41
CEFETRA BV	0,38
LOUIS DREYFUS	0,28
Total =	99,27

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