RIFS STUDY

Research Institute for Sustainability (RIFS)

Learning from Digital Transparency Initiatives in Brazil

A Call for Innovation and Collaboration ahead of the EU Forest-Risk Commodities Regulation

Potsdam, 28 March 2023

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RIFS POTSDAM

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Zusammenfassung

Die geplante Verordnung der Europäischen Union (EU) über forstwirtschaftliche Risikowaren verlangt von Unternehmen, die in den oder aus dem EU-Markt verkaufen, die Bereitstellung von Geolokalisierungsdaten der Produktionsgebiete. Zur Umsetzung der obligatorischen Sorgfaltspflicht schreiben die Regulierungsbehörden die Nutzung von EU-Datenerfassungs- und Analyseinstrumenten wie dem Raumfahrtprogramm der Union (EGNOS/Galileo und Copernicus) und der EU-Beobachtungsstelle vor. Darüber hinaus empfiehlt der Gesetzentwurf, auf bestehenden öffentlich oder privat verfügbaren Datenquellen und Überwachungsinitiativen aufzubauen. In dieser Arbeit werden digitale Transparenzinitiativen in Brasilien untersucht, um den Beitrag der digitalen Technologien zur Rückverfolgung der sozio-ökologischen Herkunft von Produkten zu verstehen. Als Rohstoffproduzent und Heimat des größten Regenwaldes der Welt bietet der brasilianische Fall Lehren für die Umsetzung der EU-Abholzungsverordnung und bietet gleichzeitig die Möglichkeit, über das Potenzial des Technologie- und Wissenstransfers aus dem globalen Süden nachzudenken. Darüber hinaus können staatliche und nichtstaatliche Akteure durch die Nutzung vorhandener Datensätze und digitaler Artefakte wie in Brasilien digitale Innovationen fördern, den Wert für die Gesellschaft steigern und Wege für eine verstärkte transnationale Zusammenarbeit eröffnen. Die Fallstudie zeigt, dass es mehrere hochwertige offene Datenquellen und digitale Plattformen gibt. Das Haupthindernis für die Umgestaltung des brasilianischen agroindustriellen Komplexes liegt eher in der Verwirklichung institutioneller als technologischer Innovationen. Insbesondere müssen die brasilianische Regierung und die Agrarindustrie von rückwärtsgewandten Narrativen und Handlungen Abstand nehmen, einschließlich des Datenmissbrauchs und der Instrumentalisierung von Maßnahmen im Zusammenhang mit digitalen Technologien, die mit der aktuellen globalen Klimakrise unvereinbar sind. Während Unternehmen, Behörden und die Zivilgesellschaft sich darauf verlassen können sollten, dass die brasilianischen digitalen Initiativen die Einhaltung der Abholzungsvorschriften überprüfen, muss die EU einen kooperativeren Ansatz verfolgen, um Brasilien bei der Bewältigung seiner dringenden politisch-institutionellen Herausforderungen zu unterstützen.

Summary

The upcoming European Union (EU) forest-risk commodities regulation requires companies selling to or from the EU market to provide the geolocation data of production areas. To implement the mandatory due diligence requirements, regulators prescribe using EU data collection and analysis tools such as the Union's Space programme (EGNOS/Galileo and Copernicus) and the EU Observatory. Furthermore, the draft law recommends building on existing publicly or privately available data sources and monitoring initiatives. This paper examines digital transparency initiatives in Brazil to understand digital technologies' contribution to tracing products' socio-environmental origin. As a commodity powerhouse and home to the world's largest rainforest, the Brazilian case offers lessons for implementing the EU Deforestation Regulation while presenting a chance to reflect on the potential of technology and knowledge transfer from the Global South. Moreover, by building on existing datasets and digital artifacts as those in Brazil, state and non-state actors may foster digital innovation, increase value to society, and open paths for enhanced transnational collaboration. The case study shows several high-quality open data sources and digital platforms exist. The major obstacle to transforming the Brazilian agro-industrial complex lies in realising institutional rather than technological innovations. Specifically, the Brazilian government and agribusiness must abandon retrograde narratives and actions, including data misuse and the instrumentalization of policies related to digital technologies, which are incompatible with the current global climate crisis. While operators, authorities, and civil society should rely on Brazilian digital initiatives to conduct non-deforestation compliance checks, the EU must adopt a more collaborative approach to help Brazil address its pressing political-institutional challenges.

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Contents

1 Introduction

The European Union (EU) is one of the biggest drivers of deforestation, after China and ahead of India and the United States (Marzano, 2023). For this reason, the upcoming EU forest-risk commodities regulation imposes new supply chain obligations on companies to curb deforestation and forest degradation driven by the expansion of agricultural land (Council, 2022b, Article 1§1(a)). Once in force[1], due diligence obligations will apply to companies placing specific commodities and derived products on the EU market and those exporting from it. The most recent provisional agreement encompasses products that contain, have been fed with or made using cattle, cocoa, coffee, oil palm, rubber, soya, and wood.[2]

In view of the implementation of the EU Deforestation regulation, this text is structured as follows. This introduction offers relevant background information about the regulation and discusses potential contributions of resorting to and integrating existing digital technologies to achieve deforestation-free global supply chains. It also presents Brazil's credentials as a crucial case study for learning from digital transparency initiatives that provide information on sustainability challenges connected to commodity production and trade. Next, the chosen qualitative research methodology is explained, followed by the case study findings covering the shortcomings and contributions of Brazilian digital initiatives. The final section concludes with concrete suggestions for reviewing the EU approach towards deforestation and other similar policies based on the lessons learned from the Brazilian analysis.

1.1 The EU Geolocation Requirement

According to the EU Deforestation Regulation, a company selling to or from the Union market[3] must submit a due diligence statement to disclose steps taken to verify compliance and explain risk assessments (Council, 2022b, Articles 3 and 4). In their statements, companies must provide, among others, the geolocation of all plots of land where the relevant commodities were produced (Article 9§1(d)).[4]

[1] On December 6, 2022, the Council and the European Parliament reached a provisional agreement pending formal adoption in both institutions. Once the Regulation is in force, operators and traders will have 18 months to implement the new rules, with micro and small enterprises enjoying a longer adaptation period (Commission, 2022; Council, 2022a).

[2] The European Parliament, in its plenary vote, expanded the Commission's original list (cattle, cocoa, coffee, oil palm, soya, wood and products) to include swine, sheep and goats, poultry, palm-oil-based derivates, maize, rubber, and products, including charcoal and printed paper products (European Parliament 2022, Article 1§1, introductory part, Amendment 83). Besides, the Parliament invited the Commission to analyse products such as sugar and ethanol to expand the Regulation's scope during future review processes (European Parliament News 2022). On December 6, the provisional political agreement between the Council and the Parliament (Council, 2022b) took maize, for example, out of the first version of their list, mostly due to fear that the already tense situation on the world's food markets due to the war in Ukraine could be further aggravated (Kafsack, 2022).

[3] More precisely, the EU regulation uses the term operators, which refers to "any natural or legal person who, in the course of a commercial activity, places relevant products on the Union market or exports them from the Union market" (Council, 2022b, Article 2(12)).

[4] According to the Commission's original proposal, companies must ensure access to information linking commodities to land, providing the geolocation coordinates of all plots of land where commodities were grown (Commission, 2021). The EU Parliament introduced the possibility of polygon mapping (Parliament, 2022, Amendment 123), a request by operators arguing it facilitates implementation (European Parliament News 2022). Specifically, Parliaments' version required companies to deliver geolocation coordinates, latitude, and longitude for

Companies' due diligence statements will be verified by competent authorities designated by member states (Articles 13 and 14). In parallel, the European Commission will operate a three-tier system classifying countries or parts thereof as low, standard, or high-level risk areas (Article 27). Enhanced scrutiny will apply to companies selling commodities from high-risk areas (Articles 12, 14, 14a).[5]

To comply with the EU upcoming Regulation, a company selling to or from the EU must be able to trace the origin of its products back to production areas and show that they have been produced in accordance with the relevant legislation of the country of production and on land that has not been subject to deforestation after December 31, 2020 (Article 2(8) and 3(a,b))[6]. Yet, commodity traceability can be challenging, especially for grains such as corn and soya (Zanon, 2021). These commodities change hands many times after leaving a farm's gate and can be mixed during storage, processing, and transportation (Article 10§2(f)(g)). The complexity of the soya supply chain[7], for example, often obscures who trades and purchases this commodity, making it difficult to track and guarantee its origin (Heron, Prado, & West, 2018; KPMG, 2013; Vasconcelos et al., 2020).

Although challenging, commodity chains are still mappable if every company trading with the EU records all entries and exits. Besides, after years of experience with voluntary sustainability standards and commitments, one would expect companies to know by now who their direct and indirect suppliers are and have systems in place to address socio-environmental problems connected to their supply chains.[8] Similarly, the Commission's original proposal reads:

all plots of land or of all points of a polygon for the plots of land where the relevant commodities and products were produced (Article 9§1(d)). According to ISEAL (2020), a polygon is a series of points or vertices connected to form a ring, which offers a more accurate picture than single-point coordinates by differentiating the boundaries of certified activities. Polygon mapping requires special Geographical Information System-(GIS) software or Google Earth. In the provisional agreement between the Council and the Parliament (Council, 2022b), a threshold for the mandatory use of polygons is established (Article 2(29)), which should be evaluated during the review process (Article 32). According to Article 2(29), *"'geolocation' means the geographical location of a plot of land described by means of latitude and longitude coordinates corresponding to at least one latitude and longitude point and using at least six decimal digits. For relevant commodities other than cattle, for plots of land of more than 4 hectares, the geographical location shall be provided using polygons, meaning sufficient latitude and longitude points to describe the perimeter of each plot of land".*

[5] Operators whose commodities and products have been produced in low-risk areas are subjected to simplified due diligence, i.e., they do not need to fulfil the risk assessment and risk mitigation obligations under Articles 10 and 10a. To enforce the regulation, a competent authority (of the country where the commodity or product was placed on the EU market or exported from) shall, among others, take immediate interim measures to suspend the placing or making available on the Union market of those relevant products from high-risk areas (Article 14a). As in the provisional deal, competent authorities were tasked "to carry out checks on 9% of operators and traders trading products from high, 3% for standard-risk countries and 1% from low-risk countries, to verify that they effectively fulfil the obligations laid down in the regulation. In addition, competent authorities will check 9% of the quantity of each of the relevant commodities and products placed, made available on, or exported from their market by high-risk countries" (Council, 2022a, par.7).

[6] In the case of relevant products that contain or have been made using wood, deforestation-free means "that the wood has been harvested from the forest without inducing forest degradation after December 31, 2020" (Article 2(8)(b)).

[7] Better characterized as agro-industrial systems, commodities like soya supply very different kinds of industries (Lemos, Guimarães, Maia, & Amaral, 2017; Silva & Falchetti, 2010). For example, soya's main derivatives (soya meal and oil) produce food, animal feed, biofuel, and other chemicals (Lemos et al., 2017). Consequently, soya is often consumed indirectly – e.g., embedded in meat products (Vasconcelos et al., 2020) – and remains a largely invisible product not always listed as an ingredient. Because of such difficulty, European supermarket chains have announced efforts to measure the soya footprint in their animal products (e.g., ALDI, 2022; REWE, 2019).

[8] By now, companies should be able to identify the social and environmental risks associated with their supply chains and take appropriate countermeasures. Additionally, many European companies actively participated in the formulation of corresponding supply chain laws, such as the German Due Diligence Act (Bundestag, 2021), and

> "**Geographic information linking products to the plot of land is already used by industry and certification organizations, as well as on relevant EU legislation**. Directive (EU) 2018/2001 requires information on the "sourcing area" for problematic countries. A series of EU rules ensures the traceability of beef "from birth to death," including via means such as **ear tags, bovine passports and a computerised database**" (Commission, 2021, p.14, emphasis added).

