IIIEE Theses 2024:14

From forests to markets

Assessing emergent behaviours of the EUDR on smallholder palm oil producers

Javier Arenas Alonso

Supervisor

Lisa Heldt

Thesis for the fulfilment of the
Master of Science in Environmental Management and Policy
Lund, Sweden, May 2024

Published in 2024 by IIIEE, Lund University, P.O. Box 196, S-221 00 LUND, Sweden,
Tel: +46 – 46 222 02 00, Fax: +46 – 46 222 02 10, e-mail: iiiee@iiiee.lu.se.

ISSN 1401-9191

Acknowledgements

I want to express my gratitude towards everyone who has supported and uplifted me on this journey, academic and vital. These past two years have been the adventure of a lifetime with an extraordinary bunch of people at the IIIEE. It has been a challenge at times, low-key stressful, but a very empowering and full-circle experience so I want to thank anyone who has taken part in it.

Thank you to my supervisor, Lisa, for supporting my work with knowledge, critical feedback and confidence in my abilities. I got valuable insights and food for thought from our conversations, as well as informal and reassuring moments that boosted my confidence in this work. Our sessions, although stressful, were a good check-in point with reality and a way to stay on track.

Thanks to my peer reviewers, Simone, Jonelle, Ariel and Sanchita, for going over this work and kindly providing feedback and suggestions on how to tackle this topic. Thank you Jessika, for raising critical questions, giving us hope and useful tips on how to do research design and unlock the true potential of our theses.

Thank you to my interviewees for taking time from busy schedules to share your experiences, you insights and bring the palm oil reality a bit closer. A lot is yet to be done in terms of deforestation, but it was inspiring to see such drive and intent to meet sustainability goals in an inclusive manner. A special shoutout to Patricia, Ariel and Sascha for helping me find and contact interviewees, you went the extra mile to ensure my thesis had valuable and actionable output.

To my beautiful B29, meeting you and spending these two years with you has been a pleasure. It has been an honour to walk, run, study and stress among such a kind and bright group of people that I now consider family. You have taught me respect, self-worth and emotional intelligence, all while laughing it off and organizing events to keep the cult alive! I couldn't have asked for a better batch. Another huge thank you to my Delphi people, the Cool Kids, mis queridas delfinas and the Spanish gang in Lund, for making it feel like home and providing a safe (and fun) space to enjoy everyday life.

Last, thanks to my mother, Placi, my sister, Angie, and all my friends and family back home, even the ones who are in our memories. Thanks for encouraging me to come to Sweden and live this experience. Your moral support and perspective were always the reason to keep going.

Shoutout to everybody, I had fun!

Abstract

The new deforestation-free products regulation (EUDR) is driving significant change in agricultural commodities. From traceability requirements to deforestation-free production, this policy will force supply chains to adapt and ensure that products entering the EU market are free of deforestation. In the palm oil sector, the supply chains in producing countries will have structural difficulties in complying, especially with the most at-risk and primary suppliers, smallholders. At the same time, these supply chains are highly complex, adaptative and dynamic, leading to a lack of visibility and structural opaqueness that can prevent any action towards its implementation. This study highlights the barriers and opportunities of EUDR implementation in palm oil, while analysing emergent behaviour from smallholders and the use of technology to achieve timely compliance. The present study employs two theoretical frameworks to analyse the implementation of the policy requirements: the multi-tier supply chain (MTSC) and complex adaptative systems (CAS) theories that allow for a simplified perspective on the dynamics of the palm oil sector while acknowledging the complexity and dynamic nature of its supply chain. The research utilizes a qualitative case study approach, gathering empirical data through 16 semi-structured interviews to different agents of the palm oil sector in Malaysia and Indonesia, as well as 4 webinar and several documents and websites to triangulate data and analyse it using qualitative content analysis in NVivo. The results show that pre-existing and contextual barriers exist, like competing legalities, land and traceability issues and smallholders being poorly established in the system. However, emergent behaviours by smallholders and technology show possible trade-offs and spillovers that can enhance and compel fast adoption, like catalysing group certifications, tackling low-hanging fruit tech requirements and increasing collaboration and connectivity with the supply chain. Topics like blockage at the midstream level and data governance were also raised and signaled as future topics of analysis.

Keywords: deforestation, palm oil, smallholders, complex adaptative systems, emergence, traceability

Executive Summary

In recent years, the urgency to address anthropogenic climate change has escalated, driven by the need to significantly reduce greenhouse gas emissions to avoid irreversible damage. Deforestation and land-use changes are substantial contributors to these emissions, accounting for roughly a quarter of the global total. Commercial agriculture, which drives more than 80% of global deforestation, is particularly implicated in the expansion and clearing of land for forest-risk commodities (FRCs) like palm oil, soy, and beef. In response, the European Union, a significant importer of these commodities, has introduced the European Union Deforestation Regulation (EUDR). This regulation mandates that products entering the EU market must be deforestation-free, legally produced, and traceable to their origins. The EUDR represents a crucial step towards sustainable supply chain management (SSCM), aiming to mitigate the EU's contribution to global deforestation and promote environmental sustainability.

However, the implementation of the EUDR poses significant challenges, particularly for smallholder farmers in palm oil-producing countries such as Indonesia and Malaysia. These smallholders, who collectively manage substantial portions of palm oil production, often operate within complex and opaque supply chains characterized by informal land ownership and limited access to resources and technology. The stringent traceability and legal requirements of the EUDR create substantial barriers for these smallholders, who may struggle to comply without adequate support. While it is widely recognized the fragility of smallholders in agricultural supply chains, research on the barriers and limitations to their inclusion and their agency in those supply chains, as well as the role of emergent tools like technology, remains limited.

Aim and Research Questions

The general aim of this research is to help inform supply chain stakeholders by identifying barriers and limitations in a sound implementation of the EUDR, incorporating a holistic perspective that recognises distributional effects across and within agents of producer countries. Understanding the effects of the regulation on the palm oil supply chains and smallholders, in particular, will allow for a better and just implementation that achieves sustainability at all levels, environmentally and socially. Specifically, this thesis aims to provide the necessary knowledge for better implementation by supply chain agents and eventual evaluation by policymakers, observing the entirety of the value chain, making sound and targeted decisions to distribute the resources to distribute compliance costs, and understanding the potential value of new technologies in doing so.

RQ1: What are the barriers and opportunities of the EUDR implementation in palm oil supply chains?

RQ2: What are the likely effects of the EUDR on smallholders in the palm oil supply chain?

RQ3: What is the potential role of technology in addressing the limitations of the EUDR implementation for smallholders?

Conceptual framework

Ithe present sutdy employs two theoretical frameworks to analyse the process of traceability and deforestation-free legal implementation in multi-tier supply chains: the **multi-tier supply chain (MTSC) theory and complex adaptative systems (CAS) theory**. MTSC theory provides a framework for understanding the main sustainability strategies and management for

downstream companies, while CAS theory allows for a deeper undertanding of the behaviour of the supply chain and how sustainable actions can influence their dynamics. Thus, these two theories are joined to provide a deeper understanding and explain the complexities of the palm oil supply chain and emergent behaviours arising from the EUDR implementation efforts in it.

Methods and Research Design

The research adopts a qualitative case study approach, collecting empirical data through 16 semi-structured interviews with stakeholders across the palm oil supply chain in Malaysia and Indonesia. Additional data were gathered from 4 webinars and various documents, in order to increase data quality and provide better context for the data collected in the interviews. The main approach to data collection and analysis is multi-perspective, as this study includes perspective from actos alongside the supply chain (downstream and upstream) and different stakeholders (certification schemes, technology providers, NGOs and academia). The data underwent a comprehensive analysis process using qualitative content analysis in Nvivo and then examining the identified themes agains the research questions.

Analysis

Research question one found four barriers and two opportunities when analysing the effect and integration of the EUDR in the palm oil sector. The barriers include: 1) competing legalities and frameworks between the EU and producing countries, 2) land rights and issues due to informal tenure of the land and geographical dispersion, 3) poorly-connected smallholder participation due to their position at the end of the upstream supply process and limited by the opaque midstream sector and las, 4) traceability issues stemming from competiteness and informal sales at the aggregation level. Two opportunities were identified: 1) certifications with access to the market, knowledge of the ecosystem and good practices previous to the EUDR and 2) technologies like mobile applications, drone mapping and blockchain were found to be the opportunities and low-hanging fruit that can ensure a better implementation of the EUDR.

Research question two and three's rationale stems from the use of the CAS theory. As smallholders represent a signficant share of the production, this thesis aimed to focus on them as an emergent agent in the EUDR implementation and technology as an emergent tool to achieve compliance, understanding that targeted action at different levels than downstream could potentially enact systematic change in the supply chain. Therefore, **research question two** found that the EUDR effect on smallholders would depend on the level of connectitivity and resource share with the rest of the supply chain, and the bottom-up approaches emerging from smallholders. This thesis found that exclusion risks exacerabating poverty and reducing livelihood opportunities for smallholder, therefore compeling supply chain actors to increase their traceability so smallholders can be included and engage in fair prices and continuous relations with other suppliers.

Last, thesis **research question three,** can be answered as follow: technologies like Technology plays a crucial role in addressing the limitations of EUDR implementation for smallholders by providing robust solutions for traceability, transparency, and compliance. Advanced technologies such as blockchain can ensure secure and immutable records of the supply chain, enhancing trust and accountability. Remote sensing and satellite imaging technologies enable real-time monitoring of land use, helping to verify compliance with deforestation-free requirements. These technologies can significantly reduce the burden of compliance by automating data collection and providing smallholders with the tools needed to prove their adherence to EUDR standards. However, challenges such as distrust in data governance and the high initial costs of technology adoption must be addressed. Building trust through

transparent data management practices and providing financial and technical support to smallholders are essential steps to ensure successful technology integration and compliance with the EUDR.

Conclusion and Recommendations

This thesis has the following contributions to research and practice. First, it provides a comprehensive overview of the current barriers and limitations for EUDR adoption in the palm oil supply chain. Using the MTSC and CAS theory enhances the understanding of supply chain complexity and the existence of emergent behaviour and hostpots where a supply chain can develop action to change and drive sustainable supply chain management. The identified emergent themes like smallholders and technology highlight the areas that require further research, as well as the efficacy of technology roll-out, operationalization of certification schemes, multi-stakeholder collaboration for policy integration and data governance.

In conclusion, the EUDR has a faulted implementation pathway due to the not recognizing differences and dynamics in the palm oil supply chain. Although challenges for smallholders exist when it comes to supply chain integration, emergent behaviours like bottom-bottom collaboration and use of technology can bridge the barriers and create attainable compliance throughout the whole supply chain. While the path towards compliance is complex, collaborations and projects that support emerging behaviours serve as catalysts for progress, guiding supply chains to EUDR adoption and overall balanced and distributed sustainability. With more commodities joining the effort, responsible practices and equitable management of supply chains can achieve deforestation-free products from sustainably managed supply systems.

Table of Contents

List of Figures

List of Tables

Abbreviations (if required)

4F - Farmers For Forest Protection Foundation

CAS - Complex adaptative systems

EUDR - European Union Deforestation-free products Regulation

FFB - Fresh Fruit Bunches

GDPR - General Data Protection Regulation

GIS - Geographic Information System

HCS-HCV - High Carbon Stock-High Conservation Value

ISPO - Indonesian Sustainable Palm Oil

MPOPC - Malaysian Palm Oil Certification Council

MSPO - Malaysian Sustainable Palm Oil

MTSC - Multi-tier supply chain

NGOs - Non-governmental organizations

PRISMA - Palm Resource Information and Sustainability Management

RSPO - Roundtable on Sustainable Palm Oil

SIMS - Sawit Intelligent Management System

SPPL - Surat Pernyataan Pengelolaan Lingkungan (Environmental Management Statement Letter)

SSCM - Sustainable Supply Chain Management

STDB - Surat Tanda Daftar Budidaya (Cultivation Registration Letter)

1 Introduction

In recent years, the urgency to tackle anthropogenic climate change has become unsurmountable (IPCC, 2022). To avoid irreversible damage, it is paramount to quickly reduce greenhouse gas (GHG) emissions. Deforestation and land use change contribute to roughly a quarter of global greenhouse emissions, altering the carbon cycle and reducing the ability of the Earth to store the carbon emitted from human activities (IPCC, 2019). Forest degradation and net deforestation have driven the loss of 170 million hectares of forests between 1990 and 2010, reducing the benefits that forests have on animal and human life – carbon sink or temperature balance– and creating additional risks to ecosystems –like fires and pests– (FAO, 2022).

Commercial agriculture is estimated to drive more than 80% of the deforestation in the planet (Kissinger et al., 2012). Certain commodities, characterized as forest-risk commodities (hereafter called FRCs), account for 40% of annual deforestation and are the main driver for agricultural expansion and clearing of land (FAO, 2022). This dynamic will keep expanding due to demographic growth, setting up an issue for ever-increasing deforestation and bringing the natural systems to the edge of irreversible damage (Rockström et al, 2009). Thus, to tackle climate change and emissions through deforestation, multiple public and private initiatives have been developed. While no binding multilateral agreements have been negotiated, deforestation commitments have been linked tangentially to environmental, trade and climate change agreements (Cesar de Oliveira et al., 2024), and exacerbated by the alarming speed of global tree coverage loss in this millennium (Global Forest Watch, 2022). To fill the gap of public governance, many private-led intiatives have also been developed by major brands, traders and investors to erradicate deforestation from their supply chains (WWF, 2021; CDP and Accountability Framework Initiative, 2022). In addition to tackling this issue, jumpstarted by the 2014 New York Declaration on Forests and followed by the Glasgow Declaration on Forests and Land Use, there has been a common individual will of countries to commit to ending deforestation by 2030 (European Commission, 2021).

Acknowledging its role in global deforestation –as the EU market contributes to 16% of imported deforestation, only second to China (WWF, 2021) – the European Union initially created a regulation that excluded wood products linked to deforestation from entering the EU market, the European Timber Regulation (EUTR). But to commit further to eliminating deforestation in 2030, the EU has developed the European Deforestation-free product Regulation (commonly known as EUDR). Following the rationale of the EUTR, this policy requires companies to ensure that the products placed in the EU market and from it are legal and not linked to deforestation (European Commission, 2023a). In this new iteration, the scope of the policy increases from wood products to forest-risk: soybean, coffee, cocoa, wood, rubber, cattle, palm oil and its derivates.

As global FRC supply chains are complex and opaque, the challenge to achieve sustainable supply chain management stems from increasing traceability and transparency (Renier et al., 2023; Skidmore et al., 2021; zu Ermgassen et al., 2022). Thus, the new EUDR mandates disclosure on companies about the commodities' origin and transparency to ensure that illegal practices and products do not enter the EU Single Market (European Commission, 2023). This opens the door for technology to ensure traceability and compliance, like blockchain or remote sensing. As disclosure improves transparency and mandates awareness in FRC supply chains, the potential effects on forest-risk commodities could be the reduction in deforestation through good practices, the isolation of non-compliant suppliers and the ability to oversight companies that don't align with the market sustainable practices.

1.1 Problem definition

While the EUDR aims to reduce deforestation by increasing transparency and traceability in agricultural supply chains, policies that regulate the entry to the EU Single Market by establishing barriers or tariffs can heavily affect the distributional equity of the regulation itself, especially in the dynamics between the Global North and Global South (Zhunusova et al., 2023). Especially, the effects on smallholders[1], as they play a crucial role by managing one-quarter of global forests and contribute to a third of global crops in the global market (Zhunusova et al., 2024; Ricciardi et al., 2018).

As the policy is to be implemented in 2025, its extended reach makes the effect on smallholders interesting to observe, especially the potential trade-offs between ecological and socioeconomic ambitions (Spaiser et al., 2019), like the aim to reduce emissions and deforestation and improve the living conditions of smallholders (European Commission, 2023). In order to ensure a just transition, European policies aim to consider social development while developing climate ambitions through policy coherence for development (EU State of the Union, 2022; Zhunusova et al., 2024). In the case of the EUDR, the disadvantages to smallholders are reflected in the regulation body of text (European Commission, 2023) but do not specify what actions and measures could be enacted to support them, leaving a gap that is selected as the research problem for this thesis.

The complexity of forest-risk commodities supply chains makes the study of the EUDR a singular one. These have been defined as opaque and highly complex, making it difficult to track the impact and origin of the commodities under scope (Skidmore et al., 2021). How the EUDR and its due diligence system requirements are going to affect countries has been studied (Cesar de Oliveira et al., 2024; Tankam & Lescuyer, 2024), but an approach to understanding how the policy will affect specific supply chains is lacking. A commodity-driven approach allows to analyze how the specific supply chain and its stakeholders shape the concept of transparency and how smallholders interact.

From the commodities included by the legislation, soya and beef/cattle lack smallholder dominance and have lesser importance when understanding how its supply chains, especially smallholders, will react to stricter transparency and traceability. The case of palm oil is of high relevance, as 70% of the EU imports come from two countries in the same region: Indonesia and Malaysia (Zhunusova et al. 2024). Due to production being geographically close and intertwined (UNDP, 2020) and smallholder dominance being high, with 28 and 42%, respectively (Zhunusova et al., 2024), this case seems relevant to understand how smallholders will be affected by the regulation in such a homogeneous sector.

This regulation includes a highly technical and specific requirements to trace and track commodities to plots of agricultural land. Whereas the previous EUTR only required easily-accessible information –like buyer information or country of harvest–, the EUDR obliges companies to include geolocations and time ranges of production (European Commission, 2023). This new regulation puts the focus on technology as the main tool for achieving transparency and traceability,

[1] As an official definition of smallholder is not provided by the regulation, in this thesis, the concept of smallholders will be considered as "smallholders, Indigenous People and local communities" as defined by the Fair Trade Advocacy et al (2021). This definition and association between the three concepts is used in the body of text of the European Union Deforestation-free Regulation so this thesis adopts it for continuity purposes.

In summary, this thesis explore the mechanism through which the EUDR will be implemented in the palm oil supply chain and its trickle down effect on smallholders, as decision-making process at a public and corporate level can be improve if adaptative EUDR strategies are implemented and results formulated. Additionally, the role of technology can be expanded to observe the synergies between technology development and smallholder inclusion.

1.2 Aim and research questions

The general aim of this research is to help inform supply chain stakeholders by identifying barriers and limitations in a sound implementation of the EUDR, incorporating a holistic perspective that recognises distributional effects across and within agents of producer countries. Understanding the effects of the regulation on the palm oil supply chains and smallholders, in particular, will allow for a better and just implementation that achieves sustainability at all levels, environmentally and socially. Specifically, this thesis aims to provide the necessary knowledge for better implementation by supply chain agents and eventual evaluation by policymakers, observing the entirety of the value chain, making sound and targeted decisions to distribute the resources to distribute compliance costs, and understanding the potential value of new technologies in doing so.

Therefore, the research questions addressed in this thesis are the following:

RQ1: What are the barriers and opportunities of the EUDR implementation in palm oil supply chains?

RQ2: What are the likely effects of the EUDR on smallholders in the palm oil supply chain?

RQ3: What is the potential role of technology in addressing the limitations of the EUDR implementation for smallholders?

Scope and delimitations

This thesis strives to offer significant insights into the subject matter, yet it is crucial to recognize its constraints. Its structural delimitation is on selecting the palm oil supply chain, which provides a selected case study and limits the applicability of the research to the global market, but the patterns in the findings can be abstracted to other supply chains or be the basis of future research.

On a specific level, this study centers around three limtations. First, the focus on the palm oil will be directed to Indonesia and Malaysia, therefore not including the entire flow of this commodity to the EU, but addressing the largest exporters and assuming its representativeness for the supply chain. Second, the data collection is limited by the lack of available information and relevant stakeholders. Although efforts were made to ensure diversity in the selection process, the findings may not fully capture the perspectives and experiences of all relevant stakeholders on the subject. Considering the complexity of reaching to smallholders and the time frame and resources for this sutdy, it is mentionable that the smallholder perspective will be reduced and some aspects of the research may not be covered exhaustively due to this limitations. Last, qualitative research is not without risk of potential research bias, that aim to be mitigated by rigorous data analysis procedures and data triangulation that can increase the reliability and credibility of this study.

It is mentionable that the policy is still under development, so this thesis only analysis the case of the EUDR up until February 2024, when the literature review and conceptualization of the research was established.

1.3 Ethical considerations

The impact of my research is not traced to unintegral practices. The study is not funded in any way by an organization, therefore my interest and purpose are solely personal. Understanding that inequality and social aspects might entail strong opinions on the policy or vested interests by participants, I ensured to remain objective and provide the totality of findings to prevent taking sides and disregarding unexpected results.

Participation was voluntary, and I strived to prevent any harm to participants by stating the purpose and process of the research as transparent and explicit as possible. Additionally, all interviewees were asked for consent to record the conversation and transcribing processes. To ensure anonymity where required and given the option to stay anonymous, participants will not be referred to by their names and the use of the data collected will strictly follow the GDPR rules under Lund University's ethical guidelines.

1.4 Audience

The findings of this thesis may be of interest to a wide variety of stakeholders. However, this thesis may result in relevance primarily for supply chain agents and policy stakeholders. Other intended audience members come from academia, companies, NGOs and, ultimately, the general public.

For supply chain agents, this thesis aims to investigate the dynamics and complexity of the palm oil supply chain, while analysing the level of adoption and potential barriers and drivers to the EUDR implementation, therefore involving palm oil producer and upstream suppliers as well as downstream EU companies. Additionally, other expected audience are technology providers and NGOs that can receive some insight about the role of technology in policy adoption and reducing the barriers, especially to smallholders; also, to NGOs that aim to create programmes and support smallholder livelihood. In policy, the main audience are policy evaluators that engage in the development and improvement of the policy, as this thesis aims to pinpoints hotspots and critical dynamics of the policy implementation and configuration.

1.5 Disposition

This thesis is organized as follows: Chaper 1 introduces the topic by outlining the research problem addressed in this thesis, the research questions that drive the investigative process and the aim for the thesis. It also addresses the necessary limitations of the research, as well as its intended audience and any relevant ethical concern that are identified. Chapter 2 provides a general background of the research area of this thesis, and states the two main theoretical frameworks and terms that will guide the data collection and analysis. Chapter 3 reviews the main literature and delves into the specifics of the EUDR and the role of smallholders and technology in supply chains. Chapter 4 presents the main findigns from the qualitative case study. Chapter 5 delves into a discussion based on the aims of the thesis and compares the findings to the previous studies in the field and other relevant literature, while presenting recommendations to the audiences and outlining areas for future research in SSCM.. Finally, Chapter 6 presents the main conclusions of the work.