Furthermore, while there is a need to prevent certain batches from being settled multiple times, monitoring technologies based on satellite imagery, blockchain and others can play a key role in dealing with commodities' traceability challenges – as recognized by the EU proposal itself.

1.2 Digital Technologies in EU Law

In its legal draft, the EU recognizes the potential of digital technologies for implementing non-deforestation requirements (Council, 2022b, Recital 21) and recommends using some EU tools to support implementation. This partially contradicts the findings that "[l]egal frameworks [often] tackle questions of what to address rather than prescribing tools for data collection and analysis" (Matthess, Kunkel, Xue, & Beier, 2022, p.12). According to the Commission's explanation of Article 9, §1(d):

> "Requiring the plot of land or farm where the commodity has been produced allows for **the use of satellite images and positioning – widely available and free-to-use digital tools – to check whether a product or commodity is compliant or not. […] The Union has developed its own satellite Positioning, Navigation and Timing (PNT) technology (EGNOS/Galileo) and its own Earth observation and monitoring system (Copernicus).** Both EGNOS/Galileo and Copernicus offer advanced services, which provide important economic benefits to public and private users. Therefore, satellite images and positioning stemming from the use of EGNOS/Galileo and Copernicus **can be part of the information used for compliance checks**"(Commission, 2021, p. 11, emphasis added).

In addition to the EGNOS/Galileo and Copernicus, the regulation draft also refers to an EU Observatory on deforestation, forest degradation, changes in the world's forest cover, and associated drivers launched by the Commission (Council, 2022b, Recitals 22, 33 and Article 15§2(c)). The establishment of this EU Observatory was announced back in 2019 (Commission, 2019), and the Deforestation Regulation envisages that:

> "[…] the **EU Observatory should facilitate access to information on supply chains** for public entities, consumers and business, providing **easy-to-understand data and information linking deforestation, forest degradation, and changes in the world's forest cover to EU demand/trade for commodities and products**. The EU Observatory should thus support the implementation of this Regulation by providing **scientific evidence in regard to global deforestation and forest degradation and related trade** […]" (Council, 2022b, Recital 22, emphasis added).

Additionally, the EU Observatory should participate in the development of an early warning system combining research and monitoring capacity (ibid.).

Since parts of these EU tools are yet to be designed or implemented, some specifics remain unclear. The EU regulation recommends building on existing initiatives, including publicly or privately available data sources and monitoring tools (Council, 2022b, Recital 22 and Article 15§2(c)). For example, connected to the spirit of a partnership approach, in which the Union and its member states are called to support producing countries to reduce deforestation, the Regulation mentions the use digital of technologies and

some even pushed for even stricter requirements, not least because companies that already perform due diligence have competitive advantages over others that do not (*Interview `European Supermarket Supply Chain Manager´*).

geospatial information, "[b]uilding upon the experience and lessons learned in the context of the already existing initiatives" (ibid., Recital 21). Besides, the EU Observatory is expected not only to build on publicly or privately available data sources and monitoring tools but also cooperate with competent authorities, relevant international organisations, research institutes, nongovernmental organisations (NGOs), operators, traders, third countries and other relevant stakeholders (ibid., Recital 22).

Still, the current legislative proposal does not specify which existing initiatives, datasets, and digital technologies one should build on or resort to for collecting, monitoring, reporting, and verifying data. Before coming to them, one could ask why competent authorities, the EU Observatory, companies, and others should rely on existing initiatives in the first place.

1.3 No Need to Reinvent the Wheel

This paper argues that information on existing public and private digital transparency initiatives on commodity-driven deforestation, forest degradation and other connected sustainability challenges is needed. EU institutions, the competent authorities of the member states, companies, and others should resort to and integrate available data and monitoring tools when implementing the Deforestation Regulation. Using existing datasets and digital artifacts may foster digital innovation and increase value to society while opening paths for enhanced transnational collaboration.

These arguments stem from theoretical concepts such as "digital sustainability", "sustainable digital artifacts" (Stuermer, Abu-Tayeh, & Myrach, 2017, p.247) and a "layered modular architecture" explaining "digital innovations" (Yoo, Henfridsson, and Lyytinen 2010).[9] In a few words, Stuermer et al. (2017, p.261) argue that, differently from natural resources, which face the challenge of overconsumption, it is "desirable from the societal perspective that digital artifacts, which potentially have a positive impact on sustainable development are used as much as possible". First, using a digital artifact does not impair its use by its creators. Second, the costs of innovating decrease by relying on and combining existing datasets and technologies. Third, the more people have access to and use existing digital artifacts, the value to society increases. Similarly, with a layered modular architecture, i.e., combining existing digital artifacts (e.g., datasets and software technologies plus web technologies) to create innovative tools, a digitized product can be simultaneously a product and a platform as it enables others to innovate in ways previously impossible by relying on only a handful of people (Yoo et al. 2010).

In the context of fighting global deforestation, there has been a dramatic expansion in the use of different technologies to protect forests.[10] In addition to a well-known role of geo-satellites in forest governance (e.g, Oliveira & Siqueira, 2022; Rajão & Jarke, 2018), computer infrastructures – also in combination with cutting-edge digital technologies such as the Internet of Things (IoT), Artificial Intelligence (AI) approaches like machine learning (ML), and Distributed Ledger Technologies (DLT, or simply "Blockchain") – have been used for traceability and monitoring compliance checks.

[9] Similarly, the "Principles for Digital Development" – a unification of previous efforts by UN, WHO, and UNICEF, among others, to align global digital development and innovation along principles that stress "reuse and improving" existing work – innovate using an "open approach to help to increase collaboration" based on an understanding of the "particular structures and needs in an existing country, region or community", as in https://digitalprinciples.org/, last accessed on February 15, 2023. I thank Malte Reißig for pointing me to this literature.

[10] For example, going beyond just observing deforestation from space, the Global Ecosystem Dynamics Investigation (GEDI) mission uses a geodetic-class, light detection and ranging (lidar) laser system aboard the International Space Station (ISS) to measure forests' biomass density and map the Amazon in 3D (GEDI, 2022; Kidangoor, 2022). Such data confirms the importance of forests such as the Amazon in the carbon cycle (e.g., deforestation's carbon emissions and forests' carbon absorption) and identifies specific areas that could benefit from carbon-based conservation initiatives.

For example, data-processing computer programs treat and combine heterogeneous digital data linking deforestation in production areas to buyers and investors (e.g., Rajão et al., 2020; Vasconcelos et al., 2020; Vasconcelos et al., 2019). Information can be collected through or provided by IoT, and everything connected to the internet or interacting with it can be geo-located (WCO/WTO, 2022, p.57). AI, including ML, facilitates handling big data accurately, detecting and predicting patterns more precisely than humans can (ibid., p.65). Blockchain, in turn, enables traceability platforms to onboard supply chain actors scattered all over the globe and – through its characteristic of housing "immutable data" and often decentralized operations and governance mechanisms – provide a relatively secure digital chain of custody with trustworthiness and availability beyond what a single operating entity can provide (e.g., Kamble, Gunasekaran, & Sharma, 2020; Lenzing, 2020; Saurabh & Dey, 2021).[11] The different enabling features of each one of these technologies suggest using them in combination. Blockchain platforms, for instance, can integrate data on supply chain nodes via IoT devices, transmitted via Peer-to-Peer (P2P) protocols, or more centralized cloud-based solutions (Saurabh & Dey, 2021).

However, digital technologies also impose challenges, including high initial cost and complexity, and potentially high (indirect or subsequent) operational costs, for society or the environment, as is especially the case for the development and use of blockchain[12] (Kouhizadeh & Sarkis, 2018; Varriale, Cammarano, Michelino, & Caputo, 2020).[13] Before that, another crucial challenge to reusing digital artifacts as much as possible and exploiting their full potential through developing new or deepening existing collaborations is the lack of awareness and availability of information: "Individuals or organizations may not be aware that relevant knowledge exists or are unaware of where or how to find it" (Stuermer et al., 2017, p.251). To create awareness among EU institutions, member states' competent authorities, companies and others about existing digital non-deforestation monitoring and traceability tools, I propose turning attention to Brazil.

1.4 Why Brazil?

Brazil is among the countries most likely to be affected by the EU Regulation on deforestation-free supply chains (Marzano, 2021b, 2022). Among the commodities falling under the EU regulations' scope, Brazil is the world's leading soya, beef, poultry, and coffee exporter (ComexStat, 2022). Soya, for example, is Brazil's top exported product, and the country has taken the lead as the largest soya bean producer in the world. China is currently the leading buyer of Brazilian soya (60%), beef (54%) and individually responsible for 23% of Brazilian foreign sales of poultry (ComexStat, 2022). Europeans, in turn, are the biggest importers of Brazilian coffee – about 50% of Brazilian coffee exports went to the EU market in 2020 – and the EU's shares of Brazilian soya, beef and poultry exports in the same year were 16%, 5%, and 2%, respectively (ibid.).

Many sustainability challenges are connected to commodity production in Brazil, including deforestation, biodiversity loss, soil and water degradation, pesticide use, child labour, slavery, land grabbing, and disrespect for the rights of indigenous peoples and traditional communities (Bastos Lima & Persson, 2020).[14] While the agribusiness sector was responsible for 27,4% of the Brazilian gross

[11] Blockchain technology allows the same copy of a ledger to be instantly available to all parts of the network "in the most updated, trusted, secure and immutable manner" (WCO/WTO, 2022, p.37).

[12] Blockchain comes with several sustainability concerns, such as increased energy consumption for mining, storage and operations, and fixed costs of tech infrastructure and maintenance, system implementation, and management skills (Kouhizadeh & Sarkis, 2018; Varriale et al., 2020).

[13] Bitcoin Energy Consumption is an example of a Blockchain with very high (environmental) operating costs; and ChatGPT is an example of AI technology with high costs in the Social Supply Chain when involving Sourcematter. I thank Malte Reißig for bringing these examples through his comments on an early version.

[14] As discussed in a webinar organized by the European Centre for International Political Economy (ECIPE, 2021) on the role of trade policy in tackling deforestation, the question of what are the key drivers of deforestation in

domestic product (GDP) in 2021 (Cepea-USP, 2022), the agriculture, forestry, and other land use (AFOLU) sector alone responded to about 70% of Brazilian total greenhouse gas (GHG) emissions (SEEG, 2022). AFOLU sector's impact makes Brazil one of the few countries with the most GHG emissions not associated with energy, as is often the case elsewhere (Marzano, 2022).

Because of these challenges, Brazilian agricultural commodities producers have long been in the spotlight. Soya producers, for example, can face up to 33 voluntary sustainability standards (VSS) to export to the EU, 27 to the United States, and 25 to China (Thorstensen & Mota, 2019, p.60). Market pressures have increased recently (Marzano & Monteiro, 2020). Recent data shows deforestation in Brazil's Amazon at its highest level since 2006 (INPE, 2022), and a dramatic increase in violence (land grabbing and killings) against indigenous peoples, mainly in the Amazon (CIMI, 2021). Under this daunting scenario, major European asset management firms threatened to "divest from beef producers, grains traders and government bonds in Brazil if they do not see progress in resolving the surging destruction of the Amazon rainforest" (Spring, 2020, par.1).

Despite such dreadful environmental and social performance, Brazil showed in the past that it is possible to break the link between agricultural production and deforestation. A 70% deforestation decline between 2005 and 2013 was the primary credential for the Brazilian leadership role in the global climate agenda (Marzano, 2019). Combined with political will, the fight against deforestation was possible thanks to streamlined and transparent monitoring and enforcement systems based on satellite data, field visits, and embargoed lists (Gibbs et al., 2015; Nepstad et al., 2014).

Indeed, using technologies to fight deforestation is not new, and Brazil is a prominent case of how governmental and non-governmental data transparency has been altering forest governance for decades (Oliveira & Siqueira, 2022; Rajão & Jarke, 2018). Besides, in the context of the EU upcoming Deforestation Regulation, a study by May and Ozinga (2021a), for example, compiles several governmental and NGO datasets and monitoring systems in Brazil and concludes that the EU Observatory should integrate/build on various Brazilian high-quality forest monitoring systems[15] (Fern, 2021, p.1).[16] With the Brazilian case, their study shows that the major challenge is not data availability, but harmonising, aligning, linking, and interpreting available deforestation, land use, trade, and other data, and using it to track commodities:

> "It is, however, **not the raw data but the interpretation of the data that is the more time-consuming element and how to link these deforestation data with land use, tenure and trade data**" (May & Ozinga, 2021a, p.64, emphasis added).
> "A **reliable means for tracing farm by farm on the ground, to provide information for procurement decisions by traders is also needed**. The major beef packers and supermarket chains have sunk capital into devising their own systems for traceability, which are closed to public scrutiny. The question is then what kind of information can be provided to buyers on the relative risks associated with data on individual farms, and **how this can best be aggregated using the tools at the disposal of agents in the supply chain**" (ibid., p.33, emphasis added).

Brazil does not have a simple answer. Illegal logging, mining, and land grabbing are more responsible for deforestation in Brazil than agricultural production per se, although, over time, frontiers of deforestation also become agricultural production areas.

[15] Some information is less understood or mapped than others – in Brazil, this is the case of a lower data coverage of human rights impacts and social risks (May & Ozinga, 2021a, p.59).

[16] The authors added some specific recommendations, e.g., the EU Regulation should require companies to disclose their customs data, which has a tax code that allows tracking commodities back to the source (May & Ozinga, 2021a, p.59); the EU Observatory should integrate new scientific testing methodologies like DNA analysis and isotope testing to link a commodity to its location of origin (ibid., p.67-68).

Building on such recent efforts to provide information on Brazil's decades-long experience in fighting deforestation ahead of the EU Deforestation Regulation (Fern, 2021; IPAM, 2022a, 2022b; May & Ozinga, 2021a, 2021b), this paper contributes by revisiting selected Brazilian initiatives to analyse how and to which extent digital technologies have been used to overcome transparency and traceability challenges such as the ones mentioned above related to data processing and provision. Following this overview of what is at stake, in this paper, I ask what are the shortcomings and contributions of digital initiatives in Brazil to increased sustainability in forestry and commodity supply chains. The goal is to draw lessons to implement the EU's geolocation requirement to achieve deforestation-free global supply chains. By focusing on Brazil, this study is innovative in that it opposes the more usual approach focused on North-South[17] flows of technologies and knowledge.[18]

[17] Despite acknowledging that definitions of Global South and even the term itself are contested, here I use it to refer to countries that historically, or at least for the last few centuries, "have been engaged in trade flows dominated by countries and actors from the developed Global North" according to Horner and Nadvi (2018, p.207-208).

[18] Regarding technology transfers, geographical theoretical and empirical imbalances happen not only at the state-level analysis. It also happens regarding the role of non-state actors: "Particularly, there is a focus on the role of "lead firms", typically from the Global North, in transmitting technologies and knowledge about environmental standards and policies to suppliers as well as enforcing environmental governance strategies in global value chains, especially in the Global South" (Kunkel, Matthess, Xue, & Beier, 2022, p.3).

2 Methodology and Limitations

Similar to GVC case studies, in which qualitative research, often based on a combination of primary and secondary data collection, has prevailed (Fridell, 2018, p.20), this paper conducts a qualitative case study research focused on the Brazilian agro-industrial complex and its global value chains (GVCs) – paying particular attention to soya and cattle chains. Specifically, I started by analysing documents such as codes of conduct, corporate reports, regulations, media coverage, trade data statistics, and publicly available speech acts. Based on my desk research, I identified a growing number of digital transparency initiatives in Brazil, most of them in the form of open-access digital platforms covering different sustainability challenges connected to commodity production and sometimes linking it to global trade (more information in the following sections).

Next, I conducted 15 semi-structured interviews with relevant stakeholders (from September to December 2022). I started interviewing land conservation experts in Brazil to gather background information about the current state of affairs regarding deforestation and technological innovations. Next, I interviewed developers of and contributors to selected digital transparency initiatives (Table 1). The initiatives were chosen according to the attention they received in documents and initial interviews. Selected digital initiatives are, however, illustrative and do not intend to cover all the existing ones in Brazil.

Digital Transparency Initiatives	Brief Description
Startup DataBoi	Biometric cattle tracking, monitoring and certification app
Legal Amazon in Data Project (*Amazônia Legal em Dados*)	Free access online platform providing an integrated view of the nine states of the Legal Amazon. It comprises 113 indicators on 11 themes (e.g., science and technology, demographics, social development, education, economy, infrastructure, institutions, environment, sanitation, health, and safety). Promoted by *Uma Concertação Pela Amazônia* and developed by *Consultoria Macroplan* with support from the *Instituto Arapyaú*.
System for Observation and Monitoring of the Indigenous Amazon (*Sistema de Observação e Monitoramento da Amazônia Indígena*-SOMAI)	Online platform providing scientific information about deforestation, land use, vegetation, biodiversity, hydrography, infrastructure, carbon stock and weather forecasts in indigenous lands. Created by the Amazon Environmental Research Institute (*Instituto de Pesquisa Ambiental da Amazônia*-IPAM).
The TimberFlow Platform	Online platform providing visualizations of all the stages and patterns of production, transport, processing, and commercialization of timber from the Amazon. Partnership between the

	Institute for Forest and Agricultural Certification and Management (*Imaflora, Instituto de Manejo e Certificação Florestal e Agrícola*) and an academic group in mathematical and computational sciences (*Instituto de Ciências Matemáticas e de Computação*-ICMC at the University of São Paulo-USP).
Applied Territorial Intelligence (*Inteligência Territorial Aplicada*)	Online platform scheduled for launch in 2023 by the Amazon Environmental Research Institute (*Instituto de Pesquisa Ambiental da Amazônia*-IPAM). Creates a "sustainability index" involving land conflict, climate risk, environmental licensing, work situation and a whole set of regulations, including some international ones.
MapBiomas	A collaborative network formed by NGOs, universities, and technology startups, which produces annual land cover and land use mapping and monitors surface water and fire scars monthly with data from 1985. The project also validates and produces reports for each deforestation event detected in Brazil since January 2019 with the product MapBiomas Alerta.
AtlasAgropecuário	Online platform providing visualizations about where, what, how much, who, how and with what consequences agricultural production occurs in Brazil. Created by the Institute for Forest and Agricultural Certification and Management (Imaflora, *Instituto de Manejo e Certificação Florestal e Agrícola)* together with a geoprocessing laboratory at the University of São Paulo (USP/Esalq - Luiz de Queiroz College of Agriculture).
trase.earth	Data-driven transparency initiative linking deforested areas at the municipal level with trade flows of commodities such as beef, soya, and palm oil. Partnership between the Stockholm Environment Institute, Global Canopy, and others.
Green Label (*SeloVerde*)	A universal and transparent governmental socio-environmental traceability system assessing illegal deforestation in both direct and indirect cattle suppliers. It may also be extended to include other commodities (soya's monitoring of indirect suppliers is under development). Pioneered by the State of Pará, Brazil, and under adoption by the state of Minas Gerais.

I asked each interviewee a set of questions, and if needed, I sent follow-up questions via email. These questions were:

1. To what extent do your efforts to create a digital platform build on existing datasets and technological devices?
2. Judging from the specific technology applied in each case, what has been successfully implemented, and what were the challenges encountered during the development of the initiative?

3. Do companies and others (could) use this initiative to monitor deforestation and conflict in supply chains?
4. Have any concrete steps been taken to collaborate with the EU to transfer knowledge, technology, and experience tracking deforestation?
5. Did policies related to digital technologies in the EU or Brazil affect cooperation?

Most interviewees were conducted via zoom and lasted about one hour. For data protection, I always asked interviewees to sign a consent, including permission to record the interview and attribute name/position. Yet, since many of the topics discussed are commercially or politically sensitive, I decided on anonymity, naming only the selected initiative my interviewees contributed to and/or the institution they work for. This way, I could respect interviewees' privacy while fulfilling this study's important goal: To provide information on the existing initiatives, datasets, and technologies to help foster digital innovation.

I transcribed the first interviews manually. Later, I used the software Buzz[19], which builds on Open AI Whisper. As it provides Speech-to-Text functionality and runs on the researcher's computer, Buzz allows for privacy-preserving automatic transcription of the interview recordings without using any cloud services operated by third parties. I conducted interviews in Portuguese and translated transcripts into English.

Based on the data collected, I identified the shortcomings and contributions of Brazilian digital initiatives, focusing on capabilities needed when using digital technologies to provide information to trace and evaluate the socio-environmental impacts of commodity production and trade.

The next section presents the clustered findings of my case study. Before coming to the findings, I recognize that limitations/biases in my qualitative research methodology influenced the results. Specifically, an emphasis on political-institutional challenges (section 3.2 below) might be explained by my law and international relations background as well as the fact that many of my interviewees were part of their institutions' engagement team – usually the people responsible for giving interviews –, who are not necessarily technology experts. However, even technology experts I interviewed also highlighted political-institutional challenges.

Another reason for the prominence of political-institutional challenges is the context in which interviews took place: Between the 2022 presidential elections in Brazil and the start of Lula's new administration (January 1st, 2023). Yet, as a Brazilian closely following the national political turmoil in the previous years, I can hardly say the attention given to political-institutional problems is surprising. Above all, answers by interviewees reflect the recent Brazilian climate change and democracy crises and stress how one crisis feeds the other[20]. A striking example thereof is that, as I finish writing this study, a far-right coup attempt happened in Brazil (January 8th, 2023) with the alleged participation of the agribusiness sector (Zafalon, 2023).

[19] Version 0.5.8, MIT License Copyright (c) 2022 Chidi Williams https://github.com/chidiwilliams/buzz/

[20] According to Bruno Latour, in an interview given to a Brazilian newspaper, "if Brazil finds a solution for itself, it will save the rest of the world […] the political and environmental crises form a perfect storm in the country, where the main issues of the coming decades are visible" (Amaral, 2020, my translation).

3 Digital Initiatives in Brazil: Shortcomings and Contributions

This section presents the case study findings regarding the shortcoming and contribution of digital initiative in Brazil in two main parts. The first part focuses on technological innovations – as this research originally proposed – and the second part turns to political-institutional challenges connected with creating and applying digital initiatives, as it became the most prominent topic when conducting interviews.

Overall, relevant data exist. Yet, a few datasets still need to be made publicly available, some have quality problems, and many are scattered. By addressing one or more of these data challenges, an increasing number of digital platforms in Brazil offer high-quality data and tools for public and private action toward increased sustainable commodity production and trade. Technological solutions allow for better data capture, processing, and provision, often relying on a combination of computerised databases, software, and web technologies. To a lesser extent, AI and blockchain also play a role in data capture, processing, and provision. High costs and complexity help explain an untapped digital potential when it comes to using such cutting-edge technologies. Yet, a focus on technological challenges fails to give the full picture.

In Brazil, political-institutional rather than technological challenges impose a greater barrier to fighting deforestation. Specifically, parts of the Brazilian government and agribusiness rely on narratives and actions, including data misuse and the instrumentalization of policies related to digital technologies, which are incompatible with the current global climate crisis.

3.1 Technological Innovations per the Brazilian Case

To facilitate the presentation of the findings on data problems and digital solutions, I cluster results about technological innovations per the Brazilian case according to a three steps data management process (Figure 1). Through the analysis of my interview data, I develop this simple process pipeline to give an overview of the steps developers usually follow to build digital transparency platforms. In a few words, throughout the digital process, developers use multiple technologies (e.g., geo-satellites, software, web technologies, AI) to collect, process (treat, reinterpret, add, combine, etc.), and provide data useful for conducting compliance checks in agri-food supply chains (*data collection → data process → data provision*).