2 Background and theoretical framework

This chapter provides a contextualization of the research problem under the framework of sustainable supply chain management and the EUDR, adding on the developments done in the last months to its implementation. Additionally, it develops this thesis' theoretical framework based on multi-tier supply chains and the complex adaptative systems theories (See Section X and X). The framework serves as the theoretical lens in which the data analysis and the response to the research questions are embedded.

2.1 Complex multi-tier supply chains

This thesis centers around the multi-tier supply chain, which encapsulates a complex system comprising of a focal company (also known as lead company), its multiple tiers of suppliers, and buyers interconnected within the supply chain network (Gong et al., 2021). To analyze supply chain dynamics, research puts a focus on a pivotal company, the focal company, as a large and powerful actor that creates and governs the supply chain network to produce good and services for the end customer. The focal company purchases good and services from their direct suppliers located in the first tier –or supply stage– of the supply chain. First-tier suppliers have their own individual network of suppliers that can have subsequentially other tiers in them. From the focal company standpoint, these are sub-suppliers or indirect suppliers, also called middle-tier or low-tier suppliers depending on the distance from the focal company in the supply chain system. Another way to differentiate tiers in supply chains is through the flow of supply chain activity: downstream (focal company and its buyers), midstream (first- and middle-tier suppliers) and upstream (low-tier suppliers, raw material producers) companies.

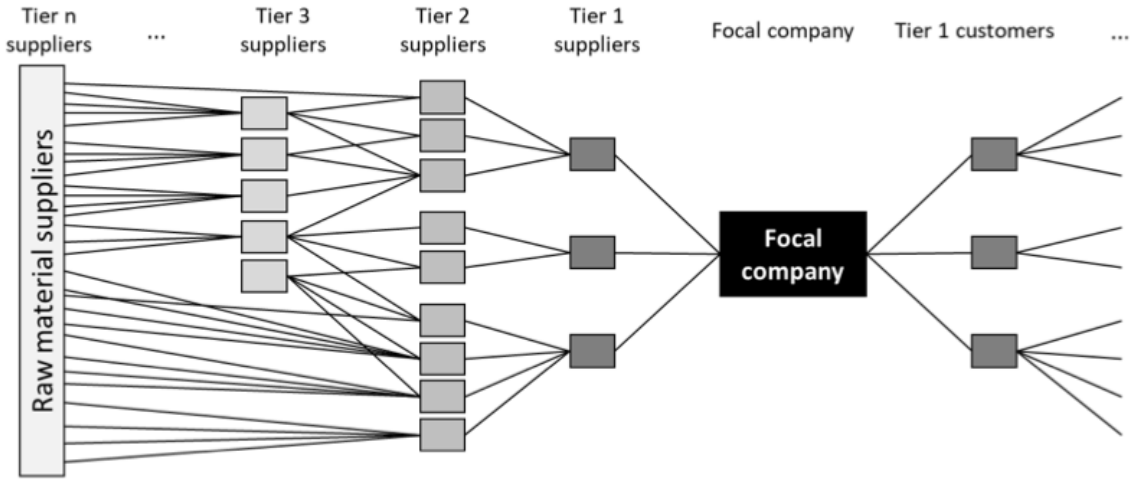

Figure 2-1. Simplified scheme of multi-tier supply chain

Source: Heldt, 2020.

Agricultural supply chains are often characterized for their opacity and complexity (Skidmore et al., 2021). From a theoretical perspective, multi-tier supply chains are characterized for complex dynamics, where "multiple sourcing and frequent exchanges of sub-suppliers occur", increasing the complexity and reducing visibility and knowledge about actors in the supply chains and their relationships (Hofstetter & Grimm, 2019). The level of complexity is determined by the number of suppliers, their diversity and their inter-relationships (Choi & Krause, 2006, p. 637), and driven by globalisation, increased specialization and outsourcing of production processes (Ebinger & Omondi, 2020).

As many companies have limited understanding of their supply chains due to their complexity, they can increase it by exploring and understanding their supply chains. This is beneficial as complexity leads to a lack of information and low accuracy that companies have about their supply chains, posing a threat to the company's risk management (Fraser et al., 2020). Additionally, complexity can prevent companies to manage efficiently their supply chains, compeling them to focus on direct suppliers where they have clear visibility, direct communications ways and influence through contractual relations (Meinlschmidt et al., 2018; Seuring & Müller, 2008). This difficulty to manage indirect suppliers can lead to a diffusion of responsibility, with focal companies circumventing responsibility and accountability for issues distant in the supply chain (Zyglidopoulos & Fleming, 2011). In recent years, the dynamic has shifted towards stakeholders expecting companies to take responsibility for the violations of sustainability standards within their entire supply chain (Ebinger & Omondi, 2020; Hofstetter & Grimm, 2019). This is due to what Hartmann & Moeller (2014) call the chain liability effect, where consumers hold a focal single firm responsible for behaviors and incidents upstream. This phenomenon is caused by lack of understanding of the company's supply chain control and existence of incidents.

2.2 Theoretical framework

For this thesis, two theories on supply chains are utilized: the multi-tier supply chains theory (MTSC) and complex adaptative systems theory (CAS). When analyzing the structure of supply chains, MTSC understands SSCM as a linear process with an established hierarchy where specific factors influence the choice of strategy, offering a clear and comprehensive framework for understanding and managing supply chains. However, this approach has its limitations in understanding the dynamism and complexity of multi-tier supply chains. On the other hand, CAS emphasizes that supply chains are non-linear complex systems where results are difficult to predict. They are characterized as adaptative systems that show spontaneous behaviour, self-organization and adaptability to changing circumstances. This approach to supply chains makes for a better understanding of supply chain behavior and how sustainable management can affect its dynamics. For this study, both theories are representative to the reality of the object of study and therefore applied to highlight the different aspects of agricultural supply chains that might enter in contact with the EUDR.

2.2.1 Multi-tier supply chains theory

Agricultural supply chains, and specifically forest-risk commodities, can be formally analyzed through a multi-tier supply chain theory lense proposed by Tachizawa and Wong (2014). According to this theory, a multi-tier supply chain is formed by multiple layers of suppliers and buyers, each with specific goals, limitations and relationships. This structure is characterized by its formality and linear flow, focusing on a "lead firm" that is attributed responsible for the economic activity (Tachizawa and Wong, 2014). Additionally, the theory expands on the complex dynamics between multiple tiers of suppliers and buyers and exploring the practices and governance mechanisms companies use for managing their low-tier suppliers, encompassing the factors that influence their decisions.

Tachizawa and Wong identify four types of governance mechanisms to manage multi-tier relationships with suppliers: direct, indirect, work with third party and don't bother. To analyze the strategies that companies will adopt to deal with the EUDR requirements and how this affects smallholders as a supply chain unit (RQ1 and RQ2), it is required to identify the four types of governance mechanisms that are currently implemented in agricultural supply chains. An overview of the mechanisms and relevant practices is shown in Table 2.1.

Table 2-1. Four types of governance mechanisms in supplier multi-tier management

Type	Characteristics
Direct	Focal companies are capable of by-passing first-tier suppliers to establish a direct connection with low-tier suppliers and monitor, regulate and collaborate with them to improve the environmental and social performance
Indirect	Focal companies establish an indirect contact with low-tier suppliers typically through an intermediary first-tier supplier
Work with third party	Focal firms engage in partnerships or assign duties to external organizations to develop sustainability criteria, enforce industry self-governance, adopt voluntary guidelines, etc.
Don't bother	Companies concentrate on their first-tier suppliers and do not possess any knowledge about their lower-tier suppliers, nor do they intend to exert any influence over them

Source: Gong et al., 2021; Tachizawa & Wong, 2014; p. 651-652, 656

Tachizawa and Wong add onto the many factors influencing the adoption and effectiveness of governanace mechanisms, such as power, stakeholder pressure, material criticality, industry, distance, dependency and knowledge resources (Tachiezawa & Wong, 2014; Gong et al., 2021). For agricultural supply chains, these factors can be evaluated to understand the dynamics of the value chains and what factor/s the EUDR encapsulates. An overview of the contingency variables is shown in Table 2.2.

Table 2-2. Contingency variables

Factor	Description of the factor
Power	The influence that a firm has over its supply chain partners.
Stakeholder pressure	The level of demand for a company's behaviour from different stakeholders.
Material criticality	The impact that certain materials have on the final product sustainability.
Industry	The specific industry or sector in which a firm operates.
Distance	This can be understood in terms of geographical distance as well as cultural or operational differences
Dependency	Dependency is related to the degree to which firms are reliant on their supply chain partners.
Knowledge resources	The availability and accessibility of knowledge and information regarding sustainability practices.

Source: Tachizawa & Wong, 2014

The MTSC theory proposed by Tachizawa and Wong is chosen for the theoretical framework as it contributes to understanding the relationships and dependencies between the sets of suppliers in agri supply chains, especially smallholders and farmers, located in the upsstream end and least visible for most supply chains.

2.2.2 Complex adaptative systems theory

While MTSC successfully explains supply chains by focusing and providing a rigid structure, CAS views supply chains as highly dynamic and complex systems that cannot be predicted nor controlled (Choi et al, 2001; Touboulic et al, 2018). The theory challenges the traditional structure that MTSC and the existing SSCM research implicitly assumes about the focal company that unilaterally can control and manage sustainability challenges.

CAS theory offers a modern and valuable framework for understanding supply chain management by emphasizing the emergent, dynamic and adaptative nature of supply chain systems. As Surana et al (2005) highlights, the constant change of organizational and market trends mean that supply chains need to be adaptative to be efficient, therefore creating a case for supply chains to be adaptative and complex in sustainability, as this factor is currently driving a change in the economy (McKinsey, 2022).

Choi et al. (2001) explains the CAS framework for supply chains. It comprises of three dimensions: internal mechanisms (agents and schema; self-organization and emergence; connectivity; dimensionality), external environment (dynamism; rugged landscape) and the co-evolution of the supply chain (quasi-equilibrium; non-linear changes; non-random future). Departing from a the rigid view that MTSC proposes for supply chains, CAS emphasizes the agency of actors (beyond the focal company) in the shaping and development of the system through interactions and dynamics between them. Agency is shaped by the actor's schema, i.e the "norms, values, beliefs and assumptions" (Choi et al., 2001) that shape the actor's behaviour. Additionally, agents' connectivity and dimensionality refer to the relations and linkages existing throughout the system that shape their agency. And autonomous agents can shape the overall evolution of the supply chain with no single company steering it due to its self-organization and emergence (Choi et al., 2001; Touboulic et al., 2018; Abbasi & Varga, 2021).

The environment in which the supply chain develops is dynamic –ever-evolving– and with a rugged landscape, making them difficult to map (Touboulic et al., 2018). This difficulty gives the company a specific visible horizon, the range of their known tier suppliers (Carter et al., 2015). Last, the internal mechanisms and environment are always under a process of co-evolution that shapes the CAS over time, fluctuating between quasi-equilibrium and non-random futures in a non-linear pattern. A summarized version of the factors interacting in complex adaptative systems for suppy chains is presented as Figure 2.1.

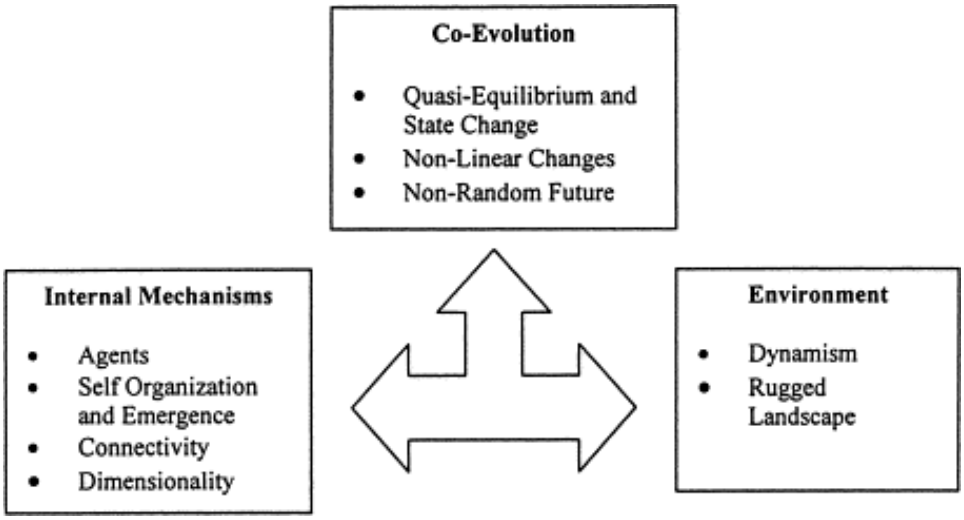

Figure 2-2. Complex adaptative systems framework.

Source: Touboulic et al. (2018)

This theory is chosen as it encapsulates the reality of agri-food systems more accurately. In Touboulic's (2018) article, the author applies the CAS system to the issue of decarbonizing a food supply network. It argues that traditional approaches to carbon reduction have not been successful as they fail to account for the complexity and interconnectivity of the food supply chain. The author proposes a new approach based on CAS principles, notably through collaboration and cooperation between agents and understanding the dynamic environment in which they perform. Additionally, the theory highlights the emergent role of technology in dealing with the complexities of supply chain systems, as it would enhance the adaptability, responsiveness and interconnectivity of the system.

In conclusion, CAS applies to this thesis, as it acknowledges the potential agency of upstream suppliers (which include smallholders/farmers) in the agri supply chains and the rugged landscape and dynamics, where the EUDR implementation might be affected by unpredictable events. Additionally, it serves as the basis for RQ3, where I aim to study the emergent potential of technology in agri supply chains.

2.2.3 Discussion

By joining both theories, I aim to express the need to consider agricultural supply chains as both traditional and emergent systems for this thesis. MTSC provides a good rigid structure about the verticality of tiers and the relationships that appear between actors in the system, whereas CAS recognizes that supply chains are highly adaptative and not all sustainability challenges can be tackled from the focal company, or with a vertical perspective. While supply chains have power dynamics that can be explained with MTSC, this study and research problem requires of a dynamic understanding of supply chains to study the impact of the EUDR regulation, the potential role of low-tier suppliers in the sustainability of FRC supply chains and the role of technology to enhance SSCM in the case study.

Overall, I consider MTSC as the theoretical area of my research and CAS as a reconsideration of the rigidity of the framework. As Touboulic et al (2018) posit, there are continuous tensions between control and emergence, in supply chain, as "a focal firm may exert control over the system, but this will depend on their ability to change the schema of other agents and the rules

upon the system is based" (Touboulic et al., 2018; p. 317). Therefore, for this research process, it is sound to use both frameworks to expand the potential outcomes of this thesis.

3 Literature review

The literature review is performed from an outside flow. First, it aims to provide an introduction to the agricultural supply chains and its specific characteristics. Second, explain the role of smallholders and farmers in those supply chains in order to then make an in-depth analysis of the EUDR regulation and its raison d'etre. Last, an analysis about the role of technology both in the EUDR and FRC supply chains will be explained as the main cornerstone of this policy.

3.1 Sustainable supply chains and agricultural commodities

The trade of agricultural commodities is the mainstay of the global economy, providing a large number of resources –food, fibers, fuels, etc.– to consumers in the world. Their supply chains are characterized for their opaqueness and high complexity, making it difficult to track both the impact and origin of food products (Skidmore et al., 2021). Additionally, commercial agriculture is formed by long and extensive flows that spread throughout the world from very specific locations, making sustainability risks concentrated at the location of production (zu Ermgassen et al., 2022). With such a vast supply system, the dominant strategy in the agri-food sector is indirect sourcing, reducing the visibility of the supply chain (zu Ermgassen et al., 2021).

For the case of palm oil, production is highly focalized, as Malaysia and Indonesia account for 84% of the palm oil production, with annual flows of palm oil to the EU reaching more than 5 million tonnes (IDH, 2023). And zu Ermgassen et al. (2022) makes the point that indirect sourcing can be localized, thus making a case for opaqueness even in approximately accurate locations. The palm oil supply chain starts with the harvest of palm oil in plantations (which can be of smallholder ownership of industrialized production), where the fresh fruit bunches (FFB) are transported to a mill either directly or through local aggregators. The mills are mostly independent –known as "third-party" mills– and only some are operated by traders. After the milling, the product is transported to refineries and then sold to traders. The full flow of production is detailed in Figure 3.1. In these supply chains, traders establish supplier development strategies like contracting land for smallholders or develop company schemes like "plasma schemes": companies that acquire new growing land for palm trees are legally obligated to give one fifth of the new land to smallholder farmers (zu Ermgassen et al., 2022; Mongabay, 2023).

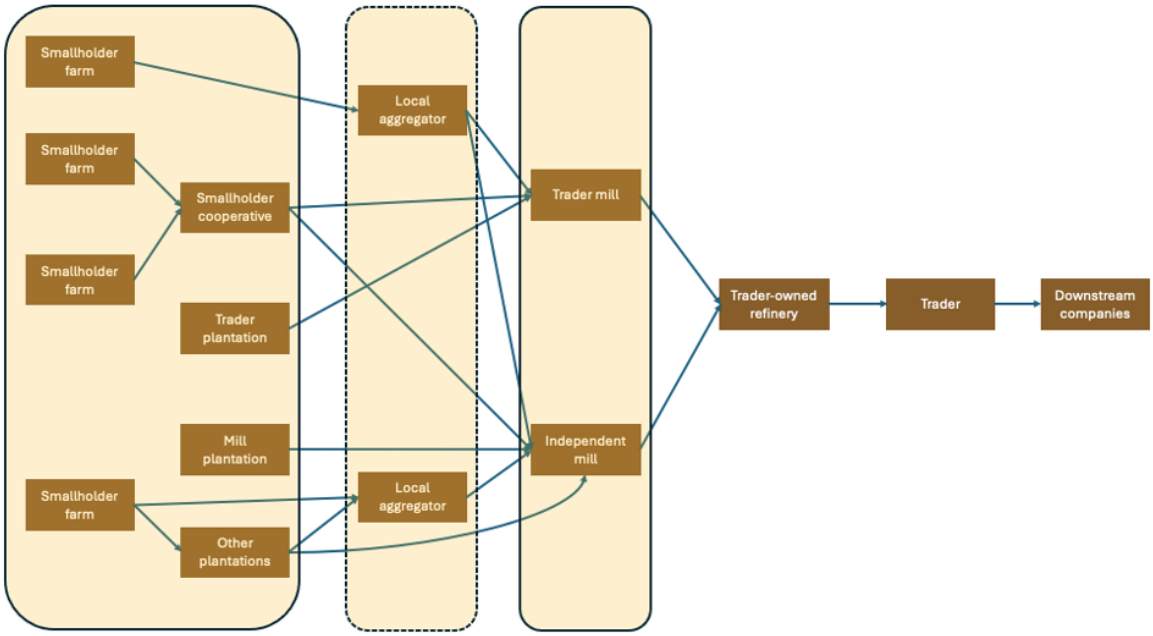

Figure 3-1. Palm oil upstream supply chain structure.

Source : Own, adapted from zu Ermgassen et al. (2022)

Traders or other mid-stream actors (conceptualized in literature as "intermediaries", "brokers", "value chain managers", "suppliers" or "partners"), who are involved in the commodification, consolidation and product transformation of palm oil products, then store, transport and process the commodity (Reardon et al., 2021). Such actors play a connecting role in their supply chain, between downstream and upstream, with deep knowledge of production and consumer demands and the ability to navigate cultural and political context. Thus, they are enablers of sustainability in supply chains (Reardon, 2015). The product then reaches the European Union market or other international markets.

Due to indirect sourcing being the flagship strategy for agricultural commodities and low traceability, sustainability efforts in supply chains are difficult and provide a case for localized and minimal action to reduce imported deforestation. Additionally, problems like meteorological events and high segregation in secondary markets (i.e agricultural commodities can be sold unprocessed or highly processed as raw materials for other markets), create pressure and diffusion in the supply networks (Davis et al., 2021).

3.2 Smallholders in agricultural supply chains

According to the definition of smallholder provided by Fair Trade Organization (2021), a farmer that holds a plot of land of small size, Indigenous People and local communities are considered smallholders (Fair Trade Organization et al., 2021). The definition varies between bodies and organizations, but a common range for smallholders is land size between 2 and 50 hectares, accounting for minor differences between commodities and geography (Lowder et al., 2016). Additionally, smallholders conduct independent activities in their holding, for which they hold ownership, tenure rights or any equivalent title granting them control over land, and who are not employed by a company but possibly associate with one (Fair Trade Organization et al., 2021).

With an estimated 500 million farms worldwide with less than 2 ha contributing to overall food systems (Lowder et al., 2016), smallholders contribute greatly to overall agri-food supply chains. Being a high proportion of those, their livelihood is usually highly vulnerable and dependent on their integration in global supply chains, as integration has been linked to increased capability to "achieve desired livelihood and socio-ecological outcomes" (Grabs et al., 2021; Dou et al., 2020). Their farming thus concentrates on subsistence farming and the production of consumption crops, not cash crops (IEEP, 2022). Nonetheless, the contemporary global food system tends to intertwine inequality, power imbalances, and marginalization, posing a challenge to sustainable supply chain management (McMichael, 2009).

In the case of palm oil, smallholders in Malaysia and Indonesia constitute 41% of production with 2,6 million smallholders and 27% of production with 450000 smallholders, respectively (Fair Trade Organization et al., 2021), thus needing to be included in efforts to improve palm oil sustainability. There are two types of smallholders: independent and organized. The former are not linked to any organization and work independently on their farms, with the latter have farms that are managed or connected with federal government or companies (MPOCC, n.d). This is the case of plasma scheme farmers in Indonesia, that have higher security due to contract that ensure flow of FFB to the companies and ensure labour to smallholders. In Malaysia, the schemes are developed with governmental agencies (MPOCC, n.d).