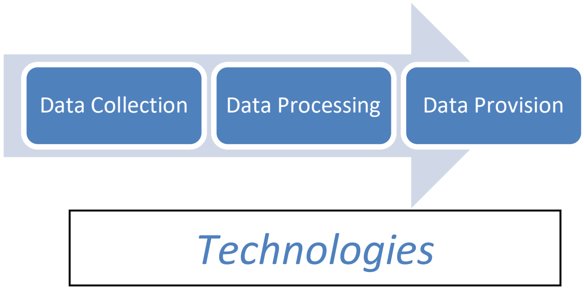

Figure 1, Own Work: General data management process to build digital transparency and traceability platforms. Technological tools help conduct each of its three main steps: data collection → data process → data provision.

Since the composability of digital artifacts for innovation is at stake (as argued in section 1.3), when distributed among actors/entities, this general data management process should be seen as circular: Ones' "*data provision*" is the source/base for others' "*data collection*" (figure 2). This way, each digital initiative can also work as a platform enabling others to innovate (Yoo et al. 2010). Thus, figure 1 is a simplification useful for presenting results: As an analytical lens, I take the three steps of a typical data process to assign each piece of information gathered in the literature and interviews to one of the three process steps. However, figure 2 helps recognizing that data availability challenges, for example, faced by some during data capture, as I discuss below, are often caused by choices regarding data provision made by others.

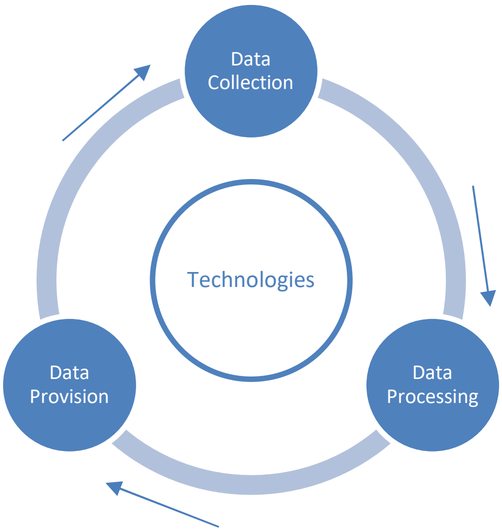

Figure 2, Own Work: General data management process is circular and distributed among actors: Ones' "data provision" is the source/base for others' "data collection", thus allowing for digital innovations.

For introducing data problems and digital solutions, I start by exploring examples of Brazilian initiatives that cover different sustainability challenges connected to commodity production (and sometimes trade) (3.1.1). Later, I narrow it down and delve into data provision initiatives focused on deforestation (3.1.2). Finally, I discuss issues related to technology cost and complexity (3.1.3).

3.1.1 Introducing Data Problems and Digital Solutions

As per my interviews, data is always the first step in any transparency and traceability initiative. And the overall perception is that data is available in Brazil, provided by public or private institutions.[21] Yet, data problems exist, including absent, low-quality, and scattered information. An increasing number of transparency and traceability initiatives in Brazil provide digital solutions to these data problems while aiming to offer subsidies for public and private actions in the sustainability realm.

First, regarding *data collection*, some Brazilian digital initiatives face data problems such as non-existent or unavailable data. For instance, creating a database from scratch was the first challenge faced by the Startup DataBoi[22]. In creating a biometric reader traceability app, DataBoi uses algorithms to scan the cattle's' snouts – which have unique and permanent markings like human fingerprints. To train an algorithm to recognize cattle's' snouts, developers first created a considerable database of cattle's' snouts pictures (*Interview `DataBoi Developer´*).

Another *data collection* problem relates to data inconsistency or precarious data generation processes. For example, according to developers of the Legal Amazon in Data Project[23], "informality in the [Legal Amazon[24]] region is very high. So, the official data has its limitations. This may be due to a lack of statistical representativeness or outdated data provision. In some cases, institutions use different structures for each data release, and it is very rare to find an organization that provides data through an API[25]" (*Interview `Legal Amazon in Data Project Developer´*).

In some cases, data may be of poor-quality demanding treatment as part of the *data processing step*. The Brazil's Rural Environmental Registry (CAR) is a prominent example. CAR is an electronic registry, compulsory for all rural properties, forming a database linking each landholder to land use in his particular property (Gibbs et al., 2015; Vacchiano, Santos, Angeoletto, & Silva, 2019; Vasconcelos et al., 2019). CAR is aimed at evaluating compliance with minimum legal conservation requirements (as in the Brazilian Forest Code[26]), but it has an "Achilles' heel" (Vacchiano et al., 2019, p.120): CAR is self-declaring, i.e., relies on self-reported data that environmental agencies must validate. Yet, the validation process is often delayed.

Technology can help to overcome substantive conflicting or false CAR information. Rajão et al. (2020, Supplementary Materials, p.6-8), for example, applied a set of algorithms to remove spatial inconsistencies and overlaps, cleaning-up the CAR data before using it in their research (Rajão et al., 2020, Supplementary Materials, p.6-8).[27] Another example starting to be implemented by the Brazilian

[21] This is also in line with what was mentioned in section 1.4 by reference to Fern (2021, p.1); May and Ozinga (2021a).

[22] More information about DataBoi at https://www.databoi.com.br/, last accessed on March 6, 2023.

[23] More information about the Legal Amazon in Data Project at https://amazonialegalemdados.info/, last accessed on March 6, 2023.

[24] The Legal Amazon corresponds to the area of operation of the Superintendency of Development of the Amazon (*Superintendência de Desenvolvimento da Amazônia*-SUDAM), delimited under Article 2 of *Lei Complementar* No. 124 of January 3rd, 2007.

[25] Application Programming Interface (API) is a set of standards that enables cross-platform communication. Through APIs, developers can create new software and applications that communicate with other platforms.

[26] According to the Brazilian Forest Code (Law 12.651/2012), landholders must conserve native vegetation in their property (e.g., 80% of properties in the Amazon, which means private owners may use the remaining 20% of private properties for growing crops or as pastureland – also called legal deforestation).

[27] When the overlapping area, i.e., "self-overlaps and/or overlaps with the INCRA's (*Instituto Nacional de Colonização e Reforma Agrária*) land tenure database" was less than or equal to 5% of the total area of the property,

Forest Service (SFB-*Serviço Florestal Brasileiro*) is a CAR Streamlined Analysis system (*Análise Dinamizada*).[28] Differently from manual analysis, a streamlined analysis checks CAR records in an automated way, identifies inconsistencies and automatically proposes its rectification. In its last stage, the CAR Streamlined Analysis verifies data adequacy to the Brazilian environmental legislation, and landowners with liabilities may voluntarily adopt vegetation recovery methods as proposed by an interactive information system (WebAmbiente) (Chiavari, Lopes, & de Araujo, 2021).[29]

Data scattered in multiple databases is another challenge in the data processing phase. Data must not only be collected (*data collection*) but also combined (as part of the *data processing*) and provided in a single and easy-to-understand digital platform (data provision). The Legal Amazon in Data Project mentioned above, powered by MacroPlan analytics, is one example of multiple data – a wide range of socioeconomic indicators (e.g., science and technology, demography, social development, education, economy, infrastructure, institutional, environment, sanitation, health, and safety) about the Legal Amazon states – being brought together (through *data processing*) in one integrated digital platform (*data provision*) to subsidize public policy discussions.

Another example is the System for Observation and Monitoring of the Indigenous Amazon (*Sistema de Observação e Monitoramento da Amazônia Indígena*-SOMAI[30]). According to its website, SOMAI combines in "one large online library" information about deforestation, land use, vegetation, biodiversity, hydrography, infrastructure, carbon stock and weather forecasts in indigenous lands. Created by the Amazon Environmental Research Institute (*Instituto de Pesquisa Ambiental da Amazônia*-IPAM), SOMAI was envisaged as a tool for reporting, in real-time, socio-environmental crimes occurring within indigenous lands. SOMAI uses official databases, but individuals can also plot information via cell phones through the Indigenous Climate Alert (*Alerta Clima Indígena*-ACI) app, a mobile extension of SOMAI.[31] Users can select SOMAI's different layers to compare whether there are interactions between selected data and generate maps and reports.

Also based on official but scattered databases, the TimberFlow Platform[32] creates, in a single platform accessible online, visualizations of all the stages and patterns of production, transport, processing, and commercialization of timber from the Amazon.[33] The TimberFlow Platform aims to help (national and

the record was classified as "CAR Premium" in contrast to the "CAR Poor" category (more than 5% overlapping) (Rajão et al., 2020, Supplementary Materials, p.7).

[28] Supported by the Startup gov.br, a program of the Ministry of Economy providing federal agencies with multipurpose teams to accelerate the digitalization of public services, the CAR Streamlined Analysis Platform was formulated by the Brazilian Forestry Service (SFB) and developed by the Federal University of Lavras (UFLA). Incipient implementation is happening in states like Amapá, Amazonas, Distrito Federal, Paraná and Rio de Janeiro.

[29] Landowners with liabilities may voluntarily adhere to an environmental regularization program (*Programa de Regularização Ambiental*-PRA) and use WebAmbiente, an interactive information system developed by the Brazilian Agricultural Research Corporation (*Empresa Brasileira de Pesquisa Agropecuária*-Embrapa) to assist decision making, which suggests vegetation recovery methods best suit to a given area.

[30] More information about SOMAI at https://somai.org.br/, last accessed on March 6, 2023.

[31] IPAM provided training and capacity building to indigenous peoples for using technologies within the framework of SOMAI and ACI (*Interview `IPAM Representative´*).

[32] TimberFlow Version 1.0 is based on a 2017 dataset from the State of Pará, and "[p]rovides map-based visualization of forest products shipping orders (GFs); [d]isplays transactions between every two companies and the user could filter data by company name and id, municipality, product, forest species or time period" (Lentini & Vieira, 2020, slides 25-33). Limitations of Version 1.0 include: "User interface vastly compromised by dataset increase" (ibid.).

[33] Beyond dispersed data, developers of the TimberFlow Platform faced additional data challenges. Some databases used as sources were made public only recently (e.g., the Document of Forest Origin (*Documento de Origem Florestal*-DOF), issued by the Forestry Products Origin Control National System (*Sistema Nacional de Controle da Origem dos Produtos Florestais*-Sinaflor) since 2006, which started to be opened in 2018). Others are still

international) buyers to map their timber chains, a first step in evaluating risks. Resulting from a partnership between the Institute for Forest and Agricultural Certification and Management (Imaflora, *Instituto de Manejo e Certificação Florestal e Agrícola*) and an academic group in mathematical and computational sciences (*Instituto de Ciências Matemáticas e de Computação*-ICMC at the University of São Paulo-USP), all its programming is open source with codes that can be used by other organizations. In its 2.0 version, data is aggregated at the municipality level, and data download and sanitization became automated (Electronic Design Automation-EDA), improving application performance and robust frontend/backend architecture (Lentini & Vieira, 2020, slide 32). In the word of one of TimberFlow creators: "We are very excited about this platform! I cannot minimize it, because we, the civil society, basically went ten years without information […] So, I think that, very humbly, what the platform tries to bring is a way for society to see this data" (*Interview `TimberFlow Developer´*).

Finally, a platform called Applied Territorial Intelligence, scheduled for launch in 2023 by IPAM, brings together several databases and is even called "the Netflix of sustainability indicators" by its developers (*Interview `IPAM Representative´*). Focusing on the territorial scope, developers try to create a kind of sustainability index or parameter that involves land conflict, climate risk, environmental licensing, work situation and a whole set of regulations, including some international ones. Destined to be a multifunctional and multipurpose platform, the Applied Territorial Intelligence system intends to reach different audiences and be used for different purposes: "Design and implementation of territorial management policies; business and investment decisions; and society to monitor whether public and private activities are effectively bringing positive or negative impacts to the territory and the people who live there" (*Interview `IPAM Representative´*). For this, software was developed internally to collect information, and other technologies are being explored: "I always tell our team to think with the vision of a public or business administrator, who wants to press a button and have a quick response in a single page and not a 300-page encyclopaedia. So, we need to use AI" (*Interview `IPAM Representative´*).

The Legal Amazon in Data Project, SOMAI, the TimberFlow Platform, and the upcoming Applied Territorial Intelligence are examples of Brazilian digital platforms in which data is created, captured, treated, and combined to provide general information on what happens in a specific territory. In the next paragraphs, I concentrate on data challenges and solutions by focusing on Brazilian digital transparency platforms focused on commodity-driven deforestation.

3.1.2 Digital Initiatives on Commodity-Driven Deforestation

Regarding *data collection*, the backbone of Brazilian non-deforestation initiatives consists of two satellite-based monitoring systems developed by the Brazilian Institute for Space Research (*Instituto Nacional de Pesquisas Espaciais*-INPE): PRODES (*Projeto de Monitoramento do Desmatamento na Amazônia Legal por Satélite*[34]), consolidated in the 1990s, and, since 2004, DETER (*Sistema de*

not publicly available (e.g., the System for Commercialization and Transportation of Forest Products (*Sistema de Comercialização e Transporte de Produtos Florestais*-SISFLORA) of the Brazilian states of Mato Grosso and Pará). Access to SISFLORA-Pará was granted through the Brazilian law on access to information (LAI-*Lei de Acesso à Informação*, 12.527/2011), while technical cooperation agreements guaranteed access to SISFLORA-Mato Grosso. Additionally, the platform cannot yet show the flow of timber per consuming country as the Export Document of Forest Origin (Export DOF) is not publicly available (*Interview `TimberFlow Developer´*). Other minor problems the TimberFlow Platform faces include slightly different data covering periods and updating. More information about TimberFlow at https://timberflow.org.br/, last accessed on March 6, 2023.

[34] More information about PRODES at http://www.obt.inpe.br/OBT/assuntos/programas/amazonia/prodes, last accessed on March 6, 2023.

Detecção de Desmatamentos em Tempo Real[35]). PRODES calculates annual deforestation in the Legal Amazon and DETER detects deforestation in real-time. Because of their different data configurations (e.g., level of aggregation and temporality), each system achieves different results (Rajão & Jarke, 2018). Rajão and Jarke (2018) show that their complementary features have shaped environmental activism and public policy toward the Amazon rainforest. PRODES aggregated data has been used to press the Brazilian government to create policies and legislations to fight deforestation (e.g., the creation of the 2003 Plan to Control and Fight Deforestation-PPCDAm). DETER real-time disaggregated monitoring data has allowed targeted policy interventions (e.g., environmental law enforcement activities conducted by the Brazilian Institute of the Environment and Renewable Natural Resources-IBAMA).

Importantly, PRODES and DETER are key data sources that have been combined (through *data processing*) with other datasets to link deforestation to land use. For example, by cross-tabulating georeferenced data from PRODES with registries of land holdings and regularisation such as the Brazil's Rural Environmental Registry (the abovementioned CAR), Brazil's Federal Public Defender's office (*Ministério Público Federal*-MPF) created an instrument called *Amazônia Protege* (Amazon Protects), which detects illegal deforestation at the property level (May & Ozinga, 2021a, p.19).

NGOs, too, have developed their own monitoring deforestation systems and used them in combination with different datasets for *data provision*. MapBiomas[36], for instance, is a collaborative network showing the links between deforestation and commodity production in Brazil by crossing CAR registries with its own deforestation alerts, land use, and land cover maps (Fern, 2021, p.2). According to MapBiomas' website, it uses Google Earth Engine platform technology and provides scripts to facilitate access to MapBiomas collections, which can be accessed directly at QGis through a PlugIn. The codes used by MapBiomas to produce maps are available in the MapBiomas code repository on GitHub[37], and a Temporal Visual Inspection (TVI) tool facilitates and streamlines the process of interpreting satellite series for training and calibrating image classification algorithms.

Another example of a fully digital application that offers visualisations of land use changes inside property boundaries is the AtlasAgropecuário, created by Imaflora together with a geoprocessing laboratory at the University of São Paulo (USP/Esalq - Luiz de Queiroz College of Agriculture). In the AtlasAgropecuário, several databases (e.g., MapBiomas, CAR, INCRA-*Instituto Nacional de Colonização e Reforma Agrária* registries) are joined on a mainframe supercomputer using SQL language to provide visualizations about, according to Imaflora's website[38], "where, what, how much, who, how and with what consequences [agricultural] production occurs in Brazil".

Despite their importance, initiatives like MapBiomas and AtlasAgropecuário fall short of telling an important part of the story: the whole journey undertaken by a commodity after it leaves the production area. In other words, "**the missing link is with the supply chain in the EU**" or in any other end-market (Comments by Tassio Azevedo, coordinator of MapBiomas, according to a webinar report by Fern, 2021, p.2, emphasis added). Others refer to this problem:

[35] More information about DETER at http://www.obt.inpe.br/OBT/assuntos/programas/amazonia/deter/deter, last accessed on March 6, 2023.

[36] More information about MapBiomas at https://mapbiomas.org/, last accessed on March 6, 2023.

[37] MapBiomas Processing Codes Depository available at https://github.com/mapbiomas-brazil, last accessed on March 6, 2023.

[38] More information about AtlasAgropecuário at https://atlasagropecuario.imaflora.org/, last accessed on March 24, 2023 and it was down for maintenance.

> “We clearly **still have insufficient knowledge between trade and commodity production and need data to show a clear link between e.g. a soybean from a deforested area to the product on the EU market**. For human rights violations, this link is even more difficult. […]. The [EU] Observatory could create an environment for **collaboration and cooperation between groups monitoring deforestation from the third sector, as well traders and the financial sector**” (Comments made by Peter May, consultant and professor at the Federal Rural University of Rio de Janeiro, according to the webinar report by Fern, 2021, p.2, emphasis added).

Fortunately, robust trade and supply chain datasets have been created to address this gap. It is worth highlighting trase.earth[39], a data-driven transparency initiative that stands out by linking deforested areas at the municipal level with trade flows of commodities such as beef, soya, and palm oil. Although Trase is not a Brazilian initiative, Brazil was the first place analysed due to, among others, the overall data availability in Brazil:

> “The priority was given to where the greatest impact is Besides being the country with the highest deforestation index to produce commodities, Brazil is also the country with the most transparency. It is where there is more data and information publicly available. So, Brazil was the perfect candidate to start Trase’s application. Although it is not a Brazilian initiative, Trase’s founders speak Portuguese, circulate very well in Brazil, and have contact with several Brazilian NGOs and researchers” (*Interview `Trase Contributor´*).[40]

Trase “calculates the deforestation risk incurred by each buyer, based on the deforestation happening in the municipalities from which they source products” (May & Ozinga, 2021b, p.12). By using a Spatially Explicit Information on Production to Consumption Systems (SEI-PCS) model (Godar, Persson, Tizado, & Meyfroidt, 2015), Trase developers unlocked the power of spatially explicit datasets[41] to map supply chains’ net effect of deforestation on the ground. To automate and make their basic model software more accurate, Trase resorts to, among others, ML and recurrently publishes their applications’ new versions and outcomes (*Interview `Trase Contributor´*).[42]

According to their website, by accessing trase.earth, companies, financial institutions, governments, and campaigning organisations worldwide can make better decisions about nature, forests and people. Besides, Trase, together with other institutions (Imaflora, *Instituto Centro de Vida*-ICV), has been releasing issue briefs uncovering global market exposures (Vasconcelos et al., 2020; Vasconcelos et al., 2019).[43] Vasconcelos et al. (2020), for example, combined PRODES, CAR, Trase, and other data to find that, in the state of Mato Grosso, Brazil, 80% of the illegal soya-driven deforestation takes place in only 2% of the total number of its soya farms (400 farms, mostly large properties). Also, they found that “[o]ver 80% of the soy produced on farms where illegal deforestation took place is estimated to be exported to global markets – 46% to China and 14% to the EU” (ibid., p.1). Specifically,

[39] Trase is a partnership between the Stockholm Environment Institute, Global Canopy, and others. More information about Trase at https://www.trase.earth/, last accessed on March 6, 2023.

[40] Brazil was the most transparent when Trase was launched, but Indonesia has more transparency today. However, the impact of agricultural commodities for deforestation and related GHG emissions remains much larger in Brazil than in Indonesia (*Interview `Trase Contributor´*).

[41] Trase’s model builds on models like the multi-region input-output analysis (MRIO) by Kastner et al. (2014) and the Input-Output Trade Analysis (IOTA) model IOTA, developed by the Stockholm Environment Institute (SEI) York centre (https://www.york.ac.uk/sei/sei-york-tools/).

[42] Changes in data availability impacted 2019-2020 Trase data on Brazilian soy and deforestation, forcing Trase to adapt its model, causing not only delays in its recent release but also making it non-comparable with the 2014-2018 data (Reis & Prada Moro, 2022; Trase, 2022a, 2022b). More on that in section 3.2.

[43] Trase’s methodological work is regularly published in peer-reviewed journals and its model is open (*Interview `Trase Contributor´*).

a third of the EU's total imports of Brazilian soya comes from Mato Grosso, and 20% of that is likely to be contaminated with illegal deforestation (ibid., p.1).

These results were possible due to researchers' reliance on multiple technological tools. As in Vasconcelos et al. (2020, Methodological Note), "georeferenced datasets were standardized in a unique system of coordinates with conical projection according to Lambert and datum SIRGAS 2000". In Vasconcelos et al. (2019, Methodological Note), "all spatial procedures were based on map algebra operations and were carried out in ArcGIS 10.4".

Remarkably, scientists at the Federal University of Minas Gerais (UFMG), Brazil developed an innovative geoprocessing tool – Dinamica EGO[44] **–** to handle big data challenges. Using this high-powered software, researchers were able to treat and merge existing heterogeneous datasets (including CAR, PRODES, AgroSatelites, Trase) into a common geospatial database while overcoming processing and storage capacity problems. Dinamica EGO allowed researchers to run full parallel processing tasks, reducing processing time without a need for cloud computing or large servers, and frog-leap spatial resolution from 60 to 5 meters (ibid., Supplementary Materials, p.4-5).[45] The research group, which today has about 40 people, showed not only a high scientific generation capacity. They transformed scientific capacity into technological capacity, i.e., "we crossed the famous innovation valley of death, because one thing is the idea, another thing is the product" (*Interview `SeloVerde's Information System Developer'*).

Relying on these technological innovations, a study recently published in Science Magazine under the heading "*The rotten apples of Brazil's agribusiness*" is one of the first to "explicitly link illegal deforestation on individual rural properties to their agricultural production and exports to EU countries" (Rajão et al., 2020, p.246). Rajão et al. (2020, p.246) show that "roughly 20% of soy and at least 17% of beef exports from both [Amazon and Cerrado] biomes to the EU may be contaminated with illegal deforestation". Besides, they pinpoint the 2% of the properties in the Amazon and Cerrado biomes responsible for 62% of all potentially illegal deforestation, displaying a small but very destructive portion of the Brazilian agribusiness sector (both farmers and traders) that fails to comply with Brazilian environmental laws (ibid., p.248). Moving from paper to policy, a Green Label (*SeloVerde*)[46] scheme is being implemented in the Amazon state of Pará and relies on the technical assistance of Dinamica EGO developers. Differently from trase.earth, which allows tracing commodities back to municipalities, the SeloVerde system provides transparent traceability of direct and indirect suppliers of cattle and soya producers at the farm-level.[47]

Based on the overview of selected Brazilian initiatives conducted so far, two general preliminary conclusions about data problems and digital solutions can be drawn: 1) To a large extent, official data exist (though in varying quality and scope) and is publicly available in Brazil, enabling digital innovation as shown in the initiatives presented above; and 2) Web technologies, computerised databases, software, and other technological tools help to capture data, process low-quality and scattered figures, provide information in open formats and redistribute it in more easy-to-access digital platforms. Yet,

[44] More information about Dinamica EGO at https://csr.ufmg.br/dinamica/ and https://csr.ufmg.br/radiografia_do_car/pt/home/, last accessed on March 6, 2023.