Issues for smallholders:

- smallholders lacking necessary registration letters (STD-B).
- unregistered and unmapped smallholders, considered a challenge for traceability with overlapping land claims, bureaucratic confusion, and unofficial fees.
- smallholders have limited access to oil palm mills due to the absence of partnerships between companies and smallholders.
- complex and opaque supply chain further complicates efforts to establish a traceability system that tracks products from where they are grown to where they are exported. (FairTrade International et al., 2021)

In Indonesia, there are three broad categories of producers: large private plantations, smallholders, and state-owned plantations. Total land use for palm oil in the country is 14.32 million hectares. According to data from Indonesia's Statistic Agency (BPS, 2018), large private plantations account for 55% of this land use, with smallholders making up 41% and state-owned plantations just 4%. Productivity is skewed towards large private plantations which account for 60% of total production. Indonesia has, to date, been slow to expand its palm oil refining capacity. In Malaysia, palm oil production is concentrated in Sabah (31%), Sarawak (17%), Johor and Pahang (15%). The palm oil processing industry is particularly well developed in Malaysia and local companies, such as IOI and Sime Darby, are leaders in the global palm oil industry (Fair Trade International et al., 2021) . In 2020, the country capped its palm planted area to 5.86 million hectares in 2020. Out of this total area, the mature area is estimated at 5.23 million hectares or 89% (Fair Trade International et al., 2021)

Smallholder farmers find themselves in a more challenging position than the large plantations. Their yields are generally lower, partly due to aging trees and ineffective access to Good Agricultural Practices (GAP) and inputs (Woittiez et al., 2017). Smallholders typically lack the knowledge and/or funding to upgrade their practices, adopt the latest technology, enable rejuvenation, and obtain affordable quality inputs. Further, they have little negotiating power and the pricing system is opaque – they rarely know how much they will be paid by the mill

(FairTrade International et al., 2021). This lack of transparency dissuades smallholders from making beneficial investments. Rejuvenation of their land is constrained by lack of access to funding and smallholders cannot afford a temporary production drop following replanting. These challenges are often heightened in the case of independent smallholder farmers who do not have the support of a nucleus farm (Zhunusova et al., 2023).

Currently, only a small percentage of smallholders are certified by RSPO, ISPO or MSPO. This is because certification is complex and expensive, and often requires farmers to agree not to extend their planted area. It takes at least two years to see the full results of improved practices and certification requires notable documentation, including land titles (FairTrade International et al., 2021). While commitments to restrict farming to existing land slows deforestation, it inhibits a key avenue available to smallholders for improving their livelihood. Even if smallholders obtain certification, there is no guarantee that their costs will be fully covered by subsidies or price premiums or, importantly, that a level playing field is created by making these practices mandatory (FairTrade International et al., 2021).

3.3 EUDR

The European Union is the main importer of deforestation second to China and has committed to protect and restore the world's forests as part of their climate strategy, the European Green Deal. The EUDR is a regulation within the European Green Deal from 2019, highlighting the importance of the EU commitment on "Stepping up EU Action to Protect and Restore the World's Forests". For the purpose of this research, the literature review conducted for the regulation goes in depth but is limited to February 2024. Any further development of the regulations and its implementation is left out of this research in order to have a rigid framework to conduct this research.

It is the update of the previous regulation on deforestation, that covered wood and timber products, the European Union Timber Regulation (EUTR). It was initially developed in 2019, and passed in 2023, increasing transparency in the FRC supply chains through due diligence systems (henceforth called DDS) of a wider set of products than the EUTR to minimize the EU's contribution to global deforestation. The regulation requires a due diligence process, to ensure traceability to specific production plots, legality, and no forest conversion after December 31, 2020 (Fauziyah et al., 2024). This due diligence requires companies to provide increasingly granular insights on traceability and to illustrate how they prevent and tackle environmental and social risks.

The three main pillars of the policy established in article 3 are: 1) traceability, 2) legality and 3) deforestation-free status. The regulation states that commodities cannot be placed in the European market if they don't fullfil these three elements (European Commission, 2023a). First, products are to be traceable through a DDS, that must include information and data (quantity, geolocation, dates), a risk assessment and measures to mitigate said risks. Second, commodities are to be produced in accordance to national legislation of production countries. Last, product must not have been located in areas where there was unsurmountable proof of land conversion after December 31, 2020 (European Commission, 2023a). Regarding the due diligence process, the regulation includes a benchmarking system according to the level of risk of producing forest-risk commodities. This will consist of three categories (high, standard and low risk) to analyze countries and will determine the level of scrutiny that is required in their due diligence statements, although it is yet to be determined and can be subject to further changes. Figure 3.2 states the specific requirements of the DDS in comparison to the EUTR.

DUE DILIGENCE SYSTEM REQUIREMENTS

INFORMATION GATHERING	
EUTR	Product information
	Country of harvest information
	Supplier and buyer information
	Quantity
	Compliance information on relevant legislation
Additional for EUDR	Geolocation coordinates and time range of production
	Information that the product is deforestation-free including forest degradation-free after December 31, 2020

RISK ASSESSMENT	
EUTR	Prevalence of illegal harvesting, including armed conflict
	Assurance of compliance with applicable legislation
	Supply chain complexity
Additional for EUDR	Country origin concerns like corruption level and risk based on benchmarking system
	Reliability and validity of sources
	Presence of forests and prevalence of deforestation and forest degradation
	Risk of product mixing with unknown origin

RISK MITIGATION	
EUTR	If no negligible risk, mitigation measures and procedures have to minimize risk to negligible risk
Additional for EUDR	See EUTR Risk Mitigation

Figure 3-2. DDS requirements from EUTR and EUDR

Source : Van Rijn, 2022

Smallholders are included in the regulation as a relevant stakeholder to consider when developing the systems of the EUDR and the EU has established that smallholders, in its majority, are not placing products in the EU market, therefore being exempt of any legal obligation (European Commission, 2023b). But they are obliged to comply with the information queries that operators that are under the regulation require, like land ownership or proof of not land conversion before the cut-off date (European Commission, 2023b).

3.4 Role of technology in reducing deforestation

The EUDR introduces the role of technology in tracing and monitoring agricultural commodities to ensure that their production is deforestation-free. Technologies like blockchain for traceability or remote sensing for monitoring can play a significant role in deforestation-free practices, considering the technology requirements stated in the regulation (European Commission, 2023a).

Digital traceability systems, powered by blockchain technology, offer a robust solution for tracking the origin of agricultural commodities from production to consumption. Such systems can ensure compliance with the EUDR by providing immutable records of the supply chain, thus preventing the entry of products linked to deforestation (Aung & Chang, 2014; De, 2021). This approach enhances transparency and accountability, enabling businesses and consumers to make informed decisions that align with environmental sustainability goals.

Furthermore, satellite imaging and remote sensing technology have emerged as powerful tools for monitoring land use changes and detecting deforestation in real time. These technologies can be integrated with AI algorithms to analyze vast amounts of data, allowing for the early identification of unauthorized land-use changes and enabling swift action to prevent further damage (Reiche et al., 2018; Gibbs et al., 2020). Also, this technology has a long history in biodiversity and ecosystem conservation, supporting monitoring of habitats, reforestation efforts, and emerging cases of quantifying ecosystem services (Rose et al., 2015; Turner et al., 2003; Huang, Cao, Xu, Fan, & Wang, 2018). By leveraging these technologies, companies or stakeholders can more effectively enforce the EUDR, as they allow for continuous surveillance of at-risk areas and the verification of compliance by suppliers. This capability is critical in ensuring that agricultural practices within supply chains are indeed striving for deforestation-free practices.

In addition, predictive analytics and machine learning can optimize supply chain operations to reduce the need for land expansion, which is a primary driver of deforestation. By accurately forecasting demand and optimizing crop yields, these technologies can help minimize waste and improve land use efficiency (Thornton et al., 2019; Li et al., 2020). This not only contributes to the sustainability of agricultural practices but also supports the objectives of the EUDR by reducing the pressure on forests for agricultural expansion. The implementation of these technological solutions within the framework of the EUDR signifies a move towards more sustainable and responsible agricultural supply chains in the European Union, highlighting the critical role of technology in achieving environmental conservation and sustainability goals.

4 Methodology

In this chapter, research design and methods for data collection and analysis are reported and justified with a discussion on potential limitations and measures to address them.

4.1 Research design

The aim of this research is to explore and unveil the potential impacts of the EUDR on palm oil supply chains, focusing on smallholders and the potential implications of technology to assist on a smooth implementation. The research design is therefore constructed considering three qualities of the research problem:

- the regulation specificities are under development at the time of research (February 2024): the Regulation is out, but specific implementation tools are yet to be developed
- agricultural supply chains are very complex and opaque, with smallholders usually diffused, making it difficult to engage and include their perspectives
- literature review shows that academic research on smallholders in supply chains focuses on how to strenghten their livelihoods, rather than zooming in their role in FRC supply chain
- the existing research gap on synergies between technology and smallholder development.

These factors suggest that research as well as practitioners could benefit from an in-depth thesis project that analyzes and condenses insights about limitations, unexpected effects and opportunities faced by supply chain when abiding with this regulation. The pre-emptive chronology of this thesis –as the regulations has not been implemented yet– and its reach to the vast global supply chains suggests that an exploratory case-based approach would be useful. Studying cases (or in this case specific commodities) is considered particularly suitable for such novel situations where prior research is limited and complexity high (Verschuren, 2003), providing the audience with deep and actionable input. Acknowledging the complexity and the need for an in-depth and refined analysis of the problem, case studies generate relevant and context-dependent knowledge that is most useful for practitioners (Flyvbjerg, 2006), especially for complex structures like supply chain systems (Pagell & Shevchenko, 2014). This approach is not without drawbacks, being commonly criticized for having limited reliability and validity (Yin, 2018). Nonetheless, they can be advantageous in achieving a holistic analysis considering a myriad of contextual factors and using multiple sources of data (Yin, 2018). Therefore, the research design consciously accepts the potential disadvantage of reduced transferability of results in favour of achieving a deep level of analysis and relevance for practitioners.

As Cresswell & Creswell (2018) highlights, "if a concept or phenomenon needs to be explored and understood because little research has been done on it or because it involves an understudied sample, then it merits a qualitative approach" (Creswell & Creswell, 2018, p.57). As aforementioned, there is a lack of data about the effects of the EUDR because it has yet to be implemented and this aims to be an ex-ante analysis. Thus, due to the novelty and complexity of the research problem, a qualitative approach is suitable to better understand the effects of the EUDR in the selected case study and provide the necessary knowledge for better and just implementation of the EUDR in countries and supply chains.

Considering the rather limited path of this research, the dominant researcher's worldview is pragmatic in order to prioritize the research problem rather than the methodology, adjusting the latter to favour understanding the former (Rossman & Wilson, 1985; Creswell & Creswell, 2018).

4.2 Data collection

This thesis draws on documents and interviews. To get the best understanding of the research problem, a purposeful selection of participants is necessary, consequently following a multi-perspective approach to be able to triangulate the information, reducing bias and strenghtening the validity of the findings (Verschuren, 2003).. As the scope of the thesis is palm oil and the geographical constraints are limited to Indonesia and Malaysia due to their market share, participants were identified in these two countries, focusing on upstream suppliers in the producing countries. First, upstream and downstream companies were identified to provide perspective to explore the complexity of the EUDR implementation in producing companies and traders. Second, NGO and association participants were contacted to receive a non-corporate localised perspective about the intertwinement and connectivity between different tiers of suppliers, mostly between producing companies and smallholders. Then, smallholder associations and social NGOs were contacted to provide their vision on the challenges of the EUDR implementation in low-tier levels. Last, technology providers were contacted to understand the possibilities and innovative behaviours in the palm oil supply chain. All prospective participants are found and contacted using professional social network platforms (e.g LinkedIn), the researcher and thesis supervisor's own network, and are selected according to the following criteria: 1) expertise and position, 2) experience in SSCM, 3) availability for the interview and 4)language barrier. Additionally, as mentioned before, participants were also selected to provide insights on different perspectives on the thesis field: downstream companies, upstream companies and stakeholders, NGOs and technology providers. To incentivise their participation, access to the thesis results are offered.

The data collection methods are selected according to the nature and configuration of the research questions, and are as follows:

Table 4-1. Data collection methods

Research Questions	Data collected	Methodologies
RQ1: What are the barriers and opportunities of the EUDR implementation in palm oil supply chains?	List of factors that limit EUDR implementation List of factors that can enhance EUDR implementation	- Literature review - Semi-structured interviews with upstream and downstream companies involved in SSCM, NGOs and academics focusing on zero-deforestation commitments.
RQ2: What are the likely effects of the EUDR on smallholders in the palm oil supply chain?	Observed practices towards smallholders with EUDR Types of scenarios for smallholders after implementation	- Semi-structured interviews with NGOs and industry associations involved in palm oil - Semi-structured interviews with smallholders and smallholder associations
RQ3: What is the potential role of technology in addressing the limitations of	Emergent initiatives for smallholder inclusion in palm oil	- Literature review - Semi-structured interviews with NGOs and upstream suppliers

the EUDR implementation for smallholders?	Challenges and drivers of technology implementation	- Semi-structured interviews with agrifood-oriented technology providers

The data collection process is conducted in several steps. First, webinars and podcasts are consulted to understand the basis of the regulation in FRC supply chains, as well as to scout for potential interviewees. Second, semi-structured interviews are conducted to get deeper insights on the findings. Last, desktop research of websites and reports is conducted in order to validate and triangulate information from the interviews. These interviews are held online using videoconference tools (e.g Zoom, Google Meets and Teams), and interview guides are developed for each participant group (upstream companies, smallholder associations, NGOs, technology providers, etc), and each interview is recorded, transcribed, coded and stored according to Lund University ethical guidelines.

Questions are adjusted when necessary in order to adapt to participants and to potential dynamics that are developed during the interviews, and the questionnaire allows to tailor questions to the diversity of participants while ensuring to collect comparable data. All questions are open-ended and are adjusted as the process evolves, based on insights gained from prior interviews. The interview duration was between forty and sixty minutes, depending on the interviewee's schedule and knowledge of the subject.

4.3 Data analysis

For data analysis, the thesis conducted a qualitative content analysis using the software NVivo. The coding framework was developed through a deductive process based on the literature review and theoretical framework. After the data collection, codes are revised and updates during the coding process based on new information, through an inductive approach. This process is an adaptation of Mayring (2000) process that has been used in the supply chain research context (Beske et al., 2014; Engert, Rauter, & Baumgartner, 2016; Seuring & Müller, 2008b) .

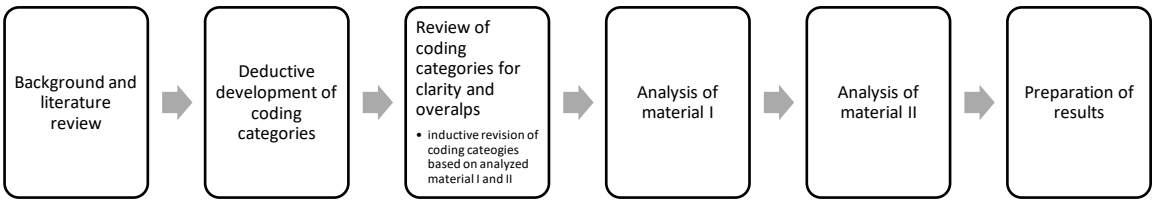

Figure 4-1. Process of data analysis

Once a final version of the codes is reached –as some of them can be unified, subdivided or complemented with new codes–, the relevant data from desktop research, interviews and other sources is collected, coded and stored in Nvivo based on code structure. Information is analysed under each code and key themes are synthesized to provide answer to the research questions. Interpretation of the results is conducted by summarizing findings by themes, and then a framework of the relations between the identified parts of the research is developed.

4.4 Limitations

Limitations of these methods are mainly the difficulty to find relevant participants that are willing to be interviewed, particularly influenced by the time constraints of a master thesis. Including other sources (like podcasts, webinars and public joint letters from industry sector) is aimed to provide a broader data base and compensate for the lack of interviews. However, this can provide superficial and non-specific insights, specifically on the implementation process of the regulation and organizational challenges to include smallholders. In the case of the interviews and documents, negative aspects of the research and sensitive information is expected to be less present, as part of the biases and publicity aspects of the research topic. To reduce the aversion to answering questions and be able to provide a realistic and truthful image of the problem, information concerning how the data is stored, anonymized, used and published is provided at the beginning of each interview. Additionally, information is expected to be limited by cognitive biases like hindsight bias (retrospective sensemaking) or confirmation bias. As I'm gonna be interviewing a sector that overall is against of the EUDR as a policy, when disclosing information or highlighting some data, people might use that data to prove their preconceived point. To mitigate this, interviews will try to be focused on current situations (for hindsight bias) and will be asked counterbalancing questions that probe deeper into their responses in order to confirm or deny their claims.

Most of the data was collected in March 2024, before the implementation of the EUDR and therefore data collected is subject to invalidity or changes happening after the data collection timeline. As mentioned at the beginning of this chapter, this thesis recognizes the constant actualization and development of the EUDR and thus acknowledges that new considerations of the regulation will appear and change the potential outcome of the EUDR, but for research quality purposes, the findings and abstractions in this thesis will be spoused to the research timeline and will not include potential developments in the regulation.

Last, in order to provide higher level of validity to their claims, different stakeholders are interviewed, in different levels of affection within the value chains of FRCs. As they will be differently affected by the regulation (strategizing for the adoption of the regulation –companies–, claiming usefulness –certifications– or selling their services –technology provides), the data collection process is expected to provide a comprehensive picture of the research problem.

5 Findings

In this section, an overview of the intended effects of the EUDR on palm oil is provided, explicitly the barriers and opportunities arising from the EUDR implementation. The challenge and role of smallholders and technology are also studied and analysed. Moreover, the structure of palm oil supply chains is analyzed through a MTSC and CAS framework.

5.1 Barriers of implementation for EUDR in palm oil

Many barriers can be identified when analysing the implementation of the EUDR in the palm oil sector. Four barriers have been identified: competing legalities and frameworks, land rights, smallholder participation and traceability.

5.1.1 Competing legalities and frameworks

The EUDR as a policy introduces requirements for placing products on the EU market, with emphasis on three factors: traceability, legality and deforestation-free status. Compliance with the regulation stems from abiding by practices and definitions presented in the regulation, like forest, deforestation, primary forest, etc. But, as presented by public letters from GAPKI (the Indonesian Palm Oil Association) and NGOs like Solidaridad and Wild Asia, definitions from the EUDR are different from the existing legal frameworks in producer countries.

First, as explained above, the definition of forest is different among national frameworks. The EU bases its definition of forest on the FAO definition "*land with tree crown cover (or equivalent stocking level) of more than 10% and an area of more than 0.5 hectares. The trees should be able to reach a minimum height of 5 metres at maturity in situ*" (European Commission, 2023a). The definition is dependent on the consideration of degradation and land use, with low alteration of the land use not considered degradation, but a significant change in land use. Therefore, what is considered degradation depends on the level and the EUDR sets a very ambiguous and generalized limit on forest degradation. Figure 5.1 visualizes forest degradation ruling to understand what level of degradation is considered uncompliant.

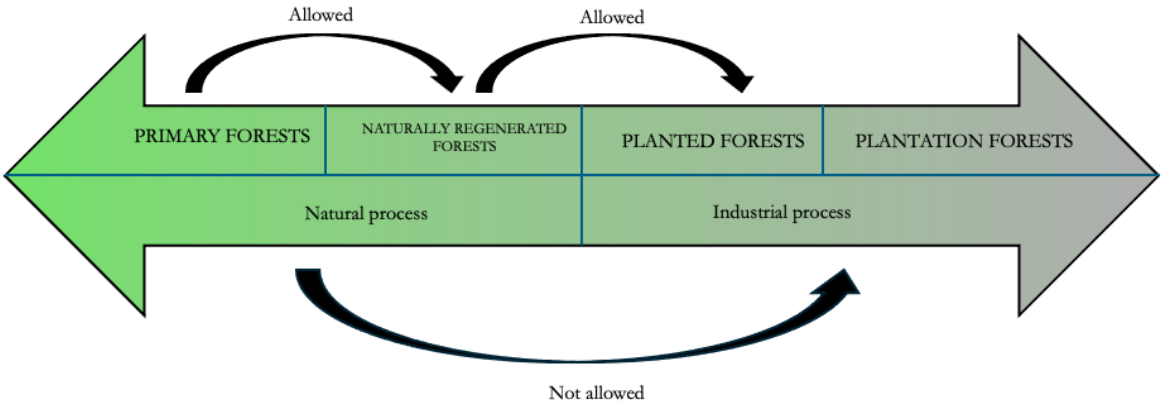

Figure 5-1. The EU Deforestation Regulation's rules on forest conversion.

Source : Own illustration, based on Palmer, 2024

Then, the EUDR does not state the definition of smallholder nor a dichotomy to identify them. The regulation considers the size of small farms in four hectares, but does not state explicitly that smallholders are the ones with small farms (European Commission, 2023a). On

the other side, RSPO defines smallholders as having less than 50 hectares, Malaysia as those with up to 40 hectares and Indonesia defines smallholders as having less than 25 hectares in Agrarian law and 2 hectares in Law 19/2023 (Solidaridad et al., 2023). Actions towards smallholder inclusion through cooperation as stated in article 30 of the regulation become challenging as there is no common framework and definitions [P]. Additionally, as the Independent Smallholder Association of Palm Oil in Indonesia (SPKS) states, smallholders and other producers are being put in the same category when mapping where does palm oil production come from and what type of farms exists. According to them, from the 6.72 million hectares of smallholder production, only 1.9 million hectares are considered smallholder farms according to Indonesian regulations, and the rest are passing as smallholders but truly being SMEs (SPKS, 2022).

It is still unsure the measures that will be implemented to reduce the friction between legalities, but countries are still working on finding a common ground between their regulations and legalities, mainly through the recently instated Ad Hoc Joint Task Force on the EUDR [P].

5.1.2 Land rights

The palm oil sector is highly informal as stated in the literature review. Land is differently managed and administrated according to their production status. From land owned by international companies to plantations owned by mills to small farms belonging to independent smallholder, palm oil land is highly complex. As a highly opaque and decentralized sector, the EUDR poses an issue for compliance which stems from land titles and operational licenses [C, D, E, G].

In order to comply with the EUDR, it is mandatory to legalize and create traceability of commodities to their place of origin, the farms where they have been produced. In Indonesia government data on oil palm plantations is highly fragmented and inconsistent [E, G] among their agencies and authorities which impedes a correct mapping of farms, as a study from 2021 reveals (Mongabay, 2023a). The main issues when complying with the EUDR are, according to interviewees, lack of operating licenses and lack of land titles that can be used in traceability [H, G]. The reason behind is suggested to be the informal ownership of land and the lack of administrative ruling in the regions.

First, most productive arable land, in the case of smallholders, is passed on generationally from parents to children without formal title and therefore titles are not accessible to farmers [F, M]. Evenso, farmers that lack a land title are often not aware of the size of their farms, which extends the need for land mapping in order to create the polygons required by the regulation [H]. Secondly, the land is highly geographically dispersed and invisible to administration, creating a *de facto* independence on farmers that sometimes is contested when land encroachment happens [H]. Land encroachment also happens with Indigenous people. There is land associated to customary rights (Indigenous people) and the formalization of land titles has been connected to state pressure, as once the land titles are official, the government can actually claim that land as part of the state and enforce predatory policies [L]. In Malaysia, there is less customary land because of the british colonization, but in Indonesia it is still relevant [L]. Cases like the Murut in Malaysia or Dayak in Indonesia signify the current problems that Indigenous communities still face in recognizing their land titles (The Ecologist, 2016; Human Rights Watch, 2019).

As an example, farmers sometimes find their land being used for production by a company, and due to lack of knowledge of the size and location of their farm, they are unable to contest the illegal use of their land [H]. The bureaucracy and legal uncertainties have created a hostile

environment for smallholders' access to resources and financing [F], as banks and financial institutions are wary of extending loans or credit to individuals without clear land titles or contested land titles due to encroachment (Mongabay, 2023b).

Last, even with land titles and rights to land, the EUDR implementation will be limited due to distrust of the institutions. Various interviewees highlighted that farmers in Indonesia are reluctant to share their land titles to protect their data privacy, as they don't trust in correct data management and governance by institutions and companies [B, F, G, H, O, P] and it exposes the geolocation and land specificities of the producers [F, H].

5.1.3 Smallholder participation

Many public joint letters have situated smallholders at the core of the EUDR, due to their fragile and detached participation in the palm oil supply chains. As the EUDR imposes a high level of traceability and requirements, smallholders will struggle to comply due to lack of resources and salience in the supply chains (GAPKI, 2022; SPKS, 2022). As their production is directly tied to livelihood and income, smallholders are at risk of losing income and increasing poverty in rural areas of producer countries (GAPKI, 2022; SPKS, 2022; Solidaridad et al., 2023).

Heavily reliant on middlemen for market access, smallholders are distant from the usual activities of supply chain management. Their role in the supply chain is sometimes compared to a "buffer supply", as they can not be predicted and relied on for constant supply [I]. Adding to this, as it has been stated in the previous subsection, smallholders tend to have issues showing proof of land titles and legalities, as well as geo-location requirements of their production areas (Solidaridad et al., 2021).

Individually, smallholders have less ability to comply with the deforestation, legality and traceability requirements [C, D, I, J]. As explained in the previous subsection, smallholders have land title issues that limits traceability efforts and legality compliance, as well as issues to guarantee and provide proof of production in a non-deforested land [C]. Some actions have been driven to reduce the compliance cost of individual smallholders through natural grouping efforts, with smallholders in areas of the vicinity attempting to comply by getting together and reduce the overall cost. Nonetheless, achieving compliance has been proven costly. Table 5.1, developed by SPKS, shows the investment threshold for independent smallholders to achieve EUDR compliance. Compliance is assumed to be done through the most cost-effective way, through group certifications, but the graphic represents the individual cost per smallholder.

Table 5-1. Approximate cost of EUDR compliance for smallholders in Indonesia

Activity for compliance	Cost estimation (€)
Socialization with farmers for ISPO/RSPO/EUDR compliance assistance	300/village
Mapping, data collection and traceability, including to generate STDB and garden polygon data	12/hectare
GAP training to farmers	24-30/farmers
Issuance of SPPL and STDB	Cost STDB: 3/farmer SPPL: 1/farmer
Formation of cooperative	420/cooperative

RSPO/ISPO certification (this cost include data collection, STDB, training)	210/hectare
No Deforestation (HCS-HCV) Implementation	17200/Village
Cooperative-based traceability and data-base center	18000 one-time cost + 1500 maintenance/year
Estimated approximate of total cost (one time cost, excluding annual costs such as forest protection, audit, etc.)	**2440/farmer**

Source: SPKS (2024)

When it comes to their activity in the supply chains, smallholders are expected to be excluded due to non-compliance with the EUDR (GAPKI, 2022; Solidaridad et al., 2023). As mentioned, their participation is highly informal and of low scale –with land sizes of around two hectares–, relying heavily on dealers and collectors that buy their FFB and they sell it to the mills [G] (GAPKI, 2022). Therefore, the potential of mixing between EUDR-compliant FFBs and non-compliant is high, making the segregation of palm oil flows difficult to achieve and therefore excluding smallholders from supply chains, even with compliant FFBs [C] (GAPKI, 2022; Solidaridad et al., 2023). All in all, the burden of proof of deforestation-free and legality compliant production lies with smallholders, even with good traceability systems.

5.1.4 Traceability

As explained in the literature review, the palm oil supply chain is highly dispersed and informal, with many levels of suppliers and agents between production sites and mills. With an extensive network of mid-stream suppliers, traceability poses a significant issue. One interview highlights that "traceability into the systems is as good as impossible because there is so much processing, so much intermediation, so little knowledge" [I]. With established and large producer plantations, traceability is manageable to a certain level, but the fear of mixing compliant FFB with non-compliant is still strong [J]. Additionally, the level of granularity and data validations is still very low, and there's "heavy reliance on what our suppliers can provide in terms of insights" [O].

Focusing on mid-stream suppliers, it is highlighted by the interviewees that the hotspot of traceability stems from the mid-stream system. Traceability and the informality of the low-tier suppliers are beneficial for mid-stream actors due to competitiveness, as they want to keep their shares of the market and their relationships [I]. The transactions at this level are informal and based on trust, where there is minimal documentations other than a "receipt" of the number and weight of FFB collected and payed for (Solidaridad et al., 2023). Some farmers even sell their FFB to independent collection centers. Thus, traceability to the farm, as most interviewees refer to, is complex.

Nonetheless, some actions have been implemented to achieve traceability to the farm. Commercial solutions have appeared to map the supply chains and create platforms to increase traceability, like Veritas [J] or Koltiva [H], that engage with technology to trace commodities and training for smallholders to apply good agricultural practices (PriceWatersCooper, 2023; 3keel, 2024). These platforms will allow the different suppliers and actors participating in the supply chain to validate and confirm step-by-step compliance with EUDR or, in previous years, certification requirements from RSPO, ISPO or MSPO [D, J, K]. They also allow for the mitigation of potential non-compliances and risks existing in the supply chains, as its satellite imagery tools check the deforestation-free conditions of the producing land, later

consulting countries and companies about the potential deforesting land areas and therefore, driving the removal of these lands from productive activities [J].

5.2 Opportunities in implementation for EUDR in palm oil

The opportunities for the EUDR to enact a smooth implementation and where the focus of compliance should delve into are twofold: certifications and technology.

5.2.1 Certifications

In general, the role of voluntary sustainability standards, which include certifications, is very relevant to ensure sustainability within supply chains, as explained in the literature review from this thesis (Zhunusova et al., 2023; de Oliveira et al., 2024). In the palm oil sector, the predominant certification schemes are: the Roundatble for Sustainable Palm Oil (RSPO), the Indonesian Sustainable Palm Oil (ISPO), the Malaysia Sustainable Palm Oil (MSPO) and the Rainforest Alliance, which from April of 2021, phased out their palm oil certification programme (Rainforest Alliance, 2021). While the first one is an international certification, ISPO and MSPO are national certifications developed by the Indonesian and Malaysian government to increase palm oil competitiveness in the global market (FairTrade International et al., 2021). In 2023, with the enactment of the EUDR, the global palm oil sector referred to these established and strong certifications as potential allies to the implementation of the regulation, due to its verification, monitoring and requirement correlation (Solidaridad et al., 2023). In the case of RSPO, 93% of the palm oil entering the EU market is certified by them, being the largest certification scheme and leading one in palm oil [D]. Therefore, it has been advocated that, among others, this certification have been seen as a similar framework as the one the EUDR aims to enact, and raising questions about the integration of the certifications with the regulation [E, G, K].

A gap analysis performed by the certification recognizes the close framework that RSPO has comparing to the requirements of the EUDR [D]. Among others, the main gaps identified are:

- Deforestation definition: the definition of forest within EUDR is a quantitative general threshold value, while RSPO it is qualitative site-specific methodology, the HCS-HCV high conservation value. Additionally, the EUDR does not consider exemptions that are included in the RSPO, like the High Forest Cover Countries from the RSPO principles and criteria (RSPO, 2023)
- Legality: the EUDR requires that information on legality is transferred through the supply chain, whereas RSPO does not require this transfer, reducing the effectiveness of checks and monitoring (RSPO, 2023)
- Geolocation: the EUDR polygon traceability is not mentioned in the RSPO principles and criteria. Additionally, the EUDR definition of plot of land difers from the one provided by the certification, as polygons are not mentioned by RSPO (RSPO, 2023).

The MPOC, the body regulating the MSPO certification, also developed a gap analysis to understand the correlation between the terms and conditions of the certification and the EUDR [F]. The main highlights are:

- Deforestation definition: the definition is broader and less specific within MSPO terms, including conversion to plantation forests. Additionally, the EUDR defines degradation but the MSPO does not include the term (MSPO, 2024).
- Legality: the MSPO is consistent with national laws and regulations, but includes and develops further the topic of customary rights and Indigenous communities, with

special mention of the Free Prior and Informed Consent (FPIC) processes for use of customary land (MSPO, 2024).
- Geolocation: MSPO does not include several components of the geolocation and traceability requirements of the EUDR. Namely: the quantity of relevant products and the geolocation specificities –date of production and multiple geolocation points if commodities have been produced in different plots of land– (MSPO, 2024).

As the gap analysis show and interviewees respond, certifications are very close to compliance with the EUDR requirements [D, E, F, P]. It is a common view in the palm oil sector that certifications consequentially should be recognized as a tool for EUDR implementation, but the European Union has rejected their participation [A, B, C, D, E, F, G, H, I, P]. Certifications are viewed as actors that enact and put in practice the values of the regulation while serving the purpose of including local and contextual considerations [E]. Furthermore, certifications have the role of being on the ground and having local context with an international perspective [I]. As seen in the gap analysis, certifications like MSPO recognize and support FPIC processes and other local aspects of production, understanding the local dynamics between stakeholders –mills and smallholder farmers– (MSPO, 2024). Certifications recognize customary land rights and its issues, therefore, when farmers don't have titles, they can still be certified [L].

As well as being a similar framework of compliance as the EUDR, certifications have succeded in creating a platform to "connect actors across the value chain" [L] and "align on critical issues such as deforestation and protecting the livelihoods of smallholder farmers" (IDH, 2023). One interviewee recognizes the role of these certifications as "platforms to talk" and "discuss how to move forward with sustainability" [L, P]. On top of that, certifications go further than the EUDR and are still relevant to have when the regulations is enacted in 2025 because they consider social and governance aspects, like labour and human rights, land grabbing, etc. and enable good agricultural practices in the plantations and farms [P].

As previously mentioned, certifications have various ways to support suppliers and act as middlemen in the supply chain knowing the local context, mostly smallholders. The RSPO has developed continuous programmes to support smallholders and the implementation of the EUDR:

- Smallholder Support Fund (RSSF): this initiative provides financial support for oil palm smallholders by engaging and training approximately 46000 smallholders to reach international markets [D] (RSPO, n.d). This Fund can be of support to smallholders aiming to create traceability systems, initiating a documentation system or receive an audit (RSPO, n.d).
- Independent Smallholder Credit (ISH): this framework of credits compensates smallholders that produce in a sustainable way with premiums that allow them to keep producing sustainably. Because certified smallholders might sell to uncertified mills –due to location constraints– and obtain a lower price, this credit mechanism allows "certified smallholders to convert 1 tonne of their FFB volume to 1 credit in addition to the sale of their physical supply" (Eco-Business, 2023). Currently, 22% of palm oil imports in the EU are RSPO credits, therefore, European companies can still support smallholders and do supplier development through these credits to account for the distortions in prices and smallholders exclusion that are expected to happen with the enactment of the regulation in 2025 [D].

While certifications can be seen as an opportunity to implement the EUDR coherently and comprehensively, they are not without issues. They are run based on assurance through an

audit system that is risk-based, taking samples, and the samples get smaller proportionally the larger the group of farmers [I]. Therefore, certifications cannot guarantee full compliance. Additionally, certifications have the issue of having proved that their added value is not always significant in the market for farmers to seek certification schemes, as premiums can fluctuate, especially with independent smallholders [L].

5.2.2 Technology

Currently, the technological developments have allowed a better environmental and managerial control over agricultural commodities. Blockchain and remote sensing were described in the literature review as the main resources to support the implementation of the EUDR. Other technological aspects have been stated by interviewees and will be analysed in this section.

First, mobile applications that record transactions between farmers and buyers, creating a history of purchase that would allow for traceability have been implemented by companies like Agunity [J]. This technology is expensive, and it would require large sums of capital to reach all levels of suppliers [F, J]. Nonetheless, the overall cost of technology diffusion in supply chains is only comparable to the visibility that the suppliers have of the supply system; in highly visible supply chains, the need for technology are reduced, as good agricultural practices and correct communication pathways are established [J, K] . Second, drone mapping allows for the correct sizing of land when applying or creating the polygons of data points that start traceability [I, J, K]. Last, blockchain and database instruments are relevant to input the data and perform data analysis and monitoring what the polygons and GPS points are [I]. These last one is riskier with smallholder data, as it can change year to year [I]. As one interviewee mentioned: "A traceability database is only as good as how you maintain that database, because again, even if you're doing this massive effort at one point in time, in a year's time, it can look completely different in who is buying and selling to who" [I]. With the EUDR, it is even a consideration that the cost of compliance is high, therefore due diligence is not done even if the product is compliant and cannot be mixed in transportation (Innovation Forum, 2024).

The main actors in the palm oil supply chain that are pivotal for a correct implementation of technology towards EUDR compliance are the mills [I, H]. As the center of informal and formal flows of FFB, traceability and noncompliances stem from the processing stages at the mills [H]. Therefore, it is advised that traceability and technological programmes to diffuse into the supply chain comes from mills, that can drive change in mid-stream suppliers –like aggregators and collectos–, and create records of transactions happening at the low-tier levels [H].

All in all, the use of technology is seen as a potential opportunity for all stakeholders to coordinate and monitor to ensure compliance [B, H]. Land mapping, satellite monitoring, drone verification and on-ground inspection can reduce the cost and time spent achieving compliance [H]. Further comments on the role of technology for EUDR compliance will be discussed in section 5.4.

5.3 Effect of the EUDR on smallholders

In this subsection, the effect of the EUDR on smallholders will be explained and analyzed. Smallholders are characterized for their low level of knowledge and subsistence livelihood drive [H]. All the same, their production accounts for one-third of the global production of palm oil (FairTrade International et al., 2021). Therefore, the effect of the regulation on such a salient group of suppliers will change the configuration of the supply chain [A].

Smallholders can be divided in two subgroups, as we have discussed in the literature review. The **scheme smallholders** (or "plasma" smallholders in Indonesia), are linked directly to companies or company resources [E], whereas the independent smallholders are small-scale farmers that own land that is managed by them [C]. First, scheme smallholders are directly contracted to work for big palm oil companies or have contracts to be part of the roster of producers that supply to a company. Thus, they have access to finance, resources and supplier development programmes by producer companies and EU companies on "smallholder inclusion" [D, I]. With the EUDR coming to fruition, it is expected that these smallholders, working with a company, are mostly compliant with the EUDR through their certification [C, F, G]. As the MSPO and ISPO are currently mandatory for all plantations and palm oil production activity, it is expected that scheme smallholders fall under their –or RSPO– certification and therefore, close to EUDR compliance. This is shown as 93% of the palm oil coming to Europe is RSPO certified [D], so the supply chain is mostly certified and close to EUDR compliance. Even with non-compliances, "producers will still be supported and encourages to become more sustainable in their production even if in the short term they might find themselves excluded from the European market" (Innovation Forum, 2024).2

Independent smallholders, on the other side, are the majority of smallholders in the palm oil sector. They rely on their own capital and tend to suffer more poverty than scheme smallholders due to the uncertainty and discontinuous flow of money in their production [C]. Therefore, with the upcoming entry into force of the EUDR, all interviewees agree that smallholders will be excluded from the supply chains [A, B, C, D, E, F, G, H, I , J, K, L, M, N, O, P]. For buyers, this is their main strategy to achieve compliance [J, L] with the regulation, as the fines for non-compliance are significant –up to 4% of net annual revenue–. In the supply chain system, this differentiation will happen at the refinery/mill level, which will source mainly from large plantations or corporate mills [L]. While EU companies will have at least 18 months to identify and engage with any smallholder in their supply chain to prepare for the new traceability requirements, it is expected that they will not be able to do it on time, as some interviewees have pointed out that the production process of palm oil starts around August every year for the finished output to be accessible in the European market in January [I, P]. Therefore, compliant production should happen already in August 2024 [I, O, P].

Overall, it can be seen that independent smallholder will be mostly affected, as their production is already considered secondary and used as buffer supply [I]. The main reason of their supply exclusion is their detachment from the supply chain, their lack of resources –mostly coming from big companies– and support to achieve traceability and their problems with formal production as discussed in the previous section about land rights [A, E]. While they will be severely affected, the short-term solution that some companies have found is to divest the palm oil flows to areas outside of the EU, as India and China still represent 34% of the supply chain (3keel, 2024). On this subject, some interviewees considered that it would be a good short-term solution while companies develop their traceability systems [A, E, F, H, J, K], but others consider that imports going to other markets end up eventually in European markets and have to be compliant [C] and that it could slow progress towards deforestation-free palm oil, as traceability would not be prioritized in the supply systems [D, G, P].

Different **initiatives** have been developed in response to the changes in the palm oil supply chain. Acknowledging the role of smallholders, especially independent smallholders (that account for the majority of the production), several bottom-up initiatives have been created, as emergent behaviour. Top-down initiatives are common in supply chaim management, as part of supplier development [A, G], namely developing credit lines or loans, provide technical assistance and brokering between providers to ensure traceability levels [O]. Among bottom-

up initiatives, two have been highlighted by interviewees: group certification and platforms for smallholder assistance [B, C, D, I, J, L, P].

To support smallholders and reduce the individual burden of compliance, group certifications or collective certifications have been introduced first for certifications –like RSPO– and now extrapolated to EUDR [L]. Group certifications relate to a unification of different smallholders to put up with the upfront cost of certification [C]. There can be village groups, subvillage group or natural grouping [L]. Natural groping recognizes the emergent behaviour of farmers in palm oil, broadening the scope not only to cooperatives nor legal structures[L]. It recognizes problems in grouping, as "if you're a village and even a village could be split into two or three, like, it's not easy to get everybody to work together. If you're a family of four or five or your five neighbors, want to call yourself a group, that's a natural grouping, so we recognize that and that allows different groups of different sizes and forms to be certified" [L]. These efforts have been made by smallholder associations, like SPKS and supported by financing institutions and certifications in order to bring smallholders into formal supply chains [C, D].

Additionally, platforms for smallholder assistance have been developed in order to provide resources and include smallholders further, as well as limit the challenges that the EUDR suppose for these low-tier suppliers (SPKS, 2024). An example is the Farmers For Forest Protection Foundation (4F) in Jakarta. The initiative, developed in collaboration with smallholders and local and indigenous communities from various regions in Indonesia, aims to promote responsible deforestation-free practices that enhance the welfare of small farmers and indigenous groups (Tanahair, 2023). It is intended to be a mechanism for incentive and benefit, identifying top areas of action for smallholders to act upon: mapping smallholders, legalizing customary forest, GAP training, livelihood support, traceability systems, strenghthening smallholders' village institutions, legal land right support and market access and fair price (SPKS, 2024).

5.4 Technology as an emergent factor for smallholder inclusion

As explained in the literature review, technology has the potential to support increased traceability as required by the EUDR. From blockchain to remote sensing, many technological tools and instruments are set to interact with the EUDR and have an impact on the disadvantageous position of smallholders. For the EUDR, traceability, satellite imagery (for compliance) and data collection tools are the main areas of interest for companies and NGOs alike [H, J, K].

Companies and traders consider that traceability enforcement is the most pressing requirement, followed by data gathering and verification [H, J]. Traceability, viewed from an EUDR perspective, is embodied by due diligence statements. These statements require geolocation and ways to trace selected products. With a highly dispersed supply chain, palm oil has high levels of intermediation that pose a significant problem to traceability [I]. Nonetheless, the sector is among the highest traceable of all agricultural commodities [I] (Innovation Forum, 2023).

Regarding the requirements of the EUDR, different technological tools are relevant. Traceability can be achieved through blockchain and records of transactions in databases, as well as creating platforms that allow for tracing and registering the process activities throughout the value chain [K]. The EUDR legality component requires ensuring the assurance of legal production of palm oil, which tends to be associated with demonstrating operational and land licenses. Ensuring access to land titles through platforms or demonstrating land titles is supported by drone verification of the plot of land [H, P] and

mapping of the farm to create a digital register through polygons –defined in the regulation as "geographical location of a plot of land described by means of latitude and longitude coordinates corresponding to at least one latitude and one longitude point and using at least six decimal digits" (European Commission, 2023a). This verification can also be done for farms smaller than 2 ha with a geolocation point (European Commission, 2023a). Last, the deforestation-free status can be achieved through remote sensing and satellite monitoring, with layered and updated/segregated maps that allow for a good representation of land use in the production regions [D, J].

Smallholders have low access to technology in the palm oil supply chains. Some programmes have been developed to make technology more accessible to farmers, like the "Ulula Worker Lina App" (OWL), a platform co-created between the technology provider Ulula and the NGO Wild Asia, creating a node for information on sales of FFB, sustainable practices, etc (*How Integration of Ulula Tech Benefits Wild Asia Group Scheme Palm Oil Smallholders - Ulula*, 2023). But most of the projects on smallholder digitization are made within supplier development programmes of traders and exporters, that is not available for analysis [P]. Additionally, as explained before, certifications and their tools are currently being adapted for EUDR compliance, like the RSPO CTTS that includes "remote sensing verification for plots of land, batch traceability to ensure traceability to plantation, downloadable plantation/geolocation boundary data […], and a GIS dashboard that downstream RSPO members will be able to use to inform sourcing decisions" (European Commission, 2023c). Thus, the potential for transferability of EUDR requirements to current certification programmes is highly possible and a consideration that interviewees have expressed [A, C, E, G].