[45] As previously mentioned, Rajão et al. (2020, Supplementary Materials) also resorted to algorithms for removing CAR spatial inconsistencies and overlaps and validated their Forest Code modelling exercise by comparing results with those from IPAM and Imaflora.

[46] More information at https://www.semas.pa.gov.br/seloverde/, last accessed on March 6, 2023.

[47] SeloVerde is a universal, governmental, and transparent initiative, which includes all farmers in the system, is led by the government of Pará, and includes direct and indirect suppliers *(Interview `SeloVerde's Information System Developer').*

interviewees called attention to the fact that high cost and complexity hamper the use of more advanced technologies, such as AI, in their digital platforms, which could facilitate data capture, processing, and provision.

3.1.3 Technologies' High Cost and Complexity

Although modern traceability means like DNA analysis, isotope testing, and livestock iris code exist, their implementation is expensive. The same happens with AI and blockchain, which could be combined with existing initiatives as those presented above to improve data management processes. Take blockchain, for example. From big retailers' perspective, "everybody runs away from blockchain because it is really expensive. When we started discussing it, we saw the budgets and concluded that we must pass on the costs, but consumers do not want to pay for it" *(Interview `European Supermarket Supply Chain Manager´*). Also, no farmer wants to bear the high costs of blockchain and other technologies (*Interview `DataBoi Developer´*). In this regard, experts call attention to the fact that the best technology is not the most modern one. The best technology is the one that farmers can use on their farms – also referred to as "the technology myth" (IPAM, 2022b, p.3) – or is simply available, reusable, adaptable, etc. (Stuermer et al., 2017), out of which initiatives can build applications.

In the Brazilian experience, we learn that actors do not necessarily need to bear high technological costs since open digital platforms and data are the infrastructures – the lower layers in the "layered-modular architecture" (Yoo et al. 2010) powering the higher layers of services, applications – enabling actors to innovate. Using such services and applications, supply chain managers in European traders/buyers/businesses, for instance, can identify socio-environmental risks connected to particular commodities with just a few clicks (Marzano, 2023). But these digital platforms rely on a combination of computerised databases, software, and web technologies with which data is captured, processed, and provided. Despite a few of these applications and services now manage to link deforestation with commodity production and sometimes trade, high cost and complexity hinder the use of cutting-edge technologies to their full potential.

The fact that the Legal Amazon in Data Project, for example, is a "minimum cost initiative" forced its developers to use "very simple" IT languages – basically R, Python, and PHP[48] (*Interview `Legal Amazon in Data Project Developer´*). Low funding also led its developers to reduce their original data scope – for instance, they used a lot of web scraping but lacked access to AI algorithms, which would allow them to, among others, bypass the reCAPTCHA test needed to access some databases. Similarly, developers of the TimberFlow Platform manifested their intentions to have AI routines with which they could easily produce a set of alerts, but this is, for now, unfeasible budget-wise (*Interview `TimberFlow Developer´*).

Other problems raised by some developers refer to data storage and documentation. For instance, Trase uses Amazon, Google, etc. to store and process data as it requires a large computational capacity. "These are things you cannot process in a normal computer. It must be supercomputers" (*Interview `Trase Contributor´*). While technological tools help address these challenges, a minimum organizational structure is also needed. Trase is hiring a data administrator – which points to an interesting aspect underlying all initiatives investigated here: transdiciplinarity is needed.[49] Not only to deal with

[48] Although these listed are all higher-lever programming languages, and each one comes with their own ecosystem, PHP, for instance, is a server-side scripting language embedded in HTML in its simplest form.

[49] According to (Nicolescu, 2014, p.19), while multidisciplinarity involves studying a research topic in several disciplines at the same time, and interdisciplinarity concerns transferring methods from one discipline to another with its goals still remaining within the framework of disciplinary research, transdisciplinarity concerns that which is at

highly complex technologies but also the intricacies of commodity-driven social and environmental problems.

For instance, despite being a socio-environmental organisation, Imaflora has an internal group of specialists dedicated to geotechnology and information technology – as is often the case now with environmental activism (see Rajão & Jarke, 2018)[50]. For building the TimberFlow Platform, creators relied on the work of engineers, information technologists, mathematicians, etc. However, many of these experts had no experience with wood chains (*Interview `TimberFlow Developer´*). Hence, different expertise had to be combined: Conservation specialists, for example, classified forest products into 13 categories to facilitate consultation. This relates to an interesting comment by one of the interviewees:

> "Technology is not only the computer, the data, the model running the software. It is how you organize all of this, which is not easy. There is a "**social technology**" needed when it comes to the interactions between experts from different fields. In our team, there are philosophers, anthropologists, social scientists, data engineers, etc." (*Interview `Trase Contributor´*).

This excerpt shows having a team with people from different backgrounds is challenging. As part of the solution to transdisciplinarity challenges, Trase also resorts to digital artifacts (e.g., SplitGraph, Metabase, Observable, Asana), which offer easy-to-access interfaces between different software so "contributors who are not IT experts but need access to information can use it without spending a whole day trying to crack codes" (*Interview `Trase Contributor´*).

In sum, technologies' high cost and complexity demand financial resources and transdisciplinarity capacities, without which the digital potential of cutting-edge technologies remains, to some extent, untapped. Although funding for capacity building and access to modern technologies would facilitate capturing, processing, and providing data, digital platforms in Brazil have also been created with less expensive technologies. In the next section, I turn to the second cluster of findings.

3.2 Political-Institutional Innovations are Needed

Whereas I started this research interested in digital technologies' role in implementing deforestation-free commodity chains, interviewees seemed more eager to talk politics (see Methodology and Limitations, section 2). "In Brazil, we do not have a technological but a political-institutional problem!" – virtually all stakeholders made similar statements. Specifically, interviewees mentioned a lack of political will from entities and individuals in the agribusiness sector and governmental institutions as the main barrier to fighting deforestation in Brazil. Also, interviewees highlighted things got worse during Jair Bolsonaro's presidency (2018-2022).

During interviews, stakeholders mentioned several examples of political-institutional challenges related to the creation/application of digital sustainability initiatives. First, coordination challenges between different chain actors were considered a key barrier to socio-environmental upgrading in the Brazilian agri-food sector. While this problem encompasses the abovementioned question of who pays for the additional costs of certification and technology use, interviewees also refer to a need to harmonize protocols and standards. The plethora of different sustainability requirements confuses producers and consumers alike and increases costs, with suppliers having to comply with multiple standards to

once between, across and beyond disciplines: "Its goal is the understanding of the present world, of which one of the imperatives is the unity of knowledge".

[50] Rajão and Jarke (2018) discuss data transparency's role in transforming socio-environmental activism and policymaking in the Amazon rainforest, and refer to, among others, NGOs developing their own data practices, enriching or curating datasets.

access specific markets (Thorstensen & Mota, 2019). Resistance to harmonizing protocols and standards comes from powerful chain actors willing to impose their own schemes but also NGOs, who want to sell their own private certification. As one interviewee puts it, a similar problem applies to technological solutions: "Today, you have a competition to see who has the best solution. There is a market in Brazil, a tradeshow ("*feira*"), with each institution trying to show theirs as the best technology".[51]

It became clear that, even for participants of the same production chain, upstream and downstream actors have very different interests hindering the construction of a positive agenda on socio-environmental commitments. On the one hand, European buyers lack knowledge and trust in Brazilian suppliers – which the availability of high quality, reliable and trustworthy data could help to build or regain. To avoid reputational risks, buyers have been resorting to various measures. As a first step, big retailers usually ask for certification (*Interview `European Supermarket Supply Chain Manager´*).[52] However, when possible, companies seek local alternatives (e.g., the Donau Soja Organisation[53]) and go as far as to completely renounce specific foreign suppliers (e.g., ALDI Nord excluded Brazilian beef in their supply chains[54]). ALDI Nord (2022) justified its decision by arguing that Brazilian beef supply chains are highly complex and hard to monitor. Given rising deforestation rates and fires in Brazil, which have been constantly denounced in the European media, retailers also wanted to avoid reputational risks connected to a reality they do not understand and stakeholders they do not necessarily trust (*Interview `European Supermarket Supply Chain Manager´*).[55]

On the other hand, Brazilian suppliers' general opinion is that Europeans always find ways to justify adopting protectionist measures (see Marzano, 2021b; Marzano, 2022). Indeed, there is much criticism of what is seen as a punitive approach to sustainability requirements in agricultural production and trade coming from abroad. As one interviewee puts it: "This whole agenda has always come upon them [farmers] as punishment: fines, moratoria, exclusions, embargoes…". Although positions vary depending on how directly suppliers interact with and are dependent on specific foreign buyers, Brazilian suppliers recently adopted an increasingly `open clash approach´ in negotiation processes like the EU-Mercosur Trade Agreement or reaction to the EU Deforestation Regulation.

As per my interviews, such changes result from sustainability issues becoming very politicized and polarized in Brazil in recent years. Brazilian suppliers, backed by the federal government (especially in the past four years), increasingly adopted a very conservative and sometimes even climate denialistic discourse – astonishing as it goes against the agribusiness sector's own economic interests. After all, damages to the Brazilian socio-environmental image abroad have only increased agribusiness

[51] Another interviewee highlighted, however, that not only cooperation but also competition between institutions in providing better solutions can be positive. What is reprehensible is when some do not want to offer solutions but only advance their own interests.

[52] In some cases, sustainability requirements are accompanied by support to suppliers in implementing better production practices. For instance, the REWE Group, in cooperation with Fairtrade, offers training programmes designed to provide better income and improved living and working conditions for small orange producers in Brazil (REWE, 2021, p.226).

[53] Member companies of the Donau Soja Organisation support the cultivation of deforestation- and GMO-free soya in the Croatian region of Zupanja. More information about the Donau Soja Organisation at https://www.donausoja.org/, last accessed on March 6, 2023.

[54] The renunciation of Brazilian beef applies to all new supplier contracts for fresh and frozen meat from summer 2022 (ALDI, 2022, p.10). More information about Aldi's commitment at https://www.aldi-nord.de/unternehmen/verantwortung/umwelt/forest-protection.html, last accessed on March 6, 2023.

[55] Although one could question the impact of retailer' decisions to exclude Brazilian beef in their supply chains given that Brazilian meat makes ups for a very small part of the EU market (e.g., less than 1% of ALDI SOUTH Group's is from Brazil (RepórterBrasil, 2021)), the decision per se is significative as it shows Brazilian products being negatively perceived abroad.

exposure to unilateral demand-side obligations such as the EU Deforestation Regulation (see Marzano, 2022). Controversial positions towards socio-environmental issues are reflected in how governmental institutions and agribusiness entities engage with data transparency. While, in some cases, low access to technologies and lacking capacities result from regional socio-economic inequalities in Brazil, in others, the problem refers to poor governance and even a conscious decision to hold or misuse data and data policies.

Take the Brazilian CAR system, for example. While the latest technological advance called CAR Streamlined Analysis (mentioned above in section 3.1) seems promising to overcome the need to validate farmers' self-declared information about the conservation areas in their properties, there is a prior problem in the CAR model itself (*Interview `SeloVerde's Information System Developer´*). In the CAR Streamlined Analysis, you first need to rectify the features of the terrain and only then regularize the property. It wastes time by blocking the entire process, which should instead focus on environmental legal compliance:

> "CAR's goal is not to make reliable cartography of Brazil but to identify non-compliant producers and have them compensate or restore forests. If a producer wrongly depicted a river on his property, but the forest is in the right place, why do I have to keep asking him to rectify his record? What is the gain in terms of implementing the Forest Code? To tackle this problem, the **CAR 2.0** project, being deployed in some municipalities of Pará and Minas Gerais, does a 100% automated analysis while ignoring some features declared by the producer. If no environmental liability is detected, that's it! It's over! Goodbye! That record gets out of the queue and let us focus on where the problems really are." (Interview `SeloVerde's Information System Developer´).

Another example of an institutional rather than technological problem is the Amazon Soya Moratorium, created in 2006 and considered the world's main zero-deforestation benchmark (WWF-Brasil, 2016). The Soya Moratorium is a voluntary agreement not to trade nor finance soya produced in areas deforested in the Amazon biome from 2008 onwards (Bastos Lima & Persson, 2020, p.5). Despite some important results (Gibbs et al., 2015; Rudorff et al., 2011), the Moratorium's main weakness is that compliance does not happen at the farm-level – it monitors only areas of the land where soya is grown. Hence, companies by from farms that may still be linked to deforestation connected to other crops or pastures (Vasconcelos et al., 2020).

However, more worrying than poor governance is when state and non-state actors consciously decide to withhold information or misuse data. Interviewees mentioned that companies and state actors often instrumentalize the Brazilian data protection regulation (LGPD-*Lei Geral de Proteção de Dados*, 13.709/2018)[56] to avoid granting access to data. Connected to the idea that data is power, some pointed out that data hiding, or data opacity, could be attributed to a biased nationalist ideology permeating the Brazilian state bureaucracy and the agribusiness sector. Since data expose actors to scrutiny – and thus potentially to substantial criticism – there are cases in which data access is denied upfront or actors pull back in data availability.[57]

[56] The LGPD was enacted to protect the fundamental rights of freedom and privacy and the free development of the personality of natural persons. It covers processing personal data, including in digital media, by natural persons or legal entities governed by public or private law (Article 1). While the LGPD is mostly focused on commercial uses of personal data, instrumentalizing this law to deny access to socio-environmental information about commodity production distorts its purpose and disregards its specific exceptions about data use for public policy and research applications (*Interview `SeloVerde's Information System Developer´*).

[57] Digital rights movements in Europe have been fighting for more transparency and freedom of information laws, including a right to access data about matters of public interest (e.g., environmental data). I thank Malte Reißig for calling my attention to such movements.

An example recurrently referred to by interviewees is changes in the official Brazilian trade balance release due to the possibility that users could identify the socio-environmental and economic performance of specific companies. During Temer and Bolsonaro's presidencies, a new ComexStat platform replaced the previous governmental online consultation system for foreign trade statistics (Aliceweb). With that, Trase and others lost access to important data used in their digital platforms, such as those connecting producing municipalities and export port facilities (*Interview `Trase Contributor´*).

Similarly, companies often hold on to their data, denying access by arguing that it contains commercially sensitive information. Indeed, since traders compete for both commodity suppliers and buyers, they often do not want to share information about their contracts. Some sectorial entities of the Brazilian agribusiness even menaced to sue Trase because their data is "completely wrong and damage traders' reputation" (*Interview `Trase Contributor´*). However, companies often deny access when asked to share data so developers can calibrate their models. According to the interviewee, in the Indonesian palm oil sector, a more cooperative relationship with Trase was possible.

Government and agribusiness' short-term vision went as far as to include ideological appropriation of data, denounced by researchers as "creative statistics", "fake controversies', and "pseudo-facts" on deforestation (as in Rajão et al., 2022; Vacchiano et al., 2019). The dismantle of pre-existing knowledge infrastructures and transparency regime under Bolsonaro's government has also been criticized as counter-activism in an effort "to establish a competing *alethurgy*, i.e an assemblage of procedures and rituals that claim to manifest the "truth" about the Amazon" (Oliveira & Siqueira, 2022, p.1). In short, these terms refer to the misuse of scientific credentials by resorting to, among others, poor data such as the self-declared conservation units declared by farmers (CAR) to deny the existence/size of the socio-environmental challenges in Brazil.[58]

Under these grim political circumstances, Brazilian research centres and NGOs have stepped in. MapBiomas and others (e.g., the Deforestation Alert System for Legal Amazonia (SAD) by Imazon-Amazon Institute of People and the Environment[59]) became reliable "go-to source[s]" under Bolsonaro's term when lack of funding caused delays on INPE releases (May & Ozinga, 2021a, p.19-20). However, governmental and agribusiness institutions still showed resistance toward data transparency and non-deforestation enforcement even when technical support was offered.

While SOMAI, for example, used information from its digital platform to alert IBAMA about environmental crimes in indigenous areas, the link with this environmental body was severed during Bolsonaro's term. The SOMAI team decided to continue developing the platform at the request of the indigenous people, who, "in a non-systematic way, use the data to report crimes to the *Ministério Público*, or publish open letters, for example" (*Interview `IPAM Representative´*). Another example of resistance to adopting digital initiatives concerns the SeloVerde scheme, which, although implemented by the subnational government of Pará with the technical assistance of the software developers, has been under attack by cattle farmers, who want to restrict access to the information (de Abreu, 2021)[60].

In sum, many in the Brazilian government and agribusiness, which should be leading the fight against deforestation, instead, have lacked political will. It became visible in their instrumentalization of data

[58] A prime target of such criticism is Evaristo de Miranda, a researcher at Embrapa, who has been called the hidden fabricator (*fabulador oculto*), guru, and ideologist of Bolsonaro's environmental policy (Esteves, 2021).

[59] More information about Imazon-SAD at https://imazon.org.br/publicacoes/faq-sad/, last accessed on March 6, 2023.

[60] Cattle farmers argue that access to SeloVerde should be granted only to themselves and public servants, thus excluding consumers and others (de Abreu, 2021).

and data policies to reinforce obsolete positions and even adopt plain climate denialism. Looking at Brazil, data is (publicly) available enabling digital innovation (despite all the challenges/problems), and digital technologies are also available to deal with and support data management, despite challenges of cost and complexity. Still, political-institutional challenges hinder using digital initiatives to their full potential. Going back to the general digital data management process introduced above (Figure 1), for each of its three steps, namely *data collection, data processing,* and *data provision*, I identified shortcomings and contributions in the Brazilian experience, and summarized them in Figure 3.

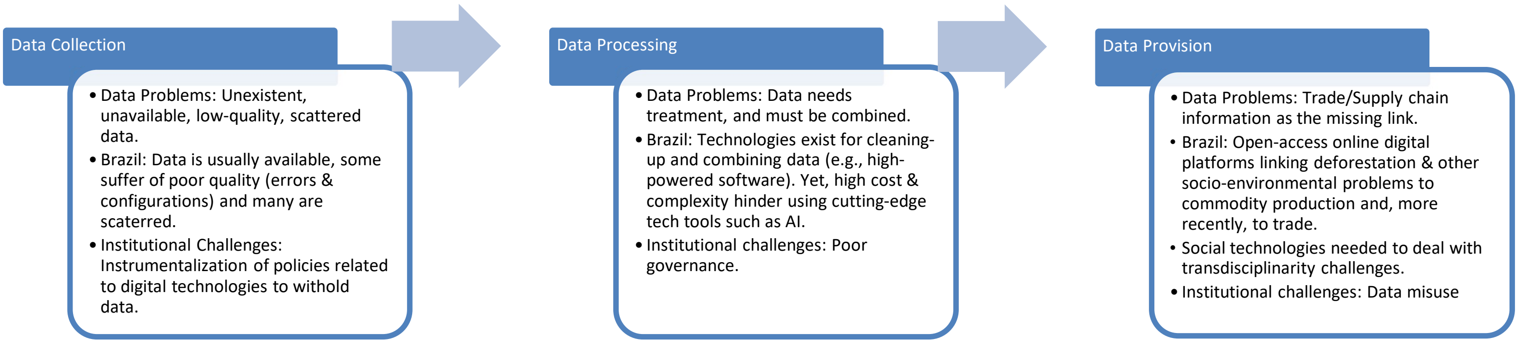

Figure 3, Own Work: Technological and Institutional Shortcomings and Contributions from Brazilian Initiatives as per the General Data Management Process.

After recognizing the shortcomings and contributions of the Brazilian experience with digital transparency and monitoring platforms, especially the pressing need for more institutional than technological innovations, the next section proposes pathways for non-deforestation and other similar policies moving forward.

4 Policy Recommendations and Conclusion

While it is still unclear whether the EU regulation will catch on internationally, depending on China and other major consuming countries following suit with similar requirements (Marzano, 2021b, 2022, 2023)[61], some actions can be taken now to help protect biodiversity and communities worldwide. Based on the findings of this study, I propose combining the EU approach with existing digital solutions in a collaborative manner to conduct due diligence compliance checks[62] while addressing Brazilian political-institutional challenges hindering socio-ecological advancements.

It is important to recognize that collaborative efforts between the EU and Brazilian stakeholders already exist. Most of the developers of and contributors to Brazilian digital initiatives I interviewed mentioned some collaboration with the EU, ranging from a broad European interest to knowing existing initiatives to financial support. IPAM, for instance, was asked to map initiatives and identify potential technologies that the EU could use to do compliance checks in the framework of the Deforestation Regulation. Focused on cattle ranching, IPAM organized a dialogue series (IPAM, 2022a, 2022b), which resulted in a report that provides an overview of the traceability arrangements applied to beef and leather chains in Brazil (Froehlich et al., 2022).

When it comes to interactions between digital platforms and the EU, Trase, for example, considers the EU Deforestation Regulation itself to be one of the most successful examples of Trase's impact (*Interview `Trase Contributor´*).[63] Trase also feels responsible for changes adopted by the EU Parliament, such as the expansion of the regulation's scope to encompass conversion of other wooded lands in addition to forests in its definition of deforestation (Parliament, 2022, Amendment 88, Article 2§1(1)) – a decision later reversed[64]. Requested by the Greens/European Free Alliance (EFA) group in the European Parliament, Trase produced an in-depth and comprehensive study on the amount of deforestation that would be addressed depending on the different scopes and definitions of forest adopted in the legislation (Richens, 2022; Trase, 2022c). Besides, Trase has developed studies, monitoring,

[61] As a major commodity-consuming country, China must be on board if demand-side non-deforestation pressures are expected to be truly effective (Marzano, 2021b, 2022, 2023). In its Deforestation Regulation, the EU recognizes China's importance by proposing dialogue and cooperation with other big consumer countries to encourage, among others, their adoption of similar deforestation-free measures (Council, 2022b, Recital 20 and Article 28§5).

[62] Despite the examples mentioned in this study, the language barrier is one important challenge hindering international buyers and others from using some Brazilian digital platforms. As it often happens to sustainability reports from Brazilian companies, "almost everything is in Portuguese" (*Interview `European Supermarket Supply Chain Manager´*). For example, the Legal Amazon in Data Project plans not only to add more socio-economic indicators: "We also want to translate the information into Spanish and English. Today it is only in Portuguese, due to these resource limitations" (*Interview `Legal Amazon in Data Project Developer´*).

[63] For monitoring their impact, Trase also uses a digital system called MEL-Monitoring, Evaluation and Learning (*Interview `Trase Contributor´*).