Some **initiatives** from the side of certifications have been developed to bridge the gap for traceability. Traceability was already a mandate within certifications and other voluntary standards, but the existence of the EUDR has compelled radical change and improvements. In Malaysia, the Malaysia Palm Oil Board developed the Sawit Intelligent Management System (SIMS), and the MPOPC developed the e-MSPO as a digital platform for MSPO-certified entities (European Commission, 2023c). These platforms allows the recording of transactions, access to public data on the palm oil market, automatization of daily records, generating a quality declaration for the EU market, etc. Internationally, RSPO has also developed their own traceability system, PRISMA (Palm Resource Information and Sustainability Management) that converges stakeholders with relevant and updated data for better decision-making and organized information (RSPO, 2024). For smallholders, these types of traceability tools ensure access to FFB transactions and access to FFB purchase prices (RSPO, 2024), as well as access to loans due to lower risk presented to the financial market [K]. Other benefits from accessing and monitoring information through traceability include independence to seek higher prices and understanding monthly/yearly yields, thus leading to optimization and foresight [K]. Or recording of history of production and sales, which leads to access to finance as verification on good practices [J].

Reduced accessibility to these technologies poses a significant threat to EUDR compliance, as this regulation requires an advanced level of granularity and a "farm to fork traceability is nearly impossible" [I]. Especially in palm oil, the hotspot of opaqueness that exists within the mid-stream suppliers between mill and farms significantly reduces the diffusion of traceability in the supply chain [I, O, P]. Therefore, large investments in creating procedures for traceability and invest on the formalization of the upstream levels of the supply systems are necessary [I, H, L, O, P].

As the EUDR requires transparency, data information is to be collected. Data on location, administrative, bureaucratic and legal information is mandatory to fulfill both the EUDR and certification schemes. For certification schemes, the scope and size of traceability is limited to the certification scheme, whereas the EUDR has an international scope that ranges from the EU market to independent and informal production networks in Indonesia, Malaysia and other palm oil-producing countries [L]. A challenge and risk for data management is that data is passed onto other actors of the system, not only the competent authorities and traders [I]. In the EU context, one interviewee questions the validity of data usage with the GDPR ruling, as plot data is still personal data of farming location and address, so "the farmers has the rights to be forgotten", but there are not provisions about data management in the regulation [L]. Data governance and privacy is then required to have a fair and just use of the data collec, ted in the traceability efforts within the system, and therefore presents an issue to the emergent use of technology to support smallholders.

From a pragmatic perspective, smallholders lack financial and technical capabilities to achieve all the levels of compliance and technological integration. Therefore, categorizing with the order of priorities, the first technology stated by interviewees is drone verification to achieve legality to access land titles [C, F, I, M, P]. Then, satellite monitoring to provide context for deforestation-free claims [F, H, P].

5.5 Palm oil supply chains through a MTSC lense

The palm oil sector is characterized for an indirect approach regarding their governance mechanisms established by the MTSC framework. That indirect approach is supported by literature (zu Erngassen et al., 2021; zu Erngassen et al., 2022) and subsequently, has been supported by data collection. This approach is taken as agents in the palm sector express the limitation and opaqueness that exists in the lower tier levels of the supply chain, therefore making it challenging to establish a high level of connection [O, A, F]. Driven by multiple levels of agents in the low-tier supply at an informal level, the indirect approach is considered as a "cost-effective way" to reach sustainability goals in a company [E]. Nonetheless, with the establishment of the EUDR and its traceability requirements, companies and upstream suppliers are starting to rely on certifications like RSPO or other national schemes (like MSPO and ISPO) to reduce risks of compliance with the regulation [A, B, D]. This expansion on the governance mechanism can be considered as "work with third party", as per Gong et al. (2021) and Tachizawa & Wong. (2014), due to stakeholder pressure and industry demands driven by the EUDR and transparency trends. Therefore, it can be seen that companies in palm oil have both an indirect and "work with third party" approaches, that is aligned with literature like Heldt & Beske-Janssen (2023) that states that companies can use multiple approaches to their SSCM.

5.6 Palm oil supply chains from a CAS perspective

To further understand how the EUDR affects palm oil sector, the national palm oil supply systems of Indonesia and Malaysia have been studied. Using the CAS perspective, the supply chains were analysed and contrasted. Figure 5.2 presents an abstraction of the CAS theory onto the case study of palm oil.

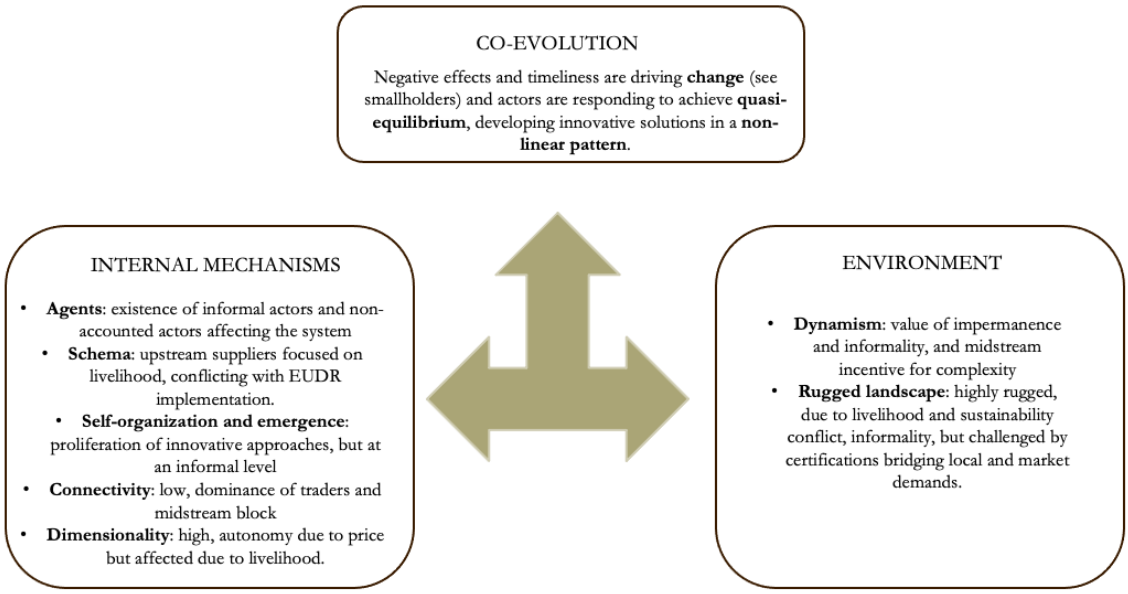

Figure 5-2. Reframing of the CAS theory on the palm oil supply system case study

Source : Own illustration, based on Touboulic et al. (2015).

5.6.1 Internal mechanisms

The CAS framework introduces the internal mechanisms of the supply chains: agents, schema, connectivity, dimensionality, and self-organization/emergence (Touboulic et al., 2019). As previously stated, the **agents** of the supply chain are not only the companies and suppliers that exist within the system, but also the relevant stakeholders that affect the engagement of said system, like regulators, civil society, NGO, industry associations, etc. In the palm oil sector, apart from formal agents, the supply chain is conformed of informal agents that exist at a mid-stream level, as well as NGOs, cooperatives and other informal level of aggregation of low-tier suppliers [L].

Their interactions are paced by the set of rules and values regarding environmental management that dominates the supply chain, the **schema**. While downstream companies like Cargill, Musim Mas or Sime Darby have sustainability compromises at the core of the value chain (Innovative Forum webinar, [A, O]), lower-tier suppliers and mid-stream actors don't consider sustainability and deforestation as a central or relevant part of their practice [I, D, E, H]. These actors, which are located in producer countries with high levels of poverty and under-average living conditions, participate in supply chains in order to subsist and care mostly about the price of FFB they can get from traders and how to make palm oil production less resource-intensive [F, C]. Therefore, there is friction when it comes to sustainable supply chain management of palm oil that contributes to the complexity of this supply system.

With the addition of the EUDR, the supply system is being introduced to a new paradigm for deforestation that might differ between levels of suppliers. The EUDR uses the definition of deforestation and forest from FAO, which is "land spanning more than 0.5 hectares with trees higher than 5 metres and a canopy cover of more than 10%, or able to reach these thresholds" (European Commission, 2023a). This definition differs from both the Indonesian one, which states that "forest land is a specific land area that is designated or stipulated by the government

to be maintained as permanent forest"; and the Malaysia one through their national certification MSPO, where deforestation is banned on "natural forests, protected areas and High Conservation Value areas considered by the government after 31st December 2019" (MSPO, 2021). Through existing differences about deforestation and how to tackle it, agents are being driven by uncertainty and confusion, without driving sustainable change in palm oil systems (Innovation Forum podcast). Additionally, all agents of the supply chain have a top-down schema [A,E,F], that reinforces the role of focal companies or downstream suppliers as leaders with the power to control the supply chain.

When it comes to **connectivity**, the palm oil supply chain is highly connected and has different relationships between stakeholders, depending on their place in the stream of supply. Upstream suppliers have differing connectivity levels, due to the multitude of suppliers and stakeholders operating from the mid-stream supply to farmers and its low visibility. The mid-stream suppliers are considered a "mid-stream network" rather than individual supply chains, as they have high levels of indirect and informal connectivity between each other and with producers [I]. The existence of multiple local aggregators, distributors, and transporters in the palm oil sector between the production in farms and the processing in mills increases this informal connectivity even further. On the other side, the downstream suppliers have formal connectivity based on traceability and contracts that allows them to interact and influence the sustainability of the supply chain. As Touboulic et al (2019) states, a supply chain can have connectivity with low quality connections, which can be applied to the case of palm oil, as suppliers are connected but only through the processing of the FFB and not having knowledge of its partners upstream [A, G].

Although informal connectivity is preponderant in palm oil, the supply chain lacks **dimensionality**, i.e the degree of independence within suppliers. The palm oil sector is a vertically-integrated market, with strong power asymmetries lead by prices and production. Therefore, at the upstream level, agents have low independence and can be controlled through the prices of FFB in the market and the demand presented by traders. Independent producers, for example, are used sometimes as a buffer for demand and supply fluctuation [I, O], whereas producers under company schemes are driven by the company interests [G, K].

Last, the supply chain is observing self-organization and certain levels of **emergence**, as organizations like SPKS and Fair Trade International are developing projects with low-tier suppliers to support them through finance to develop capabilities to achieve sustainability (Eco-Business, 2023). While these grassroots and bottom-up projects are in need of finance and assistance from international companies, certifications and traders [C, G, M], their behaviour within the supply chain can be considered emergent, as they aim to solve issues in an innovative and proactive way, understanding their level of agency.

5.6.2 Environment

The environment of a supply chain is relevant to its dynamics, as the CAS framework presents (Touboulic et al., 2018). The two factors affecting a supply system environment are: rugged landscape and dynamism. The sector has a **rugged landscape** that is still underdeveloped, as there is not a level of inclusion that bridges the different levels of suppliers, except for certifications that include and are validated by most agents in the supply system [D, O]. To make sense of the supply chain, there needs to be an understanding of the level of **dynamism**. For palm oil, the upstream suppliers are highly dynamic, valuing impermanence and being able to seek higher prices in the market, as well as having a short-term intention with their crops, wanting to sell in order to make income accessible throughout the year [I]. Therefore, the market looks very different and changes dynamically, making it dififcult to track the sale of

FFB to mills and understand trends in the market, as it changes day to day and year to year [I, M] (European Commission, 2023c).

As the palm supply chain is organized, dynamism is encouraged in the lower tiers due to the different levels of agents in the early stages of production. As explained in the literature review, the existence of a vast number of aggregators, distributors and transporters creates an ever-changing and chaotic network, with opportunistic behaviour. Local aggregators change their practices and sometimes locations to respond to a fluctuating demand [E, G, H]., thus making it difficult to predict or to engage with them in order to incorporate sustainable practices.

5.6.3 Co-evolution

In complex adaptative systems, supply chains are developed and engage in co-evolution, as feedback from the different agents creates new dynamics that are in the same way affected by other co-dependent dynamics. Currently, in the case of palm oil, there are tensions existing between the downstream and upstream suppliers, mainly due to different schemas as explained before: buying firms (most of which are located in Europe) have a concept of sustainability and environmental practices that are not shared with upstream suppliers (located in producer countries). With the enactment of the EUDR, companies and different levels of suppliers are improving relationships and increasing collaboration, mainly through certifications like RSPO, ISPO and MSPO [C, D, I].

6 Discussion

The aim of this chapter is to critically review the findings of this thesis and provide a foundation for the conclusion. First, the results are analysed against the research questions and aims for this thesis, and significant considerations are abstracted and discussed. Second, the research methods will be evaluated and its limitations discussed, as to reflect on the appropriateness in terms of design and process. Finally, the section will conclude with suggestions for further research and practical applications.

The research questions addressed in this thesis are as follows:

RQ1: What are the barriers and opportunities of the EUDR implementation in palm oil supply chains?

RQ2: What are the likely effects of the EUDR on smallholders in the palm oil supply chain?

RQ3: What is the potential role of technology in addressing the limitations of the EUDR implementation for smallholders?

6.1 Discussion on main findings and conclusions

The implementation of the EUDR has been the focus of growing attention both in academic literature (de Oliveira et al., 2024; Zhunusova et al., 2024), but mostly of companies and regulators that aim to predict its effects and impacts on the selected commodities under the regulation. However, there is a significant gap of understanding how the EUDR is impacting overall SSCM and agricultural supply chains. Moreover, there is a need to understand the impact of the regulation on specific areas that are understudied like smallholders or low-tier suppliers and technology as an emergent actor in the palm oil sector.

The present study employs two theoretical frameworks to analyse the process of achieving sustainability in multi-tier supply systems: the multi-tier supply chain (MTSC) theory (Gong et al., 2021; Tachizawa & Wong, 2014) and the complex adaptative systems (CAS) theory (Choi et al., 2021; Carter et al., 2015; Toubulic et al., 2018). MTSC theory offers a clear and straightforward framework for understanding the key factors and methodologies for sustainable supply chain management, focusing on the importance of collaboration among stakeholders in different levels of the supply chain and integrating sustainability factors into strategic decisions of the supply system. As a very rigid and vertical theory, the complexity and dynamism of multi-tier supply chains is difficultly captured by MTSC. Alternatively, the CAS theory provides a broader description of supply chains as complex adaptative supply systems that exhibit emergent behaviour, dynamism and adaptation to changing environments. Therefore, using this theory allows a deeper understanding of sustainable supply chain management and its dynamism is affected by sustainable interventions.

The use of these frameworks stems from trying to understand how the EU deforestation-free regulation will affect the palm oil supply chain and how the system will react to it. As discussed in the literature review, agricultural supply chains tend to use an indirect approach in their supplier governance mechanism, as supply chain visibility is low and highly informal (zu Erngassen et al., 2021). It is foreseen that, with the EUDR in place, there will be a "shift towards more established structures […], that are able to have some governance in place to collect information and to manage it" [O]. The reason behind this shift is the focus of the EUDR: transparency and traceability (European Commission, 2023a). It can be seen that the

aim of the EUDR is then to increase visibility and traceability in the supply chain, by means of a direct supply system approach to SSCM, so that sustainability efforts in the EU are followed by the producing countries via the supply chain. Therefore, the EUDR can be explained through a MTSC lens, that recognizes verticality and focuses on "focal companies" to drive change alongside the supply systems, as power dynamics can be leveraged by first-tier suppliers to ensure sustainability practices cascade down to low-tier suppliers (Gong et al., 2021).

Because of the complexity of supply networks, it is believed that it is a difficult, resource-intensive process to effect meaningful changes within them (Choi et al., 2001; Carter et al., 2015b), such as transitioning them towards a more environmentally sustainable path. To overcome these challenges, there has been a rise in network-level collaborations (Hamprecht et al., 2005; Fadeeva, 2005).

Additionally, recent research has characterized supply chains, not only as interconnected and interdependent, but also adaptative, capable to respond to external forces and changing environment in a dynamic and often unpredictable manner (Choi et al., 2001). Thus, this thesis has used CAS theory to provide a better understanding of the dynamism of supply chains, mostly due to complex local relationships and contextual factors that affect the levels of suppliers in palm oil.

As the EUDR focuses on downstream –it sets up requirements for EU companies that are then translated into lower tiers of the supply chain–, there is a need to understand the upstream levels of the supply chain and the CAS theory permits the analysis of the EUDR impacts through an upstream perspective, focusing on emergent and non-predictable behaviours. Acting upon the right angles and through collaboration, significant changes in the palm oil supply chain can be achieved. From a CAS perspective, as Toubloulic et al. (2018) highlight, focal firms cannot exercise complete control over the whole supply chain, so a study of relevant stakeholders with the ability to influence the supply chain and applying pressure on other is relevant. Thus, this thesis identified smallholders as potential emergent stakeholders driving up change in an FRC supply chain, and technology as a tool to achieve sustainable supply chain management and support smallholders in their emergence.

6.1.1 Barriers and opportunities in EUDR implementation

Research question one identified key barriers and opportunities that influence the adoption of the EUDR in the palm oil sector. Multiple barriers were found to be related to structural forces that are embedded on the nature of the palm oil supply chains and its producing countries. Similar to the findings of de Oliveira et al. (2024), significant barriers were found both in pre-emptive stages of the EUDR implementation, as well as compliance barriers. First, the competing legalities and frameworks between downstream stakeholders –the European Union countries– and producer countries –mainly Indonesia and Malaysia– are misaligned, creating supplier tiers with differences in the valuation of sustainability in the supply system and increasing the possibilities of sustainability-related risks, with producer countries and companies having less restrictive definitions of forests and deforestation than downstream companies. Thus, different schemas –considered as "norms, values, beliefs and assumptions that are shared among the collective" (Choi et al., 2001, p. 353)– reduce the potential level of collaboration between agents of the supply chain (Touboulic et al., 2018).

Another barrier influencing the sound implementation of the EUDR is the underdeveloped system of land rights. With producer countries having informal systems of land acquisition and inconsistent and contested land titles, producers cannot prove the origin of their products with traceability to the farms. As the findings address, land rights issues can exclude suppliers from

the palm oil supply chain or restrict their supplier inclusion or development, in formal structures, through land grabbing or land encroachment. Similar conclusions have been perceived in academic research about other commodities in Vietnam, East Africa and Guatemala (Zhunusova et al., 2023; Pachehco et al., 2018; Hirsch et al., 2015). Therefore, land titles need to be supported in palm oil to increase the connectivity and therefore the possibility of developing sustainable initiatives in supply chains.

Compliance barriers like smallholder participation and traceability can also deter the correct implementation of the EUDR. These two factors directly affect the connectivity and visibility of the palm oil supply chain, increasing the complexity of the system (Choi et al., 2001). First, smallholders were found to have informal and detached relationships with other tiers of the supply system, which reduces the potential diffusion of the EUDR requirements and poses a threat to their livelihoods. Aligning with research, smallholders are seen as a fragile network of agents that are detached from any action of SSCM, which reduces their possibilities to achieve their incentives, mainly income (Dou et al., 2020). Additionally, their low income reduces their possibility to comply with the EUDR requirements, as the potential cost of compliance is high (2440 euros per farmer), even with group certification, as exemplified in Table 4. This further highlights the paradox that low connectivity to the supply chain is exacerbated by low income and viceversa, with smallholders left outside of supply chains where they can't access to aid for EUDR compliance and a fair price of goods that supports their livelihoods (FairTrade International et al., 2021). Figure 6.1 presents the routes through EUDR implementation is expected to affect suppliers and its expected effects.

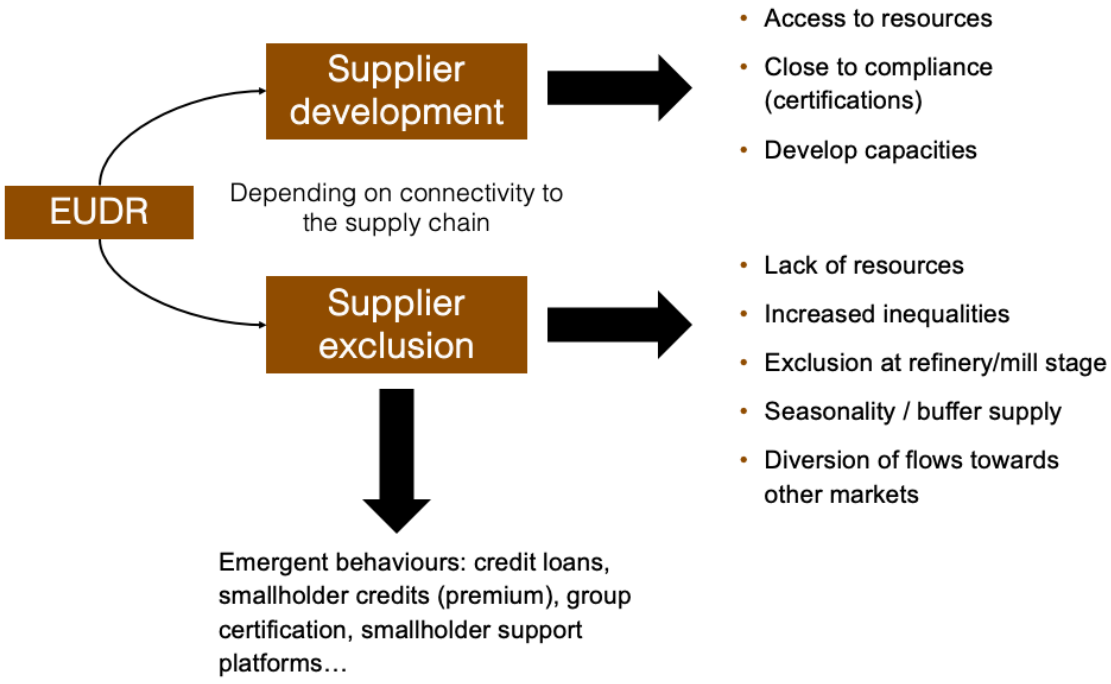

Figure 6-1. Pathways of EUDR implementation and supplier effects

Source : Own illustration.

Directly linked to the position of smallholders in the supply chain, traceability was identified as another barrier to EUDR implementation. While academic research has reviewed the role of traceability in supply chain –as the process of transferring information about the commodity origin and chain of custody–(Ebinger & Omondi, 2020; Montecchi et al., 2021), this thesis

has found hotspots for traceability issues, mainly in the midstream tier of suppliers and the access to technology. There is a high level of informality in the process of production, with midstream suppliers aggregating FFB to reach the mills, as farmers and other producers do not have processes of transportation and collection of palm oil. Additionally, the deployment of technology in supply chains is controversial, as traceability to the mill has been mostly achieved by companies owning plantations and mills, with the Universal Mill List published in 2024 with verified mill locations across the world– (Rainforest Alliance, 2024). But technology and traceability to the plantation and in the non-scheme market is currently being developed by associations and supported by NGOs like Rainforest Alliance or World Resource Institute (SPKS, 2024), where upstream companies can support this efforts, as they engage with the non-scheme market too through "buffer supply".

On the other hand, two strategic opportunities for palm oil have been identified in order to comply with the EUDR requirements. First, certifications were identified in interviews as emergent agents on the supply chain that can support SSCM, as voluntary sustainability standards have implemented in the past decade environmentally and socially responsible management practices (Depoorter and Marx, 2021). For palm oil, the effort made by RSPO and the national standards –ISPO and MSPO, which are both now mandatory– to create traceability platforms like the RSPO's PRISMA and support smallholders through smallholder funds and credits (in the case of RSPO) showcases the commitment of certifications to achieve the common goals with the EUDR, as they have well established no-deforestation criteria, assurance systems and product traceability frameworks (Cosimo et al., 2024). Additionally, certifications have expanded considerations when it comes to social and economic aspects of the palm oil supply chains, understanding the local context and providing a triple-bottom approach to SSCM. But this does not come without issues, as certifications schemes for agricultural commodities have been found ineffective in stopping conversion of land, attributed to a lack of wider uptake and regulatory loopholes in the schemes, and the challenges in their assurance system based on risk and sample monitoring (van der Ven et al., 2018). Nonetheless, certifications have the potential to support the implementation of the EUDR due to wide acceptance in the palm sector, their familiarity with the market and provision of on-the-ground information and verification (Cosimo et al., 2024). The lack of implementation of the regulation as well as the ongoing international conversations between the EU and palm oil producing countries makes the operationalization of certifications impossible to predict and define, so no conclusive statements can be abstracted in this area.

Technology has also been positioned as an emergent tool to support EUDR compliance. Comparable to certifications, technology has been deployed in the past decade in palm oil supply chains to ensure traceability and sustainable supply chain management (Thöni and Tjoa, 2015). Technology requirements from the EUDR regulation have been found to be catalyzers of supply chain visibility and transparency, as higher visibility reduces environmental risks and reduces the cost of technology (Innovation Forum, 2024). Additionally, technology for palm oil should focus on mapping out the mid-stream and upstream levels of supply, in order to tackle the gap in this levels that prevent traceability and even connectivity between supply chain agents.

Some researchers also highlight that current studies oversimplify the operationalization of transparency in the supply chain context (Fraser et al., 2020). Nonetheless, this thesis demonstrates that analyzing palm oil supply chains as complex adaptive systems enhances our comprehension of the origins and dynamics of emerging issues. This perspective also suggests strategies for addressing these challenges, even when their dynamics cannot be predicted in advance. Currently, the supply chain system is suboptimal and fails to respond adequately to

environmental pressures, making changes imperative. Supply chains both react to environmental pressures and create them, so more traceability can lead to higher pressure for visibility and transparency. In summary, traceability is not the end state of the system, but a process of many steps and actions to drive sustainability at a supply chain level, with supply chain agents being able to prepare for the coming changes and minimize the risks.

There is a high cost stemming from these barriers that potentially prevent the adoption of the EUDR in palm oil producing countries, as some studies highlight the considerable cost that all the processes and frameworks of traceability, verification and logistics will require (de Oliveira et al., 2021). But the CAS perspective considers the existence of emergent factors and opportunities that, spoused to collaboration between agents, can drive significant changes into the palm oil supply chains.

6.1.2 Smallholders in palm oil

To answer research question two, the role of smallholders in palm oil was studied and potential effects of the EUDR on this group were analyzed through interviews and content analysis of public joint letters from the industry. In line with findings from Zhunosova et al. (2024) and Köhtke et al., (2023), this study found the effects of the policy on smallholders to be mixed. Although the expected and most common behaviour will be the exclusion of smallholders and low-tier suppliers from the supply chains going to Europe, some alternatives exist and are being developed currently. Additionally, the impact of the regulation will depend on the status of the smallholders. As the study has found, there are independent smallholders and scheme smallholders, and their level of connectivity and self-organization will impact their risk of smallholder exclusion.

As zu Ermgassen et al. (2022) highlights, scheme smallholders are directly related to companies or working under their schemes, which facilitates the flow of resources. With the EUDR implementation, companies and mills that have direct relationships with their smallholders have access to formal land titles and have established traceability systems, mainly due the radius catchment policy, where plantations are set up around the mills so that the processing of FFB is done within the radius –and 24 hour perishing window– requirements (WRI, 2015). Therefore, smallholders providing to established and visible supply chains have been found free of risk, as procedures to comply with the regulation's requirements are established and will only have to adapt to specific levels of transparency and traceability that is already existing to the plantation.

Independent smallholders have a different configuration within the palm oil supply system. Some interviews have highlighted their role as "buffer supply" and "inconsistent participation in the supply chain" [I, L, P]. Therefore, they will potentially be excluded from the supply chain, as they have higher possibilities of having issues with land titles and resources to ensure traceability, like land mapping, geolocation, technology to upload and track FFB sales, etc, as stated in other studies that express the likelihood of EU operators to shorten and simplifying their supply chain to reduce transaction costs (Zhunusova et al., 2024). Nevertheless, there are possibilities for these smallholders to retain their position in the supply chains, as upstream traders might shift the flow of uncompliant palm oil to the bigger markets like China and India. This has not been investigated before, but a study from Vasconcelos et al. (2024) highlights that, while China will not engage in deforestation free policies, there might be a de-facto compliance with the EUDR due to non-divisibility (Vasconcelos et al., 2024). Non-divisibility is the "adoption of a uniform standard by multinational companies instead of tailoring their operations to comply with distinct regulatory standards" (Bradford , 2012; Drezner, 2005; from Vasconcelos et al., 2024). If traceability requirements are imposed in the market, Chinese

companies might be interested in encouraging those requirements to benefit from the convergence in traceability (Vasconcelos et al., 2024). In the case of palm oil, there is potential for companies to shift their export flows to these markets while the processes for traceability and formal bureaucratic achievements are developed.

Last, some companies are interested in supporting smallholders directly, as part of their supplier engagement strategies, and will develop them and help them to achieve compliance even if they are not part of their scheme supply [A]. This is done in order to reduce dimensionality and influence upstream tiers of the supply chain to achieve sustainability, coming from a company's SSCM.

An emergent theme from the findings is the role of midstream suppliers in producer countries. Smallholders inclusion in supply chains is highly impacted by what type of midstream dynamics exist, as they have been found to be a hotspot and a barrier for SSCM. Palm oil supply chains are divided at the processing level, with mills receiving FFBs from plantations and smallholder farms with no segregation, potentially risking the traceability and segregation standard of the EUDR. Additionally, trader companies linked to those mills are likely not monitoring the source of the FFBs, which poses a risk to smallholders that aim to receive a price for their forest-risk products. As Grabs et al. (2024) highlights, midstream actors conform a network that is interdependent and diverse (Grabs et al., 2024). This network is placed in the middle of upstream (close to production places) and downstream (close to consumers), with insights about the drivers in consumer countries and knowledge of production regions and contexts (Grabs et al., 2024). In palm oil, trader companies and its associated mills have the power to increase connectivity and enhance traceability with independent smallholders by engaging with local aggregators, compilers and logistical workers, who have the higher risk of non-compliance. Therefore, this study aligns with research (Zhunusova et al. 2024; Grabs et al., 2024) that resources and efforts to achieve readiness should focus on the hotspot that are mills and producer companies. This can turn into a change in the schema of upstream suppliers towards more sustainable production, as well as reducing the dimensionality and independence of upstream actors like aggregators and mills that might endanger the adoption of EUDR requirements. Also, fairer prices and redistributive value might allow for better conditions and deals for smallholders (Grabs et al., 2024).

Increasing visibility and connectivity for smallholders might be negative as well, according to some interviewees [C, I, N]. More visibility is seen as more possibility for a company to exercise monopolistic activities on its supply chain and reduce access to fair prices. While this was considered by interviewees, there is a lack of causality between visibility and access to fair prices, and the researcher has not found in his limited time pieces of research that align with this claim, therefore it is an avenue for further investigation. Nonetheless, it might be challenging to find this, as prices fluctuate considerably for agricultural commodities and production is very extensive.

This study confirms the position that smallholder inclusion by the time the EUDR is implemented is not achievable in current reality (Zhunusova et al., 2024; de Oliveira et al., 2023). Nevertheless, supply chains are already evolving, driven by numerous factors that will push the system toward a new state where traceability is essential. Some authors, such as Fraser et al. (2020), emphasize that traceability will eventually become standard in supply chains, a trend corroborated by this research (Fraser et al., 2020). Stakeholders at all levels of supply chains share a vision of transparency and sustainability, aiming to increase market share by eliminating actors with poor practices.

6.1.3 Technology as emergent behaviour

Research question three aims to provide an answer to how technology has become an emergent factor in the palm oil supply chain, especially to help smallholders achieve compliance. As the EUDR is heavily reliant on technology –through the DDS and traceability requirements–, its implementation and diffusion on the supply chain is required. The findings established that the necessary technologies and processes for EUDR compliance are: 1) traceability tools, 2) data gathering technology and platforms and 3) remote sensing and drone technology for verification.

First, traceability to the farm is required by the regulation, but there is a previous step to setting up traceability systems: land mapping. As stated in the first subsection of this chapter, land titles and tenure issues are deeply rooted in the lack of resources from smallholders to acknowledge the size of their farms through drone technology or remote sensing and the digitization of land titles. As smallholders face technical and financial barriers to technology adoption, they are distanced and divided from larger producers and preventing an equitable implementation of the EUDR (Cosimo et al., 2024). Second, data gathering technology and database platforms have been found to be the most advanced at the digitization process in SSCM (Ebinger and Omondi, 2020), as most certifications and upstream companies have already set stark requirements for data gathering in the past decade (Innovation Forum, 2024). Last, remote sensing and drone technology for verification of deforestation-free claims is also driving the technology needs for palm oil to achieve compliance.

Data transparency and security has been found an emergent topic on this study. In line with research (Cosimo et al., 2024; de Oliveira et al., 2023), technology is advocated to provide visibility and transparency, but the management and governance of data is poorly developed at this stage on the EUDR regulation and implementation guidelines. As an interviewee highlighted, "data must be used, not abused", as the level of traceability and data disclosure is risking business data about supply chains. Once the regulation is enacted, there will be data about geolocation points and clear visibility over the supply chain from downstream to the lower levels of upstream in producer countries, which will have to be efficiently managed in order to keep data security. Technologies like blockchain have been reflected in literature as an emergent technology that can improve supply chain transparency, enhancing risk management and supporting responsible sourcingp practices, all while ensuring a level of security and privacy of access that protect business interests and smallholders from predatory practices (Kamilaris et al., 2019; Ronaghi, 2021).

Although technological development is necessary for compliance and overall support of SSCM (Ebinger and Omondi, 2020), the use (and misuse) of data inputs in the palm oil supply chain is subject to the strategies and action points that emerge from it. VSS like certifications have driven a technologization of the supply chains, claiming that more data will increase sustainability and better visibility of the supply chain will drive deforestation-free practices and production. But research has found that zero-deforestation commitments and practices are underperforming in the palm oil sector, mostly due to lack of proper and comprehensive plans and policies (Chandra et al., 2024). This poses the question that if data improvements and higher visibility can enable zero deforestation, why VSS whose purpose is to increase transparency and data availability have not reduced deforestation? In Indonesia, deforestation free commitments in upstream only cover 23% of forests at risk and they are covered by light commtiments lacking in policy comprehensiveness and implementation and functional alignment between supply chain policies and its local context (Chandra et al., 2024).

It has been reflected about the emergent characteristics of technology to support a smooth EUDR implementation, as well as understanding the role for smallholder inclusion that stems from accessing data that allows them to position themselves in the market and understand their role, all while enabling access to finance and independence to be salient agents of the supply chain through data, transparency and knowledge of their environment –which is sometimes kept hidden by midstream actors that want to profit out of the detachment of smallholders–.

6.2 Methods and limitations

This study employs a qualitative research design incorporating case study methodologies. The primary sources of data are 16 interviews from stakeholders in academia, downstream and upstream companies, as well as 4 webinar and several websites that aimed to support data triangulation. The interviews aimed to collect the perspectives of stakeholders, and the webinars and websites aimed to support and provide a wider understanding of their insights. To organize the collected data from the interviews and other sources, a coding system was developed based on the literature analysis and theoretical frameworks.

This qualitative study's strengths identified in the research design chapter have proven to be effective, as the author has gained multi-stakeholder perspectives ranging from downstream to upstream companies, technology providers, NGO and academic professionals. Contrary to most supply chain management research with a downstream and focal company focus, this thesis focus on the perspectives and practices of smallholders –part of upstream suppliers– and midstream suppliers. By focusing on this specific set of agents, this study aimed access to the limited and shed light into a network of suppliers that has not been extensively researched, therefore closing the gap for inclusive research that studies supply chains holistically. Therefore, the chosen approach allowed to identify specific drivers and dynamics existing in palm oil that allow for a better understanding of such a complex and relatively opaque commodity supply system. The use of this specific case study provided valuable insights about the effect of the EUDR in a smallholder-prominent commodity. And later, the researcher discovered that the palm oil sector was additionally highly compliant and had similar frameworks than the ones of the EUDR, making it a case study that efficiently permits to analyze the gaps and "readiness" pathways existing with the regulation. While this can be of detriment to the study due to its lack of holistic perspective and generalizability of the findings, it provides a deep-dive into the sector and relevant stakeholders.

There were several limitations in the data collection methods due to the geography. Interviews are inherently subjective due to the perspectives about the topic of this research, but some interviews were redirected and altered due to inconsistencies and lack of interest to answer the proposed questions, as well as some business information that were not disclosed due to confidentiality. The lack of information provided by interviewees stem from both disinterest at disclosing business-sensitive and the actuality of the issue, as many participants stated that they are in the midst of analyzing and preparing for EUDR compliance, which will enter into place in 2025. Additionally, some language and culture barriers were identified, which made the processing of information and data much harder, subsequently boosted in the analysis and findings section. In order to enhance data quality, information was checked again with the relevant participants for crossreferencing an data triangulation was employed, incorporating a myriad of sources such as webinars, website, documents and observations from the interviews.. This was done ultimately to provide a more balanced and neutral perspective of the topic.

Another limitation was reaching a point of saturation during the data collection process. At the end of the interviewing process, certain level of saturation was reached, where interviewees

were not adding additional information to the study. As interviews were already schedules, the researcher decided to conduct the rest of the interviews for data triangulation and verification of statements, acknowledging the potential bias existing when this format of interview is selected. Nonetheless, the interview guideline was found useful to keep neutral questions and not engage in biases.

While the topic of research is relatively novel to research, this thesis has a strong potential for bringing new aspects of the EUDR implementation to the research field. As mentioned in the research design chapter, this thesis aims to be an ex-ante analysis, where information, recommendations and analysis stem from a prospective exercise and future thinking. As mentioned in the limitations during the first chapter, the EUDR is in constant development, so new guidelines –on risk benchmarking and implementation by competent authorities from EU member states– and the outcomes of the conversations between the EU and producing countries will alter or consolidate the findings of this thesis.

This thesis' theoretical framework was multiple: the multi-tier supply chain theory (MTSC) and the complex adaptative systems (CAS) theory. As stated in Chapter 2, MTSC possesses a vertical and downstream focus, where specific factors affect the selection of supply chain governance mechanisms. While this mechanism have been useful to understand the downstream mechanisms towards SSCM and the EUDR requirements, like the actual indirect approach or "work with third party" approach that most suppliers utilize, it does not provide the answer on how those requirements are passed on and affecting the rest of the supply chain. Therefore, although MTSC provides a good starting point for the analysis, it lacks the understanding of global commodities supply chains and the potential changes and dynamism that happens at the upstream level. Therefore, the use of CAS was introduced to account for such complexity and diversity of supply chains.

CAS theory was helpful in analyzing the complex mechanisms of supply chains, especially agricultural supply chains with such a strong base of smallholders, production distribution and narrow geographical location. The theory was capable of understanding the emergent roles of smallholders and technology and capture the essence of the EUDR, which acts upon downstream to influence the upstream levels of supply chain. This thesis assumed that the EUDR needed to have a CAS perspective, in order to understand that efforts can be set up alongside the value chain in order to achieve effectiveness, as demonstrated with smallholders that support sustainability with bottom-up initiatives and technology ensuring traceability at risk-prone areas of the supply chain –like the midstream levels–. Nonetheless, this theory comes with challenges from a theoretical perspective. The theory uses complex terminology that is not fully defined and analysed in literature (Choi et al., 2021; Touboulic et al., 2018; Carter et al., 2015). Terms like "rugged landscape", "non-linear futures" and "quasi-equilibrium" were difficult to grasp by the researchers and translated into interview questionnaires, which were attempted to explain and made simple answer much more intricate for the researcher and for the reader of this study. However, studies like Touboulic et al. (2018) that transfer the theory into a specific case study –in its case, food systems– allows practitioners and researchers to have a practical approximation of the theory in order to engage with it and apply it to other case studies, like this thesis (Touboulic et al., 2018). Overall, this thesis aimed to engage with the theory and apply its framework to enhance clarity about the dynamism and connectivity that characterize agricultural supply chains.

6.3 Implications for research and practice

This thesis provides an extensive overview of the possible and mostly plausible effects of the EUDR in palm oil, along with insights into how the regulation affects emergent actors like

smallholders and emergent behaviours like technology implementation. Through the MTSC and CAS theories, this research delves into how a downstream-oriented policy can affect upstream levels of the supply chain, as well as generate a reaction from the supply system to emerge with innovative approaches to the requirements of said policy. Through interviews with practitioners, relevant insights into the challenges of the EUDR and smallholder in palm oil have been compiled, underscoring important areas that need to be addressed.

As academic literature predominantly focuses on the downstream perspective and focal companies through MTSC (Hofstetter and Grimm, 2019; Sodhi and Tang, 2019; Tachizawa and Gong, 2021), the role of midstream and upstream agents in supply chains remains relatively underexploted. This thesis highlights the importance of including upstream actors in the implementation of the EUDR, while establishing the risk of a supply chain hostpot like midstream suppliers. Therefore, further research is required to better understand the challenges and opportunities of intervening at that level of the supply chain. Although Grabs et al. (2024) is a good example of emergent interest in midstream actors, it is one of the first projects to tackle such an opaque area of the supply chain, with higher level recommendations to for policy interventions and directed towards practitioners. These recommendations can be a good starting point for future research into the limits, strengths, innovations and dynamics occurring in the midstream levels of supply chains.

The findings of this study also underscores the importance of agents in the supply chain such as certifications and VVS schemes, that have become increasingly important and "mandatory" in current agricultural supply chains. Moreover, certifications have the power to enable good practices like verification and traceability systems into supply chains, as they do in their certification schemes. Research is then needed to understand how to leverage the knowledge and potential collaborations between certifications and public government or corporate companies and mills to ensure common frameworks for traceability, for definitions and applicability in producer countries. Additionally, there is a notable lack of research on the integration of new technologies within existing corporate structures , especially in sustainability at the supply chain level (Ebinger and Omondi, 2020). Given the ever-evolving sphere of technology, focusing on how to foster the diffusion of traceability tools and other technologies to achieve EUDR compliance is imperative. While I provide a ranking of the most pressing technology implementations, there is a need for further validation for other commodities and to research the opportunities and challenges associated with the integration of these new technologies to drive compliance.

Another potential route to investigate is the price premiums developed after the implementation of the EUDR requirements. Understanding the role of smallholders – understood from a social and income dependency perspective– in the supply chains, studies have posed the questions of pricing changes and fluctuations due to these requirements, either through procurement costs or through consumer signaling for deforestation-free products (Köthke et al., 2023; Zhunusova et al., 2024). An understanding of the compliance costs and distributional value dynamics would inform supply chains of hidden value distortion dynamics and would allow for direct action catered to smallholders, to support their transformation towards sustainable practices and their expensive investments towards compliance. Additionally, research is need in the business and financial implications for supply chain actors, as well as understanding the pathways for crediting and financial programmes that would allow smallholders and other upstream agents in palm oil to receive correct compensation for their efforts towards compliance, like the Smallholder ISH Credits by RSPO (RSPO, n.d). Furthermore, as this thesis has not provided a further analysis on the future effects of the compliance on supply chains, there is an open field of research underscored by IEEP (2022)

on positive impacts of compliance on smallholders and shaping the supply chain, like knowledge building, social capital and spillover of standards.

While this thesis has focused on palm oil due to its characteristics on smallholder salience and geographical concentration, there is a need to understand the effect of the EUDR on other commodities. Coffee and cacao have been found similar in smallholder participation in the market, but with traceability issues more prominent due to size of smallholders and processing timelines (de Oliveira et al., 2023). Their contextual differences, as well as the differences in their trade and markets makes for a relevant question of study. As it has been communicated, most smallholders, regardless of their commodity of production, are at-risk for supplier exclusion, so it is necessary to understand the possible pathways of exclusion in order to understand how different commoditiy markets and smallholders can collaborate to support themselves, and the possible lessons learned from commodity to commodity.

Last, from a practitioners and policy perspective, there are two considerations and implications for this thesis: the need for finance and programmes to support the palm oil supply chain and the relevance of this thesis for future policy evaluation. First, this thesis proves that competing legal frameworks and inconsistencies between definitions and goals are hindering the correct and timely adoption of the EUDR, ultimately affecting smallholders and upstream suppliers, while downstream suppliers have already sustainable-oriented goals in the European Union. Efforts like the EU Ad Hoc Joint Task Force between palm-producing countries and the EU to discuss adoption of the EUDR have driven the support of smallholder inclusion and programmes to finance their adscription to EUDR requirements in terms of technology, land tenure and fair pricing (EEAS, 2024). Second, this thesis and its analysis of the expected effects of the EUDR on palm oil, as well as smallholders and technology, from a CAS perspective, can support the analysis and evaluation that will happen after five years of implementation of the EUDR (European Commission, 2023a). As policy evaluation processes occur, this thesis can establish the baseline and a checklist for the policy to be evaluated against. Additionally, goals and targets can be established from the barriers in order to measure the level of compliance and development of traceability. On the other side, technology providers can understand the pathways of immersion of technology in the supply chain, knowing what the most pressing technology tools are and how to integrate it with smallholders and still be profitable.