[64] While adding conversion of other wooded lands in the definition of deforestation would have included savannah landscapes like the Brazilian Cerrado biome in the regulation's scope, the Parliament and the Council decided it will evaluate extending the Regulation's scope to other wooded lands at the latest one year after the entry into force, during the review process (Council, 2022b, Article 32).

and compliance check systems for European countries like France[65], Germany[66], and the UK[67] (the latter regarding UK's due diligence law). Finally, as part of Trase's dialogues with the EU, a system called Risk Thresholds is under development. It defines high-risk municipalities, provinces, departments, or subnational jurisdictions of each producing country where due diligence efforts should be prioritized (*Interview `Trase Contributor´*).[68]

These collaborative efforts point to positive perspectives of combining the EU approach with existing digital initiatives and solutions in Brazil. Yet, the most important information provided by the digital technologies platforms investigated here is that commodity-driven deforestation has a precise address in Brazil: It is concentrated in the hands of a few but large farmers and traded by a few and large multinationals (Rajão et al., 2020; Vasconcelos et al., 2020; Vasconcelos et al., 2019). Having this in mind, policies can be adjusted to target those most responsible for deforestation (Marzano, 2021b, 2022). Knowing the precise address of perpetrators matters for compliance checks while avoiding unintended spill over effects on sustainable farmers and other businesses (Marzano, 2022). In other words, it is important to ensure that good actors in high-risk areas are not excluded from the EU market (IDH, 2022) (*Interview `SeloVerde's Information System Developer´*).

A remarkable example of collaboration and potential use for compliance checks in this sense is the SeloVerde platform. In the final review of their article, Rajão et al. (2020) entered dialogues with national and foreign public and private stakeholders. One of the important outcomes was that the Brazilian state of Pará decided to implement the initiative, and Norway provided the seed money. Today, the EU recognizes SeloVerde as one of the most advanced platforms, as it gives information at the farm-level and encompasses indirect suppliers (*Interview `SeloVerde's Information System Developer´*). In exploring SeloVerde's contribution to assuring compliance with domestic and demand side regulations, a policy brief drafted by (de Koning, Rajão, & Romão, 2023) works as a handbook on how to use SeloVerde to meet EU data requirements. Developers expect SeloVerde to be a first-level data infrastructure of the EU due diligence process, bringing a series of very clear answers to the EU's main demands. Here is an illustrative example of how the SeloVerde platform could work:

> "On the one hand, an importer receives from the soybean-producing company in Brazil a list of CAR codes and the geographic coordinates of the production areas (of all suppliers whose soybean were mixed in the batch). This **importer enters the code into the SeloVerde system, which checks the properties** – the next version of the system will have an API to allow 100% digital communication. If the risk of deforestation is negligible, the importer records these locations in the EU register, and the due diligence is ready. On the other hand, **an NGO, for example, can take a geographical coordinate on the EU website, enter that coordinate or CAR code into SeloVerde and check on its own** what information is linked to that specific property and see if there is any inconsistency between what the company said and what the system is saying" (*Interview `SeloVerde's Information System Developer´*).

SeloVerde is a key example of valuable South-North technology and knowledge transfer. In the first interactions with the EU, Brazilian developers' impression was that, while the EU was still dealing

[65] More information about the *Tableau de bord d'évaluation des risques de déforestation* at https://www.deforestationimportee.fr/fr/tableau-de-bord-devaluation-des-risques-de-deforestation-lies-aux-importations-francaises-de-soja, last accessed on March 6, 2023.

[66] See the study "*Assessing tropical deforestation risk in Germany's agricultural commodity supply chains*" by West et al. (2022).

[67] More information about the UK dashboard at https://commodityfootprints.earth/, last accessed on March 6, 2023.

[68] As mentioned, the EU regulation foresees classifying countries or parts thereof as low, standard, or high-level risks (Article 27), and Trase's Risk Thresholds system could contribute to that.

with issues pertaining to the law's general architecture, they were already many steps ahead. As a developer puts it: "while they were talking about which ingredients would go into the pie, we were already baking cornbread". The SeloVerde initiative increasingly gained significant relevance and is currently in the advanced stage of receiving EU financial support.

In addition to compliance checks, deforestation information at the farm or subnational levels can help buyers and investors make informed decisions for nature and communities. They can, for example, ban farms or relocate their business to regions with lower deforestation risk, thus guaranteeing compliance with the EU regulation. However, while it would help avoid products contaminated with deforestation from entering the EU market, it would not necessarily improve conditions on the ground. Supply chains could be merely rearranged and split, each providing to a specific market with specific requirements. Worse, companies could withdraw from certain regions, i.e., "cut and run" (see Marzano, 2021a), leaving affected areas with less access to expertise, inputs and technology, with negative effects on employment, economic performance and sustainability. Hence, more importantly than simply avoiding risky areas, public policies and collaboration projects must focus on improving sustainability indicators precisely in areas most in need.

This also leads us back to political-institutional challenges in Brazil. Although IPAM mapped Brazilian initiatives the EU could use to do compliance checks in the framework of the Deforestation Regulation, its collaborators emphasized to Europeans that Brazil has enough technology to show security in its exports. It is not a problem of technology for verification in Europe that needs to be addressed, but the problem of deforestation itself in connection to other socio-environmental problems (*Interview `IPAM Representative´*).

Enhanced cooperation between governments, research institutes, NGOs, and industry stakeholders is needed to offset unintended consequences of the EU Deforestation Regulation while addressing political-institutional challenges. Collaboration efforts should focus not only on fighting deforestation but also creating alternative development paths away from monoculture farming (see Grabs, Cammelli, Levy, & Garrett, 2021). Importantly, Article 28 of the EU Deforestation Regulation prescribes a coordinated approach with third countries. Regarding producing countries and parts thereof, in particular those identified as high-risk, "existing and future partnerships, and other relevant cooperation mechanisms [shall] jointly address the root causes of deforestation and forest degradation" (Council, 2022b). For implementing article 28, collaboration efforts should include financial, technical, and political support for local bioeconomy solutions, which empower the most vulnerable groups such as small farmers, traditional communities, women, and indigenous peoples.[69]

In this sense, partnerships should be strengthened with public and private actors at the Brazilian federal and subnational levels to promote local solutions. Support could target the so-called jurisdictional approaches to sustainable development, i.e.:

> "governance initiatives that promote sustainable resource use at the scale of jurisdictions through a formalized collaboration between government entities and actors from civil society and/or the private sector, based on practices and policies intended to apply to all affected stakeholders within the jurisdiction" (von Essen & Lambin, 2021, p.3 as cited in Garrett, Grabs, Cammelli, Gollnow, & Levy, 2022, p.2).

[69] For example, an indigenous collective (Munduruku) was created in the Alto Tapajós region, Brazil, to structure economic alternatives to mining. More information about this initiative supported by *Projeto Saúde e Alegria* (PSA) at https://saudeealegria.org.br/redemocoronga/floresta-ativa-coletivo-munduruku-e-criado-no-alto-tapajos-para-estruturar-alternativas-economicas-ao-garimpo/, last accessed on March 6, 2023.

One example of a jurisdictional initiative is the PCI-(Produzir, Conservar e Incluir) strategy of the Brazilian state of Mato Grosso, which brings together government, private sector, producers, and civil society to define consensual goals. PCI's three axes are to increase production in already degraded areas; conserve remaining forests; and include family agriculture in the development process. PCI, however, is not a traceability initiative. Regarding the EU Deforestation Regulation, PCI would not work as a compliance tool. As put by a collaborator:

> "It is not because the Mato Grosso state has the PCI that anyone can just buy from here, and everything is fine. That is not the idea. But when you buy from a region committed to sustainability and demonstrating progress, how do you consider this in the due diligence process? I mean, you have a deforestation risk there, but you also have an associated risk mitigation process, and this recognition is what we wanted to have in the legislation. PCI has been trying to convey the message that the EU legislation itself foresees importers must also **support risk mitigation measures**, and we promote the jurisdictional approach as part of such risk mitigation" (*Interview `PCI Representative´*).

Indeed, the EU due diligence rules also include risk mitigation measures by companies such as supporting suppliers, in particular smallholders, to comply with the EU Regulation through capacity building and investments (Council, 2022b, Article 8§2(c) and 10a§1). In the Parliament's version, jurisdictional approaches gained some recognition. For identifying low and high-risk countries or parts thereof, Amendment 208 foresaw considering:

> "whether the national and sub-national jurisdiction has developed **jurisdictional approaches with the meaningful engagement of all relevant stakeholders**, including civil society, indigenous peoples and local communities, and the private sector, including micro-enterprises and other SMEs, and smallholders, to tackle deforestation, forest degradation, forest conversion, land rights violations and illegal production" (Parliament, 2022Article 27§2fa(new)).

This provision, however, did not make it into the text of the provisional agreement between the Council and the Parliament (Council, 2022b). It does not mean that jurisdictional approaches should not be considered in EU cooperation strategies. Quite the contrary, especially given that subnational governments become even more valuable partners when dialogue channels with the federal government are blocked – as seen in Brazil during the Covid-19 pandemic (Corrêa, 2021) and through the work of the Interstate Consortium For Sustainable Development of The Legal Amazon Region (*Consórcio Amazônia Legal*)[70].

In sum, digital initiatives in Brazil provide relevant information on commodity-driven deforestation and other sustainability challenges that should be combined with the EU approach to conduct due diligence compliance checks, adjust policies and measures to target those most responsible for deforestation, improve conditions in areas most in need, and support risk mitigation measures.

To conclude, the analysis of experiences in Brazil sheds light on the existing and untapped potential of digital technologies while offering lessons to fight deforestation and other socio-environmental problems on the ground. It showcases and explicates interrelations among data management issues, high-tech resource-intensity and complexity, and political-institutional issues. This study also raises questions from a software/digital supply chain perspective, more specifically on whether regulations

[70] The *Consórcio Interestadual de Desenvolvimento Sustentável* is an initiative comprising nine Amazonian states (Acre, Amapá, Amazonas, Mato Grosso, Maranhão, Pará, Rondônia, Roraima and Tocantins) to create and drive sustainable development based on shared policies and strategies. More information about the *Consórcio Amazônia Legal* at https://consorcioamazonialegal.portal.ap.gov.br/, last accessed on March 6, 2023.

and supply chain management decisions require a special data quality, trustworthiness, or reliability, as it affects economic/trade/international policy-making and therewith, the path of socio-ecological transformations in certain areas.[71] Although this investigation offers some empirical observations regarding this question, further research is needed.

The insights gained here should encourage further collaboration across the globe to build on existing digital initiatives for compliance checks and management decisions. The key lesson, however, is that fighting deforestation is more complex than implementing supply chain due diligence requirements or having technological tools to show security in exports. The Brazilian case suggests that, among all the provisions of the upcoming EU Deforestation Regulation, Article 28 on cooperation with third countries is its most important contribution, provided that it is implemented.

Looking into the future, many interviewees mentioned that a new opportunity for renewing the EU-Brazil Strategic Partnership[72] arises now with the beginning of Lula's presidential term. Indeed, since Lula's inauguration, German governmental officials, for example, visited the country and announced increased cooperation, including financial support, in the social, forestry and energy domains (Amaral, 2023). Such recent events seem to confirm the willingness of Brazilians and Europeans to seize this opportunity.

[71] I thank Malte Reißig for calling my attention to such a software/digital supply chain perspective.

[72] Although Brazil and the EU have a Strategic Partnership since 2007 (Lazarou, 2011), a series of disruptive geopolitical events – from the 2008 global financial crisis to the 2022 Russian invasion of Ukraine – helps explain the recent low point achieved in the EU-Brazil Strategic Partnership, including Brazilian negative turn in its socio-environmental agenda, and the EU's resort to mandatory demand-side due diligence requirements (Marzano, 2022).

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6 About the Author

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The **Research Institute for Sustainability (RIFS)** conducts research with the aim of investigating, identifying, and advancing development pathways for transformation processes towards sustainability in Germany and abroad. The institute was founded in 2009 as the Institute for Advanced Sustainability Studies (IASS) and has been affiliated with the Helmholtz Centre Potsdam - GFZ German Research Centre for Geosciences under its new name since 1 January 2023 and is thus part of the Helmholtz Association. Its research approach is transdisciplinary, transformative, and co-creative. The Institute cooperates with partners in science, political and administrative institutions, the business community, and civil society to develop solutions for sustainability challenges that enjoy broad public support. Its central research topics include the energy transition, climate change and socio-technical transformations, as well as sustainable governance and participation. A strong network of national and international partners and a Fellow Programme supports the work of the Institute.

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