Furthermore, there are several recommendations that can be extracted from this study for practitioners, at the supply chain level or policy level:

1. Foster collaboration between the EU and producer countries to create a common framework of legalities and definitions in order to facilitate the adoption and reduce the friction of compliance for smallholders. By engaging with the EU, common ground can be found to liberate compliance bottlenecks like land tenure and competing legal frameworks, and producer countries can support their companies and upstream suppliers by creating platforms that increase visibility and connectivity within the supply chain
2. Identify and establish collaboration between the EU and relevant palm oil certifications in order to leverage their supply chain access, verification and local knowledge. For instance, RSPO is mostly compliant with the EUDR requirements, so their local access to the supply chain and their good practices can be beneficial for all palm oil agents.
3. Explore strategies to include smallholder support in the company's supplier development programmes and draw smallholders near to the visible supply chain by financing and supporting sustainability practices in the midstream network of actors

4. Finance and establish pathways for technology implementation, prioritizing traceability systems and low-hanging fruit like land mapping and basic monitoring and traceability of sales at the upstream level, where processes are one-time and simplified, respectively.
5. Recognize the dynamic and emergent ethos of supply chains, so actions do not have to flow top-down and vertical, but understanding the hotspots and potential emergent behaviour of different agents of the supply chain, upstream and downstream.

7 Conclusions

This thesis aimed to explore the palm oil supply chain to identify how it will be affected by the EUDR and how smallholders, as the last chain of the upstream tiers in palm oil are to be affected by this regulation, with special interest in the technology emergence to support their resilience to the regulation. The policy, coming into full effect in January 2025 will impose traceability and deforestation-free requirements that will have to be followed in order to enter the EU market. While reducing deforestation, the palm oil supply chain will be seriously disturbed mostly at the upstream level in producing countries, with emerging behaviours that can drive compliance and barriers that have not been addressed by the regulation.

The objective of this research is to examine the barriers and opportunities, the necessary conditions and the effects of the EUDR on smallholders, while analysing emergent behaviour from agents in the palm supply chain. Using the MTSC and CAS frameworks, this study employs a qualitative research design incorporating components of case study methodologies. The primary source of data are 16 interviews from different stakeholders at different levels of the supply chain, supported by 4 webinars and several websites and reports from industry associatons, consultancies and research centers to triangulate and provide consistent and neutral data. To organize the collected data from different sources, a coding system was developed based on the theoretical frameworks and the literature review.

RQ1: What are the barriers and opportunities of the EUDR implementation in palm oil supply chains?

Several key barriers and opportunities were identified that either positively or negatively influence the correct implementation of the EUDR in palm oil producing supply chains. It was observed that the barriers were linked to pre-existing causes and contextual causes. Issues with land rights and competing legalities were found as preemptive barriers, due to different definitions, informal configurations of the supply system and starker frameworks caused by different schema and sustainability values between agents. Contextual barriers like smallholder participation and traceability are inherent to the supply chain, with smallholders detached from supply chains and with low resources to affront changes in the supply chain; and traceability difficult to enact as the midstream level actively fights transparency and engages in fast and dynamic environments that don't benefit from traceable processes.

However, this thesis identified two opportunities to facilitate the implementation of the EUDR via certifications and technology. Certifications have access to the palm oil market, as well as good practices and a history of implementing voluntary sustainability standards that are the blueprint for the EUDR. Therefore, enabling certifications would reduce the transaction and compliance costs and would ensure a smooth implementation of the requirements, engaging with all the agents of the supply chain. On the other hand, technology acts as a catalyzer with low cost and strong effectiveness of transparency at the supply chain level, which can drive interest and acceptance of the disclosure requirements.

RQ2: What are the likely effects of the EUDR on smallholders in the palm oil supply chain?

This study has found two scenarios for EUDR implementation at a smallholder level: supplier exclusion or supplier development. Depending on the level of connectivity of the smallholders with agents upstream at the corporate level, smallholders will be resilient to supplier exclusion, as companies have invested and built resources and relationships and will support the

compliance of their smallholders. Companies develop their smallholders and supplier to identify and ameliorate risk, engaging and creating more transparency, as their relation is contractual and long-term. On the other hand, this thesis has found that independent smallholders tend to be volatile and used as "buffer supply", which in turn leaves them more disconnected to the supply chain. As midstream actors tend to reduce visibility due to the dynamism and rapidness of their work, these smallholders are unable to create connections and build relationship with different levels of suppliers and, with its low resources and subsistence work, they are unable to comply with the requirements by themselves, which will potentially exclude them from the supply chain.

Additionally, this thesis found that, in order to avoid exclusion of smallholders, companies intend to drift the flow of palm oil to different markets like China and India, due to the rapid due date of the regulation and the lack of time to adapt and create processes at an upstream level. This would allow smallholders to continue producing FFB and the company to engage in programmes to put them up to compliance in the meantime. However, this has been contested by literature and pose a gap in research that is encouraged to pursuit.

Taking a CAS perspective, smallholders have the potential of changing the aforementioned dynamics through emergent behaviour and localized action, which has been found in palm oil through group certifications and smallholder credits. These initaitives show the dynamic and emergent behaviour of supply levels rather than a top-down approach, although support from downstream EU companies is required to scale these initiatives and achieve balanced compliance.

RQ3: What is the potential role of technology in addressing the limitations of the EUDR implementation for smallholders?

Achieving compliance through technology is a complex undertaking but a common one. Both literature and the findings support the use of technology for SSCM and has been described as an emergent tool to support innovative behaviours in the palm oil sector. From traceability to remote sensing, several technologies have been found useful to achieve EUDR readiness. This study found the most pressing technologies and the ones that are low-hanging fruit and can be done with current practices are: 1) traceability tools, 2) data gathering technology and platforms and 3) remote sensing and drone technology for verification. These technologies are already encompassing with certifications and standard palm oil practices in supply chain, so the investment and effort are alleviated by its prevalence currently in the sector.

While technology is encouraged, high levels of distrust for data transparency and governance have been found. With the amounts of data that the EUDR will compel to generate, protection against perverse activities and appropriate use is required by competent authorities and relevant supply chain agents. For this, blockchain can provide significant levels of security and provide a monitored process of data collection and sales. However, the efficacy of technology in achieving sustainability and transparency is contested and needs proper policies that enable action plans and targeted activities. Therefore, achieving traceability and technological diffusion necessitates extensive collaboration and trust among supply chain actors and requires collective agreement –stemming also from the EU regulation– on mechanisms, standards, procedures and cost sharing.

After studying the effects of the EUDR, I conclude that negative impacts are likely to occur for the current palm oil supply chain and for smallholders, driving their exclusion from value chains and putting their livelihood at risk. Technology can prevent and accelerate smallholder

inclusion and development but it requires collaboration between agents in the supply chain and aid from the EU to generate an incentive and trust in the newly-established requirements to have secure data management.

Overall, multi-stakeholder collaboration emerges as a crucial approach to address the implementation barriers, where research is crucial into success factors and pathways/conditions for fruitful collaboration. From a CAS perspective, this thesis can conclude that the EUDR needs an upstream focus and perspective, and its lack of thereof will end in smallholder exclusion due to the existing barriers that have not been addressed by the regulation. But emergent agents like certifications, empowered smallholders and technology will create opportunities and allow for an evolving landscape where numerous collaborations and initatives will appear in order to drive sustainable and attainable change to the palm oil sector. Increased participation, collaboration and conversation will generate greater regard for unintended effects of the EUDR and will be able to improve the regulation and engage more agents of the supply chain until smallholders are fully included in the supply chain and changes in the dynamics can be tackled wihtout leaving suppliers behind.

Bibliography

3keel. (2024, March 14). Palm Oil Transparency Coalition's annual assessment reveals potential for split in palm oil supply chain. 3Keel. https://www.3keel.com/global-palm-oil-supply-chain-split/

9.6.1 Policies aimed at reducing deforestation—AR4 WGIII Chapter 9: Forestry. (n.d.). Retrieved 13 December 2023, from https://archive.ipcc.ch/publications_and_data/ar4/wg3/en/ch9s9-6-1.html

Abbasi, M., & Varga, L. (2022). Steering supply chains from a complex systems perspective. European Journal of Management Studies, 27(1), 5–38. https://doi.org/10.1108/EJMS-04-2021-0030

About SIMS - SIMS. (2023, March 31). https://sims.mpob.gov.my/about-sims/

Accountability Framework Initiative. (2019). Operational Guidance on Smallholder Inclusion in Ethical Supply Chains. https://accountability-framework.org/fileadmin/uploads/afi/Documents/Operational_Guidance/OG_Smallholder_Inclusion-2020-5.pdf

Agreena: Three reasons to be excited about regenerative agriculture | Kinnevik. (n.d.). Retrieved 16 December 2023, from https://www.kinnevik.com/newsroom/stories/agreena-three-reasons-to-be-excited-about-regenerative-agriculture

Ambition Tempered by Compromise: A Legal Perspective on the EU's Deforestation Regulation | LinkedIn. (n.d.). Retrieved 6 May 2024, from https://www.linkedin.com/pulse/ambition-tempered-compromise-legal-perspective-eus-deforestation/

Aung, M. M., & Chang, Y. (2014). Traceability in a food supply chain: Safety and quality perspectives. Food Control, 39, 172–184. https://doi.org/10.1016/j.foodcont.2013.11.007

Bager, S. L., & Lambin, E. F. (2022). How do companies implement their zero-deforestation commitments. Journal of Cleaner Production, 375, 134056. https://doi.org/10.1016/j.jclepro.2022.134056

Brzezinski, B. (n.d.). Securing the position of smallholders in zero-deforestation supply chains.

Carter, C. R., Rogers, D. S., & Choi, T. Y. (2015). Toward the Theory of the Supply Chain. Journal of Supply Chain Management, 51(2), 89–97. https://doi.org/10.1111/jscm.12073

Castka, P., Searcy, C., & Mohr, J. (2020). Technology-enhanced auditing: Improving veracity and timeliness in social and environmental audits of supply chains. Journal of Cleaner Production, 258, 120773. https://doi.org/10.1016/j.jclepro.2020.120773

CDP, A. F. I. (2022). From commitments to action at scale: Critical steps to achieve deforestation-free supply chains. https://cdn.cdp.net/cdp-production/cms/reports/documents/000/006/368/original/CDP_AFI_Forest_Report_2022_%2814%29.pdf?1654614758

Cesar de Oliveira, S. E. M., Nakagawa, L., Lopes, G. R., Visentin, J. C., Couto, M., Silva, D. E., d'Albertas, F., Pavani, B. F., Loyola, R., & West, C. (2024). The European Union and United Kingdom's deforestation-free supply chains regulations: Implications for Brazil. Ecological Economics, 217, 108053. https://doi.org/10.1016/j.ecolecon.2023.108053

Chandra, A., Garrett, R. D., Carlson, K. M., Heilmayr, R., Stigler, M., Benedict, J. J., & Grabs, J. (2024a). How well does the implementation of corporate zero-deforestation commitments in Indonesia align with aims to halt deforestation and include smallholders? Environmental Research Letters, 19(4), 044054. https://doi.org/10.1088/1748-9326/ad33d1

Chandra, A., Garrett, R. D., Carlson, K. M., Heilmayr, R., Stigler, M., Benedict, J. J., & Grabs, J. (2024b). How well does the implementation of corporate zero-deforestation commitments in Indonesia align with aims to halt deforestation and include smallholders? Environmental Research Letters, 19(4), 044054. https://doi.org/10.1088/1748-9326/ad33d1

Choi, T., Dooley, K., & Rungtusanatham, M. (2001). Supply Networks and Complex Adaptive Systems: Control Versus Emergence. Journal of Operations Management, 19, 351–366. https://doi.org/10.1016/S0272-6963(00)00068-1

Choi, T., & Krause, D. R. (2006). The supply base and its complexity: Implications for transaction costs, risks, responsiveness, and innovation. Journal of Operations Management, 24(5), 637–652. https://doi.org/10.1016/j.jom.2005.07.002

Comparing the former EUTR and upcoming EUDR: Some implications for private sector and authorities—ScienceDirect. (n.d.). Retrieved 17 May 2024, from https://www.sciencedirect.com/science/article/pii/S1389934123001740

Cosimo, L. H. E., Masiero, M., Mammadova, A., & Pettenella, D. (2024). Voluntary sustainability standards to cope with the new European Union regulation on deforestation-free products: A gap analysis. Forest Policy and Economics, 164, 103235. https://doi.org/10.1016/j.forpol.2024.103235

Creswell, J., & Creswell, J. (2018). Research Design: Qualitative, Quantitative, and Mixed Methods Approaches. Sage.

Davis, K. F., Downs, S., & Gephart, J. A. (2021). Towards food supply chain resilience to environmental shocks. Nature Food, 2(1), 54–65. https://doi.org/10.1038/s43016-020-00196-3

De, S. (2021). Blockchain technology in agriculture: Applications and opportunities. Blockchain in Agriculture, 3(1), 34-47.

De-commoditizing Ethiopian coffees after the establishment of the Ethiopian Commodity Exchange: An empirical investigation of smallholder coffee producers in Ethiopia. (n.d.). https://doi.org/10.22434/IFAMR2018.0047

Depoorter, C., & Marx, A. (n.d.). Fostering compliance with voluntary sustainability standards through institutional design: An analytic framework and empirical application. Regulation & Governance, n/a(n/a). https://doi.org/10.1111/rego.12573

Dowell, L., Rosenbarger, A., & Lake, S. (2015). Palm Oil Mill Data: A Step Towards Transparency. https://www.wri.org/insights/palm-oil-mill-data-step-towards-transparency

Ebinger, F., & Omondi, B. (2020). Leveraging Digital Approaches for Transparency in Sustainable Supply Chains: A Conceptual Paper. Sustainability, 12, 6129. https://doi.org/10.3390/su12156129

Eco-Business. (2023a, November 9). Bridging the gap for smallholders amidst tightening regulations. Eco-Business. https://www.eco-business.com/opinion/bridging-the-gap-for-smallholders-amidst-tightening-regulations/

Eco-Business. (2023b, November 14). 'Smallholders are victims of the haze, not the cause': Indonesian oil palm farmers union advisor Aida Greenbury. Eco-Business. https://www.eco-business.com/news/smallholders-are-victims-of-the-haze-not-the-cause-indonesian-oil-palm-farmers-union-advisor-aida-greenbury/

European Commission. (2023a). REGULATION (EU) 2023/1115 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 31 May 2023 on the making available on the Union market and the export from the Union of certain commodities and products associated with deforestation and forest degradation and repealing Regulation (EU) No 995/2010. Retrieved from: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32023R1115&qid=1687867231461

European Commission. (2023b). EU Deforestation Regulation: An opportunity for smallholders.

European Commission. (2023c). Frequently Asked Questions – Deforestation Regualtion. Retrieved from: https://environment.ec.europa.eu/publications/frequently-asked-questions-deforestation-regulation_en

Fadeeva, Z. (2005). Development of the assessment framework for sustainability networking. Journal of Cleaner Production - J CLEAN PROD, 13, 191–205. https://doi.org/10.1016/S0959-6526(03)00126-4

Fair Trade Advocacy Office, Fern, IUCN Netherlands, Rainforest Alliance, Solidaridad, & Tropenbos International. (2021). Including smallholders in EU action to protect and restore the world's forests. https://www.fern.org/fileadmin/uploads/fern/Documents/2021/Briefing-paper-Including-smallholders-EU-action-final.pdf

Fair Trade Interantional, Fern, IUCM NL, Solidaridad, & Tropenbos International. (2021). Including smallholder in EU action to protect and restore the world's forests. https://www.tropenbos.org/file.php/2449/briefing-paper-including-smallholders-eu-action-21092021.pdf

Fauziyah, D., Naufal, F. A., Afian, S., Nisa, S. C., & Fetra, T. (2024a). Strenghtening Indonesia's Readiness to Navigate the European Union Deforestation-free Regulation through Improved Governance and Inclusive Partnership. https://madaniberkelanjutan.id/wp-content/uploads/2024/02/Madani-Insight-EUDDR-ENG.pdf

Fauziyah, D., Naufal, F. A., Afian, S., Nisa, S. C., & Fetra, T. (2024b). Strenghtening Indonesia's Readinessto navigate the EUDR through improved governance and inclusive partnership.

Financing of the CAP | Fact Sheets on the European Union | European Parliament. (2023, March 31). https://www.europarl.europa.eu/factsheets/en/sheet/106/financing-of-the-cap

Flyvbjerg, B. (2006). Five Misunderstandings About Case-Study Research. https://journals.sagepub.com/doi/10.1177/1077800405284363

Forest Carbon Stocks | Global Forest Review. (n.d.). Retrieved 6 December 2023, from https://research.wri.org/gfr/biodiversity-ecological-services-indicators/forest-carbon-stocks

Forests and Forest Risk Commodities. (n.d.). Friends of the Earth. Retrieved 27 November 2023, from https://foe.org/forests-and-forest-risk-commodities/

FRA 2020 Remote Sensing Survey. (2022). FAO. https://doi.org/10.4060/cb9970en

Fraser, I. J., Müller, M., & Schwarzkopf, J. (2020). Dear supplier, how sustainable are you? Sustainability Management Forum | NachhaltigkeitsManagementForum, 28(3), 127–149. https://doi.org/10.1007/s00550-020-00507-z

From Bean to Bar: Cocoa Traceability and EUDR Compliance – Leveraging Technology for Transparency and Accountability – Farmerline. (n.d.). Retrieved 17 May 2024, from https://farmerline.co/from-bean-to-bar-cocoa-traceability-and-eudr-compliance-leveraging-technology-for-transparency-and-accountability/

GAPKI. (2022). EU Deforestation Regulation: Impact on Indonesia [Personal communication].

Gardner, T. A., Benzie, M., Börner, J., Dawkins, E., Fick, S., Garrett, R., Godar, J., Grimard, A., Lake, S., Larsen, R. K., Mardas, N., McDermott, C. L., Meyfroidt, P., Osbeck, M., Persson, M., Sembres, T., Suavet, C., Strassburg, B., Trevisan, A., … Wolvekamp, P. (2019). Transparency and sustainability in global commodity supply chains. World Development, 121, 163–177. https://doi.org/10.1016/j.worlddev.2018.05.025

Gibbs, H., Rausch, L., Munger, J., Schelly, I., Morton, D., Noojipady, P., Filho, B., Barreto, P., Micol, L., & Nathalie, F. (2015). Brazil's Soy Moratorium. Science, 347, 377. https://doi.org/10.1126/science.aaa0181

Gong, Y., Jia, F., Brown, S., & Koh, L. (2018). Supply chain learning of sustainability in multi-tier supply chains: A resource orchestration perspective. International Journal of Operations & Production Management, 38(4), 1061–1090. https://doi.org/10.1108/IJOPM-05-2017-0306

Gong, Y., Jiang, Y., & Jia, F. (2021). Multiple multi-tier sustainable supply chain management: A social system theory perspective. International Journal of Production Research, 61, 1–18. https://doi.org/10.1080/00207543.2021.1930238

Grabs, J., Cammelli, F., Levy, S. A., & Garrett, R. D. (2021). Designing effective and equitable zero-deforestation supply chain policies. Global Environmental Change, 70, 102357. https://doi.org/10.1016/j.gloenvcha.2021.102357

Grabs, J., Carodenuto, S., Jespersen, K., Adams, M. A., Camacho, M. A., Celi, G., Chandra, A., Dufour, J., zu Ermgassen, E. K. H. J., Garrett, R. D., Lyons-White, J., McLeish, M., Niehues, I., Silverman, S., & Stone, E. (2024). The role of midstream actors in advancing the sustainability of agri-food supply chains. Nature Sustainability, 1–9. https://doi.org/10.1038/s41893-024-01296-9

Grabs, J., & Garrett, R. D. (2023). Goal-Based Private Sustainability Governance and Its Paradoxes in the Indonesian Palm Oil Sector. Journal of Business Ethics, 188(3), 467–507. https://doi.org/10.1007/s10551-023-05377-1

Greenfield, P. (2022, February 28). Deforestation emissions far higher than previously thought, study finds. The Guardian. https://www.theguardian.com/environment/2022/feb/28/deforestation-emissions-far-higher-than-previously-thought-study-finds-aoe

Grimm, J., & Hofstetter, J. S. (2019). Multi-tier sustainable supply chain management. In Grimm, Jörg; Hofstetter, Joerg S. (2019). Multi-tier sustainable supply chain management In: Handbook on the Sustainable Supply Chain. Research Handbooks in Business and Management series (pp. 526-541). Elgar https://doi.org/10.4337/9781786434272.00035 <http://dx.doi.org/https://doi.org/10.4337/9781786434272.00035> (pp. 526–541). Elgar. https://www.elgaronline.com/view/edcoll/9781786434265/9781786434265.00035.xml

Hamprecht, J., Corsten, D., Noll, M., & Meier, E. (2005). Controlling the Sustainability of Food Supply Chains. Supply Chain Management: An International Journal, 10, 7–10. https://doi.org/10.1108/13598540510578315

Hartmann, J., & Moeller, S. (2014). Chain liability in multitier supply chains? Responsibility attributions for unsustainable supplier behavior. Journal of Operations Management, 32(5), 281–294. https://doi.org/10.1016/j.jom.2014.01.005

Heldt, L., & Beske-Janssen, P. (2023a). Solutions from space? A dynamic capabilities perspective on the growing use of satellite technology for managing sustainability in multi-tier supply chains. International Journal of Production Economics, 260, 108864. https://doi.org/10.1016/j.ijpe.2023.108864

Heldt, L., & Beske-Janssen, P. (2023b). Solutions from space? A dynamic capabilities perspective on the growing use of satellite technology for managing sustainability in multi-tier supply chains. International Journal of Production Economics, 260, 108864. https://doi.org/10.1016/j.ijpe.2023.108864

Heldt, L. M. (2020). Sustainability risks in multi-tier supply chains. A dynamic capabilities perspective on integrating remote sensing technology into sustainable sourcing to

manage sustainability risks in upstream supply chains. IIIEE Master Thesis. http://lup.lub.lu.se/student-papers/record/9023050

Hirsch, D., & Terlau, W. (2015). Sustainable Consumption and the Attitude-Behaviour-Gap Phenomenon—Causes and Measurements towards a Sustainable Development. International Journal on Food System Dynamics, 6, 159–174. https://doi.org/10.18461/1869-6945-14

How Integration of Ulula Tech Benefits Wild Asia Group Scheme Palm Oil Smallholders—Ulula. (2023, April 24). https://ulula.com/resources/case-studies/tech-integration-palm-oil-smallholders-wild-asia/

How much do large-scale and small-scale farming contribute to global deforestation? (2023). FAO. https://doi.org/10.4060/cc5723en

Human Rigths Watch. (2019). "When We Lost the Forest, We Lost Everything": Oil Palm Plantations and Rights Violations in Indonesia. https://www.hrw.org/report/2019/09/23/when-we-lost-forest-we-lost-everything/oil-palm-plantations-and-rights-violations

IDH. (2022). Sustainable Palm Oil: Europe's Business. Facts, analysis and actions to leverage impact. https://www.idhsustainabletrade.com/uploaded/2022/09/221121-Palm-Oil-Report_20112022_amended_nov_final.pdf

IDH. (2023). Implementing the European regulation on deforestation-free products: Solutions for the palm oil, cocoa and coffee sectors. https://www.idhsustainabletrade.com/uploaded/2023/10/IDH_EUDR_pager_Final-Web-Ready-1.pdf

IEEP. (2022). Securing the position of smallholders in zero-deforestation supply chains. https://ieep.eu/publications/securing-the-position-of-smallholders-in-zero-deforestation-supply-chains/

Independent Smallholder (ISH) Credits. (n.d.). Roundtable on Sustainable Palm Oil (RSPO). Retrieved 16 May 2024, from https://rspo.org/as-a-smallholder/credits/

Intergovernmental Panel On Climate Change. (2022). Climate Change and Land: IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems (1st ed.). Cambridge University Press. https://doi.org/10.1017/9781009157988

International Finance Corporation. (2019). Working with Smallholders: A Handbook for Firms Building Sustainable Supply Chains. World Bank Group. doi:10.1596/978-1-4648-1277-4

Joint Press Release: The 2nd Meeting of the Ad Hoc Joint Task Force on the EUDR | EEAS. (n.d.). Retrieved 16 May 2024, from https://www.eeas.europa.eu/delegations/indonesia/joint-press-release-2nd-meeting-ad-hoc-joint-task-force-eudr_en?s=168

Kamilaris, A., Fonts, A., & Prenafeta-Boldύ, F. X. (2019). The rise of blockchain technology in agriculture and food supply chains. Trends in Food Science & Technology, 91, 640–652. https://doi.org/10.1016/j.tifs.2019.07.034

Kannan, P., Mansor, H., Abidin, H. Z., Rus, R., Hashim, K., Aman, Z., & Peng, T. S. (n.d.). Operating Model for Partnership between Smallholders and Mills: A Study in Perak and Johor, Malaysia.

Kinda, H., & Thiombiano, N. (2024). Does transparency matter? Evaluating the Impacts of the Extractive Industries Transparency Initiative (EITI) on Deforestation in Resource-rich Developing Countries. World Development, 173, 106431. https://doi.org/10.1016/j.worlddev.2023.106431

Köthke, M., Lippe, M., & Elsasser, P. (2023). Comparing the former EUTR and upcoming EUDR: Some implications for private sector and authorities. Forest Policy and Economics, 157, 103079. https://doi.org/10.1016/j.forpol.2023.103079

Li, G., Wang, X., Pereira, L. M., & Fullen, M. A. (2020). AI technology and rural revitalization in China. AI & Society, 1-12.

Lowder, S. K., Skoet, J., & Raney, T. (2016). The Number, Size, and Distribution of Farms, Smallholder Farms, and Family Farms Worldwide. World Development, 87, 16–29. https://doi.org/10.1016/j.worlddev.2015.10.041

Ma, M., & Sexton, R. J. (2021). Modern agricultural value chains and the future of smallholder farming systems. Agricultural Economics, 52(4), 591–606. https://doi.org/10.1111/agec.12637

McKinsey (2022). Toward a sustainable, inclusive, growing future: The role of business. Retrieved from: https://www.mckinsey.com/~/media/mckinsey/featured%20insights/sustainable%20inclusive%20growth/toward%20a%20sustainable%20inclusive%20growing%20future%20the%20role%20of%20business/toward-a-sustainable-inclusive-growing-future-the-role-of-business.pdf

Mcmichael, P. (2009). A Food Regime Genealogy. Journal of Peasant Studies - J PEASANT STUD, 36, 139–169. https://doi.org/10.1080/03066150902820354

Meinlschmidt, J., Schleper, M., & Foerstl, K. (2018). Tackling the sustainability iceberg: A transaction cost economics approach to lower tier sustainability management. International Journal of Operations & Production Management, 38, 1888–1914. https://doi.org/10.1108/IJOPM-03-2017-0141

Mongabay. (2023a, January 4). For Indonesian smallholders, EU deforestation rule is a threat—And an opportunity. Mongabay Environmental News. https://news.mongabay.com/2023/01/for-indonesian-smallholders-eu-deforestation-rule-is-a-threat-and-an-opportunity/

Mongabay. (2023b, October 25). Indonesia's oil palm smallholders need both state and EU support (commentary). Mongabay Environmental News. https://news.mongabay.com/2023/10/indonesias-oil-palm-smallholders-need-both-state-and-eu-support-commentary/

Montecchi, M., Plangger, K., & West, D. (2021). Supply chain transparency: A bibliometric review and research agenda. International Journal of Production Economics, 238, 108152. https://doi.org/10.1016/j.ijpe.2021.108152

Most Indonesian palm oil firms not sharing land with small farmers as required: Audit. (n.d.). Retrieved 11 March 2024, from https://news.mongabay.com/2023/07/most-indonesian-palm-oil-firms-not-sharing-land-with-small-farmers-as-required/#

MPOCC. (n.d.). Next generation of smallholders in Malaysia. https://www.mpocc.org.my/mspo-blogs/next-generations-of-smallholders-in-malaysia#:~:text=Smallholders%20are%20the%20backbone%20of,followed%20by%20Sarawak%20and%20Sabah.

MSPO. (2021). MSPO Certification Scheme. https://www.meti.go.jp/shingikai/enecho/shoene_shinene/shin_energy/biomass_sus_wg/pdf/011_e02_00.pdf

MSPO. (2024). Assessment of MSPO Certification against the requirements of the EUDR. https://www.mpoc.org.my/wp-content/uploads/2024/05/Assessment-of-MSPO-Certification-against-the-Requirements-of-EUDR.pdf

Nnoko, J. (2019). "When We Lost the Forest, We Lost Everything". Human Rights Watch. https://www.hrw.org/report/2019/09/23/when-we-lost-forest-we-lost-everything/oil-palm-plantations-and-rights-violations

Norman, M. (2021). HOW IS THE EUROPEAN UNION TIMBER REGULATION IMPACTING INDUSTRY DUE DILIGENCE AND SOURCING PRACTICES?

Pacheco, P., Schoneveld, G., Dermawan, A., Komarudin, H., & Djama, M. (2020). Governing sustainable palm oil supply: Disconnects, complementarities, and antagonisms between

state regulations and private standards. Regulation & Governance, 14(3), 568–598. https://doi.org/10.1111/rego.12220

Pagell, M., & Shevchenko, A. (2014). Why Research in Sustainable Supply Chain Management Should Have no Future. Journal of Supply Chain Management, 50(1), 44–55. https://doi.org/10.1111/jscm.12037

Palmer, A. (2024, January 27). How the EU's Definition of Forest Degradation Is Sparking Controversy in Canada [Substack newsletter]. Sustainable Forests, Resilient Industry. https://alicepalmer.substack.com/p/how-the-eus-definition-of-forest

Panwar, R., Pinkse, J., Cashore, B., & Husted, B. W. (2023). Why corporate sustainability initiatives fail to reduce deforestation and what to do about it. Business Strategy and the Environment, 32(8), 5121–5127. https://doi.org/10.1002/bse.3421

Pendrill, F., Persson, U. M., Godar, J., & Kastner, T. (2019). Deforestation displaced: Trade in forest-risk commodities and the prospects for a global forest transition. Environmental Research Letters, 14(5), 055003. https://doi.org/10.1088/1748-9326/ab0d41

Pendrill, F., Persson, U. M., Godar, J., Kastner, T., Moran, D., Schmidt, S., & Wood, R. (2019). Agricultural and forestry trade drives large share of tropical deforestation emissions. Global Environmental Change, 56, 1–10. https://doi.org/10.1016/j.gloenvcha.2019.03.002

Pirard, R., Pacheco, P., & Romero, C. (2023). The role of hybrid governance in supporting deforestation-free trade. Ecological Economics, 210, 107867. https://doi.org/10.1016/j.ecolecon.2023.107867

PricewaterhouseCoopers. (n.d.). Palm oil traceability platform offered to Europe. PwC. Retrieved 17 May 2024, from https://www.pwc.com/id/en/pwc-publications/industries-publications/consumer-and-industrial-products-and-services/plantation-highlights/august-2023/palm-oil-traceability-platform-offered-to-europe.html

Radley-Gardner, O., Beale, H., & Zimmermann, R. (Eds.). (2016). Fundamental Texts On European Private Law. Hart Publishing. https://doi.org/10.5040/9781782258674

Rainforest Alliance. (2021). Palm Oil Certification Phase Out. https://www.rainforest-alliance.org/wp-content/uploads/2021/07/Policy-for-Palm-Certification-Phase-out.pdf

Rainforest Alliance. (2024, March 4). The Universal Mill List. Rainforest Alliance. https://www.rainforest-alliance.org/business/certification/the-universal-mill-list/

Reardon, K., Padfield, R., & Salim, H. K. (2019). "Consumers don't see tigers dying in palm oil plantations": A cross-cultural comparative study of UK, Malaysian and Singaporean consumer views of palm oil. Asian Geographer, 36(2), 117–141. https://doi.org/10.1080/10225706.2019.1621187

Reardon, T., Liverpool-Tasie, L. S. O., & Minten, B. (2021). Quiet Revolution by SMEs in the midstream of value chains in developing regions: Wholesale markets, wholesalers, logistics, and processing. Food Security, 13(6). https://doi.org/10.1007/s12571-021-01224-1

Reardon, T., & Zilberman, D. (2016). Climate Smart Food Supply Chains in Developing Countries in an Era of Rapid Dual Change in Agrifood Systems and the Climate. https://doi.org/10.1007/978-3-319-61194-5_15

Reiche, J., Hamunyela, E., Verbesselt, J., Hoekman, D. H., & Herold, M. (2018). Improving near-real time deforestation monitoring in tropical dry forests by combining dense Sentinel-1 time series with Landsat and ALOS-2 PALSAR-2. Remote Sensing of Environment, 2018, 147–161. https://doi.org/10.1016/j.rse.2017.10.034

Reid, J., & Castka, P. (2023). The impact of remote sensing on monitoring and reporting—The case of conformance systems. Journal of Cleaner Production, 393, 136331. https://doi.org/10.1016/j.jclepro.2023.136331

Renier, C., Vandromme, M., Meyfroidt, P., Ribeiro, V., Kalischek, N., & Zu Ermgassen, E. K. H. J. (2023). Transparency, traceability and deforestation in the Ivorian cocoa supply chain. Environmental Research Letters, 18(2), 024030. https://doi.org/10.1088/1748-9326/acad8e

Ricciardi, V., Ramankutty, N., Mehrabi, Z., Jarvis, L., & Chookolingo, B. (2018). How much of the world's food do smallholders produce? Global Food Security, 17. https://doi.org/10.1016/j.gfs.2018.05.002

Richardson, K., Steffen, W., Lucht, W., Bendtsen, J., Cornell, S. E., Donges, J. F., Drüke, M., Fetzer, I., Bala, G., Von Bloh, W., Feulner, G., Fiedler, S., Gerten, D., Gleeson, T., Hofmann, M., Huiskamp, W., Kummu, M., Mohan, C., Nogués-Bravo, D., … Rockström, J. (2023). Earth beyond six of nine planetary boundaries. Science Advances, 9(37), eadh2458. https://doi.org/10.1126/sciadv.adh2458

Ronaghi, M. H. (2022). The effects of blockchain technology adoption on business ethics and social sustainability: Evidence from the Middle East. Environment, Development and Sustainability, 24(5), 6834–6859. https://doi.org/10.1007/s10668-021-01729-x

Rossman, G. B., & Wilson, B. L. (1985). Numbers and words: Combining quantitative and qualitative methods in a single large-scale evaluation study. Evaluation Review, 9(5), 627–643. https://doi.org/10.1177/0193841X8500900505

RSPO. (n.d.). RSPO and the EUDR implementation: A gap analysis. Retrieved 8 May 2024, from https://rspo.org/wp-content/uploads/RSPO-and-the-EUDR-Implementation.pdf

RSPO, G. (2024, February 22). Introducing PRISMA: RSPO's Certification, Trade and Traceability System for Sustainable Palm Oil Management. Roundtable on Sustainable Palm Oil (RSPO). https://rspo.org/introducing-prisma-rspos-certification-trade-and-traceability-system-for-sustainable-palm-oil-management/

RSPO Smallholder Support Fund (RSSF). (n.d.). Roundtable on Sustainable Palm Oil (RSPO). Retrieved 9 May 2024, from https://rspo.org/as-a-smallholder/support-fund/

Sauer, P. C., & Seuring, S. (2019). Extending the reach of multi-tier sustainable supply chain management – Insights from mineral supply chains. International Journal of Production Economics, 217, 31–43. https://doi.org/10.1016/j.ijpe.2018.05.030

Seuring, S., & Müller, M. (2008). From a Literature Review to a Conceptual Framework for Sustainable Supply Chain Management. Journal of Cleaner Production, 16, 1699–1710. https://doi.org/10.1016/j.jclepro.2008.04.020

Skidmore, A. K., Coops, N. C., Neinavaz, E., Ali, A., Schaepman, M. E., Paganini, M., Kissling, W. D., Vihervaara, P., Darvishzadeh, R., Feilhauer, H., Fernandez, M., Fernández, N., Gorelick, N., Geijzendorffer, I., Heiden, U., Heurich, M., Hobern, D., Holzwarth, S., Muller-Karger, F. E., … Wingate, V. (2021). Priority list of biodiversity metrics to observe from space. Nature Ecology & Evolution, 5(7), 896–906. https://doi.org/10.1038/s41559-021-01451-x

Smallholder farmers and the challenges of EUDR compliance. (n.d.). Retrieved 26 January 2024, from https://www.innovationforum.co.uk/articles/smallholder-farmers-and-the-challenges-of-eudr-compliance

Solidaridad, CPOPC, & MVO. (2023). Implications of the EUDR for oil palm smallholders [Personal communication].

Song, X.-P., Hansen, M. C., Potapov, P., Adusei, B., Pickering, J., Adami, M., Lima, A., Zalles, V., Stehman, S. V., Di Bella, C. M., Conde, M. C., Copati, E. J., Fernandes, L. B., Hernandez-Serna, A., Jantz, S. M., Pickens, A. H., Turubanova, S., & Tyukavina, A. (2021). Massive soybean expansion in South America since 2000 and implications for conservation. Nature Sustainability, 4(9), Article 9. https://doi.org/10.1038/s41893-021-00729-z

SPKS. (2024). Traceability and No Deforestation practices for fair and inclusive supply chains support Independent Smallholders in Indonesia.

Stöber, S., Huyskens-Keil, S., Odongo, W., Kataike, J., & Bokelmann, W. (2024). Editorial: Transformative food value chains for local development. Frontiers in Sustainable Food Systems, 7, 1358908. https://doi.org/10.3389/fsufs.2023.1358908

Surana, A., Kumara *, S., Greaves, M., & Raghavan, U. N. (2005). Supply-chain networks: A complex adaptive systems perspective. International Journal of Production Research, 43(20), 4235–4265. https://doi.org/10.1080/00207540500142274

Tachizawa, E., & Wong, C. Y. (2015). Towards a theory of multi-tier sustainable supply chains: A systematic literature review. Supply Chain Management, 19, 643–663. https://doi.org/10.1108/SCM-02-2014-0070

Tanahair. (2023). Farmers launch a foundation to protect forests, support farmers' welfare—Tanahair.net. https://tanahair.net/farmers-launch-a-foundation-to-protect-forests-support-farmers-welfare/

Tankam, C., & Lescuyer, G. (2024). A Comparative Analysis of the Prospective Impacts of the Eu's Deforestation Regulation on Cocoa and Timber Supply Chains in Cameroon [Preprint]. SSRN. https://doi.org/10.2139/ssrn.4693451

The rise of blockchain technology in agriculture and food supply chains—ScienceDirect. (n.d.). Retrieved 16 May 2024, from https://www.sciencedirect.com/science/article/pii/S0924224418303686

The State of the World's Forests 2022. (2022). FAO. https://doi.org/10.4060/cb9360en

Thöni, A., & Tjoa, A. M. (2015). Information technology for sustainable supply chain management: A literature survey. Enterprise Information Systems, 11, 1–31. https://doi.org/10.1080/17517575.2015.1091950

Thornton, P., Whitbread, A., Baedeker, T., Cairns, J., Claessens, L., Baethgen, W., Bunn, C., Friedmann, M., Giller, K., Herrero, M., Howden, S., Kilcline, K., Nangia, V., Ramirez-Villegas, J., Kumar, S., West, P., & Keating, B. (2018). A framework for priority-setting in climate smart agriculture research. Agricultural Systems, 167, 161–175. https://doi.org/10.1016/j.agsy.2018.09.009

Touboulic, A., Matthews, L., & Marques, L. (2018). On the road to carbon reduction in a food supply network: A complex adaptive systems perspective. Supply Chain Management: An International Journal, 23(4), 313–335. https://doi.org/10.1108/SCM-06-2017-0214

UNDP. (2020). Mapping the Palm Oil Value chain: Opportunities for sustainable palm oil in Indonesia and China. https://www.undp.org/sites/g/files/zskgke326/files/migration/cn/Palm_oil_report_EN.pdf

Urata, S., & Narjoko, D. A. (n.d.). International Trade and Inequality.

Vasconcelos, A. A., Bastos Lima, M. G., Gardner, T. A., & McDermott, C. L. (2024). Prospects and challenges for policy convergence between the EU and China to address imported deforestation—ScienceDirect. Forest Policy and Economics, 162. https://www.sciencedirect.com/science/article/pii/S1389934124000364

Verschuren, P. J. M. (2003). Case study as a research strategy: Some ambiguities and opportunities. International Journal of Social Research Methodology: Theory & Practice, 6(2), 121–139. https://doi.org/10.1080/13645570110106154

What is the role of deforestation in climate change and how can 'Reducing Emissions from Deforestation and Degradation' (REDD+) help? (n.d.). Grantham Research Institute on Climate Change and the Environment. Retrieved 6 December 2023, from https://www.lse.ac.uk/granthaminstitute/explainers/whats-redd-and-will-it-help-tackle-climate-change/

Woittiez, L., Van Wijk, M., Slingerland, M., Van Noordwijk, M., & Giller, K. (2017). Yield gaps in oil palm: A quantitative review of contributing factors. European Journal of Agronomy, 83, 57–77. https://doi.org/10.1016/j.eja.2016.11.002

World Resources Institute. (2022). The Latest Analysis on Global Forests & Tree Cover Loss | Global Forest Review. https://research.wri.org/gfr/latest-analysis-deforestation-trends

WWF. (2021). UNLOCKING SMALLHOLDER FINANCE FOR SUSTAINABLE AGRICULTURE IN SOUTHEAST ASIA. https://sustainablefinanceasia.org/wp-content/uploads/2021/03/WWF-2021-Unlocking-Smallholder-Finance-for-Sustainable-Agriculture.pdf

Yuan, W., & Zeng, Y. (2017). Study of Methods to Improve the Counselors' Scientific Research. Creative Education, 08(03), 305–311. https://doi.org/10.4236/ce.2017.83024

Zhunusova, E., Ahimbisibwe, V., Sen, L. T. H., Sadeghi, A., Toledo-Aceves, T., Kabwe, G., & Günter, S. (2022). Potential impacts of the proposed EU regulation on deforestation-free supply chains on smallholders, indigenous peoples, and local communities in producer countries outside the EU. Forest Policy and Economics, 143, 102817. https://doi.org/10.1016/j.forpol.2022.102817

Zu Ermgassen, E. K. H. J., Howard, M., Bennun, L., Addison, P. F. E., Bull, J. W., Loveridge, R., Pollard, E., & Starkey, M. (2022). Are corporate biodiversity commitments consistent with delivering 'nature-positive' outcomes? A review of 'nature-positive' definitions, company progress and challenges—ScienceDirect. Journal of Cleaner Production, 379. https://doi.org/10.1016/j.jclepro.2022.134798

zu Ermgassen, S. O. S. E., Howard, M., Bennun, L., Addison, P. F. E., Bull, J. W., Loveridge, R., Pollard, E., & Starkey, M. (2022). Are corporate biodiversity commitments consistent with delivering 'nature-positive' outcomes? A review of 'nature-positive' definitions, company progress and challenges. Journal of Cleaner Production, 379, 134798. https://doi.org/10.1016/j.jclepro.2022.134798

Zyglidopoulos, S., & Fleming, P. (2011). Corporate accountability and the politics of visibility in 'late modernity'. Organization, 18(5), 691–706. https://doi.org/10.1177/1350508410397222

Appendix I – Interview guideline

How is your organization involved in the implementation of the EUDR in supply chains?

What is the role of smallholders in the palm oil supply chain?

How aware are smallholders about what EUDR is and what it entails?

What is challenging at the moment with the implementation of the EUDR? And what has been working well or something that has eased up the process?

What are the likely reasons why you think a company may be compliant with EUDR? And what likely reasons may be for a company not to be compliant?

What are the strategies that countries are taking to support companies or farmers to be EUDR compliant?

What do you see as potential emergent behaviours from smallholders to adapt to the EUDR reality (initiatives from smallholders)?

How have company sustainability practices changed after the confirmation of implementation of the EUDR?

Do companies have the necessary knowledge for EUDR and capabilities, or do they have to find it externally?

What do you see as the role of technology in reducing the pontential impacts of the EUDR (previously mentioned)?

What is the most important technology that companies would need in order to have compliance with the EUDR? Is remote sensing or traceability tools better (blockchain)?

How do you think technology (remote sensing, blockchain) can improve the inclusion of smallholders in supply chains and help them reach compliance?

Agents: what are the main agents (drivers) of the EUDR compliance wave? International traders, countries, smallholders?

Self-organization and emergence: how self-organized is the palm oil supply chain? Do you have counter-power to drive changes that don't come from the companies?

Connectivity: how do organizations approach the EUDR compliance? Are they collaborating between them and with smallholders?

Dimensionality: Do the companies aim to have full control of this supply chain or allow any level of autonomy?

Dynamism: is this supply going to be fast-changing, with high supplier turnover (due to the EUDR restrictions)?

Rugged landscape : why is it difficult to achieve EUDR compliance? is the supply chain very opaque and difficult to map?

Appendix II – Interviews

Interviewee Role	Code for in-text reference
Sustainability manager	A
Academic	B
NGO	C
Certification officer	D
Certification officer	E
Certification officer	F
NGO	G
Technology officer	H
Academic	I
Technology provider	J
Technology provider	K
NGO Executive	L
NGO officer	M
NGO officer	N
Sustainability manager	O
NGO manager	P